UCL Eastman Dental Institute

Oral health of elite athletes and impact on performance.

Thesis submitted by

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For the degree of

Doctor of Philosophy

2020
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I, Julie Gallagher, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Oral health is integral to general health, wellbeing and quality of life. Based upon the hypothesis that oral health might affect sport performance, the aim of this PhD was to investigate the association between oral health of elite athletes and self-reported performance impacts.

Three studies were conducted: 1) a systematic review of self-reported outcome measures used to evaluate the impact of injury and illness on performance in sport, 2) a cross-sectional clinical and questionnaire-based study to investigate oral health and associated self-reported impacts, self-reported oral health behaviours, risks to oral health and opportunities for behaviour change in a representative sample of elite athletes 3) a repeated-measures study to determine the effectiveness of simple interventions, based on contemporary behaviour change theory, to improve oral health and reduce performance impacts in an opportunistic sample of elite athletes.

Study 1 identified that the Oslo Trauma Research Centre (OSTRC) overuse injury questionnaire could be modified to measure the impact of oral health problems on performance in sport. The results from Study 2 confirmed that dental caries, erosion and periodontal diseases are common in elite athletes. Although severe impacts on performance in sport were infrequent, athletes reported psychosocial impacts more frequently. Athletes said they were willing to consider adopting enhanced oral hygiene behaviours to mitigate the risks to oral health from participation in sport. Study 3 demonstrated effectiveness through improvements in athlete knowledge, self-reported oral hygiene behaviours and performance impacts.

This PhD thesis provides evidence of potential negative effects on performance in sport from oral health problems based on self-reported impacts. It also demonstrates that preventive interventions, based on contemporary behaviour change theory, appeared to have some success and therefore may reduce performance impacts in elite sport.

A new model is proposed to guide effective implementation of interventions.
Impact statement

The overall aim of this PhD was to raise awareness of the contribution that oral health makes towards general health, wellbeing and performance.

Papers presenting the findings from this PhD have been published in journals representing different branches of health research. The systematic review contributed to the body of knowledge in sports medicine, the clinical study contributed to the knowledge base in epidemiology and oral public health, and the questionnaire study increased awareness of oral health among general dentists. The intervention study is under review and has the potential to be useful in both oral health and sports medicine research.

Poster and verbal presentations have been made to different audiences through acceptance to present at conferences and symposia organised within other sections of health and social science research. The research is a popular item at the UCL Eastman postgraduate student induction day.

The self-reported outcome measure of the impact of injury and illness on performance in sport, identified in the systematic review, can be used to inform policy makers by informing on the extent and severity of a predefined health problem, it can be used to monitor athlete health and it can be used to evaluate interventions in sport.

The robust methods used in the cross-sectional study of athlete oral health and self-reported performance impacts serve as a clear model for comparative studies in other sporting populations at different levels and in other countries. In practical terms, the research has produced guidelines for dentist to follow when providing oral health screening and dental care for athletes. Oral health and impact on performance and oral health screening for athletes are modules in the new MSc in Sports dentistry at UCL Eastman Institute.

This research has identified opportunities to develop interventions that have a real chance of being effective. Requests have been received to provide oral health screening for elite athlete squads and a small team has been established to fulfil these requests. Two other elite athlete groups have indicated that they intend to provide fluoride toothpaste on prescription, via the team doctor, for the athletes in each squad.

A website (www.ucl.ac.uk.centre-oral-health-and-performance) has been established, where the information films and screening guidance are available as a resource and regular newsletters serve to maintain public engagement. The centre also has a twitter account @oralhealthsports with regular updates about relevant research.
The paper resulting from Chapter 6 (Gallagher et al 2019), was one of the top-shared articles published in the last 12 months, as part of the British Dental Journal (BDJ) Big Impact Collection.

It also received extensive global press coverage including: BBC News, Times, Telegraph, Mail Online, Guardian, BBC Radio 4’s Today, Mirror, Newsweek, i, Independent, Times of India, New York Post, Yahoo, MSN, The Australian, Radio New Zealand, Newshub (New Zealand), Malay Mail (Malaysia), The Hans India, Messagero (in Italian), Daily Times (Pakistan), LCI (France), Le Vif (Belgium), MARCA (Spain), Inverse.

The research featured on the front cover and in a profile article in the Sound Bite magazine produced for members of the Medical and Dental Defence Union of Scotland (https://www.mddus.com/resources/publications-library/soundbite/soundbite-issue-20/a-sporting-chance). It was also referenced in “Runner’s World” magazine.

This excellent media coverage, in the mainstream press demonstrates that people do care about oral health. The interest generated in the dental academic press serves to increase awareness of the importance and relevance of oral health protection in sport.
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Scientific output

Publication from Chapter 4:


Publication from Chapter 5:


Publication from Chapter 6:


Poster presentations:

Scottish Sport and Exercise Medicine Symposium 11th May 2016, National Stadium, Hampden Park, Glasgow: *Athlete-reported outcome measures of performance; a systematic review*

University College London Populations & Lifelong Health Domain Symposium 17th January 2017: *Oral Health of UK Elite Athletes and Impact on Performance*

International Olympic Committee Conference on Prevention of Illness and Injury, Monaco March 2017: *Oral health of UK elite athletes and impact on performance*

Europerio 9, Amsterdam 2018: *Oral health of UK elite athletes and impact on performance* (Presented by Professor Ian Needleman)

British Society for Oral and Dental Research Conference 2nd- 4th September 2019, Leeds: *Oral health improvement to enhance elite athlete performance*
How can we help elite athletes to have better oral health? (Presented by Professor Paul Ashley)

**Oral presentations:**


International Association of Dental Research Conference July 2018 London: Oral health in elite sport; potential for improvement

University College London School of Life and Medical Sciences Dean’s Research Day 2019, London: Going for Gold; Oral health and elite athletes
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times. I am grateful to Adnan Ali, the post graduate research administrator for his endless enthusiasm and optimism. Marianne Dang, his replacement has also been a valuable source of support. All the Masters students in the UCL Eastman Dental Hospital Unit of Periodontology have been such lovely people to share my working space with and a real inspiration to aim high. My working space has also included other PhD students and it has always been a comfort to share experiences with them. During most of this project I continued to work in the Eastman Dental Hospital Education Centre and I wish to acknowledge the friendship and continued interest in the project from all the staff and students. I wish to acknowledge the continuing willingness to listen provided by friends in the Horsham Amphibians Triathlon Club and our Saturday night badminton group, my parents, my sons Stuart and Alan and my husband Paul. Finally I must say thank you to the athletes and support staff who participated and enabled this project to become reality. It was a privilege to meet you all.
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<td>Follow up CRF</td>
</tr>
<tr>
<td>CC</td>
<td>Athlete evaluation of the presentation</td>
</tr>
<tr>
<td>DD</td>
<td>Athlete evaluation of the oral health kit</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ADHS</td>
<td>Adult dental health survey</td>
</tr>
<tr>
<td>AROM</td>
<td>Athlete reported outcome measure</td>
</tr>
<tr>
<td>BCW</td>
<td>Behaviour change wheel</td>
</tr>
<tr>
<td>BEWE</td>
<td>Basic erosive wear examination</td>
</tr>
<tr>
<td>BPE</td>
<td>Basic periodontal examination</td>
</tr>
<tr>
<td>CBC</td>
<td>Centre for behaviour change</td>
</tr>
<tr>
<td>COM-B</td>
<td>Capability, Opportunity, Capability behaviour change model</td>
</tr>
<tr>
<td>COSMIN</td>
<td>Consensus based standards for the selection of health measurement instruments</td>
</tr>
<tr>
<td>DBOH</td>
<td>Delivering better oral health</td>
</tr>
<tr>
<td>DFT</td>
<td>Decayed/filled teeth</td>
</tr>
<tr>
<td>DT</td>
<td>Decayed teeth</td>
</tr>
<tr>
<td>EPF</td>
<td>European periodontal federation</td>
</tr>
<tr>
<td>ETB</td>
<td>Electric toothbrush</td>
</tr>
<tr>
<td>ETW</td>
<td>Erosive tooth wear</td>
</tr>
<tr>
<td>EQ-5D</td>
<td>European quality of life questionnaire</td>
</tr>
<tr>
<td>FASH</td>
<td>Functional arm and shoulder</td>
</tr>
<tr>
<td>FDI</td>
<td>Federation Dental International</td>
</tr>
<tr>
<td>FINA</td>
<td>Federation International natation aquatics</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>HAGOS</td>
<td>Hip and groin outcome score</td>
</tr>
<tr>
<td>iHOT-12</td>
<td>International hip outcome questionnaire</td>
</tr>
<tr>
<td>HRI</td>
<td>Health related incident</td>
</tr>
<tr>
<td>HSAS</td>
<td>Hand shoulder and arm score</td>
</tr>
<tr>
<td>IAAF</td>
<td>International athletics association</td>
</tr>
<tr>
<td>ICC</td>
<td>Interclass coefficient</td>
</tr>
<tr>
<td>ICCMS</td>
<td>International caries classification and management system</td>
</tr>
<tr>
<td>ICDAS</td>
<td>International caries detection and assessment system</td>
</tr>
<tr>
<td>IOC</td>
<td>International Olympic Committee</td>
</tr>
<tr>
<td>ISF</td>
<td>International sports federation</td>
</tr>
<tr>
<td>KJOC</td>
<td>Kerlan-Jobe orthopaedic clinic</td>
</tr>
<tr>
<td>KTG</td>
<td>Knowledge transfer group</td>
</tr>
<tr>
<td>KTS</td>
<td>Knowledge transfer system</td>
</tr>
<tr>
<td>MIDC</td>
<td>Minimum detectable change</td>
</tr>
<tr>
<td>MID</td>
<td>Minimal intervention dentistry</td>
</tr>
<tr>
<td>NCD</td>
<td>Non communicable disease</td>
</tr>
<tr>
<td>NICE</td>
<td>National institute for clinical excellence</td>
</tr>
<tr>
<td>NK</td>
<td>Natural killer cell</td>
</tr>
<tr>
<td>OIDP</td>
<td>Oral impacts on daily performance</td>
</tr>
<tr>
<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>OSTRC</td>
<td>Oslo sports trauma research centre</td>
</tr>
<tr>
<td>PFT</td>
<td>Prescription fluoride toothpaste</td>
</tr>
<tr>
<td>PHE</td>
<td>Periodic health evaluation</td>
</tr>
<tr>
<td>PPE</td>
<td>Pre participation examination</td>
</tr>
<tr>
<td>PRISMA</td>
<td>Preferred reporting</td>
</tr>
<tr>
<td>PROM</td>
<td>Patient reported outcome measure</td>
</tr>
<tr>
<td>PUFA</td>
<td>Pulp, ulcer, fistula, abscess</td>
</tr>
<tr>
<td>RE-AIM</td>
<td>Reach, exposure,</td>
</tr>
<tr>
<td>REC</td>
<td>Research ethics committee</td>
</tr>
<tr>
<td>SCDEP</td>
<td>Scottish centre dental evidence practice</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SEM</td>
<td>Sports and exercise medicine</td>
</tr>
<tr>
<td>SFG</td>
<td>Sugar free chewing gum</td>
</tr>
<tr>
<td>SF-12</td>
<td>Short form -12 item questionnaire</td>
</tr>
<tr>
<td>SF-26</td>
<td>Short form -26 item questionnaire</td>
</tr>
<tr>
<td>S&amp;P</td>
<td>Strength and power</td>
</tr>
<tr>
<td>TRIPP</td>
<td>Translating research into injury preventive practice</td>
</tr>
<tr>
<td>UCL</td>
<td>University College London</td>
</tr>
<tr>
<td>VISA-P</td>
<td>Victoria institute of sport assessment- patella</td>
</tr>
</tbody>
</table>
1 Introduction

This PhD thesis presents the results from three research studies into the oral health of elite athletes and impacts on performance. There is a relative paucity of good quality evidence to inform on oral health within sports and exercise medicine (SEM), therefore the aims of this research were: to capture a clear understanding of the current state of the art, develop further qualitative evidence to understand the fundamental behaviours underlying the data and finally develop and test intervention measures to improve the oral health of elite athletes.

These aims were achieved by satisfying the following objectives. The first was to identify a valid outcome measure to evaluate self-reported impacts of oral health on athlete performance. The second was to measure the oral health, associated determinants of oral health and self-reported impacts of oral health problems on performance of elite athletes and explore athlete-reported oral health-related behaviours, risks to oral health and opportunities for behaviour change. The third was to develop, implement and evaluate a preventive intervention, based on contemporary behaviour change theory, in a group of elite athletes.

A review of the literature will provide background information regarding oral health and protection of athlete health. This will be followed by a statement of the study hypotheses and related research questions. The aims, methods and results of each study will then be presented and discussed in subsequent chapters. The final chapter will provide an overall summary of the results and discuss the implications for athlete wellbeing and performance and the implications for future research.

Oral health as an integral part of athlete health and wellbeing appears until recently to have been overlooked within SEM. Historically the focus of oral health research in sport was based on the provision of treatment and the epidemiology of trauma. Consequently, the research base to inform oral health in Sports and Exercise Medicine is limited in both quality and quantity (Ashley et al., 2015). Therefore further epidemiological evaluation of representative samples of athletes is required to establish the oral health needs across different sports and to establish the determinants of oral health, both of the individual and their environment (Needleman et al., 2014).

There are many challenges to the oral health of athletes, including nutrition, impaired host response, poor oral health behaviours and oral health literacy. However, there is a lack of evidence to explain the determinants of oral health in sport. Associations between oral diseases and postulated risk factors are weak if present at all. Therefore athlete-
reported oral health-related behaviours and risks to oral health need to be investigated in order to identify opportunities for behaviour change which could lead to improved oral health in athletes (Needleman et al., 2014; Ashley et al., 2015).

Protection of athlete health and prevention of health-related problems is a clearly-stated aim of the International Olympic Committee (Steffen et al., 2011, Engebretsen et al., 2014, Mountjoy and Junge, 2013). The focus of the IOC consensus statement on prevention of non-communicable diseases is on simple interventions that include behavioural change (Matheson et al., 2013). However, to be effective, prevention measures need to be acceptable to, adopted by and complied with by the athletes and sports bodies they are targeted at. Furthermore preventive measures must not have an adverse effect on participation or performance (Finch, 2006).

Evidence of efficacy of a prevention does not necessarily mean that the implementation of that intervention will be successful. Only interventions that can practically implement that evidence in sport will be effective for all participants (Verhagen et al., 2014). Interventions to change behaviour are essential in prevention (Michie and Johnston, 2012), therefore there is a need for development of a more complex model for effective implementation.

The above themes are thoroughly explored in this thesis.
2 Background

To perform at the highest level, athletes need to be well-prepared, fit and healthy. Oral health contributes towards optimum general health and wellbeing. This chapter will provide a background to understanding the determinants and consequences of oral health and disease. The concepts of sports impairment, prevention of injury and illness and protection of athlete health will then be reviewed. Finally, a summary of the extent of current knowledge regarding oral health and performance impacts in elite athletes will be discussed.

2.1 Oral health

Oral health is a fundamental component of health and physical and mental wellbeing and as such, it reflects the physiological, social, and psychological attributes that are essential to the quality of life. Therefore, excellent oral health contributes towards optimum health and wellbeing.

“Oral health is multifaceted and includes the ability to speak, smile, smell, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex.” (FDI, 2016)

Even in high-income countries, oral diseases are still a major public health problem. Dental caries and periodontal diseases are the most prevalent non-communicable diseases globally (Tonetti et al., 2017; Kassebaum et al., 2017) and the burden of oral disease continues to grow in many low- and middle-income countries (WHO, 2005; Petersen, 2009). Elite athletes as a group are younger than the general population, therefore the following overview of the epidemiology of common oral conditions will make particular reference to the prevalence of each among younger adults.

Dental caries has traditionally been the greatest threat to retaining natural teeth. It is still prevalent worldwide and is a major determinant of oral health (White et al., 2012). In 2015, untreated caries in permanent teeth was the most prevalent condition contributing to the global burden of disease; the age-standardized prevalence was 34.1% with 2.5 billion (95% UI: 2.4 to 2.7 billion) people worldwide affected (Kassebaum et al., 2017). The Adult Dental Health Survey (ADHS) 2009 (O’Sullivan et al., 2011) found that in the UK just over a third of younger adults (31% of 16-24-year-olds and 36% of 25-34-year-olds) have obvious decay (White et al., 2012).
To remain functional, teeth require support from a healthy periodontium, but severe periodontitis is now recognised as being the sixth most prevalent disease of mankind (Tonetti et al., 2017) with a global prevalence of 7.4% (95% UI 6.4-8.6). The ADHS 2009 found that good periodontal health was present in only 28% of 16-24-year-olds and furthermore, 20% of 16-34-year-olds had potentially irreversible periodontal disease (White et al., 2011).

In addition to caries and periodontal diseases, the increase in erosive tooth wear (ETW) in younger adults is causing concern to the dental profession. There is a paucity of clear information regarding the global prevalence of erosive tooth wear, however, prevalence in permanent teeth ranges between 20% and 45% (Schlueter and Luka, 2018). In the UK, tooth wear has increased by more than 10 percentage points over the past ten years with moderate wear reported as ranging from 4% in adults aged 16-24 years to 44% of adults aged 75-84 (White et al., 2012). Moderate tooth wear in 16-34 year-olds is of clinical relevance as it is suggestive of rapid ETW which may require treatment (White et al., 2012).

During the late teen years to early twenties the eruption of third permanent molars (wisdom teeth) can also influence oral health. Pericoronitis is the presence of inflammation around a partially erupted wisdom tooth and symptoms include pain, swelling and a bad taste with or without infection. Impacted wisdom teeth or adjacent teeth may develop caries due to the difficulties in effective plaque removal (Allen et al., 2009; Falci et al., 2012). Other problems reported in association with wisdom teeth include abscesses, cysts or tumours. Third molars are the most commonly impacted teeth and their removal was, historically, one of the most common surgical procedures in the UK (Mansoor et al., 2013; Sadler et al., 1993; Shepherd and Brickley, 1994).

Finally, trauma to the face and teeth (including maxillary/mandibular fractures, tooth fractures and avulsions, oral lacerations, facial lacerations and contusions) can influence oral health. Dental trauma may result from accidents during play, in the household, at work, as acts of violence or be related to travel. However 50% occur as a result of sports accidents (Gassner et al., 1999).

It has been suggested that a number of indicators of good oral health and function can be combined to produce a composite measure representing excellent oral health. The measure comprises:
- 21 or more natural teeth
- 18 or more sound and untreated teeth
- no decay detected at any site
- no periodontal pocketing of 4mm or more and no loss of attachment of 4mm or more
- no calculus or gingival bleeding

(Fuller et al., 2011)

Excellent oral health is uncommon in the UK, with only one in ten of the general population reaching this standard. However the effects of oral diseases and their treatment accumulate with age and therefore excellent oral health is more likely to be present in younger adults (Fuller et al., 2011).

The recent FDI definition of oral health moves dentistry away from the traditional model of treating disease to providing care and support for oral health (Glick et al., 2016) and this is supported by the ideology of minimal intervention dentistry (MID), a holistic patient care philosophy that encompasses the complete patient-dentist team-care approach to managing dental disease by identification and diagnosis (including risk assessment), prevention and control, treatment and recall, so educating and empowering people to take responsibility for their personal oral health (Banerjee, 2013). However, in order for people to adopt positive oral health related behaviours, they need to understand what good oral health looks and feels like, and they need to believe it is important and worth striving for.

In the next section, the assessment and management of the most common oral diseases will be reviewed.

2.2 Dental caries

Caries can be defined as “a localised chemical dissolution of a tooth surface resulting from metabolic events taking place in a biofilm (dental plaque) covering the affected tooth surface at any given time” (Kidd and Fejerskov, 2016). It results from the interaction between a susceptible tooth surface, the presence of sufficient numbers of cariogenic microorganisms and frequent exposure to dietary carbohydrates, mainly free sugars. Therefore, caries is a dietary-microbial disease (Pitts et al., 2017).

2.2.1 Clinical assessment, classification and management

Clinical caries is detected by a detailed visual inspection of clean dry teeth. Traditionally the index used to measure caries in epidemiological studies is the DMFT (Decayed,
Missing and Filled Teeth) Index. This index is a numerical count of the number of teeth affected by caries both untreated (current) and treated with restoration or extraction (past), but is not useful in clinical practice.

To address the need for a caries index for use in clinical practice, education, research and public health, the International Caries Detection and Assessment System (ICDAS) was developed (Ismail et al., 2007). The ICDAS has codes to measure sound surfaces and six stages of caries and the simplified merged codes system measures sound surfaces plus three stages of caries that are similar to clinical practice. Untreated caries is classified as initial, moderate or extensive stage. In addition, caries may be active or inactive (Pitts et al., 2013). Restorations and missing teeth can also be recorded with codes in this system. The concept of minimal intervention has led to the development of the International Caries Classification and Management System (ICCMS), which integrates ICDAS tooth assessments with risk assessment in order to plan, manage and review caries (Pitts et al., 2013).

2.2.2 Risk factors

A modern concept of caries includes consideration of how behavioural, social and psychological factors, as well as biological factors, are involved (Pitts et al., 2017). There are three, interrelated, risk factors:

**Frequent and/or prolonged ingestion of dietary sugars;** leading to acid production by biofilm bacteria. Potentially cariogenic foods and drinks include: sugared soft drinks, confectionery, cakes and biscuits, buns, pastries, fruit pies, sponge puddings and other puddings, table sugar, breakfast cereals, jams, preserves, honey, ice cream and sorbets, fruit in syrup or canned in juice. Fresh fruit juices, smoothies, sugared, milk-based beverages, sugar-containing alcoholic drinks, dried fruits, syrups and sweet sauces are also potentially cariogenic.

The main direct impact of diet is through its effect on the pH of the dental biofilm. Diets high in fermentable carbohydrates (mainly sugars) lower the biofilm pH whereas high-protein diets increase the urea concentration of saliva that can be converted by ureolytic bacteria to ammonia. Therefore diets high in proteins and fats result in a neutral biofilm pH (Pitts and Zero, 2016).

**Inadequate salivary flow rate;** resulting in prolonged sugar retention and pH depression. Salivary factors involve salivary flow rate, buffer capacity, the proximity of teeth to salivary gland orifices, and salivary film thickness and velocity at specific tooth
sites. In the absence of normal salivary flow, the pH stays at a low level for an extended time after exposure to dietary sugars. Salivary flow rate is the main factor affecting the clearance pattern of cariogenic foods and beverages. Saliva also plays an important role in modifying and buffering biofilm pH. Therefore, saliva is responsible for the recovery of low biofilm pH back towards neutrality (Pitts and Zero, 2016).

**Inadequate plaque removal;** leading to the accumulation of a thicker more pathogenic biofilm. While the dental biofilm is one of the main aetiological factors for caries, its presence on a tooth surface does not necessarily mean that caries will occur. Additionally, the effect of regular removal of plaque is difficult to separate from the influence of fluoride in toothpaste (Pitts and Zero, 2016).

### 2.2.3 Preventive measures

The publication “Developing better oral health” (DBOH) provides an evidence based toolkit for prevention of oral diseases in the general population (Public Health England, 2017). The advice for caries prevention is based on diet modification and maintaining availability of fluoride ions in the oral cavity:

- Brush last thing at night and at least on one other occasion
- Use fluoridated toothpaste with at least 1350ppm fluoride
- Spit out after brushing and do not rinse, to maintain fluoride concentration
- Reduce the frequency and amount of sugary food and drinks

For those considered to be at increased risk, a fluoride mouthwash and/or prescription of toothpaste with a concentration of 2,800ppm or 5,000ppm fluoride is also advised. Professionally applied fluoride varnish (22,600ppm) has proven efficacy regardless of caries risk, however implementation appears to be limited (Bonetti and Clarkson, 2016). Professionally applied fissure sealants are effective for prevention of pit and fissure caries, but are still underutilised (Bonetti, 2014).

### 2.3 Periodontal diseases

Gingivitis is a reversible plaque-induced inflammation of the gingivae recognised by erythema, oedema and bleeding on brushing or probing. Healthy gingivae have pocket probing depths of ≤3mm, no bleeding on probing and there are no calculus/restoration overhangs present. Persistent gingivitis can lead to irreversible periodontitis (Chapple et al., 2018). Periodontitis is a chronic inflammatory disease that can remain stable (in remission) or enter periods of exacerbation.
A person with gingivitis can revert to a state of health, but someone with periodontitis will remain susceptible even following successful therapy and therefore will require life-long supportive care to prevent recurrence of disease (Caton et al., 2018). The early stages of periodontitis may not cause symptoms but, if periodontitis is not treated, it can result in both loss of teeth and function which can have a negative impact on quality of life.

2.3.1 Bi-directional association between periodontal health and systemic disease

Periodontitis has potentially negative consequences for general health (Chapple and Wilson, 2014; Eberhard, 2019). The link between periodontitis and systemic diseases arises from a variety of sources including observational studies showing associations between systemic diseases (particularly cardiovascular disease and diabetes) and periodontitis (Suvan et al., 2015). Systemic inflammation initiated by a reaction to the organisms involved in periodontal diseases may be the causative factor for systematic disease (Chapple and Wilson, 2014). Evidence has also been gathered from interventional studies showing a possible beneficial impact of treating periodontitis on the systemic health of patients with chronic, non-communicable diseases or conditions e.g. diabetes, hypertension and stroke (Chapple and Wilson, 2014; Masi et al., 2018; D’Aiuto et al., 2018). The effects of periodontal diseases are generally cumulative therefore severity increases with age (Preshaw, 2015).

2.3.2 Clinical assessment, classification and management

The Basic Periodontal Examination (BPE) is a simple and rapid screening tool used to indicate the level of further examination needed and provide basic guidance on treatment needed (British Society of Periodontology, 2016). However, the BPE should be used for screening only and not for diagnosis. Gingivae with evidence of potential for gingivitis have pocket probing depths of ≤3mm with bleeding on probing and/or supra or subgingival calculus and/or overhangs (BPE code 1 and 2). Gingivae with evidence of potential for irreversible periodontitis have pocket probing depths of 3.5-5.5mm (BPE code 3) and/or pocket probing depths of > 5.5mm (BPE code 4).

2.3.3 Risk factors

The threshold of plaque accumulation necessary to induce gingival inflammation and impact upon its rate of progression at specific sites or at a whole mouth level varies between individuals according to both local (predisposing) factors and systemic (modifying) factors, respectively.
Local risk factors for gingivitis are those that encourage plaque accumulation at a specific site by either inhibiting its removal during daily oral hygiene practices, and/or creating a plaque retention factor such as subgingival restoration margins, oral appliances and presence of calculus. Oral dryness resulting from a lack of salivary flow, availability, or changes in quality of saliva, leads to reduced cleansing of tooth surfaces, reduced dental plaque biofilm removal and enhanced gingival inflammation. Common causes include medications that have anti-parasympathetic action, Sjögrens syndrome, and mouth breathing. Table 2.1 provides a summary of systemic risk or modifying factors that exaggerate the immune-inflammatory response to dental plaque biofilm (Chapple et al., 2018).

Table 2.1: Modifying factors that exaggerate response to plaque

<table>
<thead>
<tr>
<th>Modifying factor</th>
<th>Example</th>
<th>Mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifestyle/behaviour</td>
<td>Smoking</td>
<td>Induces microvascular vasoconstriction and fibrosis within the gingival tissues.</td>
</tr>
<tr>
<td>Diabete</td>
<td>Hyperglycaemia</td>
<td>Induces mitochondrial stress and an enhanced respiratory burst in inflammatory cells.</td>
</tr>
<tr>
<td>Diet</td>
<td>Severe vitamin C deficiency</td>
<td>Weakens capillary blood vessel walls and increased gingival bleeding.</td>
</tr>
<tr>
<td>Blood malignances</td>
<td>Leukaemia</td>
<td>Associated with signs of excess gingival inflammation in the absence of excessive plaque accumulation.</td>
</tr>
<tr>
<td>Blood malignances</td>
<td>Pre-malignant conditions</td>
<td></td>
</tr>
<tr>
<td>Pharmacological agents</td>
<td>Prescription drugs</td>
<td>Reduce saliva flow, impact endocrine function or induce gingival enlargement.</td>
</tr>
<tr>
<td>Pharmacological agents</td>
<td>Non-prescription drugs</td>
<td></td>
</tr>
<tr>
<td>Pharmacological agents</td>
<td>Recreational agents</td>
<td></td>
</tr>
</tbody>
</table>

2.4 Preventive measures

The advice provided by DBOH reinforces the importance of effective plaque removal consisting of daily disruption of plaque biofilm with a toothbrush, interdental aids and fluoride toothpaste (Public Health England, 2017). However, this depends on the ability and motivation of the individual to perform and maintain effective plaque removal. An important role of the dentist, dental hygienist or dental therapist is to encourage the patient to change and to teach the required plaque removal skills using communication techniques that engage and stimulate (SCDEP, 2014). If necessary, removal of plaque retentive factors can be achieved by a dental care professional.
2.5 Erosive tooth wear

Tooth wear is defined as loss of tooth substance due to a non-bacterial cause. Tooth wear may be due to mechanical causes such as attrition (tooth to tooth), abrasion (toothbrush or other foreign body) and erosion. Typically these processes occur together but erosion from extrinsic or intrinsic acid is a major component in pathological tooth wear (Lussi et al., 2004). ETW is multifactorial with acid as the main cause. Like caries and periodontal diseases, progression can be halted if the aetiological factors can be controlled. Physiological tooth wear occurs throughout life so the extent and severity of wear is age related (Jaeggi and Lussi, 2014). Ultimately, dental erosion can be classed as pathological when it is associated with loss of function, subjective reduction in aesthetics or pain (Schlueter et al., 2012).

2.5.1 Clinical assessment, classification and management

The Basic Erosive Wear Examination (BEWE) is similar to the BPE and links the grading of lesions with clinical management (Bartlett et al., 2008; Ganss and Lussi, 2014). The worst score in each sextant is recorded and a total calculated. This total is then linked to severity and treatment need. Scores 0-2 are considered to be no risk, scores 3-8 are considered low risk, scores 9-13 are considered medium risk and scores of 14-18 are considered high risk. However these are arbitrary boundaries and it is recognised that they may need to be reconsidered (Bartlett et al., 2008).

2.5.2 Risk factors

Although erosion is caused by acidic substances from a variety of sources, there are some individual factors that may predispose to or protect against erosion. Saliva rates, buffering capacity and differing clearance rates from various parts of the mouth may modify the severity and distribution of erosion. Current knowledge suggests that the variation in predisposition to ETW is due to differences in susceptibility of dental hard tissues to dissolution, and to differences in saliva (Buzalaf et al., 2018).

Reduced salivary flow rate; is a risk factor for ETW. Flow rate can be reduced by high levels of exercise (Frese et al., 2015), systemic disease (e.g. Sjögren’s syndrome) and some medications (Carvalho et al., 2018).

Reflux/vomiting; can increase the risk of ETW. However, to be significant, frequent reflux over an extended period of time is necessary. A raised prevalence of ETW has been identified in groups of people in which frequent and persistent regurgitation is a symptom of an underlying medical condition. Such conditions include gastro-
oesophageal reflux disorder (GORD); rumination and eating disorders with frequent vomiting e.g. bulimia nervosa. Active lifestyles, leisure and fashion trends can also be associated with greater risk of erosion, particularly when used to control weight (Kaidonis, 2012).

**Drinking and eating habits;** although the evidence to associate ETW with dietary factors is weak, evidence linking dental erosion with soft drink consumption is emerging (Lussi et al., 2004; Carvalho et al., 2018). Drinking habits are important e.g. sipping or swishing. Carbonated beverages, fruit juices, smoothies, and fruit flavoured mineral waters, are tangy or refreshing because of the acidity. Artificially sweetened diet drinks can be as acidic as normal varieties (Omid et al., 2016). Fresh fruit, and in particular citrus fruit, have erosive potential as do foods pickled in vinegar (Bartlett et al., 2011).

Some medications (e.g., acidic saliva stimulants or preparations containing acetylsalicylic acid) and dietary supplements (e.g., vitamin C tablets) are potentially erosive if they are in the form of chewable tablets or effervescent drinks. Other medications have the side effect of reducing salivary flow. The greater the amount of erosive products consumed per day, and the more often they are consumed, the greater the risk of ETW (Carvalho et al., 2018).

### 2.5.3 Preventive measures

No clear preventative advice is available from DBOH. The softened tooth surface caused by exposure to acidic products is not remineralised by saliva over short time periods. Therefore, postponing brushing after eating acidic products is not a useful preventive measure, especially as brushing is a vehicle for delivery of fluoride in the prevention of caries (Buzalaf et al., 2018).

### 2.6 Impact of oral health problems on wellbeing

Oral health problems can have an impact on quality of life through limitation in function, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap (White et al., 2012; Locker and Quinonez, 2011; Brennan and Teusner, 2015). Basic activities of daily life affected include eating, speaking, cleaning teeth, going out, relaxing including sleeping, smiling, laughing and showing teeth without embarrassment, carrying out one’s major work or role, emotional stability and enjoying contact with other people (White et al., 2012; Nuttall et al., 2011).

The impacts of oral health can be measured by recording both the frequency and the severity of problems and associated discomfort or dysfunction using self-reported
outcome-measurement instruments including questionnaires (Slade, 1997). The ADHS 2009 found that overall 16% of UK adults reported at least one oral impact occurring either frequently or very frequently in the past 12 months and this increased to 41% if impacts occurring occasionally were included. The same survey found that 17% of adults reported a severe negative effect on their ability to carry out at least one of the basic functions of daily life in the past 12 months. This prevalence increased to one third (36%) when any degree of severity of impacts was included (White et al., 2012).

In summary, the prevalence of oral diseases and their associated negative impacts in the general population remains substantial, despite the availability of simple evidence-based preventive measures. To perform at the highest level, athletes need to be well prepared, fit and healthy, and at elite level where the accumulation of marginal gains is critical, poor oral health has the potential to have a negative impact on athletic performance. The next section will review measures of performance in sport and surveillance of health in elite athletes.

### 2.7 Health, training and performance of elite athletes

For the purpose of this thesis, elite and professional athletes are defined as participants in primarily physical sport. Physical activity relates to any action that exerts the body harder than at rest whereas exercise is a form of physical activity that is specifically planned, structured and repetitive. Sport includes both physical activity and exercise, with the additional incorporation of rules that govern play, specific training programmes to improve performance and an element of competition (Budd and Egea, 2017). SportAccord (www.wikipedia) provides a useful classification of sport (Table 2.2).

#### Table 2.2 Categories of sport

<table>
<thead>
<tr>
<th>Category of sport</th>
<th>Common examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primarily physical</td>
<td>Athletics, rugby union, swimming</td>
</tr>
<tr>
<td>Primarily motorised</td>
<td>Formula One, powerboating</td>
</tr>
<tr>
<td>Primarily coordination</td>
<td>Archery, billiards</td>
</tr>
<tr>
<td>Primarily animal supported</td>
<td>Equestrian, polo</td>
</tr>
<tr>
<td>Primarily mind</td>
<td>Chess</td>
</tr>
</tbody>
</table>

Sporting events can last from seconds (e.g., jumps, throws) to weeks (e.g., Tour de France cycling stage race), with success being determined by a complex and often changing range of characteristics, including power, strength, endurance, agility, skill, and decision making (Burke and Hawley, 2018). An elite athlete is one who is on a programme at the highest level e.g. Olympic games, or professional level (Swann et al., 2012).
2015). As such they have a lifestyle that is very different to that of the average person. For example, the average elite British athlete:

- Consumes more than 1.1 million calories a year, equivalent to eating three Christmas dinners a day
- Commits six hour a day, six days a week, 12 months a year to training and competitions
- Has been working towards their Olympic or Paralympic goal for 11 years
- Seriously took up their sport at the age of 14 years and now competes in seven international competitions per year (www.insidethegames).

One study found that a sample of Olympic champions was characterised by the ability to cope with and control anxiety, confidence, mental toughness, sport intelligence, the ability to focus, competitiveness, a hard work ethic, goal-setting abilities, coachability, high levels of hope and optimism, and adaptive perfectionism (Taylor et al., 2008). However, an athlete’s approach to risk of injury and illness is influenced by many external factors other than the athlete’s best interests. For most elite athletes, sport is their means to financial security. Some athletes might be perceived as essential to the team and may therefore be allowed to participate at a higher tolerance for risk (Levy and Delaney, 2012).

Physical sports can be differentiated according to the associated type of activity. Endurance sports mainly require a submaximal effort over a prolonged period, whereas explosive sports require short bursts of high intensity (Budd and Egea, 2017). Team sports require a mix of endurance base and bursts of intensive effort. Different sports therefore require a mix of physiological qualities that are reflected in their training principles to reach peak performance. An athlete’s performance is contingent on a favourable interplay of athletic attributes and skills (biological and physiological variables), environmental and system level factors, personal characteristics and chance events (Gulbin et al., 2013). However, training and competition are the major components of an athletes’ lifestyle, therefore availability for competition is ultimately dependent upon health (both physical and psychological) and wellbeing.

The aim of training is to improve an individual’s performance in their chosen sport. Four key elements of training can be applied to the majority of sports. These are aerobic capacity development (VO₂ max), amelioration of exercise economy, increasing lactate/ventilatory threshold and strength. Flexibility training is also an important element of fitness training to reduce injury risk and ultimately improve performance (Budd and
Egea, 2017). These parameters can be measured objectively, and direct observation also includes GPS data (Borresen and Lambert, 2009).

The feelings that people perceive from their body can provide a summation of their physical condition, underlying mood and emotional state, therefore athlete self-reports of symptoms need to be included as an essential part of data collection frameworks (Timpka et al., 2014b). However, elite and professional athletes endeavour to train and compete even when ill or injured and their motivation may be intrinsic or extrinsic (due to coach and team pressures). In reality, optimal athlete health is a spectrum ranging from complete wellness to multiple existing injuries, illnesses and other health related issues (Dijkstra et al., 2014).

2.7.1 Exercise-induced immune suppression

The general basis for planned athlete performance improvement is functional overreaching (Timpka et al., 2014b). However, there is a brief period of immunosuppression after acute intense physical activity that is an immunological “window” during which an athlete may be more susceptible to infection (Brukner and Khan, 2014). The innate immune system comprises the skin, mucous membranes, phagocytes, natural killer (NK) cells, cytokines and complement factors. Cytokines and complement control and mediate immune function and help activate T- and B-lymphocytes, key parts of the acquired immune system.

The acquired immune system protects the body against specific infectious agents during both initial and subsequent challenges but strenuous prolonged exertion and heavy training are associated with depressed immune function. It has been proposed that regular moderate exercise decreases the risk of upper respiratory tract infection to below that of sedentary people whereas strenuous physical activity increases the risk above that of sedentary individuals (Gleeson, 2007).

Prolonged bouts of strenuous exercise cause a temporary depression of various aspects of immune function (e.g., neutrophil respiratory burst, lymphocyte proliferation, monocyte antigen presentation) that usually lasts approximately 3-24 h after exercise, depending on the intensity and duration of the exercise bout. Post-exercise immune dysfunction is most pronounced when the exercise is continuous, prolonged (>1.5 h), of moderate to high intensity (55-75% maximum \( O_2 \) uptake) and performed without food intake. Although elite athletes are not clinically immune deficient, it is possible that the combined effects of small changes in several immune parameters might compromise resistance to common minor illnesses (Gleeson and Bishop, 2013; Nieman et al., 1990).
The incidence of common illnesses to training load has been linked to spikes in training (Foster, 1998). Some studies in Australia have examined the relationship between mild illness and sporting performance. Although the mean negative performance effects within the group as a whole may be trivial to small, the impact on an individual could be substantial (Fricker et al., 2005; Pyne et al., 2005).

Cytokine overproduction has been implicated in chronic inflammatory periodontal diseases, therefore it is feasible that the temporary depression of immune function could contribute to episodes of periodontal disease activity. Recent data show that atherosclerotic vascular diseases and periodontal diseases interact with each other via systemic release of specific pro- and anti-inflammatory cytokines, which modulate initiation and progression of the chronic inflammatory reaction involved in both diseases (Aarabi et al., 2015).

2.7.2 No pain, no gain

Functional over-reaching can also lead to athletes becoming fatigued and experiencing pain. Pain is an unpleasant sensory and emotional experience that can be a protective output of the brain and a marker of tissue damage. However, anything that relates to the brain’s evaluation of danger to body tissue will modulate pain (Newlands et al., 2015). If the brain concludes that there is something more important than protecting a body part, then it makes the executive decision to not produce pain (Bruckner, 2012).

Many elite athletes consider pain to be a normal component of training will only acknowledge an injury when the pain prevents participation in training/competition (Bolling et al., 2018a). In elite sport there has historically been a culture of using painkillers to continue playing (Hainline et al., 2017; Harle et al., 2018). Severe pain from oral diseases usually only occurs in later stages and athletes may well be in the habit of ignoring the signals associated with early stage oral disease.

2.8 Health problems related to participation in sport

Although the health benefits of moderate exercise have been well-documented, training, nutritional considerations and competition at elite level may increase the health risks to an athlete (Dijkstra et al., 2014; Ashley et al., 2015). Data regarding the prevalence of injury and illness have been collected at the Olympic Games since Beijing 2008 (Junge et al., 2009) mainly through surveillance studies. Information from the London 2012 Olympic Games showed that 11% of athletes sustained at least one injury and 7% suffered an illness during the competition period (Engebretsen et al., 2013) and these
figures are similar to the prevalence of injury and illness recorded at other major championships (Junge et al., 2009; Edouard et al., 2014).

Historically the focus of sports and exercise medicine (SEM) was the treatment of acute injury, i.e. bodily harm resulting from the transfer of energy during participation in sport in discrete events (Timpka et al., 2014b). Sports injuries can occur during any sporting activity, event or training session and they can be classified by location, type, body-site and injury event. However, the concept of sports impairment has developed to reflect the consequences of overtraining or overuse injuries resulting from exposure to training. Therefore an injury can be categorised as either acute or overuse depending on the mechanism of injury and the onset of symptoms (Bruckner, 2012). The definition from athletics is:

“A physical complaint or observable damage to body tissue produced by the transfer of energy experienced by or sustained by an athlete during participation in athletics training or competition, regardless of whether it received medical attention or its consequences with respect to impairments in connection with competition or training.” (Timpka et al., 2014a).

However, athletes may also experience sports impairment as a consequence of illness and the definition, again from athletics is:

“A physical or psychological complaint or manifestation by an athlete not related to injury, regardless of whether it received medical attention or its consequences with respect to impairments in connection with competition or training”. (Timpka et al., 2014a)

An athlete may experience a sports impairment for some reason other than physical injury or illness, therefore the concept of sports impairment has been further expanded to include any athlete health related incident (HRI). This umbrella term includes injury, illness, burnout, overtraining etc. and the definition from athletics is:

“Any physical or psychological complaint or manifestation experienced by an athlete, irrespective of the need for medical attention or time loss from athletics activities” (Timpka et al., 2014a).

Recording of HRIs is the first stage in identifying conditions that have a negative impact on training and performance, therefore distinguishing between impairment concepts based on aetiological factors is important in the identification of appropriate preventive strategies. For example, a different approach will be required to prevent trauma compared to infection, compared to overuse injuries (Timpka et al., 2014b).
2.9 Protecting the health of elite athletes and prevention of injury/illness

The protection of an athlete’s health and preventing injuries and illnesses are top priorities for the IOC and its medical commission (Engebretsen et al., 2014). Surveillance studies are necessary for providing evidence for health development in sports as well as for developing prevention programs. Another method to decrease injuries and diseases in the elite athlete is to perform a pre-participation examination (PPE) or periodic health evaluation (PHE) of all elite athletes (Junge et al., 2009).

Primary prevention includes health promotion and prevention of conditions among those that have never had experience of the condition. Secondary prevention refers to early diagnosis and intervention to limit the development of disability and/or reduce the risk of the condition recurring. Tertiary prevention is the focus on treatment and rehabilitation to reduce/correct an existing problem attributed to an existing condition (Brukner and Khan, 2014; Pitts and Zero, 2016; Chapple et al., 2015). The classic conceptual model proposed by van Mechelen (van Mechelen et al., 1992) for prevention of sports injuries has been expanded to that proposed by Finch; the Translating Research into Injury Prevention Practice framework, or TRIPP (Finch, 2006): the initial stage for both models is that of injury and/or illness surveillance.

Systematic monitoring of injury and illness in elite athletes can generate epidemiological data which in turn can be used to identify risks and develop preventive strategies (Engebretsen et al., 2013), and this approach has been adopted by several sports federations. In 2007 the International Association of Athletics Associations (IAAF) introduced routine data collection on injury incidence and characteristics during the World championships at Osaka (Alonso et al., 2010) and data regarding the prevalence of injury have been collected at the Olympic Games since Beijing 2008 (Junge et al., 2009). In 2009, both the IAAF and the Federation Internationale de Natation (FINA) introduced pilot projects to include illness and the International Olympic Committee (IOC) added illness surveillance for the 2010 Vancouver Winter Olympic Games (Alonso et al., 2010).

Further to this, many sports have produced consensus reports for the recording of injury/illness and most measures related to health address the key concepts of symptoms and physical and psychosocial function. However, other models (Wilson and Cleary, 1995) also include the concepts of negative health perceptions and overall quality of life. Including these concepts may increase understanding of the impact of health-related incidents on performance in sport.
2.10 The impact of injury and illness on training and performance

The negative consequences of health problems include impairment, activity limitation and participation restrictions (Ljungqvist et al., 2009; Matheson et al., 2013). In order to capture these negative effects, epidemiological studies in SEM have employed definitions such as time loss, medical attention and all complaints (Clarsen and Bahr, 2014).

**Time loss:** represents the narrowest of the three consensus-recommended definitions and is the one that is likely to record the fewest incidents. An inability to participate fully in planned training and competition is a relatively reliable outcome measure, allowing for the comparison of data among different teams and across multiple seasons as athlete availability can be crosschecked with independent records. However, athletes often continue to train and compete despite the existence of injury. Common management strategies, such as the use of analgesic medications and anaesthetics, modification of the type or intensity of training and delaying treatment or rest until the off-season may lead to a large number of injuries or other HRIs being missed.

**Medical attention:** is usually recorded during large sporting events such as the Olympic Games as the information is useful for the organisers to plan for future events. The reporting of medical-attention incidents is likely to capture a far greater number of conditions than time loss and may provide a more complete picture of the true burden of injury and illness. However, attendance at an ancillary practitioner such as physiotherapists, chiropractors, athletic trainers and massage therapists may not be considered to be medical attention.

**All complaints:** is the most common consensus-recommended surveillance definition, but there are relatively few examples of it being used in its true form (i.e. registration of all HRIs, including those that do not lead to medical attention). Because surveillance studies have traditionally used medical staff to record data, these staff are unlikely to be aware of conditions not requiring medical attention.

**Athlete-reported:** outcome measures (AROMs) such as questionnaires and diaries are a relatively simple and inexpensive approach to monitoring athlete health and the impact of HRIs on performance (Saw et al., 2015a). They provide an athlete-orientated perspective of how an athlete feels and performs, which in turn is more likely to capture the nuances of all HRIs including mild or chronic conditions that do not prevent an athlete from continuing to participate in training or competition (Clarsen et al., 2013).
In summary, athletes need to remain healthy in order to participate in demanding training programmes designed to produce the performance improvements that can lead to success in competition at elite level. Surveillance of athlete health using objective measures is an important component of the management of athlete health and AROMs can add useful information from the athlete’s perspective. Traditionally the focus of surveillance has been on acute injury and the consequences measured in time loss. However there is growing recognition of the need to consider all aspects of athlete health and wellbeing within the elite sport environment in order to protect athlete health for the future (Weissensteiner, 2015).

2.11 Oral health and disease in elite and professional athletes

Oral health is an integral part of athlete health that appears to have been overlooked. Previous research indicates that oral health in elite or professional athletes is poor and at best is no better than in non-athlete disadvantaged populations (Needleman et al., 2013; Ashley et al., 2015; Needleman et al., 2014; Needleman et al., 2016; White et al., 2011). Table 2.3 presents a summary of the prevalence of oral conditions reported in these studies. Although it is difficult to identify a control group, these results suggest that the prevalence of caries, ETW, and gingival inflammation is consistently higher in athletes than in the general population.

<table>
<thead>
<tr>
<th>Study</th>
<th>Caries</th>
<th>ETW</th>
<th>Gingivitis</th>
<th>Periodontitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>London 2012 Olympics</td>
<td>55%</td>
<td>45%</td>
<td>76%</td>
<td>15%</td>
</tr>
<tr>
<td>Systematic review</td>
<td>15% - 75%</td>
<td>36% - 85%</td>
<td>up to 76%</td>
<td>up to 15%</td>
</tr>
<tr>
<td>English professional football 2014</td>
<td>37%</td>
<td>53%</td>
<td>80%</td>
<td>5%</td>
</tr>
<tr>
<td>Adult dental health survey 2009 (16-24 year-olds)</td>
<td>30%</td>
<td>52%</td>
<td>50%</td>
<td>29%</td>
</tr>
</tbody>
</table>

In general, the methodological quality of studies included in the systematic review was considered low (Ashley et al., 2015). The sample of athletes in the London 2012 study was subject to selection bias as the athletes had chosen to attend the dental clinic, and the results of the 2014 English professional football study, although representative, may not be generalisable as this was a sample from a single sport and entirely male. The conclusion of the systematic review was that “contrary to common perception that elite
athletes are healthy…..the oral health of athletes included in the study was poor” (Ashley et al., 2015).

The systematic review also identified five papers that reported on pericoronitis or impacted third molars and 4.6%-39% of athletes were judged to require removal of one or more wisdom teeth. The majority (82%) of all studies identified by the systematic review reported on trauma; the prevalence varied greatly between studies and sport, from 14% to 57%. Nearly one-third (30%) Olympic athletes reported a history of orofacial trauma and 17.6% presented with new trauma. One-fifth (21.7%) of the footballers reported a history of trauma due to sport.

Athletes who compete in sports that emphasise leanness or low body weight may develop disordered eating (Martinsen et al., 2010; Mountjoy et al., 2014). The acidic challenge to the teeth from repeated vomiting as in bulimia nervosa can lead to severe acid erosion (Carvalho et al., 2018).

In summary, oral health is a basic human right of athletes, but the evidence suggests consistently that it is poor, with a high treatment need. The previous focus of research was on provision of treatment and the epidemiology of trauma. Consequently, the research base to inform oral health in SEM is limited in both quality and quantity. Therefore, further epidemiological evaluation of representative samples of athletes are required to establish the oral health needs across different sports (Needleman et al., 2014; Ashley et al., 2015).

2.12 Challenges to oral health in sport

Oral diseases can, to an extent, be considered lifestyle diseases. Although genetics are key determinants, particularly for periodontal diseases (Jepsen et al., 2018), oral health may be compromised by the daily routines of an elite athlete. The demands of training, travel and competition can alter the body’s homeostasis and make it difficult to fit in with conventional lifestyle expectations. The requirement to fuel training and competition with refined carbohydrate and/or acidic sports nutrition products can increase the risk of caries and ETW. Alterations in saliva flow during hard effort can increase the risk of caries, ETW and gingival inflammation. Post exercise dips in immune function may increase the risk of periodontal diseases (Needleman et al., 2014; Needleman et al., 2018).


2.12.1 Nutrition

Nutrition and training interact to promote effective adaptation and optimal competition performance, therefore fueling strategies during training should match the demands of the session. During competition, the key role for nutrition is to address the specific limiting factors that would otherwise cause fatigue or a decrement in performance (Burke, 2015). To maintain immune function, athletes should eat a well-balanced diet sufficient to meet their energy requirements.

An athlete exercising in a carbohydrate-depleted state experiences larger increases in circulating stress hormones and a greater perturbation of several immune function indices. Conversely, consuming carbohydrate during exercise attenuates rises in stress hormones such as cortisol and appears to limit the degree of exercise-induced immunosuppression, at least for non-fatiguing bouts of exercise (Gleeson et al., 2001). Athletes including distance runners (Needleman et al., 2018) and professional jockeys, have been reported to engage in disordered eating (Wilson et al., 2014; Scoffier et al., 2011).

2.12.2 Salivary flow

During exercise, an athlete switches from nose to mouth breathing, which causes increased cooling and drying of the respiratory and oral mucosa (Brukner and Khan, 2014). Long training sessions may result in decreased salivary flow due to dehydration and mouth breathing (Bryant et al., 2011). One study investigating the impact of endurance training on oral health in 35 non-elite triathletes and 35 non-exercising controls, found no difference between athletes and non-active controls regarding caries prevalence and salivary parameters measured during inactivity. However, in the triathlete group, a significant correlation was found between total caries experience (not active caries) and the cumulative weekly training time ($r = 0.347$, $P = 0.04$); the mean BEWE score was significantly higher in the triathlete group ($p = 0.001$).

In a sub-sample of 15 triathletes tested after maximum workload using incremental field running tests, saliva flow rates decreased ($P = 0.001$ stimulated; $P = 0.01$ unstimulated) and saliva pH increased significantly ($P = 0.003$). This small study did not include elite triathletes and the training data and use of sports nutrition products was self-reported. However, due to the increased risk of erosion and caries and associated changes in saliva, the authors emphasised the need for risk-adapted preventive dental concepts in the field of sports dentistry (Frese et al., 2015).
2.12.3 Oral health related behaviours and risks to oral health

The most important behavioural factor, affecting both dental caries and periodontal diseases, is routinely performed plaque removal (oral hygiene) with a fluoride toothpaste. In addition, there is clear evidence of diet having a strong influence on caries, and there is some evidence that it affects periodontal diseases (Jepsen et al., 2017).

Social background is strongly associated with risk for dental caries and periodontitis. Furthermore, social background heavily influences the behaviour of individuals. At a personal level, an individual's perception of control (locus of control) is considered an important socio-behavioural factor in general and there is some evidence that having a strong internal perception of control contributes to the prevention and control of dental caries and periodontal diseases (Acharya et al., 2015).

A few studies that include high performance athletes have investigated athlete reported oral health-related behaviours and risks to oral health (Azodo and Osazuwa, 2013; Bryant et al., 2011; Needleman et al., 2013; Needleman et al., 2016). Questions about positive behaviours included frequency of toothbrushing, use of floss, most recent dental visit and dental advice received. Questions about risks to oral health included smoking, use of sports drinks, mouthguard type and compliance of use.

A systematic review found no evidence to support or refute poor oral health with reduced availability of dental care (Ashley et al., 2015), however the quality of the included studies was low. A study of Olympic athletes found no statistically significant association with sports drinks and caries or erosion (Needleman et al., 2013) and a study of professional footballers found no statistically significant association between caries and most recent dental visit, neither did it find an association between sports drinks and caries or erosion (Needleman et al., 2016). These data were self-reported therefore the reliability might be limited.

A study of triathletes concluded that the athletes’ pattern of consumption of sports nutrition products put them at increased risk of caries and erosion but did not report any associations between behaviour and clinical diseases (Bryant et al., 2011). Therefore, the relationship between oral health-related behaviours and risks to oral health reported by athletes and clinical measures of oral health remains unclear.

2.13 Protecting the oral health of elite athletes

Screening is a strategy used in a population to detect a disease in individuals without signs or symptoms of that disease. The intention is to identify pathologic conditions early,
thus enabling earlier intervention and management in the hope of reducing future morbidity and mortality. To ensure that screening programs confer the intended benefit, the World Health Organisation published what have become known as the Wilson-Jungner criteria for appraising a screening programme (Wilson & Jungner 1968).

The main criteria are: that the condition being screened for is an important health problem (not just on how serious the condition is, but also how common it is), that there is a detectable early stage, that treatment at an early stage is of more benefit than at a later stage and that a suitable test is available to detect disease in the early stage.

Oral diseases are preventable and even simple interventions can lead to a dramatic improvement in oral health (Twetman, 2009; ten Cate, 2013; SCDEP, 2014). DBOH identifies a range of positive changes that if adopted can improve oral health (Public Health England, 2017), but it might have limited relevance to elite athletes. Wide-scale implementation of cost-effective intervention measures and treatment protocols under real-life conditions is an ongoing challenge in sport and knowledge about effective implementation does not necessarily mean that implementation is successful (Verhagen et al., 2014).

To be effective, preventive measures need to be acceptable to, adopted by and complied with by all stakeholders in sport (Finch, 2006) and the Knowledge Transfer System (KTS) has been designed to help bridge the gap between knowledge derived from research and evidence-based usable information and tools for practice. This system combines a top down approach with input from experts and a bottom-up approach with input from the key stakeholders within sport (Verhagen et al., 2014).

To date there is a paucity of evidence to support or refute the efficacy of oral health-related interventions in sport, but social factors, lack of awareness, lack of prioritisation and demanding training regimes might make it difficult for athletes to access oral health related preventive care (Needleman et al., 2014). Not all new disease can be anticipated therefore there is potential for everyone to benefit from preventive advice, regardless of perceived risk and if preventive treatment is also offered this serves to establish new social norms for self-care based on oral health-related behaviours (Public Health England, 2017).

The behaviour change wheel (BCW) is a contemporary method for characterising and designing behaviour change interventions (Michie et al., 2011). Athletes, coaches other support staff and sports bodies may be more likely to implement the related changes in
behaviour if they are involved in their development and believe better oral health can be associated with performance gains.

In summary, there are many challenges to the oral health of athletes, including nutrition, impaired host response, poor oral health behaviours and oral health literacy. However, there is a lack of evidence to explain the determinants of oral health in sport. Associations between oral diseases and postulated risk factors are weak if present at all. Further epidemiological evaluations of representative samples of athletes are required to establish the determinants of oral health both of the individual and their environment. Athlete-reported oral health-related behaviours and risks to oral health need to be investigated in order to identify opportunities for behaviour change, which could lead to improved oral health in athletes.

2.14 Impact of poor oral health on athlete wellbeing, training and performance

As poor oral health negatively affects oral-health related quality of life (Locker and Quinonez, 2011) it is possible that such an impact could adversely affect athletic training and performance. In elite sport, any decrement in performance, no matter how small, can be catastrophic to the athlete who has invested years working toward a major competition such as the Olympics. For example, in the 100m sprint, a performance decrement of 1% (about 0.1 s for men) might mean the difference between finishing in medal contention or not. In swimming, only a 4–5% difference separates times required to qualify to compete in the Olympics from world record times (MacKinnon 2008).

AROMs of performance may provide an insight into the subtle impact of oral health problems in sport from the athlete’s perspective. At the 2012 London Olympics, impact on athlete performance and training was assessed using a modification of the shortened global evaluation of impact of oral health on quality of life, a measure that has been validated in the general population ( Locker and Quinonez, 2011). There was a substantial self-reported negative impact reported: 40% of the athletes who presented to the clinic said they were “bothered” by their oral health, 28% reported an impact on quality of life and 18% reported an impact on training or performance (Needleman et al., 2013). The same three questions, used in a survey of professional footballers, found that 45% were bothered by their oral health, 20% reported an impact on their quality of life and 7% reported an impact on training or performance (Needleman et al., 2016).

A systematic review identified three other studies that reported the impact of oral health on performance using self-reported outcome measures (Ashley et al., 2015). Although
there was no evidence that the questions had been assessed for evidence of validity in the general population or in sport, in one study at the Barcelona 1992 Olympic Games, 8% of those surveyed thought oral health problems had disturbed their training and 5% thought it had affected their sporting performance. One third of Brazilian basketball players reported increased insecurity about playing after match-related orofacial trauma and 66% felt that oral health problems could “diminish their strength” (Frontera et al., 2011).

In summary, the evidence suggests that poor oral health negatively affects the training and performance of athletes. The mechanisms behind this are not known, but may include pain, reduced wellbeing and quality of life, other psychosocial impacts and increased systemic inflammation. Inflammation has been identified as the common link between physical activity, metabolic and periodontal diseases (Eberhard, 2019; Wernicke et al., 2018).

The questionnaires used previously in oral health and sport research have provided useful exploratory information, but their validity for use in an elite athletic population has not been assessed. Therefore, there is a need to identify a self-reported outcome measure of the impact of HRIs, with evidence of validity in sport. This can then be used to strengthen the quality of future research that aims to measure the impact of oral health on elite athlete performance.
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3 Study hypotheses and research questions

Chapter 2 presented a review of the literature and identified gaps in the knowledge base to inform on the oral health of elite athletes and impact on performance. The resulting study hypotheses and related research questions are presented in this chapter.

Study hypothesis 1: Oral health problems (poor oral health) in elite athletes are associated with negative impacts on quality of life, training and competition.

   Research question 1: Is there a self-reported outcome measure with evidence of validity in sport to evaluate the impact of oral health problems on athlete performance?

   Research question 2: What is the extent and severity of oral health problems in elite athletes?

   Research question 3: What is the extent and severity of the impact of oral health problems on performance in elite athletes?

Study hypothesis 2: Interventions based on contemporary behaviour change theory can improve oral health and reduce performance impacts in elite athletes.

   Research question 4: What are the behavioural determinants of oral health in elite athletes, and are they willing to consider making changes?

   Research question 5: Can a pragmatic oral health intervention based on contemporary behaviour change theory lead to improvements in oral health and a reduction in negative performance impacts?

Table 3.1 outlines the research questions, corresponding study designs and chapter numbers as a brief summary of the research presented in the remainder of this thesis.
Table 3:1 Thesis structure

<table>
<thead>
<tr>
<th>Research question</th>
<th>Study design</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there an outcome measure with evidence of validity in sport to evaluate the impact of oral health problems on athlete performance?</td>
<td>Systematic review.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>What is the extent and severity of oral health problems in elite athletes?</td>
<td>Cross sectional clinical observational.</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>What is the extent and severity of the impact of oral health problems on performance in elite athletes?</td>
<td>Cross sectional questionnaire-based.</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>What are the behavioural determinants of oral health in elite athletes and are they willing to consider making changes?</td>
<td>Cross sectional questionnaire-based.</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>Can a pragmatic oral health intervention based on contemporary behaviour change theory lead to improvements in oral health and a reduction in negative performance impacts?</td>
<td>Repeated-measures intervention.</td>
<td>Chapter 7</td>
</tr>
</tbody>
</table>

Therefore, the starting point for this PhD was to identify a self-reported outcome measure of the impact of oral health on performance with evidence of validity in sport. The following Chapter presents a systematic review of the literature that aimed to identify an outcome measure, appropriate for use in the epidemiological study.
4 Self-reported outcome measures of the impact of health problems on performance in sport: a systematic review

The literature review, presented in Chapter 2, identified several gaps in the knowledge base relating to oral health in sport. The first was the requirement for a valid self-reported outcome measure used in Sport and Exercise Medicine (SEM) research that could be used or modified to evaluate the impact of oral health problems on athletic performance. This chapter will present the background, methods and results of a systematic review that aimed to identify outcome measures of the impact of injury and illness on performance, with evidence of validity for use in an athletic population. The potential for use in SEM research, and in this project in particular, of any outcome measures identified will then be discussed.

4.1 Background

Elite athletes are very different to the general population. As a group, they are young, physically active and healthy (Andrew et al., 2010) and their daily occupation is training in order to perform at their full potential in competition. Consequently, injury or illness of otherwise insignificant severity may prevent Olympic athletes from reaching their lifetime achievement (Engebretsen et al., 2013). As they have higher levels of physical function, psychological function and perceived health than the non-sporting population, even minor morbidity consequences of injury and illness can be important (Andrew et al., 2010). For the purposes of this review, the term “injury and illness” includes any health related incident (HRI).

Standard tests can be applied by a clinician or trainer (e.g. flexibility, squat, hop and jump tests) to provide objective information regarding evaluation of various aspects of body function and physical performance (Davidson and Keating, 2014). They can also be used to measure the impact of injury and illness on performance in terms of loss of function (Davis and Bryan, 2015). Traditionally the consequences of injury and illness in sport are defined in terms of time loss and return to play, however this measure of impact is likely to capture only the very worst problems as many athletes continue to train and compete with symptoms including pain (Bolling et al., 2018a).

Instruments that aim to measure the impact of health-related incidents (HRIs) should capture the full range of consequences including outcomes that reflect the athlete’s perspective about their health and performance. (Andrew et al., 2010; Davis and Bryan, 2015). Therefore, to be comprehensive, surveillance of athlete health that aims to
capture the impact of injury and illness on performance, should include an athlete self-assessment.

Information regarding the prevalence and impact of health related incidents is important to establish the burden of health problems and inform appropriate preventive and health promotion strategies (Needleman et al., 2014; Engebretsen et al., 2014; Steffen et al., 2011).

Many consensus statements regarding collection of epidemiological data in sport use the term “recordable health-related incident” (HRI) rather than “injury”, “illness” or even “medical condition”. This reflects the aspiration to collect information including syndromic data and overuse injuries as well as those injuries leading to time loss: an “all complaints” approach (Timpka et al., 2014a; Clarsen and Bahr, 2014). The “any physical complaint” and “medical attention” definitions of injury have the potential to capture less severe HRIs but tend to be limited to use during short duration tournaments and competition, therefore monitoring athlete preparation facilitates the evaluation and adjustment of practices to optimise performance outcomes (Clarsen et al., 2013).

Athlete-reported outcome measures (AROMs), such as questionnaires and diaries, are potentially simple and cost-effective ways to monitor an athlete’s response to training. However, their efficacy is dependent on how they are implemented and used (Saw et al., 2015a). Interviews can provide a greater depth of qualitative information, but they are time consuming and require commitment from both the researcher and the participant. Additionally, previous reviews of self-reported outcome measures used in sport have found that many of the instruments were developed for use in the general population and demonstrate limited validity within athletic populations (Andrew et al., 2010; Kearney et al., 2012).

Within sports and exercise medicine there is recognition of the need for consensus regarding the methods used to record and measure health related incidents and their consequences for athletes (Andrew et al., 2010; Kearney et al., 2012; Timpka et al., 2014b). Furthermore, outcome measures should be developed with input from their target population (Terwee et al., 2007). Outcome measures of performance designed for use in the general population may not capture the nuances of impairment and impact experienced by elite athletes during training and competition (Clarsen et al., 2013). Therefore, specificity of outcome measure development to high performance sport is likely to be important. They should therefore also have evidence of validity for use within an athletic population.
4.1.1 **Self-reported outcomes**

How a person feels, and what they experience, cannot be measured objectively therefore instruments that reflect a person’s own perspective have been developed. As they have been developed primarily for use in patients, they have the collective title of Patient Reported Outcome Measures (PROMs). Davis and Bryan (2015) state that there are three primary contexts in which PROMs are used in Sports and Exercise Medicine (SEM): clinical practice, clinical research, and healthcare policy. In clinical practice PROMs can be used by patients, in order to more fully understand their condition and they can be used by clinicians, to identify improvements or decline in health outcomes over time. Ideally, an athlete-reported outcome measure (AROM) would be included in return to play assessments.

In SEM clinical research, PROMs are used to evaluate the effectiveness of surgical interventions. In health care policy, PROMs can allow positive and negative health outcomes to be assessed that, in turn, could then be used to support a case for an intervention (Davis and Bryan, 2015). However, athletes may not always seek medical care or present as patients and therefore PROMs may not be sufficient to capture all available information (Ashley et al., 2015; Davis and Bryan, 2015; Dijkstra et al., 2014; Clarsen and Bahr, 2014).

In sport, AROMs of health, wellbeing and performance can add meaningful information to that obtained from traditional physiological and biochemical performance measures (Saw et al., 2015b; Saw et al., 2015a). Research that includes the athlete’s perspective has contributed to a greater understanding of development and performance along with issues pertaining to athlete welfare and wellbeing (Saw et al., 2015b; Weissensteiner, 2015).

4.1.2 **Assessing the quality of studies on measurement properties**

Measurement of health outcomes is essential in scientific research and in clinical practice. Decisions are made based on the scores obtained therefore health status measurement instruments should be reliable and valid to reduce the risk of imprecise or biased results. The COSMIN (COngress-based S tandards for the selection of health Measurement IN struments) checklist was developed to evaluate the methodological quality of studies on measurement properties (Davidson and Keating, 2014; Mokkink et al., 2010b). Therefore, the COSMIN checklist could be useful when selecting a measurement instrument (Mokkink et al., 2010a).
The checklist has three domains. The first domain is Validity and includes the subdomains of content validity, construct validity and criterion validity. The second domain is Reliability and includes the subdomains of internal consistency, reliability and measurement error. The third domain is Responsiveness. Interpretability is also a consideration that is affected by the validity of the outcome for use in the population in which it is applied (Kelly et al., 2005).

Content validity means that the items are relevant to the demographics and desired outcomes of an elite athlete population and will have minimal floor and ceiling effects to detect subtle improvements at the high end of function. Construct validity refers to the correlation between one outcome measure and another measuring similar aspects. Responsiveness is the ability to detect change over time (Andrew et al., 2010). A reliable measure will produce the same results when applied under conditions where change is not expected. High reliability indicates that any changes are due to real change and not measurement error. Agreement can be measured with an intra-class correlation coefficient (ICC) for continuous measures (scales), with the Kappa statistic for categorical measures and Spearman correlation for ordinal variables (Andrew et al., 2010).

4.1.3 Assessing the suitability of an outcome measure

Outcome measures can be generic or specific. Generic instruments allow broad comparisons across different groups. Specific instruments focus on domains that are important to particular conditions. They are more responsive than generic instruments but do not allow comparison across different groups. Instruments should be acceptable to both the athletes and the researcher. Barriers to their use include time to complete and accessibility (Saw et al., 2015a; Valier et al., 2014). Completion time and the degree of difficulty can impact on the completeness of the data collected.

Self-administration by mail or web or at the place of data collection can be advantageous in terms of cost and resources but often at the expense of completeness. Instruments administered by a trained interviewer can be more accurate and complete but are resource intensive (Andrew et al., 2010). Item responses may be on a continuous scale, categorical or ordinal. Measures that are easy to understand, administer, score and interpret are more likely to be useful to all stakeholders in sport including athletes, clinicians, researchers, support staff, funding bodies and policy makers (Andrew et al., 2010).
4.2 **Aim**

The aim of this review was to identify which athlete reported outcomes have been used previously to evaluate the impact of all types of health problems on performance in sport. A secondary objective was to evaluate eligible outcome measures for evidence of validity and potential for use in future Sport and Exercise Medicine research including this PhD.

4.3 **Methods**

4.3.1 **Formulating the research question**

This systematic review was based on a pre-defined specific research question. This clearly formulated question guided the review process including factors such as determining eligibility criteria, the literature search for studies, collecting data from included studies and presenting findings. The research question was formulated under the headings Population, Exposure, Comparison, Outcome and Studies (Table 4.1).

<table>
<thead>
<tr>
<th>Table 4:1 PECOS table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
</tr>
<tr>
<td>Able-bodied, elite and professional athletes aged over 18.</td>
</tr>
</tbody>
</table>

"In elite and professional athletes which self-reported outcome measures have been used to evaluate the impact of injury or illness on performance in sport?"

4.3.2 **Scope: Inclusion criteria**

The focus of the review was to provide a comprehensive and critical summary of existing outcome measures therefore the eligibility criteria were set to be as broad and inclusive as possible

**Population**

Elite level sport was defined as competitive at either Olympic, international, national or professional level (Swann et al., 2015), studies were included if the participants were eligible to train and compete at a high level:

- Competitive-elite athletes regularly compete at the highest level in their sport (e.g., top divisions/leagues, or competing in the Olympic Games etc.) but have not had any success at that level.
• Successful-elite athletes not only compete at the highest level but have experienced some (infrequent) success at that standard (e.g., winning an event or a medal).

• World-class elite athletes experience sustained success at the highest level, with repeated wins over a prolonged period of time (e.g., winning gold medals in consecutive Olympics, or major competitive victories over a number of seasons).

Exposure
Recordable health-related incidents as defined in the consensus statement for Athletics (Timpka et al., 2014a) included:

• “Any physical or psychological complaint or manifestation experienced by an athlete, irrespective of the need for medical attention or time loss”

• Medical interventions to treat sports injuries

Also included were: Oral health problems

Road traffic or other incidents, and domestic accidents were excluded as they are not related to sport activity (Timpka et al., 2014a).

Outcome measures
Outcome measures were included if they were reported by the athlete including assessment in relation to illness, injury or a related intervention. They included but were not limited to: functional assessment tools, return to pre-injury sport, screening tools, patient satisfaction, health related quality of life, adverse effects, functional and generic patient-reported outcome measures (PROMS), athlete diaries, interviews, patient satisfaction surveys, return to play and questionnaires/global questions developed for use within the study. Only studies published in English language were included. Patient reported outcome measures of performance that did not include athlete/self-report were excluded.

Studies
In order to increase the sensitivity of the search, all types of studies were included: descriptive, systematic, epidemiological studies, prospective, cross sectional, case series, experimental clinical research including randomised controlled trials and non-randomised designs. Editorials and letters to the editor were excluded. As the intention was to use any appropriate outcome measure identified from the review in an epidemiological study limited to able bodied adult athletes, studies were excluded from the review based on the following criteria:
• the participants were all under the age of 16
• the participants were competing at a lower level of competition or recreational level
• the participants were disabled
• the study was undertaken with a heterogeneous sample (e.g. elite and non-elite, able-bodied and disabled, under and over age 16) without reporting groups separately.

4.3.3 Search and screening

A sensitive search strategy was devised initially in MEDLINE (Ovid version) including the following search terms: self-report* athlete* patient reported outcome measure* (Appendix A). This search strategy was modified as necessary for use in subsequent searches. Other data bases searched included: EMBASE, CINAHL Plus, SPORTDiscus with Full Text, and the Cochrane library. The searches were carried out to 26th January 2016. The reference lists of included studies were checked for other papers that might be suitable for inclusion.

One reviewer (JG) screened the titles for eligibility. Titles obviously not meeting the inclusion criteria were excluded. Titles and abstracts of remaining reports were screened independently and in duplicate by 2 reviewers (JG and RG). The full text of all potentially eligible studies was assessed for inclusion in duplicate and independently (JG and RG) resolving disagreements by discussion. Where resolution could not be achieved, a third person, experienced in conducting systematic reviews, arbitrated (IN).

4.3.4 Data abstraction

Data abstraction forms were developed to collect data outlined in the systematic review protocol. The forms were piloted on 10 studies that had been excluded from the study by both reviewers. Data were extracted in duplicate and independently by the two reviewers. Where information in a paper was unclear, the corresponding author of that paper was contacted for clarification. Data extraction related to type of study, setting where the study took place, sport, population, injury or illness regardless of need for medical attention and details of the outcomes used.

4.3.5 Quality assessment of outcome measures

Potential outcome measures to use in relation to oral health problems were assessed for evidence of validity of development using a simple pre-defined checklist. This was based
on a taxonomy and criteria for evaluation of measurement properties of health status questionnaires, used in a similar systematic review (Mokkink et al., 2010a; Terwee et al., 2007; Kearney et al., 2012). The criteria include an evaluation of content validity, internal consistency; construct validity, agreement, reliability, responsiveness, floor/ceiling effects and interpretability.

Validity evidence includes face validity (the instrument actually measures the intended construct), content and construct validity. Evidence for content validity was considered to include a clear description of the measurement aim, the target population, concepts being measured and item selection. In addition, the target population should have been involved in item selection. Evidence for internal consistency required factor analysis to be applied, with a Cronbach’s alpha value between 0.7 and 0.95. Ideally, there should have been at least 50 participants, and at least 75% of the results should support a previously defined hypothesis and minimal floor or ceiling effects apparent. Evidence for construct validity included reporting of values to show convergent validity (agreement in scores from other outcome measures that aim to assess similar constructs) and/or divergent validity (low correlation with scores from outcome measures which assess different constructs). Correlation coefficients, such as the Spearman rho or Pearson r, are most commonly reported in construct validation studies.

**Reproducibility (Agreement and Reliability)**

The outcome measure scores should reflect changes where real change has occurred rather than changes due to measurement error. Evidence for agreement included at least 50 participants and the standard error of measurement (SEM) to be reported along with smallest detectable change (SDC) and minimal important change (MIC) or convincing arguments that agreement is acceptable. Evidence for reliability required at least 50 participants and an intra-class correlation coefficient (ICC) of at least 0.7 to be reported.

**Responsiveness (Longitudinal Validity)**

Evidence for the outcome measurement instrument to detect clinically important change over time included correlation with scores from other outcome measures of the same construct. Interpretability was assessed from evidence that a (change in) score was clinically meaningful along with means and standard deviations (SDs) of scores of reference populations and participant subgroups. In addition a minimum clinically important difference (MCID) should have been defined (Davidson and Keating, 2014).
**Floor/ceiling effects**
If these are present, it is likely that extreme items are missing at the lower or upper end of the scale, indicating limited content validity. If more than 15% of respondents achieved the highest or lowest score, then a floor or ceiling effect was seen (Terwee et al., 2007).

**Interpretability**
This is the degree to which one can assign qualitative meaning to a quantitative (numerical) score. Investigators should provide information about what (change in) score would be clinically meaningful (Terwee et al., 2007; Davidson and Keating, 2014).

### 4.3.6 Data synthesis and reporting

The results were combined narratively, using tables of evidence. The characteristics of the outcomes were used to synthesise results as well as validity outcomes. Reporting of the review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Moher et al., 2009).

### 4.4 Results

The search retrieved a large number of irrelevant hits, confirming the high sensitivity and low precision. The combined total of references obtained from the electronic search strategy modified for each database was 6536 articles. After removal of duplicates and titles clearly not relevant to the research question, 1358 articles were further screened by title and abstract for consideration in full text screening. The full text of 159 articles was assessed against eligibility criteria and 21 articles were finally included. Cohen’s kappa of inter-rater reliability for article selection was 0.8. Figure 4.1 is a PRISMA flow chart of included studies.
Figure 4.1 PRISMA flow chart of included studies

Articles identified through data base search
n = 6536

Articles removed following deduplication and screening by title
n = 5178

Articles screened by title and abstract
n = 1358

Articles removed following screening by title and abstract
n = 1199

Articles screened by full text
n = 159

Articles excluded following full text screening
n = 138

Articles included in review
n = 21
Screening results

Two reviewers (JG and RG) screened the full text of 159 potentially relevant articles, independently and in duplicate against the eligibility criteria outlined in the systematic review protocol and 138 were excluded. The reasons for exclusion are outlined in Table 4.2. A full list of excluded articles is presented in Appendix B.

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included participants at lower level of performance.</td>
<td>46</td>
</tr>
<tr>
<td>Outcome not athlete reported.</td>
<td>35</td>
</tr>
<tr>
<td>Included participants &lt;16 years.</td>
<td>31</td>
</tr>
<tr>
<td>Outcome measures = neuropsychological factors.</td>
<td>10</td>
</tr>
<tr>
<td>Impact of injury/illness on performance in dance (not sport).</td>
<td>4</td>
</tr>
<tr>
<td>Impact of anxiety on performance in sport.</td>
<td>3</td>
</tr>
<tr>
<td>Impact of sleep on performance in sport.</td>
<td>3</td>
</tr>
<tr>
<td>Impact of personality on performance in sport.</td>
<td>1</td>
</tr>
<tr>
<td>Impact of psychological skills on performance in sport.</td>
<td>1</td>
</tr>
<tr>
<td>Outcome measure = quality of life.</td>
<td>1</td>
</tr>
<tr>
<td>Outcome measure = failure-based depression.</td>
<td>1</td>
</tr>
<tr>
<td>Outcome measure = emotional distress.</td>
<td>1</td>
</tr>
<tr>
<td>Participants included para-athletes.</td>
<td>1</td>
</tr>
</tbody>
</table>

Subsequently, 21 articles containing 20 different multi-item patient outcomes were included to address the first research question.

4.4.1 Characteristics of included studies

The studies represented a range of countries with the USA being the most frequent (Table 4.3). Seven categories of health problem including hip and groin, knee, shoulder, eyes, oral health, overuse injuries and illness were represented across thirty-four different sports. Ten of the twenty outcome measures were used in evaluations of medical interventions (Cohen et al., 2006; Dugas et al., 2012; Mann et al., 2009; McAllister et al., 2003; Muschawek and Berger, 2010; Naal et al., 2011; Nho et al., 2011; Pascarella et al., 2011; Philippon et al., 2010; Sansone et al., 2014).
### Table 4.3 Characteristics of the included studies

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>8</td>
</tr>
<tr>
<td>UK</td>
<td>3</td>
</tr>
<tr>
<td>Norway</td>
<td>4</td>
</tr>
<tr>
<td>Australia</td>
<td>2</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1</td>
</tr>
<tr>
<td>Sweden</td>
<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number of citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer.</td>
<td>8</td>
</tr>
<tr>
<td>Athletics.</td>
<td>7</td>
</tr>
<tr>
<td>Volleyball, aquatic, baseball, American football, lacrosse, basketball.</td>
<td>4</td>
</tr>
<tr>
<td>Equestrian, cycling, handball, skiing, swimming, wrestling, hockey, tennis, ice hockey.</td>
<td>3</td>
</tr>
<tr>
<td>Gymnastics, rugby, floor ball, archery, beach volleyball, shooting, taekwondo, weightlifting, table tennis.</td>
<td>2</td>
</tr>
<tr>
<td>Cricket, boxing, fitness, golf, judo, water polo, badminton, fencing.</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health problem</th>
<th>Number of citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip/groin.</td>
<td>8</td>
</tr>
<tr>
<td>Any injury/illness.</td>
<td>4</td>
</tr>
<tr>
<td>Knee.</td>
<td>3</td>
</tr>
<tr>
<td>Shoulder.</td>
<td>2</td>
</tr>
<tr>
<td>Oral health.</td>
<td>3</td>
</tr>
<tr>
<td>Eye.</td>
<td>1</td>
</tr>
</tbody>
</table>

### 4.4.2 Characteristics of the questionnaires used in the included studies

A descriptive summary of the 21 included studies is presented as an evidence table in Table 4.4. Studies are listed in alphabetical author order.

#### Number of items and scales

The study specific questionnaires demonstrated a range in the number of items. The OSTRC questionnaire on overuse injuries consisted of four items which were repeated three times for knee, shoulder and lower back. When this was further developed for use in measuring health problems it became a 13-item questionnaire. A number of different scales were used; nine studies had a two-category scale, eight of which were yes/no. One study used major league or minor league to ascertain the level of competition. Five studies used a three-category scale; each used a different set of words and criteria. Four studies used a four-category scale, again with different sets of words and criteria. Three studies used a five-category scale each with different criteria and one study used a six-category scale, with a different measurement tool within the scale.

#### Methods of data collection

A number of methods were used to collect the data; three used e-mail or internet and one used text messaging. Six of the studies conducted the questionnaires using telephone interviews. The time to complete the questionnaires in terms of the burden on
the respondent and the investigator was reported in three studies. This varied from no more than five minutes per day (Matthews et al., 2010) to an average of eight minutes to complete when piloted (Azodo and Osazuwa, 2013) to five separate interviews each lasting 30-45 minutes (Carson and Polman, 2012).

**Units used to measure time loss**

Return to play and time missed from training/competition were measured in units of time. Four studies used months as the measurement unit, two used weeks, four used days and two used minutes/hours. The qualitative study had no scale. An attempt to quantify the severity of the impact of injury/illness, in relation to time lost from training or competition, was made in four of the studies (Bjorneboe et al., 2011; Clarsen et al., 2013; Clarsen et al., 2014; Nilstad et al., 2014). Minimal severity was classified as 1-3 days lost, mild as 4-7 days lost, moderate as 8-28 days lost and severe as more than 28 days lost from training and/or competition.

Athlete-reported outcome measures of performance included return to play, time to return to training/competition, level of competition, perception of performance compared to pre-injury, participation limitation, reduction in volume of training and impact on performance.
Table 4.4 Characteristics of the questionnaires in the included studies

<table>
<thead>
<tr>
<th>Athlete-reported outcome measure</th>
<th>Domains Number of items</th>
<th>Question asked to measure impact on performance</th>
<th>Scale</th>
<th>Time to complete/setting</th>
<th>Population where it has been validated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Injury surveillance.</strong> Structured interview. OSTRC injury questionnaire (Bjorneboe et al., 2011).</td>
<td>History of training/playing. Presence of injury.</td>
<td>Did you participate fully in first team training and available for match selection each week? Were you selected for the match squad?</td>
<td>Yes or No.</td>
<td>Professional administered. End of season.</td>
<td>Based on questionnaire developed for use in other elite sport groups.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains</td>
<td>Number of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
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</tr>
<tr>
<td><strong>OSTRC Questionnaire on health problems</strong> <em>(Clarsen et al., 2014)</em>.</td>
<td>History of illness/injury. Impact on performance.</td>
<td>(4 items).</td>
<td>Have you had any problems participating during past week due to illness/injury/other health problem? To what extent have you reduced your training volume over the past week due to illness/injury/other health problem? To what extent have injury/illness/other problems reduced your performance during the past week? To what extent have you experienced symptoms/health complaints related to your sport during the past week?</td>
<td>As above.</td>
<td>Self-administered e-mail, followed up by telephone for clarification if needed.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains Number of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population where it has been validated</td>
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</tr>
<tr>
<td>Shoulder injury and repair. Study specific questionnaire. L'Insalata,* ASES* (Cohen et al., 2006).</td>
<td>Returning to pre-injury level of athletics. (1 item).</td>
<td>Level of return to play.</td>
<td>3 categories: Return to pre-injury level. Return in a limited capacity. Unable to play at all.</td>
<td>Professional/self-administered.</td>
<td>None. L'Insalata. ASES. Validated for use in the general population.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population where it has been validated</td>
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<td>-------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>KJOC shoulder and elbow questionnaire (Franz et al., 2013).</td>
<td>Playing with pain. Impact on performance. Relationship with coach. (10 items).</td>
<td>How difficult is it to get loose or warm prior to competition or practice? How much pain do you experience in your shoulder or elbow? How much fatigue do you experience? How unstable is your shoulder/elbow? How much have problems affected your relationship with coach/management? How much has your velocity or power suffered? What limitation do you have in endurance? How much has your control suffered? How much do you feel your arm affects your current level of competition?</td>
<td>10-point VAS score.</td>
<td>Self-administered at beginning and end of playing season.</td>
<td>Validated in overhead throwing athletes.</td>
</tr>
<tr>
<td>Illness surveillance. Athlete diary (Matthews et al., 2010).</td>
<td>Demographics. Training load. Illness behaviour.</td>
<td>Did you train? Are you ill or injured?</td>
<td>3 categories to score impact on training: Score 1 minimal = normal training. Score 2 moderate = modified training. Score 3 severe = discontinued training. Yes/No.</td>
<td>Self-administered.</td>
<td>Based on questionnaire developed by Australian Institute for Sport.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains Number of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population where it has been validated</td>
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</tr>
<tr>
<td>Hip groin injury and repair. Study specific questionnaire (Muschaweck and Berger, 2010).</td>
<td>Return to play. Pain. (5 items).</td>
<td>Resumption of sport within 28 days. Time to resumption of sport (days). Full return to sport within 28 days. Time to full return to sport (days).</td>
<td>Time: in days. Level of performance.</td>
<td>Telephone interview.</td>
<td>None.</td>
</tr>
<tr>
<td>Oral health surveillance. Study specific questionnaire (Needleman et al., 2013; Needleman et al., 2016).</td>
<td>Health behaviours. History of oral problems. Impact on performance. (3 items).</td>
<td>To what extent have you been &quot;bothered&quot; by your mouth, teeth or gums over the past 12 months? To what extent have your mouth, teeth or gums affected your quality of life over the past 12 months? To what extent have your mouth, teeth or gums affected your athletic training or performance over the past 12 months?</td>
<td>5 categories: Not at all. A little. Somewhat. A fair amount. A great deal.</td>
<td>Professional administered. During competition. During training.</td>
<td>Derived from global questions validated for use in the general population.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains</td>
<td>Number of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-----------------------------------------------</td>
<td>-------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Injury surveillance (Nilstad et al., 2014).</td>
<td>Time lost from training/competition. (3 items).</td>
<td></td>
<td>How many minutes of match play did you do last week? How many hours of training did you do last week? Have you had any illness/injury that has restricted you from full participation in one or more training sessions and/or matches last week?</td>
<td>Time in minutes and/or hours. Yes/No.</td>
<td>Self-administered. Text message.</td>
</tr>
<tr>
<td>Knee injury and repair. Study specific questionnaire, IKDC&lt;sup&gt;3&lt;/sup&gt; Lysholm knee scale. VISA-P&lt;sup&gt;4&lt;/sup&gt; (Pascarella et al., 2011).</td>
<td>Return to sport. (2 items).</td>
<td></td>
<td>Time to return to play. Level of return to play.</td>
<td>3 categories: Return to same level. Return to lower level. Not competing.</td>
<td>Professional/Self-administered.</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population where it has been validated</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td>-----------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Study specific questionnaire,</td>
<td></td>
<td></td>
<td></td>
<td>Web-based.</td>
<td></td>
</tr>
<tr>
<td>iHOT-12(^i)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAGOS(^k)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSAS, EQ-5D(^l)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS for hip function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Sansone et al., 2014).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study specific questionnaire</td>
<td>Circumstances of injury.</td>
<td>0, sat out some of game/practice.</td>
<td></td>
<td>During competition.</td>
<td></td>
</tr>
<tr>
<td>(Waicus and Smith, 2002).</td>
<td>Medical behaviour/intervention.</td>
<td>1-3 days.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consequences of injury.</td>
<td>3-5 days.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(34 items).</td>
<td>&gt;7 days.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do you have any continuing problems from your eye injury?</td>
<td>Yes/No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) = L’Insalata shoulder questionnaire, \(^b\) = American Shoulder and Elbow Surgeons Standardised Shoulder Assessment, \(^c\) = Short form-12 quality of life questionnaire, \(^d\) = Hip Outcome Score, \(^e\) = Hip Sports Activity scale, \(^f\) = Modified Harris Hip score, \(^g\) = University of California Los Angeles Activity Score, \(^h\) = International Knee Documentation Committee subjective knee evaluation form, \(^i\) = Victoria Institute of Sport Patellar Tendonitis questionnaire \(^j\) = International Hip Outcome Tool (short form 12), \(^k\) = The Copenhagen Hip and Groin Outcome score, \(^l\) = Euroquol health status questionnaire.
4.4.3 Athlete-reported outcome measures used in health surveillance

Nine different athlete-reported outcomes measures were used in ten observational (epidemiological or surveillance) studies (Azodo and Osazuwa, 2013; Bjorneboe et al., 2011; Clarsen et al., 2013; Clarsen et al., 2014; Franz et al., 2013; Matthews et al., 2010; Needleman et al., 2016; Needleman et al., 2013; Waicus and Smith, 2002; Nilstad et al., 2014). However, most were designed for use in individual studies without reference to validation. Self-reported information was used in one qualitative investigation of rugby players’ experiences following anterior cruciate ligament injury and repair, conducted over a period of rehabilitation and return to competition (Carson and Polman, 2012). Quality criteria based on a pre-defined checklist (Mokkink et al., 2010a; Terwee et al., 2007) were applied to the four questionnaires which had been used to assess impact on performance on all athletes, regardless of status as a patient, where the study was had included a reference to the validity of the outcome measure (Table 4.5).

4.4.4 Athlete versus patient reported outcomes to evaluate medical interventions

None of the athlete-reported outcomes of performance used in evaluation of medical interventions cited external validation; seven were used in conjunction with PROMs, not all of which cited validation in a sporting population. However three of the functional PROMs (iHOT-12, HAGOS, VISA-P) identified by this review have been developed and validated for use in a younger active population (Hernandez-Sanchez et al., 2014; Jonasson et al., 2014; Thorborg et al., 2011). The three generic PROMs used in the studies (SF-12, SF-36, EQ-5D) have been reviewed by another author and found to have limited validity in a sport and recreation population (Andrew et al., 2010). The Hip Sports Activity Scale (HSAS) used to identify level of sporting activity has been validated in young patients with hip disease (Naal et al., 2013).
<table>
<thead>
<tr>
<th>Athlete-reported outcome</th>
<th>Content validity</th>
<th>Internal consistency</th>
<th>Construct validity</th>
<th>Reproducibility (agreement)</th>
<th>Reproducibility (reliability)</th>
<th>Responsiveness</th>
<th>Floor and ceiling effects</th>
<th>Interpretability</th>
</tr>
</thead>
</table>
| **KJOCC**  
shoulder and elbow  
questionnaire  
(Franz et al., 2013; Alberta et al., 2010). | + Clear description of target aim. Target population and experts involved in item selection and development. | + Factor analysis Cronbach’s alpha 0.861. | + Correlates well with established PROMs for upper limb. | + Data presented and discussed regarding meaningful clinical change. | + Test-retest data reported. | + Differentiates between players with pain and without pain. | + Maximum average scores reported. | + Score of 100 indicates maximum function. |
| **OSTRC**  
Overuse injury questionnaire  
(Clarsen et al., 2013). | + Clear description of target aim. Target population and experts involved in item selection and development. | + Factor analysis Cronbach’s alpha 0.91. | + Correlates with time loss recorded by conventional measures. | 0 No information available. | 0 No information available. | + Severity score can be plotted for each athlete. | - >15% of respondents achieve highest or lowest scores. | + Severity score can be calculated out of 100. |
| **OSTRC**  
questionnaire on health problems  
(Clarsen et al., 2014). | ? Developed from OSTRC overuse injury questionnaire. | ? Factor analysis Cronbach’s alpha > 9.5. | + Correlates with time loss recorded by conventional measures. | 0 No information available. | 0 No information available. | ? Severity score can be plotted for each athlete. | - >15% of respondents achieve highest or lowest scores. | + Severity score can be calculated out of 100. |
<table>
<thead>
<tr>
<th>Athlete-reported outcome</th>
<th>Content validity</th>
<th>Internal consistency</th>
<th>Construct validity</th>
<th>Reproducibility (agreement)</th>
<th>Reproducibility (reliability)</th>
<th>Responsiveness</th>
<th>Floor and ceiling effects</th>
<th>Interpretability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of oral health problems (Needleman et al., 2013; Needleman et al., 2016).</td>
<td>- Target group not involved in item selection.</td>
<td>- No factor analysis. Cronbach’s alpha not calculated.</td>
<td>+ Tooth decay associated with self-reported impact on performance.</td>
<td>0 No information available.</td>
<td>0 No information available.</td>
<td>0 No information available.</td>
<td>0 No information available.</td>
<td>0 No information available.</td>
</tr>
</tbody>
</table>

Key: criteria met (+), criteria not met (-), criteria not enough information (0)
4.5 Discussion

The rationale, methods and results of this systematic review have been presented. The following section will summarise the key findings, discuss them in relation to similar contemporary research then discuss the strengths and limitations of this review.

4.5.1 Key findings

Most athlete-reported outcome measures of performance used to assess the impact of illness and injury identified in this review were developed for use in individual studies. Furthermore, in only few studies were any assessments of the validity of the question or questionnaires discussed. One oral health self-reported measure of impact on performance was used in two studies of Olympic athletes and professional footballers but has been validated in a general population only.

Functional PROMs such as i-HOT12, HAGOS and VISA-P, developed using the COSMIN guidelines, demonstrate validity in young, active populations but not specifically in elite sport groups (Table 4.6). The HSAS self-reported measure of athletic capability has proven validity and reliability. It would be a useful model for a tool to report the level of competition of athletes in research studies. Although rich in qualitative information, athlete interviews require a substantial time commitment from both the athlete and the researcher, as does the use of multiple PROMs.

Three athlete-reported outcome measures of impact on performance demonstrated validity in a high-performance athletic population; the OSTRC overuse injury questionnaire, the OSTRC questionnaire on health problems and the KJOC shoulder and elbow questionnaire. However, the KJOC questionnaire is specific to overhead throwing athletes. All are short and straightforward to complete and measure impact on performance in terms of athlete-reported pain/symptoms, participation, volume and quality of training/competition.

4.5.2 Strengths and limitations of the included evidence

There are challenges to drawing robust conclusions from the included evidence. In general, the data regarding the outcome measures were drawn from their use in single studies although one measure of the impact of oral health on performance was used in two separate studies (Needleman et al., 2013; Needleman et al., 2016). Few questionnaires reported development using a structured approach and involvement of the target population, limiting their validity.
4.5.3 **Strengths and limitations of the review**

**Eligibility criteria: Performance level**
In order to limit the review a decision was made to limit the participants in the studies to high performance, able-bodied athletes. This focus resulted in several studies being excluded because the studies included participants with disabilities, participants under the age of 16 years or recreational sports people who could not be separated out from the highest-level athletes. Only studies written in English were included, therefore this limited the evaluation of outcomes used in papers written in another language.

**Performance vs functional outcomes**
Return to play is dependent on a number of factors most of which are outside an athlete’s control. Included studies had to demonstrate that a self-reported outcome measure was used to evaluate the impact upon performance in elite athletes. Therefore studies which reported on the development of functional outcome measures using the COSMIN criteria, such as FASH (Malliaropoulos et al., 2014) and VISA-P (Hernandez-Sanchez et al., 2014) were excluded.

**Risk of bias and quality assurance**
In order to minimise bias the protocol was developed *a priori* and full-text screening and data abstraction were conducted in duplicate. However, one researcher (JG) completed the initial assessment of eligibility of titles and abstracts. This may have introduced bias in study selection.

4.5.4 **Comparison with other reviews**

This review supports the finding of related reviews. One systematic review of PROMs used to assess Achilles tendon rupture management (Kearney et al., 2012) applied COSMIN criteria to 17 region-specific and condition-specific outcome measures. The authors found only four were presented in articles that referenced development and/or validation of that outcome measure. Only one was developed using recognised methodology for outcome measure development.

Another systematic review of instruments used to assess outcomes of sport and active recreation injury (Andrew et al., 2010) listed seven different health status and health-related quality-of-life measures, five different functional outcome measures and three physical activity measures. The authors stated that none had been specifically designed to measure injury outcomes in a general sport and active recreation population.
One recent study of low back pain in international level rowers (Newlands et al., 2015) recommended using the OSTRC overuse injury questionnaire, demonstrating its potential for use across all sports.

The initial search was completed in 2016 and was not updated for the thesis. The OSTRC overuse injury questionnaire remains a useful self-reported measure and has been used recently to monitor the impact of groin injuries in footballers in an intervention study (Haroy et al., 2019). Continued use of this measure should lead to increased evidence of its validity as an athlete-reported outcome to measure impact of all types of HRI on performance in sport.

4.5.5 Implications for clinical practice

Consistent use of self-reported outcome measures with evidence of validity, reliability and responsiveness would lead to more reliable and comparable evidence. Despite some limitations, as a potential tool to measure athlete-reported impact on performance across a variety of sports, the OSTRC questionnaire on overuse injuries forms a model that could be adapted to evaluate the impact of any pre-defined health problem on athletic performance. The addition of items related to impact on quality of life could add value in terms of understanding the negative consequences of injury and illness in sport.

An ideal self-reported outcome measure of impact of injury and illness in sport should be simple to administer, short, and have evidence of validity within its target sporting population. It should show content validity, internal consistency and construct validity. The scores should be reproducible and reliable, showing only real changes. The measure should also be responsive to change at the lowest and highest ends of the scale, which means that floor and ceiling effects should not be present. The scores should be easy to interpret by all stakeholders and give meaningful information. As impact on performance is a measure to be used across all sports, this measure needs to be generic rather than specific (Table 4.6).
<table>
<thead>
<tr>
<th>Athlete-reported outcome measure</th>
<th>Number of questions</th>
<th>Study population</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSTRC overuse injury questionnaire. (Clarsen et al., 2013).</td>
<td>4 (For each specified region).</td>
<td>Elite athletes (313). Cycling, floorball, handball, volleyball, cross-country skiing.</td>
<td>Valid in elite sporting population. Severity score to measure impact. Useful across different athlete groups.</td>
<td>Problem must be specified in advance.</td>
</tr>
<tr>
<td>OSTRC questionnaire on health problems. (Clarsen et al., 2014).</td>
<td>4</td>
<td>Olympic candidates (313). Archery, athletics, beach volleyball, boxing, cycling, handball, kayak, rowing, sailing, shooting, swimming, taekwondo, weightlifting, wrestling.</td>
<td>Valid in elite sport population. Useful across different athlete groups.</td>
<td>Athlete will only record problems they feel relevant.</td>
</tr>
</tbody>
</table>
4.5.6 **Implications for future research**

The KJOC questionnaire is short (10 items), contains items regarding function and quality of life and is valid for use at all performance levels of sport. However, it is specific to shoulder injuries in overhead throwing athletes. The OSTRC questionnaires are generic and have been developed with input from their target population. In their basic form they are brief (4 items) but do not contain any quality of life/impact on daily activity items. Although the questionnaires appear to be very short, they do require follow up to establish the type of injury or illness to be fully informative. It may be possible to develop a questionnaire that combines elements of these two questionnaires which can then be truly universal and allow a real comparison of the impact of different health problems on athlete performance across all sports.

4.6 **Conclusions**

This review aimed to make a useful contribution to the SEM literature. Within the limits of this review there is currently no universally accepted athlete-reported outcome measure of the impact of injury/illness/HRIIs on performance in sport. Most questionnaires were designed for individual studies and their validity, reliability and responsiveness has not been reported. The KJOC shoulder and elbow questionnaire has been shown to be valid, reliable and responsive but is specific to professional baseball players. Despite some limitations, as a potential tool to measure athlete-reported impact on performance across a variety of sports, the OSTRC questionnaire on overuse injuries forms a model that could be adapted to evaluate the impact of any pre-defined health problem including oral health problems on athletic performance. The addition of items related to impact on quality of life could add value in terms of understanding the negative consequences of injury and illness in sport.

The systematic review has been published in the journal: Sports Medicine (Appendix C). Appendix D is the accompanying PRISMA checklist.

The four questions which make up the OSTRC overuse injury questionnaire were modified to specify oral health problems and included in the questionnaire used in the following chapter, to measure athlete-reported impact of oral health problems on performance in sport.
5 Oral health of elite athletes and impact on performance

The main focus of this PhD was to measure the oral health of elite athletes and self-reported impacts on performance in sport including psychosocial impacts. The previous chapter described the systematic review process to identify an AROM (athlete-reported outcome measure) that could be used to measure the impact of oral health problems on athlete performance. This chapter will present the rationale for the choice of psychosocial impact outcome measures, clinical outcome measures and indices used. The results will then be presented and the associations between oral health and athlete-reported performance impacts discussed.

It is notoriously difficult to gain access to elite athletes for research purposes. Therefore, the data were collected during oral health screening provided as a service to the athletes in the Olympic and Professional squads who participated in the study.

5.1 Introduction and background

There is a paucity of good quality evidence to inform on oral health within sports and exercise medicine (SEM). However, two previous studies have measured oral health and impact on quality of life, training and athletic performance in Olympic and professional athlete groups (Needleman et al., 2013; Needleman et al., 2016).

The studies were included in a systematic review which concluded that, in general, for all included studies the methodological quality was low due to risk of bias (Ashley et al., 2015). Many of the other studies included in the review focussed on oro-facial trauma or provision of treatment rather than measuring oral health and there was a lack of clarity and consistency regarding clinical outcomes. Other limitations were that studies included non-representative samples, use of multiple examiners without calibration, lack of clarity regarding the clinical outcomes measured and use of outcome measures of impact on performance with limited evidence of validity in sport.

In addition, many of the studies were conducted at competitions. While studies performed during high-level competition provide useful information, they are not sufficient for understanding the exposure to injury and illness risks during training. Therefore it is recommended that surveillance and epidemiological studies are conducted outside of competition (Clarsen et al., 2014).

The consensus statement “Oral health and elite athlete performance” was informed by a systematic review and subsequent discussion by participants of the symposium, Oral
Health and Performance in Sport-Learning from London 2012, 4 April 2014, UCL, London and specifically recommended:

“careful epidemiological evaluations of representative samples of athletes to establish oral health needs across different sports, the determinants of oral health both of the individual and their environment and the impact and associated mechanisms of oral health on performance” (Needleman et al., 2014).

5.2 Aim

This study therefore aimed to measure the prevalence of common oral health problems and associated athlete-reported performance impacts in a representative sample of elite athletes using clearly defined clinical indices, standardised examination conditions, a single trained and calibrated examiner and an athlete-reported outcome measure (AROM) of the impact of oral health problems with evidence of validity in sport.

5.3 Public engagement

Following the study conducted at the 2012 Olympic Games (Needleman et al., 2013), a clear engagement strategy was developed to facilitate further research in the field of oral health and elite sport. A network of contacts was established with elite sports organisations and individuals attending the International Olympic Committee Conference on Prevention of Injury and Illness in Sport (2014) and the University College London Symposium on Oral Health and Sport (2014).

5.4 Materials and methods

This was a cross-sectional observational and questionnaire study of Olympic and professional athlete groups conducted between June 2015 and August 2016. A control group was not recruited, as the objective was to measure the prevalence of oral health conditions in elite athletes specifically. There are many difficulties in identifying a valid control group where potential confounders including age, gender, sport, activity level, educational and economic background can be matched. Additionally, the constraints of time and manpower made the provision of oral health screening for a control group impractical. The design of this study was informed by the Adult Dental Health Survey 2009 (O’Sullivan et al., 2011) and two previous studies of the oral health of Olympic and professional athletes (Needleman et al., 2013; Needleman et al., 2016). It is recommended that Olympic athletes undergo regular periodic health examinations (PHE) including oral health evaluation (IOC, 2009), therefore oral health screening was offered to all athletes from Olympic and professional training squads within the network.
established through the network developed through public engagement. To maximise convenience for the athletes the researcher (JG) travelled to their training centres (Table 5.1 and Figure 5.1) to conduct the recruitment (Participant Information Sheet - Appendix F), consent (Appendix G), clinical examination and complete an oral health report for each athlete. An assistant accompanied the researcher to record the clinical data on a clinical record form designed for the study (Appendix H). Following the clinical examination, athletes were asked to complete the questionnaire (Appendix I).

Figure 5.1 An athlete completing the questionnaire and other engagement situations

All participants received a copy of their oral health report to share with the team medic and/or their own dentist (Appendix J). Athletes were encouraged to attend their own dentist for treatment, and a referral pathway to a local dental hospital was arranged for those athletes who were unable to arrange care locally.
### Table 5:1 Athlete training venues

<table>
<thead>
<tr>
<th>Photo of venue</th>
<th>Name of venue</th>
<th>Squad, no of athletes screened</th>
<th>Total days</th>
<th>Number of athletes screened</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="National Cycling Centre, Manchester." /></td>
<td>National Cycling Centre, Manchester.</td>
<td>GB Cycling.</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td><img src="image2.png" alt="National Swimming Centre, Loughborough." /></td>
<td>National Swimming Centre, Loughborough.</td>
<td>GB Swimming.</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td><img src="image3.png" alt="National Swimming Centre, Bath." /></td>
<td>National Swimming Centre, Bath.</td>
<td>GB Swimming.</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td><img src="image4.png" alt="National Sports Centre, Bisham Abbey." /></td>
<td>National Sports Centre, Bisham Abbey.</td>
<td>GB Hockey.</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td><img src="image5.png" alt="National Sports Centre, Lilleshall." /></td>
<td>National Sports Centre, Lilleshall.</td>
<td>GB Gymnastics.</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td><img src="image6.png" alt="Football Club, Training Ground, Reading." /></td>
<td>Football Club, Training Ground, Reading.</td>
<td>Reading FC.</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td><img src="image7.png" alt="Redgrave-Pinsent Rowing Lake &amp; Sherriff's Boathouse" /></td>
<td>Redgrave-Pinsent Rowing Lake, Caversham.</td>
<td>GB Rowing.</td>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>Location</td>
<td>Sport</td>
<td>Games</td>
<td>Tickets</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------</td>
<td>-------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>National Sailing Centre, Weymouth.</td>
<td>GB Sailing and Windsurfing.</td>
<td>3</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Lee Valley Athletics Stadium, London.</td>
<td>GB Athletics (track and field).</td>
<td>1</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>HIPAC, Loughborough.</td>
<td>GB Athletics.</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>The Lensbury Centre, Teddington, London.</td>
<td>England Rugby.</td>
<td>3</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>National Sports Centre, Bisham Abbey,</td>
<td>Team Sky.</td>
<td>2</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>3</strong></td>
<td><strong>352</strong></td>
<td></td>
</tr>
</tbody>
</table>
**5.4.2 Sample selection**

This was a stratified sample of UK elite athletes. As the nutritional demands and training requirements differ between sports (Jeukendrup, 2011; Stellingwerff et al., 2011; Slater and Phillips, 2011), the strata were defined as the following categories: strength and power (event lasting less than 2 minutes), endurance and mixed/team sport (Table 5.2). The categories are similar to those used in other studies investigating the consequences of injury and illness across different sports (Clarsen et al., 2014). The intention was to include as many Olympic and professional sports squads as possible within the feasible limits of a single examiner and the time frame available for screening.

Within each squad, the aim was to recruit a representative sample, defined arbitrarily as at least 75% of the senior squad. Key personnel (Dijkstra et al., 2014) from Olympic and professional squads, identified through engagement, were offered the opportunity for their athletes to participate in the research by attending for a screening examination and provision of an oral health report.

**Table 5.2 Sports invited to participate in the study**

<table>
<thead>
<tr>
<th>Strength and power</th>
<th>Endurance</th>
<th>Mixed/team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletics (track and field)</td>
<td>Cycling -track</td>
<td>Sailing</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>Cycling-road</td>
<td>Hockey</td>
</tr>
<tr>
<td>Sprint cycling</td>
<td>Rowing</td>
<td>Football</td>
</tr>
<tr>
<td>Sprint swimming</td>
<td>Swimming</td>
<td>Rugby/ Rugby sevens</td>
</tr>
</tbody>
</table>

For all sports except athletics, the team medical officer accepted the offer of screening on behalf of the squad and a designated liaison person arranged the screening appointments for each athlete on their behalf. For track and field athletes, an appointment was arranged only if the athlete indicated they would like to accept the offer of screening.

**Eligibility criteria**

- Member of elite (Olympic, international, national or professional) training/development squad
- Aged 18 years or over
- Able to understand the consent process with the aid of a translator if required
- Able to understand and complete the questionnaire with the aid of a translator if required
**Exclusion criteria**

Disability introduces a number of additional risk factors for general and oral health, including access to care and difficulties in self-management. Therefore combining data from athletes with a disability, with data from able-bodied athletes, would therefore introduce too much heterogeneity into the data set. The practical difficulties associated with collecting accurate oral health measurements for athletes with severe disabilities outside of a dedicated dental clinic setting was also an important limitation. Reluctantly, a decision was made to exclude parathletes from this study. However, for athletes with a disability who requested oral health screening this was provided where possible. This group is a priority for research but should be investigated separately.

**5.4.3 Stakeholder engagement and questionnaire development**

An advisory group was established for this project. The group included an athlete from a current Olympic training squad, a consultant in sports medicine, a past Olympic medallist, a dentist who is also an athlete, an expert in dental public health and an expert in behaviour change research. The questionnaire included items regarding demographics, self-reported oral conditions, self-assessed general health status, oral health status, psychosocial impacts and impact on performance in sport.

As described in Chapter 2, an oral health modification of the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire was used to assess impact on sport performance (Gallagher et al., 2017). However, a limitation of the OSTRC questionnaire is that it does not include any items relating to quality of life.

The Oral Impacts on Daily Performance (OIDP) questionnaire was used in the Adult Dental Health Survey for England, Wales and Northern Ireland (ADHS 2009) to measure the severity of impact of oral health problems on quality of life. However, inclusion of the entire questionnaire would have added to the time required to complete the study questionnaire. Therefore the three items deemed to be most relevant to athlete preparation were taken from the Oral Impacts on Daily Performance (OIDP) outcome measure used in the were included to assess psychosocial impacts: difficulty eating/drinking, difficulty relaxing including sleeping and difficulty smiling, laughing or showing teeth without embarrassment (Nuttall et al., 2011, O Sullivan et al., 2011).

The draft questionnaire was sent for review to members of the advisory group. Following review, it was piloted with 10 athletes aged over 18 years attending the GSK Human Performance Lab. Few changes were required, mainly instructions to complete each option.
5.4.4 **Ethical approval and research governance**

As the study included human participants but did not involve an intervention, it was considered low risk. Therefore, chair’s approval from University College London research ethics committee (REC) was sufficient (Appendix E). The REC requires that study participants are fully informed as to the purposes for which data collected during the study will be used and give their informed consent to participate. As required, copies of the paperwork were included in the application and approval was received (Project ID 6388/001). Participation in the study was entirely voluntary and with no obligation. Informed written consent was obtained from each study participant.

Data were collected anonymously with a unique identifier and did not contain any person identifiable data. The consent and information forms with identifiable information were kept in a secure, locked cabinet separately to the clinical record forms. The study researcher was a dentist, registered with the General Dental Council (number 67896). Training for both the dentist and assistant included research governance issues such as data protection policy, recruitment and consent.

5.4.5 **Clinical Examination criteria**

*Oral sepsis and pericoronitis*

The PUFA (Pulp, Ulcer, Fistula, Abscess) index was originally developed to record oral conditions present resulting from severe dental caries in children (Monse et al., 2010). It provides a measure of badly diseased and broken-down teeth which have been attacked by dental decay and is intended to complement more classical caries indices with relevant information for epidemiologists. The index is expressed by the uppercase letters PUFA when used for the permanent dentition (Table 5.3)

<table>
<thead>
<tr>
<th>Code</th>
<th>Clinical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>The opening of the pulp chamber is visible or when the coronal tooth structures have been destroyed by the carious process, and only roots / root fragments are left.</td>
</tr>
<tr>
<td>U</td>
<td>Sharp edges of a dislocated tooth with pulp involvement or root fragments have caused traumatic ulceration of the surrounding soft tissues, e.g., tongue or buccal mucosa.</td>
</tr>
<tr>
<td>F</td>
<td>Pus-releasing sinus tract related to a tooth with pulp involvement is present.</td>
</tr>
<tr>
<td>A</td>
<td>Pus-containing swelling related to a tooth with pulp involvement is present.</td>
</tr>
</tbody>
</table>
Pericoronitis was assessed as presence or absence of clinical features; the presence of pericoronitis was scored when swelling or inflammation was present in association with a partially erupted wisdom tooth.

**Gingival and periodontal health**

The Basic Periodontal Examination (BPE) was used to measure periodontal health (British Society of Periodontology, 2016). Table 5.4 lists the codes and criteria. The dentition was divided into 6 sextants upper right (17 to 14) lower right (47 to 44) upper anterior (13 to 23) upper left (24 to 27) lower anterior (43 to 33) lower left (34 to 37) and the highest score for each sextant was recorded. All teeth in each sextant were examined with the exception of third molars. A ball tip probe 0.5mm in diameter and a black band from 3.5mm to 5.5mm was used (MDDI Sterile Single Use Code S1952ST-1: Periodontal 2 Piece Examination Kit with Ball Tip Probe). The probe was “walked” round each site with a light probing force to ensure that the highest score in the sextant was recorded before moving on to the next sextant. Code * (furcation involvement) was not used.

Table 5.4 BPE criteria

<table>
<thead>
<tr>
<th>Code</th>
<th>Clinical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No bleeding on probing (black band entirely visible).</td>
</tr>
<tr>
<td>1</td>
<td>Pockets &lt;3.5mm, no calculus/overhangs, bleeding on probing (black band entirely visible).</td>
</tr>
<tr>
<td>2</td>
<td>Pockets &lt;3.5mm, supra or sub-gingival calculus/overhangs (black band entirely visible).</td>
</tr>
<tr>
<td>3</td>
<td>Probing depth 3.5--5.5mm (black band partially visible, indicating pocket of 4--5 mm).</td>
</tr>
<tr>
<td>4</td>
<td>Probing depth &gt;5.5mm (black band disappears, indicating a pocket of 6 mm or more).</td>
</tr>
</tbody>
</table>

**Erosive tooth wear (ETW)**

The BEWE was used to measure ETW (Bartlett et al., 2008). Table 5.5 lists the codes and criteria. As with the BPE, the dentition is divided into sextants and each examined in turn. All teeth in each sextant with the exception of third molars were air-dried and each surface examined to ensure that the highest score in the sextant was recorded before moving onto the next sextant.
Table 5:5 BEWE criteria

<table>
<thead>
<tr>
<th>Code</th>
<th>Clinical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No erosive tooth wear.</td>
</tr>
<tr>
<td>1</td>
<td>Initial loss of surface texture.</td>
</tr>
<tr>
<td>2</td>
<td>Distinct defect; hard tissue loss &lt; 50% of the surface area.</td>
</tr>
<tr>
<td>3</td>
<td>Hard tissue loss ≥ 50% of the surface area.</td>
</tr>
</tbody>
</table>

In scores 2 and 3 dentine is often involved.

**Dental caries**

The International caries detection and assessment system (ICDAS) was used to measure caries experience (Ismail et al., 2007). Each tooth surface was examined and scored for presence of restoration and caries separately therefore two codes were called for each surface; restoration code followed by caries code. Data were collected at tooth surface level but reported per tooth and per whole mouth at stage three or greater. Table 5.6 summarises the codes and criteria for restorations.
Table 5.6 ICDAS codes for restorations

<table>
<thead>
<tr>
<th>Code</th>
<th>Clinical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Un-restored or unsealed.</td>
</tr>
<tr>
<td>1</td>
<td>Sealant, partial (a sealant that does not cover all pits and fissures on a tooth surface).</td>
</tr>
<tr>
<td>2</td>
<td>Sealant, full (a sealant that covers all pits and fissure on a tooth surface).</td>
</tr>
<tr>
<td>3</td>
<td>Tooth coloured restoration (In the opinion of the dentist, the tooth has a tooth coloured (resin or glass–ionomer cement) restoration).</td>
</tr>
<tr>
<td>4</td>
<td>Amalgam restoration.</td>
</tr>
<tr>
<td>5</td>
<td>Stainless steel crown.</td>
</tr>
<tr>
<td>6</td>
<td>Porcelain or gold or PFM crown or veneer.</td>
</tr>
<tr>
<td>7</td>
<td>Lost or broken restoration.</td>
</tr>
<tr>
<td>8</td>
<td>Temporary restoration.</td>
</tr>
<tr>
<td>9</td>
<td>Tooth does not exist or other special cases.</td>
</tr>
</tbody>
</table>

Sound tooth surfaces have no visible caries when viewed clean and dry. Table 5.7 provides a summary of the codes for caries.

Table 5.7 ICDAS codes for caries

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sound tooth surface.</td>
</tr>
<tr>
<td>1</td>
<td>First visual change in enamel (when seen wet there is no evidence of any change in color attributable to carious activity, but after prolonged air drying (approximately 5 s is suggested to adequately dehydrate a carious lesion in enamel). A carious opacity or discoloration (white or brown lesion) is visible that is not consistent with the clinical appearance of sound enamel.</td>
</tr>
<tr>
<td>2</td>
<td>Distinct visual change in enamel (when wet there is a (i) carious opacity (white spot lesion) and/or (ii) brown carious discoloration which is wider than the natural fissure/fossa that is not consistent with the clinical appearance of sound enamel (Note: the lesion must still be visible when dry).</td>
</tr>
<tr>
<td>3</td>
<td>Localized enamel breakdown because of caries with no visible dentine or underlying shadow.</td>
</tr>
<tr>
<td>4</td>
<td>Underlying dark shadow from dentine with or without localized enamel breakdown.</td>
</tr>
<tr>
<td>5</td>
<td>Distinct cavity (&lt;50% of surface area) with visible dentine at the base.</td>
</tr>
<tr>
<td>6</td>
<td>Extensive distinct cavity with visible dentine.</td>
</tr>
</tbody>
</table>

5.4.6 Examiner and assistant training

The examiner was an experienced clinician working in a dental training establishment, therefore familiar with the use of the clinical indices and regularly confirming screening scores for referred patients with students, and colleagues. Study specific training included a detailed review of the criteria and codes for recording dental caries (Kamppi et al., 2015; Guedes et al., 2014; Shivakumar et al., 2009; Pitts et al., 2013), dental
erosion (Bartlett et al., 2008) and periodontal diseases (Gjermo, 1994). Agreement with a “gold standard” was assessed for dental caries (Dr J Khaw, Eastman Dental Hospital Education Centre) and periodontal health (Dr M Orlando, Eastman Clinical Investigation Centre). Examiner repeatability was assessed for dental caries and dental erosion. Each assistant received training to include recording of oral health data and infection control.

**Examiner calibration**

Following a detailed review of the clinical indices, excellent examiner agreement with a gold standard was confirmed for measurement of established caries (kappa 0.9) and periodontal diseases (kappa 0.8) and examiner repeatability for measurement of caries (kappa 1) and ETW (kappa1). Examiner repeatability was assessed for dental caries at the stage of caries into dentine, which is the stage where most dentists would intervene with operative treatment (ICDAS codes 4, 5 and 6). Using a series of 10 teeth, perfect agreement was achieved. Examiner repeatability was also assessed for dental erosion with a separate series of 10 teeth: again perfect agreement was achieved. An overview of the examiner training and repeatability exercises is presented in Appendix K.

**Calibration of instruments**

A random sample of 10 packs of instruments (Figure 5.2) were opened and examined under magnification x2 to ensure that the measurements were accurate to within 1mm.

**Figure 5.2 Single use exam kit**

![Figure 5.2 Single use exam kit](image)

**5.4.7 Examination procedure**

Athletes were examined supine (Figure 5.3) on a portable examination couch, under illumination from a mobile examination lamp (DARAY X100LED). Compressed air from a portable dental unit was used to dry the teeth (PDU II Standard, QDent) and a new set of sterile single use instruments (mddi code 52BT-1) used for each athlete. The specially designed CRF was used to record the clinical information at the screening appointment.
5.4.8 Practice run

A “dry run” was carried out on a convenience sample of staff and volunteers in the Eastman Clinical Investigation Centre for both the clinical examination and the self-completed questionnaire. The main aims of the dry run were to test the fieldwork protocol (Appendix L) and establish the optimum method for managing each participant efficiently and empathetically. Data were entered into a spreadsheet to identify any problems with coding.

5.4.9 Derived variables

It was necessary to create new variables that were not recorded directly in the questionnaire or the examination. These variables were constructed post data collection and ranged from simple recodes of one variable (e.g. deriving different age categories from the question asking for exact age) to complex constructions depending on a large number of variables (e.g. calculating caries at different thresholds). A full list of the questionnaire and examination derived variables is presented in Appendix M.

5.4.10 Statistical analysis

Data from the CR and questionnaire data were coded prior to data collection, then entered into a spreadsheet by an independent person prior to importing into the statistical package for analysis. Data were analysed using a standard statistical package (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY). Continuous data were assessed for normality and transformed into categorical data where appropriate. Counts and percentages summarised the categorical data and Chi squared tests or Fisher’s exact tests as appropriate were used to compare percentages in different groups (strength and power, endurance and mixed) with post-hoc Bonferroni corrections and calculation of odds ratios as appropriate. Standard errors and confidence intervals at the
95% level were calculated for key findings. A significance level of 5% was selected for all hypothesis tests.

5.5 Results

All sports contacted agreed to participate and oral health screening was provided for 256 (72.7%) athletes on podium potential/placement programmes for the 2016 Rio Olympic Games and 96 (27.3%) professional athletes (352 in total) across 11 sports (Figure 5.4).

Eight questionnaires were not returned due to time constraints. Therefore, the demographic data for age, ethnicity and educational status was available for 344 participants.

Figure 5.4 Olympic and professional squads screened and percentage contribution towards the sample

The main reason for non-attendance at the screening appointment was training or competing elsewhere, however the target of 75% completeness was achieved in all sports except athletics (26.3%, 95% CI 17.8-36.9). Overall, 79.4% (95% CI 75.4-83.0) of eligible athletes were screened (Figure 5.5).
5.5.1 Characteristics of the group

The median age of the participants was 25 years (range 18-39) and 67.0% were male (Table 5.8). Two hundred and seventy-five (80.4%, 95% CI 75.4-83.9) athletes recorded ethnicity as white British, and 162 (47.4%, 95% CI 41.9-52.4) said they had or were studying for a University degree (Table 3.7). There were 50 (14.2%, 95% CI 10.9-18.3) athletes in the strength and power category (athletics, gymnastics, sprint cycling and sprint swimming), 143 (40.6%, 95% CI 35.6-45.8) in the endurance category (swimming, cycling, rowing,) and 159 (45.2%, 95% CI 40.0-50.4) in the mixed category (football, rugby, hockey, sailing).
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group</td>
<td>352</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>236</td>
<td>67.0</td>
</tr>
<tr>
<td>Sport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycling</td>
<td>51</td>
<td>14.5</td>
</tr>
<tr>
<td>Swimming</td>
<td>46</td>
<td>13.1</td>
</tr>
<tr>
<td>Athletics (track and field)</td>
<td>21</td>
<td>6.0</td>
</tr>
<tr>
<td>Rowing</td>
<td>60</td>
<td>17.0</td>
</tr>
<tr>
<td>Hockey</td>
<td>46</td>
<td>13.1</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>15</td>
<td>4.3</td>
</tr>
<tr>
<td>Sailing</td>
<td>15</td>
<td>4.3</td>
</tr>
<tr>
<td>Football</td>
<td>26</td>
<td>7.4</td>
</tr>
<tr>
<td>Rugby</td>
<td>72</td>
<td>20.5</td>
</tr>
<tr>
<td>Sport category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power</td>
<td>50</td>
<td>14.2</td>
</tr>
<tr>
<td>Endurance</td>
<td>143</td>
<td>40.6</td>
</tr>
<tr>
<td>Mixed</td>
<td>159</td>
<td>45.2</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGSE or equivalent</td>
<td>40</td>
<td>11.7</td>
</tr>
<tr>
<td>A-level or equivalent</td>
<td>119</td>
<td>34.8</td>
</tr>
<tr>
<td>FE college or equivalent</td>
<td>21</td>
<td>6.1</td>
</tr>
<tr>
<td>University undergraduate degree</td>
<td>137</td>
<td>40.1</td>
</tr>
<tr>
<td>University postgraduate degree</td>
<td>25</td>
<td>7.3</td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-19</td>
<td>28</td>
<td>8.1</td>
</tr>
<tr>
<td>20-24</td>
<td>139</td>
<td>40.4</td>
</tr>
<tr>
<td>25-29</td>
<td>117</td>
<td>34.0</td>
</tr>
<tr>
<td>30-34</td>
<td>52</td>
<td>15.1</td>
</tr>
<tr>
<td>35-39</td>
<td>8</td>
<td>2.3</td>
</tr>
<tr>
<td>Ethnic background</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>275</td>
<td>80.2</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elite category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olympic</td>
<td>256</td>
<td>72.7</td>
</tr>
<tr>
<td>Professional</td>
<td>96</td>
<td>27.3</td>
</tr>
</tbody>
</table>
The demographic make-up of the endurance and mixed sports categories was similar, but those in the strength and power category were younger and composed more females and athletes from ethnic groups other than white British (Figure 5.6). Table 5.9 shows the demographic information for the group including Olympic and professional categories:

Figure 5.6 Demographic makeup of each sport category

![Graph showing demographic makeup of each sport category]

Table 5.9 Demographics of the group, sport category and elite category

<table>
<thead>
<tr>
<th>Sport / sport category</th>
<th>Median age (Range)</th>
<th>Age &lt; 24 n (%)</th>
<th>Gender (male) n (%)</th>
<th>white British n (%)</th>
<th>With / studying for University degree n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group (N = 344, N=352 for gender)</td>
<td>25 (18-39)</td>
<td>167 (48.5%)</td>
<td>236 (67%)</td>
<td>275 (80%)</td>
<td>162 (47%)</td>
</tr>
<tr>
<td>Sport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rugby (72)</td>
<td>25 (19-31)</td>
<td>28 (42%)</td>
<td>59 (82%)</td>
<td>54 (80%)</td>
<td>29 (44%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>27 (18-39)</td>
<td>13 (22%)</td>
<td>34 (56%)</td>
<td>54 (90%)</td>
<td>47 (78%)</td>
</tr>
<tr>
<td>Cycling (51)</td>
<td>25 (18-38)</td>
<td>25 (46%)</td>
<td>38 (74.5%)</td>
<td>29 (62%)</td>
<td>4 (8.5%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>21 (18-30)</td>
<td>38 (83%)</td>
<td>31 (67%)</td>
<td>46 (100%)</td>
<td>16 (35%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>25 (22-35)</td>
<td>18 (39%)</td>
<td>22 (48%)</td>
<td>46 (100%)</td>
<td>40 (67%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>21 (18-35)</td>
<td>23 (88.5%)</td>
<td>26 (100%)</td>
<td>11 (42%)</td>
<td>2 (7%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>24 (19-31)</td>
<td>14 (67%)</td>
<td>9 (43%)</td>
<td>7 (33%)</td>
<td>15 (71%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>22 (18-30)</td>
<td>11 (73%)</td>
<td>8 (53%)</td>
<td>13 (86%)</td>
<td>2 (13%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>29 (25-36)</td>
<td>0</td>
<td>9 (60%)</td>
<td>15 (100%)</td>
<td>7 (46%)</td>
</tr>
<tr>
<td>Sport category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>22.5 (18-31)</td>
<td>35 (70%)</td>
<td>25 (50%)</td>
<td>31 (62%)</td>
<td>16 (32%)</td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>25 (18-39)</td>
<td>63 (45%)</td>
<td>96 (67%)</td>
<td>118 (85%)</td>
<td>68 (49%)</td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>25 (18-36)</td>
<td>69 (44.8%)</td>
<td>116 (73%)</td>
<td>126 (82%)</td>
<td>78 (51%)</td>
</tr>
<tr>
<td>Elite category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olympic (256)</td>
<td>25 (18-39)</td>
<td>122 (48%)</td>
<td>140 (55%)</td>
<td>228 (89%)</td>
<td>149 (58%)</td>
</tr>
<tr>
<td>Professional (96)</td>
<td>25 (18-38)</td>
<td>49 (51%)</td>
<td>96 (100%)</td>
<td>52 (55%)</td>
<td>14 (15%)</td>
</tr>
</tbody>
</table>
5.5.2 Oral health and function

All athletes had more than the minimum number of natural teeth (21) for a functional dentition and 327 (93%, 95% CI 89.69-95.18) had at least 18 sound and untreated teeth (Figure 5.7). The overall median number of teeth retained among the athletes was 30 (28-32) and ranged from 22 to 32 retained natural teeth. The median number of sound and unrestored teeth was 27 (23-30) and ranged from 12 to 32.

Figure 5.7 Proportion of athletes in each sport category with \( \geq 18 \) sound and untreated teeth

5.5.3 Dental caries

Table 5.10 shows that 173 (49.1%, 95% CI 43.96 – 56.62) athletes had an established carious lesion in at least one tooth. The average number of teeth affected by an established carious lesion can be calculated, but this does not provide a true picture of the burden of disease as there are a substantial proportion of athletes without any caries. Of those with caries (DT > 1), the median number of teeth affected was two (range 1-13).

Caries prevalence did not vary significantly with age, gender, ethnicity or education however there were differences between sports and sports categories (Table 5.11). The prevalence of established caries in athletes with DT \( \geq 1 \) was highest in rugby (61.1%, 95% CI 49.55 to 71.55) and football (61.5%, 95% CI 42.48 to 7.63) and lowest in rowing (33.3%, 95% CI 22.69 to 45.98). The proportion of athletes with DT \( \geq 1 \) in the mixed sport category, (56%, 95% CI 48.2 to 63.5) was higher than that in endurance, (38.5%, 95% CI 31 to 46.4) with an odds ratio of 2.03 (95% CI 1.29 to 3.22). This was statistically significant (P=0.004).
### Table 5:10 Proportion of athletes with caries by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Number of athletes with caries (%)</th>
<th>Chi squared test</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group N=352</td>
<td>173 (49.1%)</td>
<td></td>
<td>1.04 (0.68-1.59)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>82 (49.1%)</td>
<td><strong>P = 0.914</strong></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>85 (48%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>120 (50.8%)</td>
<td><strong>P = 0.367</strong></td>
<td>1.23 (0.79-1.92)</td>
</tr>
<tr>
<td>Female (116)</td>
<td>53 (45.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>132 (48.0%)</td>
<td><strong>P = 0.587</strong></td>
<td>0.90 (0.53-1.52)</td>
</tr>
<tr>
<td>Other (69)</td>
<td>35 (52.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>93 (51.7%)</td>
<td><strong>P = 0.235</strong></td>
<td>1.27 (0.83-1.95)</td>
</tr>
<tr>
<td>Has/studying for degree (162)</td>
<td>73 (45.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sport category</strong></td>
<td></td>
<td><strong>P = 0.004</strong></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>29 (58.0%)</td>
<td><strong>S+P v Endurance</strong></td>
<td>2.21 (1.15-4.25)</td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>55 (38.5%)</td>
<td><strong>P = 0.078</strong></td>
<td>2.03 (1.28-3.22)</td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>89 (56.0%)</td>
<td><strong>S+P v Mixed</strong></td>
<td>1.09 (0.57-2.06)</td>
</tr>
</tbody>
</table>

*Bonferroni correction

### Table 5:11 Odds ratio of caries in different sports

<table>
<thead>
<tr>
<th>Sport (n)</th>
<th>Number of athletes in sport with caries (%)</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowing (60)</td>
<td>20 (33.3%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (72)</td>
<td>44 (61.1%)</td>
<td>3.14 (1.54-6.43)</td>
<td><strong>0.002</strong></td>
</tr>
<tr>
<td>Cycling (51)</td>
<td>25 (49.0%)</td>
<td>1.92 (0.89-4.15)</td>
<td>0.095</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>19 (41.3%)</td>
<td>1.41 (0.64-3.12)</td>
<td>0.400</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>21 (45.7%)</td>
<td>1.68 (0.76-3.70)</td>
<td>0.198</td>
</tr>
<tr>
<td>Football (26)</td>
<td>16 (61.5%)</td>
<td>3.2 (1.23-8.32)</td>
<td><strong>0.017</strong></td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>12 (57.1%)</td>
<td>2.67 (0.96-7.38)</td>
<td>0.059</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>8 (53.3%)</td>
<td>2.29 (0.73-7.20)</td>
<td>0.158</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>8 (53.3%)</td>
<td>2.29 (0.73-7.20)</td>
<td>0.158</td>
</tr>
</tbody>
</table>
5.5.4 Restored teeth

Restorations are placed mainly to treat caries, however some restorations are placed to improve aesthetics or to repair damage caused by trauma. Nearly three quarters (252) of athletes had at least one restored tooth. For those with one or more restorations (71.6%, 95% CI 66.66 – 76.06), the median number of teeth affected was 4 (range 1 - 19). Almost one third (103, 29.5%) of athletes had five or more restored teeth (Figure 5.8).

The proportion of athletes with restorations did not vary significantly with gender, educational status or ethnicity although prevalence was higher in men, those with higher educational status and white British athletes (Table 5.12). The proportion of athletes with restorations varied statistically significantly by age with athletes aged 25 or older having a higher prevalence of restored teeth than athletes aged 24 years or younger (P <0.001).

Total caries experience can be measured as the sum of teeth with either caries or a restoration present (DFT ≥1). More than three quarters (288, 91.8%) athletes had DFT ≥1. The proportion of athletes with DFT ≥1 did not vary significantly between sports categories (p=0.664). The category with the highest DFT was endurance (120, 83.9%, 95% CI 76.96-89.10). Figure 5.7 also shows that fewer than one third (27.9%) of athletes had received preventive care from a dental professional in the form of fissure sealants. For those with fissure sealants, the median number was 2 (IQR 1-4, range 1-12).

Figure 5.8 Proportions of athletes in each sport category with caries and restorations
Table 5:12 Restored teeth and proportions of athletes with restorations by group characteristics

<table>
<thead>
<tr>
<th>Restorations present</th>
<th>Median (IQR)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fissure sealed teeth (≥ 1)</td>
<td>2 (1-4)</td>
<td>1-12</td>
</tr>
<tr>
<td>Restored teeth (≥ 1)</td>
<td>4 (2-6)</td>
<td>1-19</td>
</tr>
</tbody>
</table>

**Restored teeth by sport category**

<table>
<thead>
<tr>
<th></th>
<th>Median (IQR)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength and power (n = 50)</td>
<td>2 (1-5)</td>
<td>0-10</td>
</tr>
<tr>
<td>Endurance (n = 143)</td>
<td>2 (1-7)</td>
<td>0-19</td>
</tr>
<tr>
<td>Mixed (n =159)</td>
<td>2 (1-6)</td>
<td>0-15</td>
</tr>
</tbody>
</table>

**N = 352**

<table>
<thead>
<tr>
<th></th>
<th>Number of athletes with restorations (%)</th>
<th>Chi squared test</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes with any restoration</td>
<td>252 (71.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athletes with ≥ 5 restored teeth</td>
<td>103 (29.5%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Characteristics of the group (n)**

<table>
<thead>
<tr>
<th></th>
<th>Number of athletes with restorations (%)</th>
<th>Chi squared test</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>P &lt; 0.001</td>
<td>0.32 (0.19-0.53)</td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (167)</td>
<td>102 (61.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 25 years (177)</td>
<td>147 (83.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>P = 0.453</td>
<td>1.15 (0.71-1.87)</td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>172 (72.9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (116)</td>
<td>80 (69.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>P = 0.761</td>
<td>0.98 (0.54-1.76)</td>
<td></td>
</tr>
<tr>
<td>White British (272)</td>
<td>198 (72%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (69)</td>
<td>50 (74.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>P = 0.277</td>
<td>0.72 (0.45-1.16)</td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>125 (69.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has/studying for degree (162)</td>
<td>122 (75.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport category</td>
<td>P = 0.793</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>36 (72.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>105 (73.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>111 (69.8%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>S+P v Endurance</th>
<th>S+P v Mixed</th>
<th>Endurance v Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength and power (50)</td>
<td>0.93 (0.45-1.91)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>0.84 (0.51-1.38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>1.11 (0.55-2.25)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.5.5 Erosive tooth wear

Figure 5.9 shows the distribution of scores related to suggested risk levels (Bartlett et al., 2008).

**Figure 5.9 BEWE scores for sports categories**

However, as the average age of an elite athlete is younger than the general population, an arbitrary score of 7 was set to indicate the presence of erosive tooth wear that could be considered to be in excess of normal physiological wear (Figure 5.10).

**Figure 5.10 Proportions of athletes with BEWE scores**

Overall 148 (42%, 95% CI 37.0 to 47.26) of athletes had at least one tooth with signs of ETW. There was a statistically significant difference between the genders; 48.7% of men and 28.4% of women had a BEWE score of ≥7 (P=<0.001). In terms of severity 41 (11.6%) scored between 9 and 13. ETW was most prevalent in football (73.1%) and least prevalent in sailing (26.7%) and rowing (26.7%). Table 5.13 shows the difference in proportions of athletes with a BEWE score ≥7 in different sports. Table 5.14 shows that ETW differed significantly between mixed (51.6%) and endurance (35%) sports categories (OR 1.98, 95% CI 1.25 to 3.15, P = 0.015).
Table 5:13 Proportion of athletes with BEWE score ≥ 7 by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Number (%) with BEWE score &gt; 7</th>
<th>Chi squared test p - value</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N = 352)</td>
<td>148 (42%)</td>
<td></td>
<td>1.34 (0.87-2.06)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>777 (46.1%)</td>
<td>P = 0.220</td>
<td></td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>69 (39.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td>P = &lt; 0.001</td>
<td>2.40 (1.48-3.85)</td>
</tr>
<tr>
<td>Male (236)</td>
<td>115 (48.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (116)</td>
<td>33 (28.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td>P = 0.423</td>
<td>1.36 (0.79-2.35)</td>
</tr>
<tr>
<td>White British (275)</td>
<td>120 (43.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (69)</td>
<td>25 (37.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
<td>P = 0.115</td>
<td>0.92 (0.60-1.40)</td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>61 (37.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>84 (46.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sport category</strong></td>
<td></td>
<td>P = 0.004</td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>16 (32.0%)</td>
<td>S+P v Endurance P &gt;0.999*</td>
<td>0.87 (0.44-1.74)</td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>50 (35.0%)</td>
<td>Mixed v Endurance OR 1.98 (1.25-3.15)</td>
<td></td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>82 (51.6%)</td>
<td>S+P v Mixed P =0.072*</td>
<td>0.44 (0.23-0.86)</td>
</tr>
</tbody>
</table>

*Bonferroni correction

---

Table 5:14 Odds ratio of BEWE score ≥ 7 for different sports

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number of athletes in sport with ETW (%)</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowing (60)</td>
<td>16 (26.7%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (72)</td>
<td>38 (52.8%)</td>
<td>1.68 (0.77-3.67)</td>
<td>0.196</td>
</tr>
<tr>
<td>Cycling (51)</td>
<td>16 (26.7%)</td>
<td>0.96 (0.39-2.34)</td>
<td>0.928</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>23 (50%)</td>
<td>1.5 (0.64-3.53)</td>
<td>0.354</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>21 (45.7%)</td>
<td>1.26 (0.53-2.97)</td>
<td>0.598</td>
</tr>
<tr>
<td>Football (46)</td>
<td>19 (73.1%)</td>
<td>1.06 (0.45-2.5)</td>
<td>0.902</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>2 (9.5%)</td>
<td>0.5 (0.09-2.79)</td>
<td>0.430</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>9 (60%)</td>
<td>2.25 (0.67-7.55)</td>
<td>0.189</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>4 (27.7%)</td>
<td>0.55 (0.15-2.02)</td>
<td>0.364</td>
</tr>
</tbody>
</table>
5.5.6 Periodontal health

Excellent periodontal health (BPE code 0 as worst score) was present in 4 (1.1%, 95% CI 0.3-3.0) athletes (Figure 5.11). Gingival bleeding on probing/calculus or other plaque retentive factors present (BPE codes 1 or 2) as the worst finding was present in 272, (77.3%, 95% CI 72.6-81.3) of athletes and a pocket probing depth of ≥4 mm (BPE code 3 or 4) in a further 76 (21.6%, 95% CI 17.6-26.2). Self-reported bleeding when cleaning teeth at least occasionally was reported by 39.0% (95% CI 34.0-44.1) of athletes (Figure 5.12). Periodontal condition did not vary significantly by gender, educational status, ethnicity, sport or sport category, however there was a significant association with age; athletes in the older age group had a higher prevalence of BPE codes 3 or 4 (Table 5.15). In terms of extent, 87.5% (95% CI 83.3-90.3) of athletes had a BPE score of at least 1 in three or more sextants that is at least half the mouth affected (Table 5.16).

Figure 5.11 BPE score by sport category

Figure 5.12 Self-reported gingival bleeding and observed condition
### Table 5:15 Periodontal condition (Worst BPE score) by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Number (%) with BPE = 0</th>
<th>Number (%) with BPE = 1 or 2</th>
<th>Number (%) with BPE = 3 or 4</th>
<th>95% CI</th>
<th>95% CI</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N=344)</td>
<td>4 (1.1%)</td>
<td>272 (77.3%)</td>
<td>76 (21.6%)</td>
<td>72.60 - 81.35</td>
<td>17.60 - 26.19</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = 0.012</td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>4 (2.4%)</td>
<td>134 (80.2%)</td>
<td>29 (17.4%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>0</td>
<td>130 (73.4%)</td>
<td>47 (26.6%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = 0.642</td>
</tr>
<tr>
<td>Male (236)</td>
<td>3 (1.3%)</td>
<td>179 (75.8%)</td>
<td>54 (22.9%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (116)</td>
<td>1 (0.9%)</td>
<td>93 (80.2%)</td>
<td>22 (19%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = 0.082</td>
</tr>
<tr>
<td>White British (275)</td>
<td>4 (1.5%)</td>
<td>216 (78.6%)</td>
<td>55 (20%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (69)</td>
<td>0</td>
<td>46 (68.7%)</td>
<td>21 (31.3%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = 0.678</td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>1 (0.6%)</td>
<td>124 (76.5%)</td>
<td>37 (22.8%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>3 (1.7%)</td>
<td>139 (77.2%)</td>
<td>38 (21.1%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sport category</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = 0.747</td>
</tr>
<tr>
<td>Strength and power (n=50)</td>
<td>0</td>
<td>36 (72.0%)</td>
<td>14 (28.0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endurance (n = 143)</td>
<td>2 (1.4%)</td>
<td>112 (78.3%)</td>
<td>29 (20.3%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed (n = 159)</td>
<td>2 (1.3%)</td>
<td>124 (78.0%)</td>
<td>33 (20.7%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 5:16 Extent of periodontal diseases by BPE score

<table>
<thead>
<tr>
<th>BPE code</th>
<th>1-2 sextants</th>
<th>3-4 sextants</th>
<th>5-6 sextants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>1 or 2</td>
<td>39</td>
<td>11.1</td>
<td>130</td>
</tr>
<tr>
<td>3 or 4</td>
<td>66</td>
<td>18.8</td>
<td>9</td>
</tr>
</tbody>
</table>

#### 5.5.7 Pericoronitis and oral infections

The prevalence of oral infections was low. At the time of clinical examination four (1.1%, 95% CI 0.3-3.0) athletes showed clinical signs of infection around wisdom teeth. However, 12 (3.4%, 95% CI 1.9-5.9) athletes had at least one PUFA finding.
5.5.8 Differences between elite athletes and the general population

It was not possible to recruit a control population specific to this study. The ADH 2009 survey provides data from clearly defined age categories, although it is likely that the clinical data presents an underestimate of the true prevalence of the common dental diseases. However, with clearly defined criteria, it is possible to make a cautious comparison between this group of athletes and a group of people of a similar age (16 to 24 years and 25-34 years, combined data) as these data are available from the ADH 2009 (Table 5.17).

The Chi squared test for with Yates continuity was applied. There are statistically significant differences between elite athletes and a general UK population for caries (p<0.001), periodontal diseases (p=0.006) and ETW (p<0.001). The odds of caries and ETW appear to be increased in elite athletes by 1.92 and 2.20 respectively. However, the odds of BPE score appear to be reduced in this sample of elite athletes by 33%, compared to the ADH2009 data.

Table 5:17 Comparison with athletes and the general population (aged 16-34) primary caries

<table>
<thead>
<tr>
<th>Clinical indicator</th>
<th>Elite Athletes (%)</th>
<th>UK population (%)</th>
<th>Chi squared test</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caries (ICDAS ≥ 3)</td>
<td>173 (49%)</td>
<td>522 (33.5%)</td>
<td>P &lt; 0.001</td>
<td>1.92 (1.52-2.43)</td>
</tr>
<tr>
<td>BPE 3 or 4</td>
<td>76 (21.6%)</td>
<td>449 (28.9%)</td>
<td>P = 0.006</td>
<td>0.67 (0.51-0.89)</td>
</tr>
<tr>
<td>ETW (moderate or severe (9-13))</td>
<td>42 (12%)</td>
<td>90 (5.8%)</td>
<td>P &lt; 0.001</td>
<td>2.20 (1.50-3.23)</td>
</tr>
</tbody>
</table>

5.5.9 Self-reported general health, oral health

In order to obtain an overall picture of perceived general health and oral health, the athletes were asked to self-assess their status. Figure 5.13 shows the results for the Olympic athletes and professional athletes. Nine in ten athletes (90.1%, 95% CI 86.48 to 92.87) assessed their general health as very good or good (Table 5.18). However self-assessed oral health status was lower (Table 5.19). Seven in ten (69.2%, 95% CI 64.11 to 73.84) assessed their oral health at this level. Self-reported general health status did not vary by gender, age, ethnicity, educational status, sport or sport category. Self-assessed oral health status varied by gender with the odds of women assessing their oral health as good or very good twice that of men (P=0.002). Self-assessed oral health also varied by ethnicity with the odds of athletes from other ethnicity groups assessing their oral health as good or very good being half that of white British athletes (P=0.041).
Just over half of footballers assessed their oral health as very good or good (57.7%, 95% CI 38.92 to 74.48).

Figure 5.13 Self-assessed general health and oral health reported by Olympic and professional athletes
### Table 5:18 Self-assessed general health status by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Number reporting general health Very good/good (%)</th>
<th>Odds Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All (344)</strong></td>
<td>310 (90.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>148 (88.6%)</td>
<td>1</td>
<td>0.471</td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>162 (91.5%)</td>
<td>1.39 (0.68-2.83)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>205 (89.9%)</td>
<td>1</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Female (116)</td>
<td>105 (90.5%)</td>
<td>1.07 (0.50-2.25)</td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>251 (91.3%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Other (69)</td>
<td>57 (85.1%)</td>
<td>0.55 (0.25-1.20)</td>
<td>0.196</td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>148 (91.4%)</td>
<td>0.66 (0.23-1.89)</td>
<td>0.441</td>
</tr>
<tr>
<td>No degree (182)</td>
<td>160 (88.9%)</td>
<td>0.76 (0.37-1.55)</td>
<td>0.561</td>
</tr>
<tr>
<td><strong>Sport category</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>44 (88%)</td>
<td>1.34 (0.43-4.25)</td>
<td>0.616</td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>122 (87.1%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>144 (93.5%)</td>
<td>1.51 (0.53-4.33)</td>
<td>0.441</td>
</tr>
<tr>
<td><strong>Sport</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>53 (88.3%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>61 (91%)</td>
<td>1.34 (0.43-4.25)</td>
<td>0.616</td>
</tr>
<tr>
<td>Cycling (47)</td>
<td>42 (87.5%)</td>
<td>1.11 (0.33-3.75)</td>
<td>0.367</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>40 (87%)</td>
<td>0.88 (0.27-2.82)</td>
<td>0.830</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>43 (93.5%)</td>
<td>1.89 (0.46-7.76)</td>
<td>0.375</td>
</tr>
<tr>
<td>Football (26)</td>
<td>26 (100%)</td>
<td>7.43 (0.41-35.08)</td>
<td>0.175</td>
</tr>
<tr>
<td>Athletics (23)</td>
<td>18 (85.7%)</td>
<td>0.79 (0.02-3.39)</td>
<td>0.754</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>13 (86.7%)</td>
<td>0.86 (0.16-4.63)</td>
<td>0.859</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>14 (93.3%)</td>
<td>1.85 (0.21-16.30)</td>
<td>0.580</td>
</tr>
</tbody>
</table>
Table 5:19 Self-assessed oral health status by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group</th>
<th>Number reporting oral health Very good/good (%)</th>
<th>Odds Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All (344)</strong></td>
<td>238 (69.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>119 (71.3%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>119 (67.2%)</td>
<td>0.88 (0.52-1.31)</td>
<td>0.489</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>145 (63.3%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Female (116)</td>
<td>93 (80.2%)</td>
<td>2.314 (1.36-3.93)</td>
<td><strong>0.002</strong></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>198 (72%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Other (69)</td>
<td>39 (58.2%)</td>
<td>0.542 (0.31-0.94)</td>
<td><strong>0.041</strong></td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>117 (72.2%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>119 (66.1%)</td>
<td>0.750 (0.47-1.19)</td>
<td>0.270</td>
</tr>
<tr>
<td>Sport category</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>32 (64%)</td>
<td>0.87 (0.44-1.71)</td>
<td>0.687</td>
</tr>
<tr>
<td>Endurance (143)</td>
<td>96 (68.6%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Mixed (159)</td>
<td>110 (71.4%)</td>
<td>1.10 (0.68-1.79)</td>
<td>0.703</td>
</tr>
<tr>
<td>Sport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>43 (71.7%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>47 (70.1%)</td>
<td>0.93 (0.43-2.0)</td>
<td>0.851</td>
</tr>
<tr>
<td>Cycling (47)</td>
<td>31 (64.6%)</td>
<td>0.77 (0.34-1.75)</td>
<td>0.526</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>31 (67.4%)</td>
<td>0.82 (0.03-1.88)</td>
<td>0.635</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>36 (78.3%)</td>
<td>1.42 (0.58-3.50)</td>
<td>0.441</td>
</tr>
<tr>
<td>Football (26)</td>
<td>15 (57.7%)</td>
<td>21.32 (1.23-36.48)</td>
<td><strong>0.035</strong></td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>14 (66.7%)</td>
<td>0.79 (0.27-2.30)</td>
<td>0.666</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>9 (60%)</td>
<td>0.59 (0.18-1.92)</td>
<td>0.384</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>12 (80%)</td>
<td>1.58 (0.40-6.31)</td>
<td>0.516</td>
</tr>
</tbody>
</table>


5.5.10 Self-reported oral health problems

The proportions of athletes reporting oral health problems were: 7.7% (95% CI 5.3-11.0) current pain or problem related to teeth, 26.7% (95% CI 22.3-31.6) sensitivity to hot or cold, 23.3% (95% CI 19.1-28.0) swelling/infection around wisdom teeth in previous 12 months, 12.8% (95% CI 9.7-16.7) sport-related dental trauma in previous 12 months (Figure 5.14)

Figure 5.14 Self-reported oral health problems by sport category

5.5.11 Self-reported psychosocial impacts

Overall, 169 (49.1%, 95% CI 43.9-54.4) athletes reported a non-zero score for one or more psychosocial impacts within the previous 12 months: difficulty eating or drinking; 119 (34.6%, 95% CI 29.8-39.8), difficulty relaxing (including sleeping); 52 (15.1%, 95% CI 11.7-19.3), difficulty smiling, laughing or showing teeth without embarrassment; 59 (17.2%, 95% CI 13.5-21.5). Figure 5.15 shows the psychosocial impacts reported by Olympic and professional athletes. The proportion of athletes reporting any psychosocial impact did not vary significantly by age, gender or ethnicity (Table 5.20). However, the odds of an athlete from the mixed sport category reporting any psychosocial impact were 40% less than from the endurance category (Table 5.21). This was close to being significant (P=0.051). The prevalence of self-reported psychosocial impacts was highest in cyclists (64.6%) and lowest (41.7%) in rowing (OR 2.7, 95% CI 1.2-6.0, P = 0.013).
Figure 5.15 Proportion of Olympic and professional athletes reporting psychosocial impacts

- Difficulty eating or drinking
- Difficulty relaxing including sleeping
- Difficulty smiling, laughing, showing teeth without embarrassment

Legend:
- Whole group
- Olympic athletes
- Professional athletes
Table 5:20 Psychosocial impacts by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Difficulty eating/drinking</th>
<th>Difficulty relaxing including sleeping</th>
<th>Difficulty smiling, laughing, showing teeth without embarrassment</th>
<th>At least one psychosocial impact</th>
<th>Odds Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n = 344)</td>
<td>119 (34.6%)</td>
<td>52 (15.1%)</td>
<td>59 (17.2%)</td>
<td>169 (49.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (167)</td>
<td>57 (34.1%)</td>
<td>31 (18.6%)</td>
<td>31 (18.6%)</td>
<td>85 (50.9%)</td>
<td>1.15 (0.75-1.75)</td>
<td>0.524</td>
</tr>
<tr>
<td>≥ 25 years (177)</td>
<td>62 (35%)</td>
<td>21 (11.9%)</td>
<td>28 (15.8%)</td>
<td>84 (47.5%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>81 (35.5%)</td>
<td>29 (12.7%)</td>
<td>37 (16.2%)</td>
<td>112 (49.1%)</td>
<td>0.99 (0.64-1.56)</td>
<td>&gt; 0.999</td>
</tr>
<tr>
<td>Female (116)</td>
<td>38 (32.8%)</td>
<td>23 (19.8%)</td>
<td>22 (19%)</td>
<td>57 (49.1%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>87 (31.6%)</td>
<td>36 (13.1%)</td>
<td>44 (16%)</td>
<td>130 (47.3%)</td>
<td>0.64 (0.38-1.10)</td>
<td>0.109</td>
</tr>
<tr>
<td>Other (69)</td>
<td>32 (47.8%)</td>
<td>16 (23.9%)</td>
<td>15 (22.4%)</td>
<td>39 (58.2%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>57 (35.2%)</td>
<td>22 (13.6%)</td>
<td>25 (15.4%)</td>
<td>77 (47.5%)</td>
<td>0.96 (0.59-1.38)</td>
<td>0.600</td>
</tr>
<tr>
<td>No degree (182)</td>
<td>62 (34.4%)</td>
<td>30 (16.7%)</td>
<td>33 (18.3%)</td>
<td>91 (50.6%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sport category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength &amp; power 50)</td>
<td>21 (42%)</td>
<td>9 (18%)</td>
<td>9 (18%)</td>
<td>27 (54%)</td>
<td>0.99 (0.52-1.90)</td>
<td>0.972</td>
</tr>
<tr>
<td>Endurance (140)</td>
<td>52 (37.1%)</td>
<td>20 (14.3%)</td>
<td>27 (19.3%)</td>
<td>76 (54.3%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Mixed (154)</td>
<td>46 (29.9%)</td>
<td>23 (14.9%)</td>
<td>23 (14.9%)</td>
<td>66 (42.3%)</td>
<td>0.63 (0.39-1.01)</td>
<td>0.051</td>
</tr>
</tbody>
</table>
Table 5:21 Psychosocial impacts by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Difficulty eating/ drinking</th>
<th>Difficulty relaxing including sleeping</th>
<th>Difficulty smiling, laughing, showing teeth without embarrassment</th>
<th>At least one psychosocial impact</th>
<th>Odds ratio (95%CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rowing (n=60)</td>
<td>19 (31.7%)</td>
<td>8 (13.3%)</td>
<td>5 (8.3%)</td>
<td>25 (41.7%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (n = 67)</td>
<td>20 (29.9%)</td>
<td>11 (16.4%)</td>
<td>10 (14.9%)</td>
<td>29 (43.3%)</td>
<td>1.07 (0.53-2.16)</td>
<td>0.854</td>
</tr>
<tr>
<td>Cycling (n = 47)</td>
<td>24 (50%)</td>
<td>10 (20.8%)</td>
<td>8 (16.7%)</td>
<td>31 (64.6%)</td>
<td>2.71 (1.23-5.99)</td>
<td><strong>0.013</strong></td>
</tr>
<tr>
<td>Swimming (n = 46)</td>
<td>13 (28.3%)</td>
<td>7 (15.2%)</td>
<td>15 (32.6%)</td>
<td>27 (58.7%)</td>
<td>1.80 (0.84-3.85)</td>
<td>0.133</td>
</tr>
<tr>
<td>Hockey (n = 46)</td>
<td>14 (30.4%)</td>
<td>5 (10.9%)</td>
<td>6 (13%)</td>
<td>20 (43.5%)</td>
<td>1.08 (0.49-2.34)</td>
<td>0.852</td>
</tr>
<tr>
<td>Football (n = 26)</td>
<td>8 (30.8%)</td>
<td>7 (26.9%)</td>
<td>6 (23.1%)</td>
<td>12 (46.2%)</td>
<td>1.2 (0.47-3.03)</td>
<td>0.699</td>
</tr>
<tr>
<td>Athletics (n = 21)</td>
<td>11 (52.4%)</td>
<td>2 (9.5%)</td>
<td>5 (23.8%)</td>
<td>12 (57.1%)</td>
<td>1.87 (0.68-5.1)</td>
<td>0.224</td>
</tr>
<tr>
<td>Gymnastics (n = 15)</td>
<td>6 (40%)</td>
<td>2 (13.3%)</td>
<td>3 (20%)</td>
<td>8 (53.3%)</td>
<td>1.6 (0.51-4.98)</td>
<td>0.418</td>
</tr>
<tr>
<td>Sailing (n = 15)</td>
<td>4 (26.7%)</td>
<td>0</td>
<td>1 (6.7%)</td>
<td>5 (33.3%)</td>
<td>0.7 (0.21-2.30)</td>
<td>0.557</td>
</tr>
</tbody>
</table>
5.5.12 Self-reported impacts on performance in sport

Overall, 110 (32%) athletes reported a non-zero score for one or more sport performance impacts within the previous 12 months (Figure 5.16): difficulty in participating in normal training and competition; 9% (95% CI 6.39 to 12.54), reduced training volume; 3.8% (95% CI 2.16 to 6.42), performance affected; 5.8% (95% CI 3.75 to 0.86) and experienced oral pain; 29.9% (95% CI 25.34 to 34.99).

Figure 5.16 Self-reported impacts on performance in sport

The relationship between self-reported sport performance impacts and the characteristics of the group was investigated and reported as odds ratio. The proportion of athletes reporting any impact on performance in sport did not vary by age, ethnicity, education (Table 5.2), sport or sport category (Table 5.23). However, the odds of reporting an oral impact on sport performance was reduced by 41% in men compared to women (OR = 0.59, 95% CI 0.37-0.95; P= 0.030).
Table 5:22 Sport performance impacts by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of the group (n)</th>
<th>Difficulty participating in normal training</th>
<th>Reduction in volume of training</th>
<th>Performance affected pain</th>
<th>Experience of pain</th>
<th>At least one impact on sport performance</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All N = 344</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (167)</td>
<td>14 (8.4%)</td>
<td>8 (4.8%)</td>
<td>12 (7.2%)</td>
<td>5 (32.9%)</td>
<td>57 (34.1%)</td>
<td>1.21 (0.77-1.91)</td>
<td>0.405</td>
</tr>
<tr>
<td>≥ 25 years (177)</td>
<td>17 (9.6%)</td>
<td>5 (2.8%)</td>
<td>8 (4.5%)</td>
<td>48 (27.1%)</td>
<td>53 (29.9%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>13 (5.7%)</td>
<td>6 (2.6%)</td>
<td>9 (3.9%)</td>
<td>61 (26.8%)</td>
<td>64 (28.1%)</td>
<td>0.59 (0.37-0.95)</td>
<td>0.030</td>
</tr>
<tr>
<td>Female (116)</td>
<td>18 (15.5%)</td>
<td>7 (6%)</td>
<td>11 (9.5%)</td>
<td>42 (36.2%)</td>
<td>46 (39.7%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>27 (9.8%)</td>
<td>10 (3.6%)</td>
<td>15 (5.5%)</td>
<td>78 (28.4%)</td>
<td>84 (30.5%)</td>
<td>0.69 (0.39-1.21)</td>
<td>0.196</td>
</tr>
<tr>
<td>Other (67)</td>
<td>4 (6%)</td>
<td>3 (4.5%)</td>
<td>5 (7.5%)</td>
<td>25 (37.3%)</td>
<td>26 (38.8%)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>11.7% (19)</td>
<td>4.9% (8)</td>
<td>4.9% (8)</td>
<td>32.1% (52)</td>
<td>35.2% (57)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>No degree (182)</td>
<td>12 (6.7%)</td>
<td>5 (6.7%)</td>
<td>12 (6.7%)</td>
<td>51 (28.3%)</td>
<td>53 (29.4%)</td>
<td>0.76 (0.48-1.19)</td>
<td>0.229</td>
</tr>
<tr>
<td>Sport category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength and power (50)</td>
<td>4 (8%)</td>
<td>2 (4%)</td>
<td>4 (8%)</td>
<td>22 (44%)</td>
<td>23 (46%)</td>
<td>1.86 (0.96-3.60)</td>
<td>0.066</td>
</tr>
<tr>
<td>Endurance (140)</td>
<td>12 (8.6%)</td>
<td>4 (2.9%)</td>
<td>8 (5.7%)</td>
<td>42 (30%)</td>
<td>44 (31.4%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Mixed (154)</td>
<td>15 (9.7%)</td>
<td>7 (4.5%)</td>
<td>8 (5.2%)</td>
<td>39 (25.3%)</td>
<td>43 (27.9%)</td>
<td>0.85 (0.51-1.39)</td>
<td>0.511</td>
</tr>
<tr>
<td>Sport (n)</td>
<td>Number (%) reporting non-zero score for each impact</td>
<td>Odds ratio (95%CI)</td>
<td>P value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficulty participating in normal training</td>
<td>Reduction in volume of training</td>
<td>Performance affected...</td>
<td>Experience of pain.....</td>
<td>At least one impact on sport performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowing (n=60)</td>
<td>5 (8.3%)</td>
<td>1 (1.7%)</td>
<td>1 (1.7%)</td>
<td>16 (26.7%)</td>
<td>18 (30%)</td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>Rugby (n = 67)</td>
<td>5 (7.5%)</td>
<td>3 (4.5%)</td>
<td>5 (7.5%)</td>
<td>16 (23.9%)</td>
<td>18 (26.9%)</td>
<td>0.86 (0.39-1.86)</td>
<td>0.696</td>
</tr>
<tr>
<td>Cycling (n = 47)</td>
<td>6 (12.5%)</td>
<td>3 (6.3%)</td>
<td>7 (14.6%)</td>
<td>20 (41.7%)</td>
<td>20 (41.7%)</td>
<td>1.73 (0.77-3.84)</td>
<td>0.179</td>
</tr>
<tr>
<td>Swimming (n = 46)</td>
<td>4 (8.7%)</td>
<td>2 (4.3%)</td>
<td>2 (4.3%)</td>
<td>13 (28.3%)</td>
<td>13 (28.3%)</td>
<td>0.92 (0.39-2.14)</td>
<td>0.843</td>
</tr>
<tr>
<td>Hockey (n = 46)</td>
<td>7 (15.2%)</td>
<td>4 (8.7%)</td>
<td>3 (6.5%)</td>
<td>13 (28.3%)</td>
<td>14 (30.4%)</td>
<td>1.02 (0.44-2.36)</td>
<td>0.961</td>
</tr>
<tr>
<td>Football (n = 26)</td>
<td>2 (7.7%)</td>
<td>0</td>
<td>0</td>
<td>7 (26.9%)</td>
<td>8 (30.8%)</td>
<td>1.04 (0.38-2.81)</td>
<td>0.943</td>
</tr>
<tr>
<td>Athletics (n = 21)</td>
<td>1 (4.8%)</td>
<td>0</td>
<td>1 (4.8%)</td>
<td>9 (33.3%)</td>
<td>8 (38.1%)</td>
<td>1.44 (0.51-4.06)</td>
<td>0.495</td>
</tr>
<tr>
<td>Gymnastics (n = 15)</td>
<td>0</td>
<td>0</td>
<td>1 (6.7%)</td>
<td>8 (53.3%)</td>
<td>8 (53.3%)</td>
<td>2.67 (0.84-8.46)</td>
<td>0.096</td>
</tr>
<tr>
<td>Sailing (n = 15)</td>
<td>1 (6.7%)</td>
<td>0</td>
<td>0</td>
<td>3 (20%)</td>
<td>3 (20%)</td>
<td>0.58 (0.15-2.32)</td>
<td>0.444</td>
</tr>
</tbody>
</table>
A severity score, out of 100 can be calculated for impact of oral health problems on performance in sport (Figure 5.17). Nearly one-third (32%) of athletes reported a non-zero score; the highest score reported was 94.

Figure 5.17 Severity score for oral health problems

<table>
<thead>
<tr>
<th>Score</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;60 (severe)</td>
<td>1%</td>
</tr>
<tr>
<td>30-59 (moderate)</td>
<td>5%</td>
</tr>
<tr>
<td>1-29 (minor)</td>
<td>26%</td>
</tr>
<tr>
<td>Score 0</td>
<td>68%</td>
</tr>
</tbody>
</table>

5.5.13 Clinical indicators of oral health, general health status, oral health status and athlete-reported psychosocial impacts

The relationship between psychosocial impacts and clinical markers of oral health and the relationship between psychosocial impacts and self-assessed general and oral health was explored using the Chi-squared test (Table 5.24).

The presence of dental caries was associated with non-zero score for difficulty eating (P = 0.048). The presence of any PUFA lesion was also associated with non-zero scores for difficulty eating (P =0.027) and relaxing (P < 0.001).

There was a significant association for any reported impact and both self-reported poor/fair general health status (P=0.011) and self-reported poor/fair oral health status (P=<0.001).

There was also an association with self-reported poor general health and impact on relaxing including sleeping (P= 0.001). Self-assessed poor oral health was associated with all three psychosocial indicators: impacts on eating/drinking (P=0.001), impacts on relaxing including sleeping (P=0.005) and being embarrassed to smile or show teeth (P=0.001).
### Table 5:24 Psychosocial impacts by clinical indicators of oral health, self-assessed general and oral health

<table>
<thead>
<tr>
<th>Number with condition (n)</th>
<th>Number (%) reporting non-zero score for each impact</th>
<th>At least one psychosocial impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difficulty eating/ drinking</td>
<td>Difficulty relaxing including sleeping</td>
</tr>
<tr>
<td><strong>All (n = 344)</strong></td>
<td>119 (34.6%)</td>
<td>52 (15.1%)</td>
</tr>
<tr>
<td><strong>Established caries</strong></td>
<td>169 (49.1%)</td>
<td>P = 0.048</td>
</tr>
<tr>
<td>No decay (179)</td>
<td>52 (29.4%)</td>
<td>22 (12.4%)</td>
</tr>
<tr>
<td>Caries in one or more teeth (173)</td>
<td>67 (40.1%)</td>
<td>30 (18%)</td>
</tr>
<tr>
<td>Chi squared test.</td>
<td>P = 0.027</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td><strong>Any PUFA</strong></td>
<td>160 (48.2%)</td>
<td>75% (9)</td>
</tr>
<tr>
<td>No (340).</td>
<td>111 (33.4%)</td>
<td>44 (13.3%)</td>
</tr>
<tr>
<td>Yes (12).</td>
<td>8 (66.7%)</td>
<td>8 (66.7%)</td>
</tr>
<tr>
<td>Chi squared test.</td>
<td>P = 0.027</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td><strong>Periodontal condition</strong></td>
<td>125 (46.6%)</td>
<td>76 (52.1%)</td>
</tr>
<tr>
<td>BPE 0, 1 or 2 (276).</td>
<td>86 (32.1%)</td>
<td>41 (15.3%)</td>
</tr>
<tr>
<td>BPE 3 or 4 (76).</td>
<td>33 (43.4%)</td>
<td>11 (14.5%)</td>
</tr>
<tr>
<td>Chi squared test.</td>
<td>P = 0.076</td>
<td>P &gt; 0.999</td>
</tr>
<tr>
<td><strong>ETW</strong></td>
<td>93 (47%)</td>
<td>76 (52.1%)</td>
</tr>
<tr>
<td>BEWE score &lt; 6 (204).</td>
<td>68 (34.3%)</td>
<td>29 (14.6%)</td>
</tr>
<tr>
<td>BEWE score ≥ 7 (148).</td>
<td>51 (34.9%)</td>
<td>23 (15.8%)</td>
</tr>
<tr>
<td>Chi squared test.</td>
<td>P &gt; 0.999</td>
<td>P = 0.879</td>
</tr>
<tr>
<td><strong>Self-reported general health</strong></td>
<td>145 (46.8%)</td>
<td>24 (70.6%)</td>
</tr>
<tr>
<td>Very/good (310)</td>
<td>102 (32.9%)</td>
<td>37 (11.9%)</td>
</tr>
<tr>
<td>Fair- very poor (34)</td>
<td>17 (50%)</td>
<td>15 (44.1%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.057</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td><strong>Self-reported oral health</strong></td>
<td>P = 0.011</td>
<td>97 (40.8%)</td>
</tr>
<tr>
<td>Very/good (238)</td>
<td>67 (28.2%)</td>
<td>27 (11.3%)</td>
</tr>
<tr>
<td>Fair-very poor (106)</td>
<td>52 (49.1%)</td>
<td>25 (23.6%)</td>
</tr>
<tr>
<td>Number with condition (n)</td>
<td>Number (%) reporting non-zero score for each impact</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficulty eating/ drinking</td>
<td>Difficulty relaxing including sleeping</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>$P &lt; 0.001$</td>
<td>$P = 0.005$</td>
</tr>
</tbody>
</table>
5.5.14 Clinical indicators of oral health, general health status, oral health status and athlete-reported sport performance impacts

The relationship between athlete-reported impacts on performance in sport and clinical indicators of oral health, general health status and oral health status was explored using the Chi squared test (Table 5.25).

Oral sepsis was associated with difficulty participating in normal training or competition (P = 0.002), experience of oral pain (P = 0.001) and “any sport performance impact” (P = 0.005).

A statistically significant association was also indicated between self-reported oral health and oral pain (p = 0.022). Overall a significant association between oral health status and at least one impact on sport performance was indicated (p = 0.046).
Table 5: Sport performance impacts by clinical indicators of oral health, self-assessed general and oral health status

<table>
<thead>
<tr>
<th>Condition</th>
<th>Difficulty participating in normal training</th>
<th>Reduction in volume of training</th>
<th>Performance affected</th>
<th>Experience of pain</th>
<th>At least one sport performance impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n = 344)</td>
<td>31 (9%)</td>
<td>13 (3.8%)</td>
<td>20 (5.8%)</td>
<td>103 (29.9%)</td>
<td>110 (32%)</td>
</tr>
<tr>
<td>Established caries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (179)</td>
<td>14 (7.9%)</td>
<td>6 (3.4%)</td>
<td>8 (4.5%)</td>
<td>50 (28.2%)</td>
<td>55 (31.1%)</td>
</tr>
<tr>
<td>Caries in one or more teeth</td>
<td>17 (10.2%)</td>
<td>6 (4.2%)</td>
<td>12 (7.2%)</td>
<td>57 (31.7%)</td>
<td>55 (32.9%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.585</td>
<td>P = 0.915</td>
<td>P = 0.409</td>
<td>P = 0.556</td>
<td>P = 0.799</td>
</tr>
<tr>
<td>Any PUFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (340)</td>
<td>26 (7.8%)</td>
<td>11 (3.3%)</td>
<td>19 (5.7%)</td>
<td>94 (28.3%)</td>
<td>101 (30.4%)</td>
</tr>
<tr>
<td>Yes (12)</td>
<td>5 (41.7%)</td>
<td>2 (16.7%)</td>
<td>1 (8.3%)</td>
<td>9 (75%)</td>
<td>9 (75%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.002</td>
<td>P = 0.070</td>
<td>P &gt; 0.999</td>
<td>P = 0.001</td>
<td>P = 0.002</td>
</tr>
<tr>
<td>Periodontal condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPE 0, 1 or 2 (276)</td>
<td>25 (9.3%)</td>
<td>10 (3.7%)</td>
<td>16 (6%)</td>
<td>76 (28.4%)</td>
<td>80 (29.9%)</td>
</tr>
<tr>
<td>BPE 3 or 4 (76)</td>
<td>6 (7.9%)</td>
<td>3 (3.9%)</td>
<td>4 (5.3%)</td>
<td>27 (35.5%)</td>
<td>30 (39.5%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.823</td>
<td>P &gt; 0.999</td>
<td>P &gt; 0.999</td>
<td>P = 0.253</td>
<td>P = 0.126</td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEWE score &lt; 6 (204)</td>
<td>20 (10.1%)</td>
<td>8 (4%)</td>
<td>12 (6.1%)</td>
<td>62 (31.3%)</td>
<td>65 (32.8%)</td>
</tr>
<tr>
<td>BEWE score ≥ 7 (148)</td>
<td>11 (7.5%)</td>
<td>5 (3.4%)</td>
<td>8 (5.5%)</td>
<td>41 (28.1%)</td>
<td>45 (30.8%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.452</td>
<td>P = 0.786</td>
<td>P &gt; 0.999</td>
<td>P = 0.553</td>
<td>P = 0.727</td>
</tr>
<tr>
<td>Self-reported general health</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very/good (310)</td>
<td>23 (7.4%)</td>
<td>9 (2.9%)</td>
<td>14 (4.5%)</td>
<td>87 (28.1%)</td>
<td>93 (30.0%)</td>
</tr>
<tr>
<td>Fair - very poor (34)</td>
<td>23.5%</td>
<td>4 (11.8%)</td>
<td>6 (17.6%)</td>
<td>16 (47.1)</td>
<td>17 (50%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>P = 0.006</td>
<td>P = 0.030</td>
<td>P = 0.008</td>
<td>P = 0.029</td>
<td>P = 0.021</td>
</tr>
<tr>
<td>Number with condition (n)</td>
<td>Difficulty participating in normal training</td>
<td>Reduction in volume of training</td>
<td>Performance affected</td>
<td>Experience of pain</td>
<td>At least one sport performance impact</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Self-reported oral health</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very/good (238)</td>
<td>20 (8.4%)</td>
<td>9 (3.8%)</td>
<td>11 (4.6%)</td>
<td>62 (26.1%)</td>
<td>68 (28.6%)</td>
</tr>
<tr>
<td>Fair-very poor (106)</td>
<td>11 (10.4%)</td>
<td>4 (3.8%)</td>
<td>9 (8.5%)</td>
<td>41 (38.7%)</td>
<td>42 (39.6%)</td>
</tr>
<tr>
<td>Chi squared test.</td>
<td>(P = 0.684)</td>
<td>(P &gt; 0.999)</td>
<td>(P = 0.210)</td>
<td>(P = 0.022)</td>
<td>(P = 0.046)</td>
</tr>
</tbody>
</table>
5.5.15 Self-reported oral health problems and athlete-reported performance impacts

The relationship between psychosocial impacts and self-reported oral health problems (Table 5.26) and the relationship between sport performance impacts and self-reported oral health problems (Table 5.27) was explored using the Chi squared test.

When multiple hypothesis testing is conducted, a more stringent level of significance should be set, such as 1% rather than 5%.

However, several self-reported oral health problems had a statistically significant association with athlete-reported impacts on wellbeing or sport performance: current pain or problem related to teeth (P = < 0.001), sensitivity to hot or cold (P = 0.006) and history of swelling or infection around wisdom teeth P = 0.001.

For general health status, there were statistically significant associations between relaxing (including sleeping) and all sport performance impacts.
Table 5: Psychosocial impacts by self-reported oral health problems

<table>
<thead>
<tr>
<th>Self-reported problem</th>
<th>Difficulty eating/drinking</th>
<th>Difficulty relaxing including sleeping</th>
<th>Difficulty smiling, laughing or showing teeth without embarrassment</th>
<th>At least one psychosocial impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n = 344)</td>
<td>119 (34.6%)</td>
<td>52 (15.1%)</td>
<td>59 (17.2%)</td>
<td>169 (49.1%)</td>
</tr>
<tr>
<td>Current pain/problem</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (325)</td>
<td>104 (32.8%)</td>
<td>40 (12.6%)</td>
<td>51 (16.1%)</td>
<td>146 (46.1%)</td>
</tr>
<tr>
<td>Yes (27)</td>
<td>15 (55.6%)</td>
<td>12 (44.4%)</td>
<td>8 (29.6%)</td>
<td>23 (85.2%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td>( P = 0.030 )</td>
<td>( P &lt; 0.001 )</td>
<td>( P = 0.127 )</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Sensitivity to hot or cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (258)</td>
<td>74 (29.2%)</td>
<td>37 (14.6%)</td>
<td>42 (16.6%)</td>
<td>113 (44.7%)</td>
</tr>
<tr>
<td>Yes (94)</td>
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<td>17 (18.7%)</td>
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</tr>
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<td>( P = 0.800 )</td>
<td>( P = 0.772 )</td>
<td>( P = 0.008 )</td>
</tr>
<tr>
<td>Bleeding when cleaning teeth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (215)</td>
<td>54 (30.7%)</td>
<td>19 (10.8%)</td>
<td>27 (15.3%)</td>
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</tr>
<tr>
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<td>44 (39.3%)</td>
<td>23 (20.5%)</td>
<td>18 (16.1%)</td>
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</tr>
<tr>
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<td>( P = 0.169 )</td>
<td>( P = 0.035 )</td>
<td>( P &gt; 0.999 )</td>
<td>( P = 0.053 )</td>
</tr>
<tr>
<td>History of wisdom tooth swelling*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (270)</td>
<td>72 (27.5%)</td>
<td>33 (12.6%)</td>
<td>39 (14.9%)</td>
<td>106 (40.5%)</td>
</tr>
<tr>
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<td>47 (57.3%)</td>
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<td>20 (24.4%)</td>
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</tr>
<tr>
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<td>( P &lt; 0.001 )</td>
<td>( P = 0.031 )</td>
<td>( P = 0.068 )</td>
<td>( P &lt; 0.001 )</td>
</tr>
</tbody>
</table>

*Previous 12 months
Table 5.27 Sport performance impacts by self-reported oral health problems

<table>
<thead>
<tr>
<th>Self-reported problem</th>
<th>Difficulty participating in normal training</th>
<th>Reduction in volume of training.</th>
<th>Performance affected….</th>
<th>Experience of pain….</th>
<th>At least one sport performance impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n = 344)</td>
<td>31 (9%)</td>
<td>13 (3.8%)</td>
<td>20 (5.8%)</td>
<td>103 (29.9%)</td>
<td>110 (32%)</td>
</tr>
<tr>
<td>Current pain/problem</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (325)</td>
<td>23 (7.3%)</td>
<td>10 (3.2%)</td>
<td>16 (5%)</td>
<td>83 (26.2%)</td>
<td>89 (28.1%)</td>
</tr>
<tr>
<td>Yes (27)</td>
<td>8 (29.6%)</td>
<td>3 (11.1%)</td>
<td>4 (14.8%)</td>
<td>20 (74.1%)</td>
<td>21 (77.8%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*P &lt; 0.001</td>
<td>*P = 0.120</td>
<td>*P = 0.098</td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
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<tr>
<td>Sensitivity to hot or cold</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (258)</td>
<td>25 (9.9%)</td>
<td>12 (4.7%)</td>
<td>14 (5.5%)</td>
<td>68 (26.9%)</td>
<td>72 (28.5%)</td>
</tr>
<tr>
<td>Yes (94)</td>
<td>6 (6.6%)</td>
<td>1 (1.1%)</td>
<td>6 (6.6%)</td>
<td>35 (38.5%)</td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*P = 0.468</td>
<td>*P = 0.214</td>
<td>*P = 0.913</td>
<td>*P = 0.053</td>
<td>*P = 0.028</td>
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<tr>
<td>Bleeding when cleaning teeth</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (215)</td>
<td>16 (9.1%)</td>
<td>5 (2.8%)</td>
<td>9 (5.1%)</td>
<td>44 (25%)</td>
<td>48 (27.3%)</td>
</tr>
<tr>
<td>Yes (137)</td>
<td>8 (7.1%)</td>
<td>4 (3.6%)</td>
<td>5 (4.5%)</td>
<td>35 (31.3%)</td>
<td>38 (33.9%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*P = 0.716</td>
<td>*P &gt; 0.999</td>
<td>*P &gt;0.999</td>
<td>*P = 0.306</td>
<td>*P = 0.284</td>
</tr>
<tr>
<td>History of wisdom tooth swelling*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No (270)</td>
<td>18 (6.9%)</td>
<td>6 (2.3%)</td>
<td>11 (4.2%)</td>
<td>64 (24.4%)</td>
<td>70 (26.7%)</td>
</tr>
<tr>
<td>Yes (82)</td>
<td>13 (15.9%)</td>
<td>7 (8.5%)</td>
<td>9 (11%)</td>
<td>39 (47.6%)</td>
<td>40 (48.8%)</td>
</tr>
<tr>
<td>Chi squared test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>*P = 0.024</td>
<td>*P = 0.024</td>
<td>*P = 0.044</td>
<td>*P &lt; 0.001</td>
<td>*P &lt; 0.001</td>
</tr>
</tbody>
</table>

*Previous 12 months
5.6 Discussion

This chapter has presented the findings from the analysis of data collected during oral health screening provided to 352 elite athletes from 11 different elite squads training in the UK between June 2015 and September 2016. The athletes in this study were young, fit, healthy and able-bodied. In this study, 90% of athletes assessed their general health as very good or good, but only 69.2% assessed their oral health as very good or good.

At a basic level, the clinical data indicated that all athletes had a functional dentition; the number of sound and unrestored teeth indicated that they have the potential to maintain good oral health in the future. However, this study also found a substantial prevalence of oral diseases and associated self-reported performance impacts in elite athletes.

5.6.1 Key findings

Excellent periodontal health was rare. Evidence of gingival inflammation at one or more sites (BPE worst score 1 or 2) was present in 77.3% (95% CI 72.6-81.3) of athletes and evidence of periodontal diseases (BPE score > 3) was present in a further 21.6% (95% CI 17.6-26.2) of athletes. There was no association with gender, ethnicity, educational status or sport category, but there was an association with age: the prevalence of BPE score > 3 was greater in athletes > 25 years (p =0.012).

The prevalence of dental caries was substantial. Moderate or severe caries (ICDAS score > 3) in one or more teeth (DT > 1) was present in 49.1% of athletes and there was no association between caries and age, gender, ethnicity or education. There were, however, differences in the prevalence of caries between sports and between sports categories. The proportion of athletes with DT >1 in the mixed/team sport category (56%, 95% CI 48.2 to 63.5) was greater than those in endurance category (38.5%, 95% CI 31 to 46.4) and this was statistically significant (p=0.009), with an odds ratio of 2.4 (95% CI 1.5-3.8). The prevalence of restored teeth (FT>1) was significantly greater in athletes > 25 years (p < 0.001).

The prevalence of ETW in this relatively young population was high. Evidence of established ETW in one or more teeth (BEWE score ≥ 7) was present in 42.0% (95% CI 37.0-47.3) of athletes. ETW was significantly associated with being male (p<0.001): the proportion of men with evidence of ETW (48.7%) was greater than the proportion of women (28.4%) with an odds ratio of 2.4 (95% CI 1.5-3.9). ETW was also associated with athletes participating in team sports (p =0.015). The proportion of athletes in the mixed/team sport category (51.6%) was greater than the proportion of athletes in the
endurance sport category (35.0%), with an odds ratio of 2.0 (95% CI 1.3 to 3.1). However, this is a reflection of the greater proportion of men in mixed sport in this study.

A cautious comparison with a similar age group in the UK general population was made. Although the data from the ADH 2009 survey may underestimate the extent of oral disease within the general population, it also includes data from people with less social support and access to healthcare than elite athletes. At best, the oral health of elite athletes is only similar to that in the general population. At worst, the odds of caries in elite athletes compared to the general population is nearly doubled (OR 1.92, 95% CI 1.52-2.43), the odds of ETW in elite athletes is more than doubled (OR 2.20, 95%CI 1.50-3.23). The odds of a more severe periodontal problem are reduced by one third (OR 0.67, 95%CI 0.67-0.89).

Non-zero impacts reported from the OSTRC questionnaire were: oral pain (29.9%, 95% CI 25.3-25.0), participation in normal training and competition affected (9.0%, 95% CI 6.4-12.5), performance affected (5.8%, 95% CI 3.7-8.6) and reduction in training volume (3.8%, 95% CI 2.2-6.4). Two thirds (69%) of athletes recorded no impact on performance from oral health problems and 26% of athletes scored between 1 and 29 which is unlikely to be of any clinical significance.

Catastrophic impacts on performance reported by elite athletes are infrequent but do occur; the highest OSTRC score reported was 94 out of a maximum possible score of 100. However, 5% of athletes scored between 30 and 59 and 1% of athletes scored more than 60, therefore overall 6% of athletes reported that in the previous year, an oral health problem had a moderate to severe impact on performance in sport.

Non-zero psychosocial impacts were reported by a greater proportion of athletes: difficulties with eating/drinking (34.6%, 95% CI 29.8-39.8), embarrassed to smile, laugh or show teeth (17.2%, 95% CI 13.5-21.5) and difficulty relaxing/sleeping (15.1%, 95% CI 11.7-19.3). There was an association between self-assessed poor oral health status and negative psychosocial impacts: eating/drinking (p = 0.001), relaxing including sleeping (p = 0.005) and confidence (p = 0.001). Those activities of daily life are essential for athlete preparation therefore, at elite level, where the accumulation of marginal gains is critical to performance, such chronic impacts could be important.

Oral sepsis resulting from extensive caries was associated with athlete-reported difficulty participating in normal training or competition (p =0.005) and self-assessed poor oral health was associated with pain (p = 0.022). Although not necessarily considered a preventable condition, a history of wisdom tooth swelling in the previous 12 months was
associated with impact on performance in sport (p < 0.001) and at least one psychosocial impact (p < 0.001). The most likely mechanisms by which oral health problems affect performance in sport are through pain and inflammation.

5.6.2 Strengths of the study

This study was designed to address the limitations of previous studies (Needleman et al., 2014) in order to provide robust quality evidence of the oral health status of elite athletes and was one of the largest studies to evaluate oral health in sport. The squads included in the sample were identified and included on a convenience basis, however a 75% - 100% sample in each squad was achieved with track and field the only exception at 25%, therefore it is reasonable to generalise the findings to elite and professional athletes in the UK.

The inclusion of different sports allowed comparison of oral health within elite sport for the first time. Sports were classified into three categories and 352 athletes were recruited from 11 separate elite training squads therefore the sample can be judged to be representative of elite athletes in the UK. The study design was informed by a national epidemiologic study conducted in the UK (O'Sullivan et al., 2011) and previous studies conducted in elite sport (Needleman et al., 2013; Needleman et al., 2016), thereby allowing the results to be placed in context relative to both the general population in the UK and elite sport.

Clinical data were collected using clearly defined outcomes, standardised examination conditions and a single trained and calibrated examiner. Standard clinical indices were used to screen for oral diseases: the International Caries Detection and Assessment System (Ismail et al., 2007), the Basic Periodontal Examination (British Society of Periodontology, 2016), the Basic Erosive Wear Examination (Bartlett et al., 2008) and the PUFA (Monse et al., 2010), thereby enabling comparison with data collected in future research studies.

Elite athletes are people who are a subsection of the general population. They just happen to be gifted in athletics (Hainline and Reardon, 2019). Therefore three questions taken from the Oral Impact on Daily Performance (OIDP) questionnaire used in the Adult Dental Health Survey (ADHS) 2009 were used to measure psychosocial impacts (Nuttall et al., 2011).

Validity is a property of the inferences that are made when interpreting scores in a specific context, rather than a property of the outcome measure or the score itself (Kelly
et al., 2005). Athlete-reported sport performance impacts were measured using an oral health modification of the OSTRC overuse injury questionnaire that was developed and validated for use with high performance athletes (Clarsen et al., 2013). When the questionnaire was administered, data were collected from each athlete during the clinical exam regarding self-reported oral health problems. Therefore, it was possible to explore associations between the presence or absence of an athlete-reported impact and observed or athlete-reported oral health problem.

5.6.3 Limitations of the study

There are many stages in a study where bias may be introduced (Petrie and Sabin, 2009).

Selection bias

A number of sports were not represented in the study; no athletes from the winter Olympic Games were included. Inclusion of athletes from an even wider variety of sports in future studies would provide an opportunity to further explore the prevalence of oral disease and associated impacts in elite sport and the influence of the elite sport environment on athlete health and wellbeing.

Measurement bias

A single examiner conducted the oral health screening therefore systemic bias could be introduced. However, the risk of bias was mitigated by training and calibration of the examiner against a gold standard. No assessment of oral cleanliness was made for either plaque or calculus and therefore it was not possible to differentiate whether a BPE score of “2” was due to presence of calculus, sub-gingival margin restoration or other plaque retentive factors.

To measure psychosocial impacts from oral health problems, three items taken from the OIDP questionnaire used in the ADHS 2009 were included in the questionnaire. Therefore a valid overall score for impact on daily activities could not be calculated. However more than 15% of athletes recorded a score of zero. In addition, more than 15% of the respondents scored zero for the OSTRC overuse injury questionnaire, indicating that a “floor” effect is present. This lack of sensitivity could be addressed in future research to develop a specific oral health in sport AROM.
Recall bias
As this was a cross-sectional study, the time reference period for athlete-reported impacts was 12 months, introducing the risk of recall bias. However, using a shorter reference period could have resulted in many problems being missed.

With all forms of self-report, it is hard to verify the extent to which athletes report the truth due to the possibility of adverse effects such as reduced chance of team selection, however, confidentiality was assured.

Observer bias
It was not possible to blind the examiner to the sport that each athlete was a participant in. Repeat examination of a sample of athletes during the screening visits to assess ongoing repeatability was not possible due to athlete time constraints. No radiographs were taken in this study and therefore the estimates of oral disease may under-report actual prevalence (Hopcraft and Morgan, 2005), however the use of radiography is driven by, and is secondary to, the results of the clinical examination (Preshaw, 2015).

5.6.4 Comparison with other studies
These data were consistent with data from previous research conducted in the UK (Needleman et al., 2013; Needleman et al., 2016; Ashley et al., 2015). Few other studies have used clinical measures of oral diseases in elite athletes, however two small studies (on professional footballers in Spain and triathletes in New Zealand) have reported on caries and periodontal health in elite athlete (Gay-Escoda et al., 2011; Bryant et al., 2011). One study also included an assessment of erosion (Bryant et al., 2011), however there was no obvious erosion detected in the study participants. However, a consistent finding, from those studies and more recent published research, is a high prevalence of dental caries and gingival inflammation in elite and well-trained athletes.

A retrospective cross sectional questionnaire study aimed to assess associations between poor oral health and re-injuries in 215 male soccer players from premier league and elite junior teams in the Netherlands, Belgium and the UK (Solleveld et al., 2015). Re-injury and oral health were measured by self-report. Other outcomes were injury anxiety, psychophysical stress, dissatisfaction with coach/team and unhealthy eating habits. The prevalence of oral health problems was similar in this study: 43% of the players reported one oral health problem and 20% two or more problems. Adjusting for other covariates, the authors concluded that there were associations between poor oral health and repeated exercise-associated muscle cramps, adding to the suggestion of an inflammatory mechanism underlying oral health and sport performance impacts.
Another cross sectional study aimed to investigate the relationship between performance and oral health in 96 Turkish male well-trained athletes, average age 20 (Yapıcı et al., 2018). Oral health was measured at a clinical examination and performance measured using objective measures including agility tests and speed tests. The prevalence of dental caries was high, at 66%, and the most frequently reported symptom was gingival bleeding (66.8%). The authors concluded that an increase in caries experience (more than four teeth affected by caries) was associated with poorer results in performance tests such as agility and speed.

The comparisons drawn between the data from in this study and the data for a similar age group from the Adult Dental Health Survey (ADHS) 2009 are similar to the comparisons made in a study of professional footballers (Needleman et al., 2016).

Performance impacts (non-zero) reported in the ADHS 2009 such as impact on eating (20%), impact on relaxing (12%), impact on smiling (15%) and impact on work (4%) were, generally, lower than those reported by the athletes in this survey who may have higher expectations of physical function, psychological function and perceived health.

5.6.5 Implications for athlete health and performance

It is important to recognize that the ADHS 2009 includes greater representation of disadvantaged populations who are known to have higher levels of oral disease. Therefore, the prevalence of oral disease in this less disadvantaged sample might be expected to be lower, however this was not the case. These findings suggest that the sporting environment might negatively influence oral health in elite athletes within this sample and it is therefore reasonable to conclude that participation in sport increases the risk of dental caries and ETW.

Associations between painful oral health problems and performance impacts were highly significant. There is not a direct correlation between the extent of a caries lesion and whether pain and discomfort is felt. However, infection and sepsis resulting from caries that spreads to involve the dental pulp can occasionally lead to serious systemic consequences, such as spreading local infection as well as to tooth loss.

Severe events such as acute dental or orofacial infections can lead to time lost from training and even competition although they occur infrequently. Chronic impacts which may not lead to time loss, but rather a reduction in quality of training, are commonly reported, and at elite level may have important consequences. Furthermore, the lifetime burden of treatment-need and effect on quality of life on athletes should be considered.
The beneficial relationship between oral health and general health is well recognised (Eberhard, 2019; D’Aiuto et al., 2018). However, the relationship between participation in sport at elite level, gingival inflammation and periodontal diseases is not yet clear. Recent research in adults with periodontitis and diabetes concluded that inflammation is the common link between physical activity, metabolic and periodontal diseases (Wernicke et al., 2018), therefore further research is required to understand more fully the mechanism underlying the association between oral inflammation, systemic inflammation and participation in sport.

The results showed a difference in the prevalence of dental caries and ETW between sports and sports categories. Most striking was the higher prevalence of both caries and ETW in the athletes from the mixed/team categories compared to endurance athletes. Team sports tend to focus on talent, whereas endurance sports tend to emphasise the importance of hard work and attention to detail. Despite having a lower standard of oral health overall, the team athletes reported fewer negative impacts. There may be some association with a difference in attitude towards health care in general. Further qualitative research is required to provide an insight into the reasons for this difference. The prevalence of ETW in this relatively young population was high and further research is required to explore the underlying aetiological, physiological and behavioural factors associated with this.

### 5.6.6 Implications for athlete health and wellbeing

A recent consensus report on the prevention and control of dental caries and periodontal diseases at individual and population level recommends the promotion of periodic comprehensive oral health assessments to allow early detection and preventive management of dental caries and periodontal diseases (Jepsen et al., 2017).

Dentists and dental care professionals have an important role to play in providing oral health screening for athletes, either at the dental surgery or as part of a pre-season PHE (periodic health evaluation).

There is a need for education of dental health professionals in the consistent use of clinical indices to allow clear information to be presented to athletes and their support staff. In addition, careful use of clinical indices that have been developed to enable recognition of oral diseases at an early stage will ensure that timely preventive advice can be given. In the case of excessive erosion associated with disordered eating, a dental health professional may be the first health care professional to identify this problem.
Regular screening and the use of effective oral health promotion strategies may minimize performance impacts from poor oral health. However, the prevention of oral disease is largely dependent upon people changing behaviour in line with professional guidance (Public Health England, 2017). Therefore, interventions which are based upon behaviour change theory (Michie et al., 2014) and include all stakeholders to improve quality and relevance may have a better chance of success (Dijkstra et al., 2014; Needleman, 2014). Further research is needed to identify appropriate evidence-based strategies to embed oral health promotion within sport.

5.7 Conclusion

The prevalence of oral diseases in Olympic and professional athletes is substantial and participation in sport at elite level is associated with an increased risk of dental caries and ETW. The association with periodontal diseases is not yet clear, however gingival inflammation is almost universally present in athletes.

Oral health problems, particularly those leading to oral sepsis such as severe caries and pericoronitis, are strongly associated with self-reported negative impacts on performance in sport, general health and wellbeing. Therefore, regular screening and the use of effective oral health promotion strategies may minimize performance impacts from poor oral health.

The prevention of oral diseases is largely dependent upon people changing behaviour in line with professional guidance, therefore future interventions that are based on behaviour change theory may have a better chance of success.

This study has been published in the journal: Community Dentistry and Oral Epidemiology (Appendix N). Appendix O is the accompanying STROBE checklist.

In sport it is recommended that research aimed at health promotion and prevention of HRIs, is based on models or frameworks that are designed to increase the likelihood of preventive strategies being effective in the sporting environment. Two such models are the Translating Research into Injury Prevention into Practice (TRIPP) model (Finch, 2006) and the Knowledge Transfer Scheme (KTS) framework (Verhagen et al., 2014). This chapter has addressed the first stage of each model, namely the collection of evidence that allows the extent and severity of the problem of the problem to be stated. In addition, the evidence presented in Chapter 2, supports the context and relevance to athletic performance.
The next step requires that the research provides a clear understanding of both behavioural inputs and outputs in relation to prevention. The following chapter presents an investigation into oral health related behaviours, risks to oral health and opportunities for behaviour change reported by the athletes who participated in the epidemiological study.
6 Oral health and risk behaviours reported by elite athletes

The previous chapter presented and discussed the methods and results of a clinical and questionnaire study that aimed to measure the extent and severity of oral diseases and associated athlete-reported performance impacts in elite athletes. The questionnaire completed by the athletes also included items relating to oral health behaviours and risks to oral health. In this Chapter, the data collected from the questionnaires completed by the athletes during the oral health screening programme will be presented and discussed.

6.1 Introduction

The oral conditions: dental caries, gingivitis, periodontitis and ETW, like all other non-communicable diseases (NCDs), share a wide range of risk factors, some of which are inherent and cannot be changed or modified such as age, gender and hereditary conditions. Others, including an unhealthy diet (particularly high sugar), tobacco, ineffective use of oral hygiene aids and infrequent or symptomatic dental attendance are subject to behaviours and lifestyle. Therefore, they are considered to be modifiable risk factors, because individual action and modification of a particular habit or behaviour is possible (Petersen, 2009). There are clinical indices available for screening that allow the onset of these oral conditions to be recognised well before operative treatment is required, therefore prevention, mainly through lifestyle or behaviour change is possible (Ismail et al., 2013; Preshaw, 2015; Carvalho et al., 2018).

In sports and exercise medicine research, studies have shown that it is possible to reduce the incidence and severity of injury through specific interventions (Bolling et al., 2018b; Dijkstra et al., 2014; Edouard et al., 2018). The same is true in oral health research (Public Health England, 2017; Pretty, 2016; Salzer et al., 2015). However, many interventions are conducted under controlled conditions and although they show efficacy this does not always translate into a lasting and meaningful effect in the real world (Bolling et al., 2018b). If preventive measures are developed and evaluated from the researcher’s perspective only, there is no guarantee that the new behaviours will be adopted by and complied with by all participants (Finch, 2006; Michie et al., 2011; Verhagen et al., 2014).

The TRIPP (Translating Injury Prevention into Practice) model was developed to address these issues when developing strategies to prevent injury in sport (Finch, 2006). The KTS (Knowledge Transfer System) was developed specifically to result in practical and sustainable interventions that link knowledge derived from research with evidence-based
usable information and tools for practice (Verhagen et al., 2014). Table 6.1 lists the stages and steps of the TRIPP and KTS research frameworks and identifies a gap between development of an intervention and effective implementation.

Table 6.1 A combined model for prevention of injury

<table>
<thead>
<tr>
<th>Tripp stage (Finch, 2006)</th>
<th>Activity</th>
<th>KTS step (Verhagen et al., 2014)</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epidemiology.</td>
<td>1</td>
<td>State the problem in context.</td>
</tr>
<tr>
<td>2</td>
<td>Establish aetiology and mechanisms.</td>
<td>2</td>
<td>Describe the evidence for prevention and potential benefits.</td>
</tr>
<tr>
<td>3</td>
<td>Develop preventive measures.</td>
<td>3</td>
<td>Establish knowledge transfer group.</td>
</tr>
<tr>
<td>4</td>
<td>Ideal conditions/scientific evaluation.</td>
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<td>Product development.</td>
</tr>
<tr>
<td>5</td>
<td>Describe intervention context to inform implementation strategies.</td>
<td>5</td>
<td>Implement and evaluate.</td>
</tr>
<tr>
<td>6</td>
<td>Implement and evaluate.</td>
<td>5</td>
<td>Implement and evaluate.</td>
</tr>
</tbody>
</table>

There is good evidence within “Delivering Better Oral Health: an evidence-based toolkit for prevention” (Public Health England, 2017) for oral health promotion and prevention outside of sport. However, the challenges to oral health from sport, and those related to implementation in this environment, confer unique characteristics that require investigation to identify effective strategies and mitigate risk (Needleman et al., 2014). Not all new diseases can be anticipated so advice and support should be offered to all athletes (Public Health England, 2017).

In summary, effective oral health promotion strategies may minimise performance impacts from poor oral health (Gallagher et al., 2018). To increase the chances of designing a successful intervention the determinants and influences of health and risk behaviours in sport need to be understood (Finch, 2006) and opportunities for behaviour change should be identified (Michie et al., 2014).

6.2 Aim

This study therefore aimed to investigate behaviours reported by athletes that could contribute towards good oral health or increase the risks to oral health. An additional aim
was to identify opportunities for introducing new or enhanced oral health related behaviours that might mitigate the risks to oral health arising from participation in sport.

6.3 Materials and methods

The athlete-reported data presented in this chapter were collected at the screening appointment offered to athletes as part of the cross-sectional study, conducted at UK elite athlete training centres between June 2015 and August 2016.

6.3.1 Stakeholder engagement and questionnaire development

The advisory group that was established and the development of the questionnaire (Appendix H) has been described in Chapter three. Items to explore self-reported oral health related behaviours were based on those used in the Adult Dental Health (ADH) Survey 2009 (Chadwick et al., 2011). They included: frequency of toothbrushing, use of additional oral hygiene methods, most recent dental attendance, type of service used, most important factor when making a dental appointment and previous dental advice received. Use of additional oral hygiene aids included electric toothbrush (ETB), fluoride mouthwash, interdental cleaning and sugar free chewing gum (SFG). Hydration is important for athletes, therefore an item to confirm consumption of water was included. Knowledge of, and use of, products considered to be risks to oral health was also explored. Risks to oral health included tobacco, sugar in usual diet and sports nutrition products. Using the method described in the Adult Dental Health survey (ADH) 2009, athletes who indicated that they consumed a serving of cakes, or sweets, or soft drinks six or more times a week were categorised as high sugar consumers (Chadwick et al., 2011) in their usual diet. Finally, athletes were asked which behaviours they would consider adopting if it would improve their oral health.

6.3.2 Statistical analysis

The questionnaire data were analysed using the same standard statistical package (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY) as reported in Chapter 5. Counts and percentages summarised the categorical data. Chi squared tests or Fisher’s exact tests as appropriate were used to compare percentages in different sports categories (strength and power, endurance and mixed) with post-hoc Bonferroni corrections and calculation of odds ratios as appropriate. Standard errors and confidence intervals at the 95% level were calculated for key findings. A significance level of 5% was selected for all hypothesis tests. This report was guided by the STROBE statement of observational studies (von Elm et al., 2007).
6.4 Results

The results reported by the demographic characteristics of the group (age, gender, ethnicity, educational status and sport category) are presented as tables in Appendix P. The data for the whole group, by Olympic or professional category and by sport or sport category are presented in this chapter.

6.4.1 Oral hygiene-related behaviours

Figure 6.1 shows an overview of oral hygiene-related behaviours reported by Olympic and professional athletes and the whole group. Overall, 323 (94.2%) athletes reported brushing their teeth at least twice daily, 190 (55.9%) athletes said they used an electric toothbrush (ETB), 148 (43.7%) athletes said they used dental floss or interdental brushes at least occasionally, 139 (40.9%) athletes said they used fluoride mouthwash at least sometimes and 120 (35.1%) athletes reported using sugar free chewing gum (SFG) at least occasionally:

![Proportion of athletes reporting oral hygiene-related behaviours](image)

Key: ETB = electric toothbrush, SFG = sugar free chewing gum, * = at least occasionally

Toothbrushing

Table 6.2 shows that regular toothbrushing is an established oral hygiene habit among all athletes regardless of sport.
Table 6.2 Frequency of athlete-reported toothbrushing by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Clean teeth am</th>
<th>Clean teeth pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N = 344)</td>
<td>334 (97.1%)</td>
<td>333 (96.8%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>65 (98.5%)</td>
<td>65 (97%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>57 (95%)</td>
<td>60 (100%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>47 (97.7%)</td>
<td>46 (95.8%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>41 (89.1%)</td>
<td>44 (95.7%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>44 (95%)</td>
<td>45 (97.8%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>26 (100%)</td>
<td>25 (100%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>21 (100%)</td>
<td>19 (90.5%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>15 (100%)</td>
<td>14 (93.3%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>15 (100%)</td>
<td>15 (100%)</td>
</tr>
</tbody>
</table>

**Additional oral hygiene aids**

Regarding the use of additional oral hygiene aids (Table 6.3), there were differences between the sports with 44 (73.3%) athletes from rowing reported using an ETB compared to 4 (26.7%) athletes from gymnastics, 36 (60%) athletes from rowing reporting interdental cleaning compared to 2 (13.3%) athletes from gymnastics. Use of fluoride mouthwash was reported most frequently in footballers. Athletes from sailing (9, 60%) and rowing (31, 51.7%) reported the highest use of SFG with footballers (1, 4.0%) reporting the lowest frequency of use.
Table 6.3 Frequency of athlete-reported use of additional oral hygiene aids by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Electric toothbrush</th>
<th>Dental floss/Interdental brushes</th>
<th>Fluoride mouthwash</th>
<th>Sugar free chewing gum</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N =344)</td>
<td>190 (55.9%)</td>
<td>148 (43.7%)</td>
<td>139 (40.9%)</td>
<td>120 (35.1%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>39 (58.2%)</td>
<td>29 (43.9%)</td>
<td>28 (42.4%)</td>
<td>22 (32.8%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>44 (73.3%)</td>
<td>36 (60%)</td>
<td>29 (48.3%)</td>
<td>31 (51.7%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>20 (41.7%)</td>
<td>22 (45.8%)</td>
<td>13 (27.1%)</td>
<td>11 (22.9%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>20 (60.9%)</td>
<td>17 (37%)</td>
<td>18 (39.1%)</td>
<td>17 (37%)</td>
</tr>
<tr>
<td>Hockey (44)</td>
<td>24 (54.5%)</td>
<td>21 (46.7%)</td>
<td>16 (36.4%)</td>
<td>18 (40%)</td>
</tr>
<tr>
<td>Football (25)</td>
<td>14 (56%)</td>
<td>6 (26.1%)</td>
<td>16 (64%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>12 (57.1%)</td>
<td>10 (47.6%)</td>
<td>11 (52.4%)</td>
<td>7 (33.3%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>4 (26.7%)</td>
<td>2 (13.3%)</td>
<td>5 (33.3%)</td>
<td>4 (26.7%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>5 (35.7%)</td>
<td>5 (33.3%)</td>
<td>3 (20%)</td>
<td>9 (60%)</td>
</tr>
</tbody>
</table>
**Water consumption**

Hydration is an important component in athlete performance. Table 6.4 confirms that overall 312 (90.7%) athletes reported drinking water on at least six days or more per week. The lowest frequency of water consumption was reported by athletes from gymnastics (10, 66.7%).

<table>
<thead>
<tr>
<th>Sport</th>
<th>Drink water &gt; 6 x week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All (344)</strong></td>
<td>312 (90.7%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>51 (85%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>67 (100%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>43 (89.6%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>42 (91.3%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>43 (93.5%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>25 (96.2%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>18 (85.7%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>10 (66.7%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>13 (86.7%)</td>
</tr>
</tbody>
</table>

6.4.2 **Risks to oral health**

Tobacco use and smoking are important risk factors for oral health. One (0.3%) athlete reported current use of smokeless tobacco. It is strongly recommended that players wear a mouthguard for hockey and rugby. In this sample 82% of hockey players, 85% of professional rugby players and 88.9% of rugby sevens reported wearing a mouthguard during competition.

**Athlete-reported consumption of sugar in usual diet**

Frequent consumption of refined carbohydrates (sugars) is a recognised risk factor for dental caries and acidic food and drinks are risk factors for ETW. Table 6.5 provides a summary of athlete-reported consumption of food and drink, considered to be high in sugar in their everyday diet. Using the method reported in the ADH 2009, 28.2% of athletes were categorised as high consumers of sugar in their regular diet. Athletes from rowing reported the highest consumption of cakes (18, 30%), confectionery (10, 16.7%) and soft drinks (25, 41.7%) and 31 (51.3%) were classified as high consumers of sugar in their usual diet.
Table 6.5 Athlete-reported consumption of sugar by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Cakes, biscuits, pastries, puddings (a)</th>
<th>Sweets/chocolate (b)</th>
<th>Soft/fizzy drinks (c)</th>
<th>High Sugar consumer (one or more of a, b or c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N=344)</td>
<td>36 (10.5%)</td>
<td>25 (7.3%)</td>
<td>74 (21.5%)</td>
<td>97 (28.2%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>2 (3%)</td>
<td>3 (4.5%)</td>
<td>2 (3%)</td>
<td>4 (6%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>18 (30%)</td>
<td>10 (16.7%)</td>
<td>25 (41.7%)</td>
<td>31 (51.3%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>7 (14.6%)</td>
<td>5 (10.4%)</td>
<td>12 (25%)</td>
<td>18 (37.5%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>3 (6.5%)</td>
<td>1 (2.2%)</td>
<td>11 (23.9%)</td>
<td>14 (30.4%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>0</td>
<td>0</td>
<td>14 (30.4%)</td>
<td>14 (30.4%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>2 (7.7%)</td>
<td>3 (11.5%)</td>
<td>4 (15.4%)</td>
<td>6 (23.1%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>2 (9.5%)</td>
<td>2 (9.5%)</td>
<td>1 (4.8%)</td>
<td>4 (19%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>0</td>
<td>0</td>
<td>2 (13.3%)</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>2 (13.3%)</td>
<td>1 (6.7%)</td>
<td>3 (20%)</td>
<td>4 (26.7%)</td>
</tr>
</tbody>
</table>
Athlete-reported consumption of sports nutrition products

The consumption of sports nutrition products (SNPs) were reported separately from sugar in usual diet. Athletes were provided with a number of options to indicate if they used sports drinks, energy bars and/or energy gels before, during or after training and before, during or after competition. Not all athletes responded to all options, therefore the responses were categorised into any use of sports drinks, energy bars and energy gels during training/competition. Regarding the use of these SNPs, 288 (85.7%, 95% CI 81.5-89.1) of the 336 athletes who provided this information reported using sports drinks at least sometimes during training/competition, 198 (58.8%, 95% CI 53.4-63.9) energy bars and 239 (70.3%, 95% CI 65.9-75.5) energy gels.

Table 6.6 provides a summary of the self-reported use of SNPs by athletes during training and competition. This data was self-reported and should be considered with caution. In this sample energy bars were the least used, ranging from lowest in the athletes from swimming 33 (7.3%) to 46 (97.6%) cyclists. Interestingly, the gymnasts were the next highest consumers (12, 80%). Energy gels were used by the majority of athletes; 14 (100%) of sailors and 47 (97.9%) of cyclists. The lowest use was reported in athletics (3, 14.3%). Use of sports drinks was reported by more than three quarters (288, 85.7%) of athletes, overall. Highest use was reported by athletes from the mixed sport category: sailing (14, 100%) rugby (58, 90.6%) and hockey (39, 90.7%).
<table>
<thead>
<tr>
<th>Sport</th>
<th>Any use of sports drink during training/competition</th>
<th>Any use of energy bars during training/competition</th>
<th>Any use of energy gels during training/competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (340)</td>
<td>288 (85.7%)</td>
<td>198 (58.8%)</td>
<td>239 (70.3%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>58 (90.6%)</td>
<td>26 (40.6%)</td>
<td>42 (65.6%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>50 (83.3%)</td>
<td>33 (55%)</td>
<td>47 (78.3%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>44 (91.7%)</td>
<td>46 (97.6%)</td>
<td>47 (97.9%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>38 (84.4%)</td>
<td>33 (7.3%)</td>
<td>24 (52.2%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>39 (90.7%)</td>
<td>20 (44.5%)</td>
<td>39 (86.7%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>20 (76.9%)</td>
<td>9 (36%)</td>
<td>17 (65.4%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>16 (76.2%)</td>
<td>8 (38.1%)</td>
<td>3 (14.3%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>9 (60%)</td>
<td>12 (80%)</td>
<td>6 (40%)</td>
</tr>
<tr>
<td>Sailing (14)</td>
<td>14 (100%)</td>
<td>11 (73.3%)</td>
<td>14 (100%)</td>
</tr>
</tbody>
</table>
### 6.4.3 Dental service considerations

**Dental attendance**

Although regular attendance for dental checks does not necessarily predict better oral health, athletes are subject to routine surveillance regarding their general health and it would be a reasonable expectation that they are encouraged to attend for regular dental checks if oral health is perceived as being a part of general health and wellbeing. Therefore, the athletes were asked when they had attended for their most recent dental appointment, including dental checks and treatment. Figure 6.2 shows an overview of the whole group. Fewer than half (136, 39.5%) of the athletes said they had attended for a dental visit within the previous 6 months.

**Figure 6.2 Frequency of most recent dental visit reported by Olympic and professional athletes**

![Bar chart showing frequency of dental visits](chart.png)

Table 6.7 shows the data for each sport. None of the sailors had attended a dental appointment in the preceding six months. Apart from the sailors, athletes from gymnastics (2, 13.3%) and athletics (3, 14.3%) had the lowest recent attendance at a dentist whereas footballers had the highest reported attendance within the previous six months (17, 65.4%).

![Table 6.7 showing data for each sport](table.png)
Table 6.7 Frequency of athletes attending ≤ 6 months by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Most recent dental visit ≤ 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (344)</td>
<td>136 (39.5%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>24 (40%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>28 (41.8%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>22 (45.8%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>22 (47.8%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>18 (39.1%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>17 (65.4%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>3 (14.3%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

**Dental care provider**

To investigate possible barriers to attendance, athletes were also asked if the provider of dental care was an NHS dentist, a private dentist or a private dental hygienist. Overall, few athletes reported seeing a private dental hygienist (34, 9.9%), however there was little difference between NHS dentist (141, 41.2%) athletes) and private dentist (147, 45.6%, 95% CI 40.5-50.9) as the provider (Table 6.8).

There were however differences between sports; receiving care from an NHS dentist was reported by 39 (65%) athletes from rowing and 29 (63%) athletes from swimming. On the other hand, 7 (14.6%) of cyclists reported receiving care from an NHS dentist at their most recent visit. Receiving care from a private dentist was reported by 11 (73.3%) of sailors and 33 (68.8%) of cyclists. Seven (26.9%) footballers reported receiving care from a private hygienist at their most recent dental visit.
Table 6.8 Frequency of dental care provider by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>NHS dentist</th>
<th>Private dentist</th>
<th>Private hygienist</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>141 (41.2%)</td>
<td>157 (45.9%)</td>
<td>34 (9.9%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>19 (28.4%)</td>
<td>42 (62.7%)</td>
<td>6 (9%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>39 (65%)</td>
<td>14 (23.3%)</td>
<td>6 (10%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>7 (14.6%)</td>
<td>33 (68.8%)</td>
<td>5 (10.4%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>29 (63%)</td>
<td>12 (26.1%)</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>18 (39.1%)</td>
<td>24 (52.2%)</td>
<td>4 (8.7%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>12 (46.2%)</td>
<td>7 (26.9%)</td>
<td>7 (26.9%)</td>
</tr>
<tr>
<td>Athletics (20)</td>
<td>10 (50%)</td>
<td>6 (30%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>Gymnastics (14)</td>
<td>4 (28.6%)</td>
<td>8 (57.1%)</td>
<td>0</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>3 (20%)</td>
<td>11 (73.3%)</td>
<td>1 (6.7%)</td>
</tr>
</tbody>
</table>

Other factors

When asked which factor was the most important when arranging a dental appointment twenty athletes were unable to pick a single factor. Of the remaining 314, overall 195 (62.1%, 95% CI 56.6-67.3) said convenience, 85 (27.1%, 95% CI 22.5-32.3) reputation of the dentist and 34 (10.8%, 95% CI 6.9-13.2) cost (Table 6.9). Although convenience was the most important factor, cost was important for six (31%) athletes from athletics.

Table 6.9 Frequency of most important factor by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Convenience</th>
<th>Reputation of dentist</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N=344)</td>
<td>195 (62.1%)</td>
<td>85 (27.1%)</td>
<td>34 (10.8%)</td>
</tr>
<tr>
<td>Rugby (59)</td>
<td>33 (55.9%)</td>
<td>18 (30.5%)</td>
<td>8 (13.6%)</td>
</tr>
<tr>
<td>Rowing (55)</td>
<td>33 (60%)</td>
<td>17 (30.9%)</td>
<td>5 (9.1%)</td>
</tr>
<tr>
<td>Cycling (41)</td>
<td>20 (48.8%)</td>
<td>19 (46.3%)</td>
<td>2 (4.9%)</td>
</tr>
<tr>
<td>Swimming (42)</td>
<td>35 (83.3%)</td>
<td>5 (11.9%)</td>
<td>2 (4.8%)</td>
</tr>
<tr>
<td>Hockey (44)</td>
<td>28 (63.6%)</td>
<td>9 (20.5%)</td>
<td>7 (15.9%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>16 (61.5%)</td>
<td>9 (34.6%)</td>
<td>1 (3.8%)</td>
</tr>
<tr>
<td>Athletics (19)</td>
<td>6 (57.9%)</td>
<td>2 (10.5%)</td>
<td>6 (31.6%)</td>
</tr>
<tr>
<td>Gymnastics (14)</td>
<td>9 (64.3%)</td>
<td>2 (14.3%)</td>
<td>3 (21.4%)</td>
</tr>
<tr>
<td>Sailing (14)</td>
<td>10 (71.4%)</td>
<td>4 (28.6%)</td>
<td>0</td>
</tr>
</tbody>
</table>

*includes only those who chose just one option

Dental advice received

The athletes were asked in the questionnaire if they recalled receiving advice about oral hygiene and diet. Advice regarding oral hygiene was received more frequently than advice about diet. Overall, 262 (76.2%) said they recalled receiving oral hygiene advice from a dental professional at some time and 206 (59.9%) said they recalled receiving advice about diet (Table 6.10). Participants from athletics reported the lowest frequency of receiving advice about both oral hygiene (12, 57.1%) and diet (8, 38.1%). Fifty-seven
(95%) athletes from rowing reported receiving advice about oral hygiene. Eight (38.1%) participants from athletics reported receiving advice about diet.

Table 6:10 Frequency of advice received by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Oral hygiene</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N=344)</td>
<td>262 (76.2%)</td>
<td>206 (59.9%)</td>
</tr>
<tr>
<td>Rugby (67)</td>
<td>48 (71.6%)</td>
<td>46 (69.7%)</td>
</tr>
<tr>
<td>Rowing (60)</td>
<td>57 (95%)</td>
<td>41 (68.3%)</td>
</tr>
<tr>
<td>Cycling (48)</td>
<td>35 (72.9%)</td>
<td>22 (45.8%)</td>
</tr>
<tr>
<td>Swimming (46)</td>
<td>33 (71.7%)</td>
<td>23 (50%)</td>
</tr>
<tr>
<td>Hockey (46)</td>
<td>35 (76.1%)</td>
<td>27 (58.7%)</td>
</tr>
<tr>
<td>Football (26)</td>
<td>16 (61.5%)</td>
<td>17 (65.4%)</td>
</tr>
<tr>
<td>Athletics (21)</td>
<td>12 (57.1%)</td>
<td>8 (38.1%)</td>
</tr>
<tr>
<td>Gymnastics (15)</td>
<td>13 (86.7%)</td>
<td>11 (73.3%)</td>
</tr>
<tr>
<td>Sailing (15)</td>
<td>13 (86.7%)</td>
<td>11 (73.3%)</td>
</tr>
</tbody>
</table>

6.4.4 Associations between sports categories and positive behaviours

The data were grouped into sports categories as athletes in different sports categories may have common behaviours. The chi-squared test for independence was used to test associations between reported behaviours and sports categories (Table 6.11). Statistically significantly fewer athletes from the strength & power category reported attendance for a dental visit in the preceding six months (p = 0.047), use of an ETB (p = 0.019) and drinking water (p = 0.001).
Table 6:11 Associations between oral health behaviour and sports categories

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Strength and power</th>
<th>Endurance</th>
<th>Mixed</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most recent dental visit within 6 months.</td>
<td>12 (24%)</td>
<td>61 (43.6%)</td>
<td>63 (40.9%)</td>
<td>0.047</td>
</tr>
<tr>
<td>Clean teeth am.</td>
<td>50 (100%)</td>
<td>131 (93.6%)</td>
<td>153 (99.4%)</td>
<td>0.005</td>
</tr>
<tr>
<td>Clean teeth pm.</td>
<td>45 (90%)</td>
<td>138 (98.6%)</td>
<td>150 (98%)</td>
<td>0.005</td>
</tr>
<tr>
<td>Use ETB.</td>
<td>20 (40%)</td>
<td>88 (62.9%)</td>
<td>82 (54.7%)</td>
<td>0.019</td>
</tr>
<tr>
<td>Use floss/other interdental aids.</td>
<td>19 (38%)</td>
<td>68 (48.6%)</td>
<td>61 (40.9%)</td>
<td>0.290</td>
</tr>
<tr>
<td>Use fluoride mouthwash.</td>
<td>20 (40%)</td>
<td>56 (40%)</td>
<td>63 (42%)</td>
<td>0.933</td>
</tr>
<tr>
<td>Use SFG.</td>
<td>15 (30%)</td>
<td>55 (39.3%)</td>
<td>50 (32.9%)</td>
<td>0.373</td>
</tr>
<tr>
<td>Drink water &gt; 6x week.</td>
<td>39 (78%)</td>
<td>125 (89.3%)</td>
<td>148 (96.1%)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Key ETB = electric toothbrush, SFG = sugar free chewing gum

6.4.5 Associations between behaviours and oral diseases

The chi-squared test for independence was used to test associations between athlete-reported behaviours and clinical indicators of oral health. There were no statistically significant associations between athlete-reported positive behaviours and ETW or periodontal status. When applied to dental caries, there were no statistically significant associations with athlete-reported positive behaviours and being caries-free (Table 6.12). There was a significant association between caries-free athletes and athlete-reported consumption of a high sugar diet (p = 0.004). This association is the opposite of what expected as dietary carbohydrate is an aetiological factor for dental caries.

Table 6:12 Caries free athletes and reported behaviours

<table>
<thead>
<tr>
<th>Athletes with no caries and reporting behaviour</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean teeth am</td>
<td>P = 0.820</td>
</tr>
<tr>
<td>Clean teeth pm</td>
<td>P = 0.286</td>
</tr>
<tr>
<td>Use of ETB</td>
<td>P = 0.365</td>
</tr>
<tr>
<td>Use floss or other interdental aid</td>
<td>P = 0.181</td>
</tr>
<tr>
<td>Use fluoride mouthwash</td>
<td>P = 0.502</td>
</tr>
<tr>
<td>Use SFG</td>
<td>P = 0.692</td>
</tr>
<tr>
<td>Drink water &gt; 6 x week</td>
<td>P = 0.720</td>
</tr>
<tr>
<td>Last dental visit in previous 6 months</td>
<td>P = 0.578</td>
</tr>
<tr>
<td>High sugar consumption (normal diet)</td>
<td>P = 0.004</td>
</tr>
</tbody>
</table>

The chi-squared test was also used to test associations between athlete-reported use of sports nutrition products and dental caries (Table 6.13). There was no statistically significant association between athlete-reported use of energy gels or energy bars,
however there was a statistically significant association with athlete-reported use of sports drinks ($p = 0.013$) and athletes with caries.

Table 6:13 Association between athlete-reported use of sports nutrition products and caries

<table>
<thead>
<tr>
<th>Athletes with caries and reporting use of</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy bars</td>
<td>$P = 0.779$</td>
</tr>
<tr>
<td>Energy gels</td>
<td>$P = 0.853$</td>
</tr>
<tr>
<td>Sports drinks</td>
<td>$P = 0.013$</td>
</tr>
</tbody>
</table>

6.4.6 Differences between athletes and the general population

The questions to explore athlete-reported oral health related positive behaviours and risks to oral health were taken from the ADH 2009 survey. It is therefore possible to make some comparisons in behaviours between people of a similar age group (16-34 years) in the general population and elite athletes. Where there were statistically significant differences in self-reported behaviours and risks to oral health, odds ratios were calculated. The odds of athletes reporting positive behaviours were greater for twice daily toothbrushing (5.30), use of an ETB (4.84) and use of floss or other interdental cleaning aid at least occasionally (3.23). The odds of athletes reporting risks to oral health were reduced by 99% for smoking and by 68% for sugar consumption in usual diet. The odds of having received diet advice were increased in athletes (4.03). Odds of having attended a private dentist for their most recent visit were 3.50 (95% CI 2.76 to 4.43) that of a similar aged group in the general population. Significantly fewer athletes than people of a similar age reported attending a dental visit in the previous six months, having attended an NHS dentist and considering cost a factor when arranging a dental visit (Table 6.14).
Table 6.14 Comparison between athletes and controls

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Athletes (%)</th>
<th>UK population (%)</th>
<th>Chi squared test</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral health related</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brush 2 x daily</td>
<td>323 (94.2%)</td>
<td>1882 (74.4%)</td>
<td>P &lt; 0.001</td>
<td>5.30 (3.38-8.31)</td>
</tr>
<tr>
<td>Use ETB</td>
<td>190 (55.9%)</td>
<td>512 (20.3%)</td>
<td>P &lt; 0.001</td>
<td>4.84 (3.83-6.11)</td>
</tr>
<tr>
<td>Use floss or other</td>
<td>148 (43.7%)</td>
<td>471 (18.7%)</td>
<td>P &lt; 0.001</td>
<td>3.23 (2.60-4.16)</td>
</tr>
<tr>
<td>Use mouthwash</td>
<td>139 (40.1%)</td>
<td>915 (36.3%)</td>
<td>P = 0.156</td>
<td>ns</td>
</tr>
<tr>
<td>Risks to oral health</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking/tobacco use</td>
<td>1 (0.3%)</td>
<td>738 (29.2%)</td>
<td>P &lt; 0.001</td>
<td>0.01 (0.00-0.05)</td>
</tr>
<tr>
<td>High sugar consumption (usual diet)</td>
<td>97 (28.2%)</td>
<td>1404 (55.3%)</td>
<td>P &lt; 0.001</td>
<td>0.32 (0.25-0.41)</td>
</tr>
<tr>
<td>Dental service considerations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Received OH advice</td>
<td>262 (76.2%)</td>
<td>1948 (78.5%)</td>
<td>P = 0.349</td>
<td>ns</td>
</tr>
<tr>
<td>Received diet advice*</td>
<td>206 (59.9%)</td>
<td>2784 (27.0%)</td>
<td>P &lt; 0.001</td>
<td>4.03 (3.24-5.03)</td>
</tr>
<tr>
<td>Most recent dental visit within previous 6 months</td>
<td>136 (39.5%)</td>
<td>1132 (45.7%)</td>
<td>P = 0.032</td>
<td>0.78</td>
</tr>
<tr>
<td>Cost a factor when arranging dental treatment</td>
<td>34 (10%)</td>
<td>414 (16.3%)</td>
<td>P = 0.003</td>
<td>0.56</td>
</tr>
<tr>
<td>NHS appointment</td>
<td>141 (41.2%)</td>
<td>1772 (78.1%)</td>
<td>P &lt; 0.001</td>
<td>0.19</td>
</tr>
<tr>
<td>Private appointment</td>
<td>157 (45.9%)</td>
<td>439 (19.3%)</td>
<td>P &lt; 0.001</td>
<td>3.50</td>
</tr>
</tbody>
</table>

6.4.7 Oral health beliefs and potential for behaviour change

The majority of athletes recognised that smoking and sugary foods and drinks including sports nutrition products could damage oral health (Table 6.15).

Table 6.15 Knowledge /beliefs about damage to oral health

<table>
<thead>
<tr>
<th>Food/drink</th>
<th>Can cause damage to mouth, teeth or gums</th>
<th>No (%)</th>
<th>Yes (%)</th>
<th>Don’t know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cakes, biscuits, puddings, pastries</td>
<td>11 (3.2%)</td>
<td>318 (92.7%)</td>
<td>14 (4.1%)</td>
<td></td>
</tr>
<tr>
<td>Sweets/chocolate</td>
<td>1 (0.3%)</td>
<td>340 (99.1%)</td>
<td>2 (0.6%)</td>
<td></td>
</tr>
<tr>
<td>Fizzy drinks and/or squash</td>
<td>5 (1.5%)</td>
<td>334 (97.1%)</td>
<td>4 (1.2%)</td>
<td></td>
</tr>
<tr>
<td>Sports drinks</td>
<td>4 (1.2%)</td>
<td>327 (95.1%)</td>
<td>12 (3.5%)</td>
<td></td>
</tr>
<tr>
<td>Energy bars</td>
<td>19 (5.5%)</td>
<td>280 (81.4%)</td>
<td>43 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Energy gels</td>
<td>15 (4.4%)</td>
<td>303 (88.1%)</td>
<td>25 (7.3%)</td>
<td></td>
</tr>
<tr>
<td>Smoking tobacco</td>
<td>6 (1.7%)</td>
<td>323 (94.2%)</td>
<td>14 (4.1%)</td>
<td></td>
</tr>
<tr>
<td>Smokeless/chewing tobacco</td>
<td>12 (3.5%)</td>
<td>280 (81.4%)</td>
<td>51 (14.8%)</td>
<td></td>
</tr>
<tr>
<td>e-cigarettes with nicotine</td>
<td>18 (5.2%)</td>
<td>213 (61.9%)</td>
<td>112 (32.6%)</td>
<td></td>
</tr>
<tr>
<td>e-cigarettes without nicotine</td>
<td>26 (7.6%)</td>
<td>189 (54.9%)</td>
<td>127 (37.1%)</td>
<td></td>
</tr>
</tbody>
</table>

Opportunities for behaviour change

The potential for behaviour-change options and athlete responses are listed in Table 6.16. When asked, 274 (79.7%) said they could or probably could reduce sugary drinks including sports drinks between meals, 308 (90.3%) said they could or probably could
use fluoride mouth wash at a different time to brushing, 282 (82.3%) said they could or probably could use dental floss/interdental brushes every day, 287 (83.2%) said they could or probably could use sugar free chewing gum, and 306 (89.0%) said they could or probably could attend regular visits to a dentist/hygienist for advice and monitoring. 157 (45.6%) of athletes said they could or probably could reduce snacking between meals including energy bars/gels. With the exception of reducing the use of energy gels/bars between meals, most athletes were positive about potential for behaviour change.
<table>
<thead>
<tr>
<th>Activity</th>
<th>No (Frequency)</th>
<th>With difficulty (Frequency)</th>
<th>Probably (Frequency)</th>
<th>Yes (Frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce snacking between meals (including energy bars/gels)</td>
<td>77 (22.4%)</td>
<td>107 (31.1%)</td>
<td>97 (28.2%)</td>
<td>60 (17.4%)</td>
</tr>
<tr>
<td>Reduce sugary drinks (including sports drinks) between meals</td>
<td>34 (9.9%)</td>
<td>33 (9.6%)</td>
<td>91 (26.5%)</td>
<td>183 (53.2%)</td>
</tr>
<tr>
<td>Brush teeth before sleeping</td>
<td>9 (2.6%)</td>
<td>1 (0.3%)</td>
<td>17 (4.9%)</td>
<td>315 (91.6%)</td>
</tr>
<tr>
<td>Only spit out toothpaste, don’t rinse with water</td>
<td>26 (7.6%)</td>
<td>14 (4.1%)</td>
<td>59 (17.2%)</td>
<td>241 (70.1%)</td>
</tr>
<tr>
<td>Use fluoride mouthwash at a different time to brushing</td>
<td>13 (3.8%)</td>
<td>19 (5.5%)</td>
<td>88 (25.6%)</td>
<td>220 (64.7%)</td>
</tr>
<tr>
<td>Use dental floss/interdental brushes every day</td>
<td>8 (2.3%)</td>
<td>48 (13.7%)</td>
<td>109 (31.7%)</td>
<td>173 (50.6%)</td>
</tr>
<tr>
<td>Use sugar free chewing gum</td>
<td>42 (12.2%)</td>
<td>11 (3.5%)</td>
<td>88 (25.6%)</td>
<td>199 (57.6%)</td>
</tr>
<tr>
<td>Regular visits to a dentist/hygienist for advice and monitoring</td>
<td>5 (1.5%)</td>
<td>32 (9.3%)</td>
<td>108 (31.4%)</td>
<td>198 (57.6%)</td>
</tr>
</tbody>
</table>
6.5 Discussion

The rationale, methods and results of a questionnaire study that aimed to increase understanding of oral health related behaviours, risk to oral health and opportunities for behaviour change in elite athletes have been presented. The key findings will now be summarised, then the strengths and limitations discussed in relation to current literature, followed by implications for athlete wellbeing and future research.

6.5.1 Key findings

In general, athletes reported favourable oral hygiene-related behaviours including toothbrushing before bed and in the morning but fewer than half had attended a dentist within the previous six months. Less than a third (28.2%) of athletes were categorised as high consumers of sugar in their regular diet. However, 85.7% reported using sports drinks at least sometimes during training/competition, 58.8% reported using energy bars and 70.3% energy gels therefore, overall, athletes should be considered to be high consumers of sugar.

Tobacco use and smoking are important risk factors for oral health and only one athlete reported currently using smokeless tobacco (the proportion of smokers in the general population is around 28%). It is strongly recommended that players wear a mouthguard for contact sports including hockey and rugby (Newsome et al., 2001), however not all the athletes from these two sports reported wearing a mouthguard. Given the higher prevalence of dental caries and erosion in the athletes from the team/mixed sport category, use of a mouthguard could perhaps be implicated in increasing the risk of caries/erosion.

Fewer than half (46%) of the athletes said that they could or probably could reduce the use of energy gels and bars but 80.4% said they could or probably could reduce sugary drinks including sports drinks. Athletes said that they would consider regular dental visits but the factor that was most important to them when arranging a dental visit was convenience. The majority of athletes said they could or probably could consider use of additional oral hygiene aids and increasing fluoride availability to improve oral health.

In this study, the athletes with the highest self-reported consumption of sugar had the lowest prevalence of caries. However, this group of athletes also reported the highest prevalence of positive oral health behaviours including: brushing before bed at night (100%), use of ETB (73.3%) and use of dental floss or other interdental aid at least
occasionally (60%) which suggests that it is possible to mitigate the risks to athlete oral health through enhanced oral hygiene habits.

### 6.5.2 Strengths and limitations of the study

This study is the first to investigate oral health beliefs and behaviours in elite athletes and a strength of this study is the number of participants and completeness of the sample screened in each sport. The questionnaire was completed independently and anonymously to limit responder bias. However, self-reported measures can be unreliable and only serve as a proxy measure for oral hygiene and dietary habits. The questionnaire provided limited information regarding whether the athletes used sports drinks, energy bars and gels on the advice of coaches and/or nutritionists, or if they used them in response to marketing/availability. Information on the content of the snacks consumed by athletes was also limited. The analyses indicated a number of interesting differences in oral health, psychosocial variables and oral health behaviours between the different sports. Use of qualitative methods such as interviews or focus groups would have yielded a much greater depth of information but would have required a greater time commitment from the athletes and the researcher that was not feasible during this PhD.

### 6.5.3 Comparison with other studies

Few studies have investigated oral health behaviours and risks to oral health in healthy young adults. The findings from this study support those from one study of Nigerian college athletes (Azodo and Osazuwa, 2013) and another study limited to triathletes (Bryant et al., 2011) which concluded by recommending “raising athletes’ awareness of their specific increased risk for dental caries and erosion and demonstrating how to optimize their oral hygiene and advice”.

Compared to a similar age group in the UK general population (White et al., 2011), athletes reported favourable oral health behaviours; 94% compared to 74% said they brushed morning and night and 43% compared to 18% said they used dental floss or interdental brushes. Elite athletes did not smoke or use tobacco; fewer were classed as high consumers of sugar in their usual diet. Interestingly, in the Adult Dental Health Survey 2009 (Chadwick et al., 2011), there was no association between self-reported high sugar consumption and caries. However, the athlete-reported use of energy gels (70%), bars (58%) and sports drinks (89%) put a greater proportion of athletes than their counterparts in the general population, into a high sugar consumption classification.
6.5.4 Implications for athlete health and performance

Reducing risks to oral health from lifestyle

Nutrition is fundamental to athlete performance (Jeukendrup, 2011; Mountjoy et al., 2015; Burke et al., 2011), and the findings from this research support a call to action that aimed to recommend strategies to prevent or mitigate the risk from nutrition to the short-term health and performance of athletes and to the long-term oral health of all active individuals (Needleman et al., 2018).

Athletes reported high consumption of energy gels and bars during training and competition, despite being aware that they can damage oral health. Furthermore, fewer than half felt that they could reduce their use of SNPs. Reducing the use of energy bars and gels was a behaviour change opportunity where there were marked differences between sports, therefore any behaviour change strategy could be potentially complicated by the need to address different motivational factors for each sport. One interesting observation was the high consumption of energy bars reported by the gymnasts. Weight control is very important for this group and this use of SNPs may be an indicator that they do not eat enough to maintain adequate energy levels. Given that the mechanisms by which carbohydrate-containing or acidic supplements can affect oral health are well established, it is important to develop mitigation strategies to reduce the risk of possible adverse oral effects while maintaining the performance benefits (Needleman et al., 2018).

Hydration is an important consideration in sport (Shirreffs and Sawka, 2011) and most athletes reported using sports drinks, but many felt that they could reduce their use. The group of athletes that reported the highest prevalence of consumption of soft drinks had sugar-free squash freely available at their training venue and it is likely that this was included as a positive response to this item in the questionnaire. However, it was not associated with increased caries or ETW in this group, therefore could be a useful alternative to proprietary sports drinks or water for hydration. For post-event hydration, milk could be substituted for proprietary sports drinks (Pegoretti et al., 2015), and plain water is adequate if combined with electrolyte and carbohydrate-containing foods such as those normally eaten during the recovery period (Shirreffs and Sawka, 2011). The use of beverages and supplements containing sugars should be discouraged (Needleman et al., 2018).

Many athletes (83.2%) would consider the use of sugar free chewing gum and there is some evidence that it may have a potential role in caries prevention (Twetman, 2009).
Therefore, future research could investigate the acceptability and effectiveness of this as a preventive intervention for sports participants.

It is recommended that dentists emphasise the importance of prevention of ill-health and reduction of inequalities of health by giving advice during consultations (Public Health England, 2017) and athletes reported receiving oral hygiene advice and advice about diet from a dental professional at some time. Dental professionals are well placed to identify potential lifestyle problems such as eating disorders and regular dental screening would provide an opportunity for early identification of all oral health problems and provision of brief oral health advice.

Sport nutrition is one of the key factors in athlete preparation and therefore well placed to deliver benefits across performance, general health, oral health and wellbeing. It would therefore make sense for strategies incorporating oral health to be jointly developed by registered sport nutritionists, oral health experts and other athlete support team members.

**Improving oral health through oral health screening and coaching**

Regular attendance for dental checks does not necessarily predict better oral health (NICE, 2004; Chadwick et al., 2011). However regular checks are important, not only to identify oral diseases at an early stage but also to maintain motivation towards a high standard of oral health (Needleman et al., 2014). Most athletes said they would attend for regular dental checks if it would improve their oral health, but convenience is an important consideration. Oral health promotion is most likely to be successful if it is embedded within overall athlete general health and performance promotion (Dijkstra et al., 2014).

The oral health screening provided for the athletes during this project was conducted at the training venues of the various sports squads and athlete attendance for oral health screening during this project was greater than 75% for all sports except athletics (track and field). This was due in part to the fact that the athletes were strongly encouraged to attend by their team medical officer. However, the athletes were free to make their own choice, and were for the most part grateful for the convenience of being able to take advantage of the screening at their training venue. Regular screening at the squad training venue should be provided by local dentists with an interest in sports dentistry.

Oral diseases such as caries, ETW and periodontal diseases do not present with pain in their early stages and athletes may delay a dental check or even treatment until they perceive that they have a problem. Athletes may not be brushing effectively as most had
evidence of gingival inflammation or risk factors present. Interdental cleaning using
dental floss or other methods is essential for optimum oral health (EFP, 2016; Public
Health England, 2017). Although less than half of the sampled athletes currently do this,
most said they would consider cleaning interdentally if it would improve oral health.
However, practical instruction is required to improve oral hygiene skills. This could be
provided by any member of the dental team including a dental therapist, dental hygienist
or dental nurse with an oral health education qualification. Therefore, oral health
screening should be followed up with an offer to provide care locally.

The recommendations to improve oral health in football (Needleman et al., 2015) should
be extended to all sports and includes: introduction of periodic oral health screening,
introduction of universal prevention/risk mitigation strategies and integration of oral
health promotion within overall athlete care.

The high recruitment rate of athletes underlines the importance of providing screening
and simple oral health promotion/preventive advice at athletes’ training centres,
preferably combined with education and coaching in practical oral hygiene skills. A
network of dentists with an interest in sport should be established, along with a clear
training programme to provide consistent screening and reporting of results along with
provision of care as required. Dentists should be prepared to conduct the screening at
the athlete training venue and provide appointments outside of regular training sessions.

Opportunities to mitigate risk through increased fluoride availability

The most important behavioural factor affecting both caries and periodontal health is
routinely performed oral hygiene with fluoride (Jepsen et al., 2017). Many athletes said
they could use a fluoride mouthwash, at a different time to brushing, therefore this could
be an opportunity to increase fluoride availability but requires a new behaviour. When
normal strength fluoride toothpaste (1000-1450ppm) is used, fluoride mouthwash used
at a different time to brushing can be advised (Marinho et al., 2016). Where caries risk
is increased, higher strength prescription fluoride (2800ppm) is indicated (Walsh et al.,
2010). Very high strength fluoride toothpaste (5000ppm) may also have a protective
effect against erosion (Pretty, 2016).

Enhancing oral health related behaviour through behaviour change techniques

To date there is no evidence to show which behaviour change technique (BCT) is best
for enhancing behaviours related to oral health (Asimakopoulou and Newton, 2015).
However, the current dominant approach to understanding health behaviour is the COM-
B model (Michie et al., 2011), and it has been suggested that interventions based on this
behaviour change theory may be successful (Newton and Asimakopoulou, 2017).
Further research including consultation with all stakeholders including sports nutritionists, sport and exercise medicine practitioners and dental professionals is needed to ensure quality and relevance within elite athlete care.

6.6 Conclusion

Elite athletes reported favourable health behaviours but had a relatively high level of dental caries, gingival inflammation and ETW. As athletes are at increased risk of dental caries and ETW, provision of regular, universal oral health screening for all elite athletes is recommended,

Athletes were aware of the risks to oral health from sports drinks, energy bars and energy gels but were unwilling to reduce their use of bars and gels for energy during training and competition. Therefore, it is important to identify appropriate risk mitigation strategies that can be implemented effectively in the elite sport environment.

Athletes said they were willing to adopt positive oral health behaviours including reduction in the use of sports drinks, attendance for regular screening and adoption of enhanced oral hygiene behaviours if it would improve their oral health. Furthermore, the results of this study suggest that positive oral hygiene behaviours can mitigate the risks to oral health in elite athletes

The most important individual behavioural factor, affecting both dental caries and periodontal diseases, is routinely performed oral hygiene with fluoride. Nearly all athletes said they brushed twice daily, and therefore using prescription strength fluoride toothpaste would increase fluoride availability without requiring athletes to make major changes in current behaviour.

This study has been published in the journal: British Dental Journal (Appendix R).

This Chapter has addressed step 2 of the TRIPP model of prevention and step 2 of the KTS for implementation of interventions. To successfully implement an intervention that requires behaviour change the model requires integration of sound behaviour change theory (Michie et al., 2014). The following chapter presents the complex process involved in testing if a behavioural intervention can improve athlete oral health.
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7 An oral health intervention implemented in elite athletes

The data presented in Chapter 5 measured the prevalence of oral health problems and associated negative performance impacts in elite athletes. The data presented in Chapter 6 provided an understanding of athlete reported oral health related behaviours, risks to oral health from participation in elite sport and opportunities for behaviour change.

This chapter will describe the development, implementation and evaluation of a pragmatic intervention study, designed with input from stakeholders that aimed to enhance oral health behaviours, thereby mitigating the risks to oral health from participation in sport. Finally, the process that was followed is presented as a new model to guide implementation of interventions in both the field of oral health and protection of athlete health and wellbeing.

7.1 Introduction and background

Poor oral health is a common finding in elite athletes. The evidence presented in Chapter 5 of this thesis confirms the results from related research studies conducted in the UK and globally (Ashley et al., 2015; Bryant et al., 2011; Gay-Escoda et al., 2011; Needleman et al., 2016; Azodo and Osazuwa, 2013; Needleman et al., 2013; Solleveld et al., 2015; Yapıcı et al., 2018; Knight et al., 2018). Oral health problems and associated impacts make a negative contribution to elite athlete health, wellbeing and performance. Like overuse injuries, they do not present with severe pain in their early stages and athletes continue to train and compete even with symptoms. Participation in sport at elite level can increase the risk both of injury and illness. The same can be said for dental caries and erosive tooth wear (ETW).

Historically sports and exercise medicine (SEM) followed a reactive injury centred model that neglected the contribution to athlete wellbeing, health and performance from other health related incidents (HRIs) including overuse injuries, low grade infection and other medical conditions including poor oral health (Dijkstra et al., 2014). However, protection of athlete health and prevention of injury, illness and other HRIs is now a clearly-stated aim of the International Olympic Committee (Steffen et al., 2011; Engebretsen et al., 2014; Mountjoy and Junge, 2013).

The document “Delivering better oral health: a toolkit for prevention” (Public Health England, 2017) provides evidence-based guidance to support oral health promotion and prevention of common oral diseases, however the evidence currently relates to the
environment outside of sport, therefore implementation in an elite athlete environment needs to be tested.

### 7.1.1 Implementation of preventive interventions

There is an abundance of evidence to support the efficacy of preventive interventions for sports injury prevention (Lauersen et al., 2014; Harøy et al., 2019; Gouttebarge et al., 2019) and numerous consensus statements and guidelines have been published. However, evidence of the effectiveness of preventive interventions remains inconsistent, and a complex approach that builds on previous systems and incorporates research from other areas of health care has been recommended (Bekker and Clark, 2016).

The original “sequence of prevention” model (van Mechelen et al., 1992) consisted of four steps: establish the extent of the problem, establish the aetiology and extent of the injury, introduce preventative measures and assess intervention effectiveness by repeating the first step. This simple model implied that research to investigate efficacy was sufficient and did not address the issues related to effective intervention and adoption of preventive behaviours by the people at whom they were targeted. However, to be effective, preventive measures needed to be acceptable to, adopted by and complied with by their target athletes, sports bodies and other key stakeholders. Therefore, the original model was expanded to become a six-stage process:

- injury surveillance,
- explain aetiology and mechanisms of injury,
- develop preventive measures,
- “ideal conditions” scientific evaluation,
- describe intervention context to inform implementation strategies,
- evaluate effectiveness of preventive measures in implementation context

This model is known as the Translating Research into Injury Prevention Practice or TRIPP (Finch, 2006).

The Knowledge Transfer System (KTS) was developed specifically to guide the development of practical and sustainable interventions linking knowledge derived from research with evidence-based usable information and tools for practice (Verhagen et al., 2014). The system follows a series of five steps the first three of which are: a statement of the problem, an investigation into the determinants of the problem and involvement of the target group in the development of the intervention including the identification of outcomes to evaluate its effectiveness. The ultimate goal of the KTS is to translate
evidence-based interventions into a usable and sustainable “product” that “works” in the “real world”.

The focus of the IOC consensus statement on prevention of non-communicable diseases is on simple interventions that include behavioural change and which are designed with an understanding of individual preferences and engagement across relevant networks (Matheson et al., 2013). Achieving and maintaining good oral health, as well as the prevention of oral disease is critically dependent upon an individual’s behaviour (Asimakopoulou and Newton, 2015).

7.1.2 Contemporary behaviour change theory

Behaviour change interventions can be defined as coordinated sets of activities designed to change specified behaviour patterns (Michie et al., 2011). The behaviour change wheel (BCW) was developed from a systematic review of frameworks of behaviour change (Michie et al., 2011), and is therefore the current dominant psychological approach to understanding health behaviour (Figure 7.1).

Figure 7.1 The behaviour change wheel and the COM-B model (Michie et al., 2011)

The BCW provides a structured approach to designing behaviour change interventions and strategies (Michie et al., 2014). It employs a systematic and comprehensive analysis of the available options using behaviour change theory and the available evidence to ensure that component parts of an intervention or strategy work together (West and Michie, 2015). At the centre of the wheel is the COM-B model of behaviour that identifies sources of behaviour that could provide opportunities for intervention (Michie et al., 2011).
• Capability (C) that is, the person having the physical skills and knowledge to perform the behaviour
• Opportunity (O), that is, access to the necessary materials and social environment such that the person feels able to undertake the new behaviour
• Motivation (M) refers to a person deciding to adopt the behaviour

Table 7.1 summarises how each of the steps in the development of the intervention related to the KTS. An addition to the KTS is the use of COM-B to guide the implementation.

Table 7.1 The Knowledge Transfer System with the addition of the COM-B behaviour model

<table>
<thead>
<tr>
<th>KTS steps</th>
<th>Processes</th>
<th>Within this project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2 evidence synthesis and description.</td>
<td>For all available evidence: Gain for the individual. Gain for society. Context for the evidence. Contemporary views.</td>
<td>Chapter 6 publication. DBOH.</td>
</tr>
<tr>
<td>Step 4 intervention (product) development.</td>
<td>Product goal. Target group. Product context.</td>
<td>COM-B model.</td>
</tr>
<tr>
<td>Step 5 evaluation.</td>
<td>Use a framework such as RE-AIM: Reach. Effectiveness. Adoption. Implementation. Maintenance.</td>
<td>Study protocol. Chapter 7 and publication.</td>
</tr>
</tbody>
</table>

DBOH = Delivering better oral health (a toolkit for prevention), KTS = Knowledge transfer system, COM-B = capability, opportunity, motivation, behaviour

7.1.3 Study designs for implementation research

The gold standard study design to evaluate the efficacy of an intervention is a randomised control trial (RCT). Participants are randomly assigned to either the study group, who receive the intervention, or the control group who do not. However, RCTs can be expensive and lack generalisability because of exclusion criteria. They may also be considered to provide evidence of what can be achieved under ideal circumstances rather than what can be achieved pragmatically in the real world (Cooper et al., 2014). The choice of research study design therefore includes practical implications. Table 7.2 presents an overview of intervention study design options.
Table 7.2 Options for intervention study designs

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomised trial</td>
<td>An experimental study in which the participants are allocated to one of two groups at random.</td>
</tr>
<tr>
<td>Controlled before-after study</td>
<td>A study where observations are made before and after the intervention in both experimental and control groups.</td>
</tr>
<tr>
<td>Interrupted time series</td>
<td>A study that uses data at multiple time points before and after the intervention. The design attempts to detect if the intervention has had an effect significantly greater than an underlying trend.</td>
</tr>
<tr>
<td>Repeated measures study</td>
<td>An interrupted time series where measurements are made in the same individuals at each time point.</td>
</tr>
</tbody>
</table>

7.2 Aim

The aim of this study therefore was to determine the effectiveness of simple interventions, based on a contemporary behaviour change model (COM-B) and developed using the KTS that could be delivered pragmatically, to elite athletes, with the potential to improve oral health and reduce performance impacts. A secondary aim was to establish a model that would be useful to guide implementation of future preventive intervention studies.

7.3 Materials and methods

Planning and implementing the intervention followed a complex process involving multiple steps and collaboration with many stakeholders.

7.3.1 Collaboration

This oral health intervention study was conducted in conjunction with an exploratory study that aimed to investigate the microbiome of elite athletes. This provided an additional incentive for performance directors to agree to athlete participation in the research.

The Knowledge Transfer Group

Step three of the KTS comprises the establishment of a knowledge transfer group (KTG) to discuss the problem statement and evidence description of steps one and two. Expert
advice was provided from scientists working at GSK, dental experts and University College London (UCL) Centre for Behaviour Change (CBC). Athletes from one Olympic training squad were approached through the team medical officer and invited to participate in a focus group to discuss and inform on the intervention study product and the study design (Figure 7.2).

Figure 7.2 The focus group

7.3.2 Product development

There are six activities in the BCW process for designing an intervention strategy and these were completed as part of KTS stage 4.

BWC activity 1: behavioural target specification

Key behaviours that have been identified as critically important for oral health include:

- Regular daily tooth-brushing with a fluoride containing toothpaste.
- Increased exposure to fluoride, including regular use of mouthwash.
- Interdental cleaning.
- Reduction in the frequency of sugar containing foodstuffs, particularly sugar containing snacks between meals.
- Regular attendance at the dentist (at least once every two years or more often on the basis of their risk of developing oral disease).
- Refrain from tobacco use or quit tobacco use if the individual currently uses tobacco products. (Newton and Asimakopoulou, 2017)

Targets for change that were identified from the athlete-completed questionnaire presented in Chapter 6 included:

- Increased availability of fluoride (mouthwash and spit not rinse)
- Reduce consumption of soft/sports drinks
- Increased frequency of interdental cleaning
- Attendance for regular dental checks

Expert advice from UCL CBC suggested that it might be more effective to intervene intensively on one or two target behaviours than to intervene less intensively on multiple behaviours (Michie et al., 2014). Therefore, the behavioural target specification was for the athletes to effectively disrupt dental plaque, including interdentally, and increase fluoride availability with prescription fluoride 2,800ppm toothpaste (PFT) twice daily.

**BWC activity 2: behavioural diagnosis (COM-B)**

In order for the behaviour to change, an increase in knowledge and motivation to avoid oral health problems and their associated impacts on wellbeing and performance was required for the entire team. Provision of the recommended oral hygiene items would enable the athletes to perform the required behaviour by increasing opportunity.

**BWC activity 3: intervention strategy selection (intervention functions)**

The strategies identified included: training and education using a sporting ambassador, provision of an oral health kit and increasing motivation with a verbal presentation by a dental expert. For elite athletes, sporting performance and appearance were identified as key motivating factors.

**BWC activity 4: implementation strategy selection (policy options)**

To support long-term implementation, an oral health promotion/education package was developed to be made available to all sports teams. Oral health screening was provided and an oral health kit created. There is strong evidence suggesting that verbal oral health promotion by dental professionals has a positive effect on recipient knowledge, behaviour and gingival health (Kay et al., 2016). The endorsement of the intervention by the medical officer and performance director of each team was also important.

**BCW activity 5: select specific behaviour change techniques**

Goal setting and planning were identified as appropriate behaviour change techniques (BCT) given the characteristics of this group. Athletes are used to following highly structured regimes for training. The goal of brushing for two minutes twice daily using PFT (prescription fluoride toothpaste) and interdental cleaning once daily was identified as the optimum behaviour. Figure 7.3 provides an overview of the stages leading to the development of the full intervention specification.
### Figure 7.3 Behaviour change wheel activities

<table>
<thead>
<tr>
<th>BCW activity</th>
<th>As it relates to the behaviour of elite athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Behavioural target specification: Identify the precise goal of the intervention in terms of what behaviour/s need/s to change, to what degree, in what way, and in whom.</td>
<td>Effective disruption of plaque on a daily basis, with prescription fluoride toothpaste (PFT).</td>
</tr>
<tr>
<td>2. Behavioural diagnosis: Find out what would need to change for the behaviour to change in terms of Capability (physical and psychological), Opportunity (physical and social) and/or Motivation (reflective and automatic) in the target population, group or individual.</td>
<td>Capability to disrupt plaque effectively and increase fluoride availability. Opportunity to use oral hygiene aids and fluoride toothpaste. Motivation to avoid oral health problems and associated performance impacts.</td>
</tr>
<tr>
<td>4. Implementation strategy selection: Choose from among a range of policy options to support long-term implementation: fiscal policy, legislation, regulation, environmental planning, communications, service provision, guidelines development.</td>
<td>Service provision: oral health screening.</td>
</tr>
<tr>
<td>5. Selection of specific behaviour change techniques: Develop a detailed intervention plan by selecting from among a range of specific behaviour change techniques (elementary components of interventions such as goal-setting, providing rewards etc).</td>
<td>Goal-setting: to brush for 2 minutes twice daily with PFT. Planning: to brush before bed and before training in the morning.</td>
</tr>
<tr>
<td>6. Drafting the full intervention specification: Create the detailed intervention specification covering all aspects of content and delivery of the intervention structured around the chosen behaviour change techniques (content) and modes of delivery</td>
<td>Capability - verbal presentation, 3 short films and screening. Opportunity - provide oral health kit. Motivation - verbal presentation and screening.</td>
</tr>
</tbody>
</table>
7.3.3 The intervention “final product”

The educational module

The oral health education module was developed to be delivered to the whole team and support staff as key stakeholders. Two key motivations for change were emphasised:

1. Performance enhancement: Poor oral health impairs performance
2. Appearance: Poor oral health can affect appearance.

Thus, oral health was not necessarily the end goal but an approach to achieving high value motivators. The final “product” consisted of a short, educational Power Point presentation (Appendix R) and three short (90-second) films featuring a “sporting ambassador” to be delivered by the study researcher (JG) to the whole squad and support team (Figure 7.4). The scripts for the presentation and short films were rehearsed and agreed with dental experts. Filming took place at the training venue of the Olympic athlete and at the University College London media studio.

The first film “Strength and conditioning for teeth” focussed on the importance of fluoride toothpaste to prevent dental caries. The second film “Strength and conditioning for gums” focussed on correct toothbrushing technique. The third film “Going the extra mile” focussed on correct technique for using floss, flosspicks and interdental brushes.

Figure 7.4 JG presenting to the whole group and the sporting ambassador featured in the films

Oral health screening and personalised feedback

Oral health screening and personalised feedback to each athlete, provided a further opportunity to enhance motivation by emphasising cognitions likely to increase the recommended behaviour (Newton and Asimakopoulou, 2017). Feedback to each athlete aimed to include the following elements: emphasise the benefits of adherence to the recommended oral hygiene routine, provide information on susceptibility to oral disease,
encourage athlete to plan where, when and how the behaviour will occur and emphasise habit formation.

*The oral health kit*

The oral health kit provided to each athlete was based on an assessment of the evidence to support the efficacy of each item in improving oral health and preventing oral disease and on recommendations in Delivering Better Oral Health (DBOH), 3rd edition (Public Health England, 2017). It consisted of a UCL Eastman Dental Institute branded washbag containing PFT, flosspicks and a manual toothbrush. An “oral health drills” card that had previously been produced for the 2015 International Olympic Conference on Prevention of Injury and Illness (Figure 7.5) was attached to the washbag, to provide a reminder of the recommended oral hygiene routine.

![Figure 7.5 Oral health drills card](image)

There is a dose-response relationship for fluoride toothpaste (ten Cate, 2013) but the maximum permitted fluoride level in over-the-counter toothpaste is 1500ppm, therefore prescription fluoride toothpaste was provided. However, due to possible athlete concerns and potential for reduced adherence to the recommendations, the toothpaste provided was Duraphat 2800 (i.e. 2,800ppm) rather than Duraphat 5000 (Colgate). In addition it was unlikely that the athletes would have root caries or dry mouth related to systemic disease or medication for a systemic disease (ten Cate, 2013).

Interdental brushes are recommended for interdental cleaning by people with periodontal diseases, (Chapple et al., 2015), however where spaces between teeth are too tight for interdental brushes to be inserted safely, “the use of floss may have a role to play” (EFP, 2016). A limitation to recommending dental floss is that people find flossing difficult to perform therefore the interdental cleaning aids provided were flosspicks (Glide Oral B, Proctor & Gamble), designed to be simpler to use.

A manual toothbrush was supplied in the oral health kit. This was a model consistent with recommendations in DBOH (Sensodyne Search 3.5, GlaxoSmithKline).
summary, the choice of toothpaste, toothbrush and interdental plaque removal device was informed by evidence, but also made with pragmatic considerations (Figure 7.6).

Figure 7.6 The oral health kit

The “Brushlink” device
Self-reported data can be unreliable particularly if the respondents feel that they should give the desired response (Petrie and Sabin, 2009). Therefore, a commercially available digital remote monitoring device was used to provide an objective measure of adherence to the recommended toothbrushing duration and frequency. The Brushlink device and app were developed originally to provide immediate feedback during toothbrushing including correct angulation of the toothbrush for a specified period of time in each quadrant of the mouth. However, in this study the device was used without this functionality as its sole purpose was to collect data about frequency of brushing and duration of each brushing episode.

The Brushlink (Figure 7.7) could be attached to either an electric or a manual toothbrush to enable tracking of brushing frequency and duration of each session (up to maximum of three minutes) provided the Brushlink app was downloaded and installed on the participant’s smart phone (Brushlink.com, 2017). To ensure athlete confidentiality a “ghost” email address was created for each study participant. A printed copy of directions regarding download and installation of the app, registration of the device and transfer of data from the device to the smart phone was given to each participant. Assistance from a Brushlink staff member was provided when the devices were distributed to groups 1 and 3. However, it was each athlete’s responsibility to install the app on their phone and register with the Brushlink website, when they had access to the internet, if this was not available at the training venue. They also had to decide which toothbrush to attach the device to if they used more than one, to remember to record each episode of toothbrushing and to “sync” the device with their phone at regular intervals.
Focus group feedback

The key stakeholders were the athletes and access to them was limited therefore the intervention was developed with input from an expert panel then taken to the focus group for evaluation and feedback. The story boards for the short films and the content of the presentation was discussed to identify what would work best to provide motivation. The content of the oral health kit and was discussed and approved and the acceptability of repeating clinical measurements confirmed (Appendix Q). A summary of the COM-B components, intervention functions and chosen strategies is presented in Table 7.3.
Table 7: COM-B model target behaviours and intervention functions

<table>
<thead>
<tr>
<th>COM-B component</th>
<th>Definition</th>
<th>Target behaviour</th>
<th>Intervention functions</th>
<th>Definition</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Psychological capability.</td>
<td>Understand how plaque causes dental diseases and how fluoride works to strengthen enamel.</td>
<td>Education.</td>
<td>Increase knowledge or understanding.</td>
<td>Educational presentation by dentist.</td>
</tr>
<tr>
<td>Opportunity</td>
<td>Social opportunity.</td>
<td>Brush teeth twice daily is accepted norm.</td>
<td>Modelling.</td>
<td>Providing an example for people to aspire to or imitate.</td>
<td>Using a “sporting ambassador” to deliver the information.</td>
</tr>
<tr>
<td></td>
<td>Physical opportunity.</td>
<td>Being able to clean teeth twice daily with fluoride toothpaste and use floss because the kit has been supplied.</td>
<td>Resources.</td>
<td>Cultural expectations.</td>
<td>Provide the oral health kit.</td>
</tr>
<tr>
<td>Motivation</td>
<td>Reflective motivation.</td>
<td>Healthy teeth are associated with looking good. Win a medal.</td>
<td>Incentivisation.</td>
<td></td>
<td>Personalised feedback following screening to include goal-setting and planning.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coercion</td>
<td>Creating an expectation of punishment or cost.</td>
<td>Poor oral health can lead to missed training/competition.</td>
</tr>
<tr>
<td>COM-B component</td>
<td>Definition</td>
<td>Target behaviour</td>
<td>Intervention functions</td>
<td>Definition</td>
<td>Strategy</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Automatic motivation</td>
<td>Automatic processes involving emotional reactions, desires (wants and needs), impulses, inhibitions, drive states and reflex responses.</td>
<td>Understand the impact of oral disease on wellbeing and performance. Wanting to perform at your best. Having the intention to brush effectively with fluoride toothpaste and use floss.</td>
<td>Persuasion.</td>
<td>Using communication to induce positive or negative feelings or stimulate action.</td>
<td>Provision of oral health kit items is free.</td>
</tr>
</tbody>
</table>
7.3.4 Study design

This was a repeated measures study, conducted at the training venues of one professional and two Olympic athlete teams. Baseline data were collected from each athlete prior to the intervention, then collected from the same athletes at two further times after the intervention. The intervention comprised: a 10-minute power point presentation by a dentist (JG) and three short films shown to the whole squad and those members of the support staff who were available, followed by oral health screening, provision of an oral health report and personalised feedback to each athlete along with an oral health kit.

A questionnaire was completed by each athlete prior to the intervention and athletes were also asked to start using the Brushlink device from the week prior to the intervention. The questionnaire and measurement of gingival health was repeated after 8 weeks and 16 weeks (+/- 4 weeks). The study ran for three field periods of July – October 2018, August – December 2018 and February - April 2019. The intervention consisted of 4 visits:

1) Pre-study visit (-1 week):
   - Gain participant consent.
   - Collect baseline questionnaire data. (Appendix X)
   - Issue Brushlink device to collect baseline toothbrushing data.

2) Study visit 1 (intervention):
   - Presentation to the whole team including athletes and medical support staff.
   - Athlete evaluation of the presentations and films.

3) Study visit 2 (4-8 weeks):
   - Collect follow up questionnaire data. (Appendix Y)
   - Clinical assessment of gingival health. (Appendix AA)
   - Supply replacement oral hygiene aids.

4) Study visit 3 (12-18 weeks):
   - Collect follow up questionnaire data.
   - Clinical assessment of gingival health.
   - Supply replacement oral hygiene aids.
• Athlete evaluation of the oral health kit. (Appendix BB)

7.3.5 Ethical approval

Ethical approval was received from UCL Research Ethics Committee Chair’s approval (Appendix T Project ID 6388/002). Athletes were given a participant information sheet (Appendix U) and they signed a written informed consent form (Appendix V).

7.3.6 Study population and sample size

Key personnel working with five squads that had participated in the study reported in Chapter 5 were contacted and offered the opportunity for their athletes to engage in this follow up project. The performance directors of three squads felt unable to commit their athletes to the research. A new professional team was invited to participate in the project when a request for oral health promotion was made to the project supervisor (IN). For two squads, the liaison person was a specialist sports nutritionist and for the other squad the liaison role was shared between the team medical officer and an athlete who was also a dentist. The plan for recruitment was confirmed with the performance director of each of the three participating squads.

A control group could not be used in the research as elite team managers did not consider attendance for repeated monitoring of a non-intervention group an appropriate use of athletes’ time. This was a pragmatic pilot study and therefore a sample size was not predefined with a power calculation. However, a good sample size for studies using a questionnaire as an outcome measure is generally considered to be 50 (Mokkink et al., 2010a) and the sample size in this study covering all three teams aimed to be at least 55 to allow for a drop-out rate of 10%.

7.3.7 Outcome measures

The primary outcomes were: a) self-reported oral health behaviours and knowledge, b) impact of oral health problems on performance in sport, c) clinically observed gingival inflammation/bleeding. Oral health behaviours were measured using items from the questionnaire used in the epidemiology study. Knowledge was measured with a questionnaire previously used in a study to oral health knowledge between dental, healthcare professionals and the public (Richards et al., 2014). This questionnaire comprised eight questions with options of true, false or don’t know. Each correct answer scored 1, therefore the maximum score was 8. Impact of oral health problems were measured using the oral health modification of the OSTRC (Oslo Sports Trauma Research Centre) overuse injury questionnaire used in the epidemiology study.
presented in Chapter 5 of this thesis (Gallagher et al., 2018). Secondary outcomes included requests for oral health kit replacement items, self-reported oral health problems, adherence to oral hygiene using the “Brushlink” device and athlete evaluation of both the presentation and the oral health kit.

7.3.8 Evaluation of the study

Athlete feedback
At study visit 2 the athletes were asked to complete a written feedback form regarding motivation to prevent oral health problems and performance impacts. At the final study visit, athletes were asked to complete a short questionnaire to evaluate the utility of the oral health kit and say whether they intended to use each item in the future.

Reflective evaluation
The evaluation of a KTS product revolves around its uptake in a real-life situation. A KTS product is expected to be developed from, or comprised of, evidence-based components and so its effectiveness does not need to be re-established. However, the translatability and feasibility of the developed products do need to be established within their intended context. A framework such as RE-AIM (www.re-aim.org) is useful for evaluating KTS products as it evaluates them specifically within their implementation context (Verhagen et al., 2014).

7.3.9 Data processing and statistical analysis

Data were collected and coded for entry into a spreadsheet. The data entry was completed by a person independent of the study. This was then imported to a standard statistical package (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY) for analysis. The data were assessed for normality and descriptive statistics were provided using mean or median and range depending on the distribution of the data. Counts and percentages summarised the categorical data. Non-parametric tests for change over time included the Wilcoxon sign rank test. Significance values for all hypothesis tests were set at 0.05.

7.4 Results

The educational module (presentation and films) was delivered to the whole team and support staff of Group 1, to athletes and some support staff of Group 2 and to athletes only of Group 3 (although the presentation was filmed by the liaison person for future dissemination if required). Not all members of all the support teams were able to attend the presentation, due to other commitments. Figure 7.8 presents the study flow diagram.
for the athletes. Of the 62 athletes recruited, seven did not complete the study. During the study period, one athlete from Group 1 transferred to another club after visit 2, one was unable to attend visits 2 and 3 due to injury and three were not available for visit 3. One athlete from Group 2 left the squad after visit 1 and another was unavailable for visit 3. One athlete from Group 3 was not available at visit 1 therefore baseline data were collected at visit 2 for that athlete.
Figure 7.8 Flow diagram of the study

**Group 1**
- Pre-study visit: Week -1
  - Recruitment
  - Questionnaire
  - Baseline toothbrushing
  - n = 30
- **Visit 1: Week 0**
  - Intervention
  - Baseline clinical data + oral health report
  - n = 30
- **Visit 2: Week 5**
  - Bleeding score
  - Questionnaire
  - not available = 2
  - n = 28
- **Visit 3: Week 16**
  - Bleeding score
  - Questionnaire
  - Evaluation of oral health kit
  - left the squad = 1
  - not available = 2
  - n = 25

**Group 2**
- Pre-study visit: Week -1
  - Recruitment
  - Questionnaire
  - Baseline toothbrushing
  - n = 18
- **Visit 1: Week 0**
  - Intervention
  - Baseline clinical data + oral health report
  - n = 18
- **Visit 2: Week 8**
  - Bleeding score
  - Questionnaire
  - left the squad = 1
  - n = 17
- **Visit 3: Week 18**
  - Bleeding score
  - Questionnaire
  - Evaluation of oral health kit
  - not available = 1
  - n = 16

**Group 3**
- Pre-study visit: Week -1
  - Recruitment
  - Questionnaire
  - Baseline toothbrushing
  - n = 14
- **Visit 1: Week 0**
  - Intervention
  - Baseline clinical data + oral health report
  - n = 14
- **Visit 2: Week 4**
  - Bleeding score
  - Questionnaire
  - not available = 1
  - additional recruit = 1
  - n = 14
- **Visit 3: Week 8/23**
  - Bleeding score
  - Questionnaire
  - Evaluation of oral health kit
  - n = 14
7.4.1 Demographics of the group

Thirty (48.4%) were professional athletes and 32 (51.6%) were from Olympic training squads. Group 1 were all male, Group 2 and Group 3 were mixed. Overall, the median age of the athletes was 24 years (range 18-33), 18 (29.0%) were female and 58 (93.5%) were white British. Eighteen (29.0%) athletes said they had taken antibiotics in the three months prior to the start of the study and 12 (21.4%) reported their use during the study period (Table 7.4).

Table 7.4 Demographics of the group

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>30</td>
<td>48.4</td>
</tr>
<tr>
<td>Group 2</td>
<td>18</td>
<td>29.0</td>
</tr>
<tr>
<td>Group 3</td>
<td>14</td>
<td>22.6</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td>44</td>
<td>71.0</td>
</tr>
<tr>
<td>Ethnicity (White British)</td>
<td>58</td>
<td>93.5</td>
</tr>
<tr>
<td>Antibiotic use reported in previous 3 months</td>
<td>18</td>
<td>29.0</td>
</tr>
<tr>
<td>Antibiotic use reported during the study</td>
<td>12</td>
<td>21.4</td>
</tr>
<tr>
<td>Age</td>
<td>Median (IQR)</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>24 (22 – 27.25)</td>
<td>18 – 33</td>
</tr>
</tbody>
</table>

7.4.2 Baseline oral health

At the baseline oral health screening appointment 17 (24.7%) athletes had evidence of established caries. No athlete had evidence of oral sepsis. There were 58 (93.6%) athletes with evidence of gingival inflammation in one or more sites, the worst BPE score recorded was 3, and twenty-nine (46.8%) athletes had evidence of ETW (BEWE score > 7) (Table 7.5).

Group 2 had the highest proportion of athletes with untreated caries (DT > 1), Group 3 had the highest proportion of athletes with previous caries experience (DFT > 1) and the prevalence of established ETW was highest in Group 3. All four (6.5%) athletes with evidence of pocket probing depth > 4mm at one or more sites were from Group 1 (Figure 7.9).
Table 7.5 Baseline oral health measures for the whole group

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Number of athletes</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dental caries</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT ≥ 1</td>
<td>17</td>
<td>24.7</td>
</tr>
<tr>
<td>FT ≥ 1</td>
<td>38</td>
<td>61.3</td>
</tr>
<tr>
<td>DFT ≥ 1</td>
<td>41</td>
<td>66.1</td>
</tr>
<tr>
<td><strong>Periodontal health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPE 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BPE 1</td>
<td>20</td>
<td>32.3</td>
</tr>
<tr>
<td>BPE 2</td>
<td>38</td>
<td>61.3</td>
</tr>
<tr>
<td>BPE 3</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>BPE 4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Pericoronitis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Erosive tooth wear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEWE score ≥ 7</td>
<td>29</td>
<td>46.8</td>
</tr>
</tbody>
</table>

DT = decayed teeth, FT = filled teeth, DFT = decayed, filled or restored teeth, BPE = basic periodontal examination worst score, BEWE = basic erosive wear examination

Figure 7.9 Baseline clinical measure of oral health for each squad

DT = decayed teeth, FT = filled teeth, DFT = decayed, filled or restored teeth, BPE = basic periodontal examination, BEWE = basic erosive wear examination

7.4.3 Comparison of study sample with epidemiological sample

Fisher's exact test was used to explore the relationship between this sample of athletes and the sample used in the main epidemiological study reported in Chapter 5. Table 7.6 provides a summary. The intervention study sample had statistically significantly less caries experience and evidence of moderate periodontal diseases. They had a higher proportion of athletes with evidence of gingival inflammation. There was no difference in terms of erosion.
### Table 7.6 Oral health of the intervention group and the epidemiology group

<table>
<thead>
<tr>
<th>Condition (n)</th>
<th>No condition (n)</th>
<th>Fisher’s exact test</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT ≥ 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>17</td>
<td>45</td>
</tr>
<tr>
<td>Elite 2016</td>
<td>173</td>
<td>179</td>
</tr>
<tr>
<td>DFT ≥ 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>41</td>
<td>21</td>
</tr>
<tr>
<td>Elite 2016</td>
<td>289</td>
<td>63</td>
</tr>
<tr>
<td>BEWE ≥ 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td>Elite 2016</td>
<td>148</td>
<td>204</td>
</tr>
<tr>
<td>BPE 1 or 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>58</td>
<td>4</td>
</tr>
<tr>
<td>Elite 2016</td>
<td>272</td>
<td>80</td>
</tr>
<tr>
<td>BPE ≥ 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>4</td>
<td>58</td>
</tr>
<tr>
<td>Elite 2016</td>
<td>76</td>
<td>276</td>
</tr>
</tbody>
</table>

DT = decayed teeth, FT = filled teeth, DFT = decayed, filled or restored teeth
BPE = basic periodontal examination, BEWE = basic erosive wear examination

### 7.4.4 Primary outcomes

**Self-reported oral hygiene behaviour**

Table 7.7 provides a summary of athlete-reported use of oral hygiene aids at baseline and at each study visit. At baseline 8 (12.9%) athletes said they used prescription fluoride toothpaste (PFT). Twenty-six (49.1%) athletes said they used an electric toothbrush (ETB) twice a day or more often, 10 (16.2%) said they used dental floss or other interdental cleaning aid at least 2-3 times per week and 25 (40.3%) athletes said they used fluoride mouthwash at least occasionally.

There was a statistically significant increase in athlete-reported use of PFT and interdental cleaning over the duration of the study. At the end of the study 45 (80.4%) athletes said they used PFT (p < 0.001) and 21 (34.0%) athletes said they used dental floss or other interdental cleaning aid at least 2-3 times a week (p = 0.013).
Table 7.7 Athlete-reported use of oral hygiene aids

<table>
<thead>
<tr>
<th>Oral hygiene aids</th>
<th>Baseline N = 62</th>
<th>Visit 2 N = 59</th>
<th>Visit 3 N = 55</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use MTB 2x day or more</td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>35</td>
<td>29</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>45.1</td>
<td>59.4</td>
<td>51.8</td>
<td>P &gt; 0.05</td>
</tr>
<tr>
<td>Use ETB 2x day or more</td>
<td>26</td>
<td>29</td>
<td>28</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>49.1</td>
<td>49.2</td>
<td>45.1</td>
<td>P &gt; 0.05</td>
</tr>
<tr>
<td>Use floss 2-3 x week or more</td>
<td>10</td>
<td>30</td>
<td>21</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>16.2</td>
<td>75</td>
<td>34</td>
<td>P = 0.013</td>
</tr>
<tr>
<td>Use normal fluoride toothpaste</td>
<td>39</td>
<td>12</td>
<td>16</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>62.9</td>
<td>20.3</td>
<td>28.6</td>
<td>P &gt; 0.05</td>
</tr>
<tr>
<td>Use prescription fluoride toothpaste (PFT)</td>
<td>8</td>
<td>47</td>
<td>45</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>12.9</td>
<td>79.7</td>
<td>80.4</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Use fluoride mouthwash at least occasionally</td>
<td>25</td>
<td>19</td>
<td>21</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>40.3</td>
<td>32.2</td>
<td>37.5</td>
<td>P &gt; 0.05</td>
</tr>
</tbody>
</table>

MTB = manual toothbrush   ETB = electric toothbrush

Knowledge

Table 7.8 shows the knowledge scores at baseline and at each study visit. A Wilcoxon Signed Rank Test revealed a statistically significant increase in athlete knowledge at the end of the study (p < 0.001).

Table 7.8 Athlete knowledge scores

<table>
<thead>
<tr>
<th>Knowledge score (max 8)</th>
<th>Baseline (N=62) Mean (SD) Median (IQR) Range</th>
<th>Visit 2 (N=59) Mean (SD) Median (IQR) Range</th>
<th>Visit 3 (N=55) Mean (SD) Median (IQR) Range</th>
<th>Wilcoxon sign rank test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD) Median (IQR) Range</td>
<td>Mean (SD) Median (IQR) Range</td>
<td>Mean (SD) Median (IQR) Range</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Knowledge score</td>
<td>5.69 (1.59) 6 (5-7) 2-8</td>
<td>6.43 (1.53) 7 (5-8) 2-8</td>
<td>6.93 (1.32) 8 (6-8) 3-8</td>
<td></td>
</tr>
</tbody>
</table>

Impact on sport performance and psychosocial impacts

Table 7.9 provides an overview of the athlete-reported performance impacts. The scores ranged from 0-82 at baseline and at the end of the study, and from 0-69 at the mid-point of the study. At baseline, 32 (51.6%) athletes reported an OSTRC score of zero; the median score was 0 (IQR, 0-8) and 14 (22.6%) athletes recorded a score of 16-82. At visit two, the number of athletes reporting a zero OSTRC score had increased to 46 (80.7%) and the median score remained at 0 (IQR 0) with two athletes (3.5%) recording a score of 16-69. At visit three all but one athlete reported an OSTRC score of zero, the median score was 0 (0) and the one athlete (1.82%) recorded a score of 82. A Wilcoxon Signed Rank Test revealed a statistically significant reduction in athlete-reported impacts on performance in sport at the end of the study (p < 0.001).

Psychosocial impacts were measured using the same three questions as in the epidemiological study presented in Chapter 5 (difficulty with eating, sleeping/relaxing and
socialising). At baseline 21 (33.9%) athletes recorded a score of zero psychosocial impacts; the median score was 1 (0-2) and 7 (1.3%) athletes recorded a score of more than three. At visit two, the number of athletes with a zero psychosocial impact increased to 37 (63.8%); the median score was 0 (0-1) and 1 (1.7%) athlete recorded a score of more than three. At visit three 36 (65.5%) athletes recorded a score of zero, the median score was 0 (0-1) and no athlete recorded a score of more than three. A Wilcoxon Signed Rank Test revealed a statistically significant reduction in athlete-reported psychosocial impacts (p < 0.001) at the end of the study.

**Table 7.9 Performance impact scores**

<table>
<thead>
<tr>
<th></th>
<th>Baseline (N =62)</th>
<th>Visit 2 (N = 57)</th>
<th>Visit 3 (N=55)</th>
<th>Wilcoxon sign rank test</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSTRC score (max 100)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Range</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>0.87 (14.54)</td>
<td>2.75 (9.60)</td>
<td>2.73 (11.31)</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>0 (0-8)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-82</td>
<td>0-69</td>
<td>0-82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychosocial score (max 12)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Wilcoxon sign rank test</td>
</tr>
<tr>
<td></td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Range</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>1.47 (1.92)</td>
<td>0.64 (1.36)</td>
<td>0.56 (1.32)</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>1 (0-2)</td>
<td>0 (0-1)</td>
<td>0 (0-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-8</td>
<td>0-9</td>
<td>0-3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Gingival inflammation**

Table 7.10 provides an overview of the gingival bleeding scores recorded at baseline and at each study visit. Overall, the gingival bleeding scores were low, however there was a marked variance in the gingival bleeding scores due to high scores in a few individual athletes; the median gingival bleeding score at baseline was 10% (IQR 5-15, range 1-36). The median score decreased at visit 2 to 7.5% (IQR 4-14, range 0-51) then increased to 10.5% (IQR 6.6-16, range 0-35) at visit 3. A Wilcoxon Signed Rank Test revealed that there was no statistically significant change in athlete gingival health at the end of the study (p = 0.952).

**Table 7.10 Gingival bleeding scores**

<table>
<thead>
<tr>
<th></th>
<th>Baseline (N=62)</th>
<th>Visit 2 (N=59)</th>
<th>Visit 3 (N=55)</th>
<th>Wilcoxon sign rank test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td>Median (IQR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Range</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>Bleeding score (max 100)</td>
<td>11.57 (8.11)</td>
<td>10.44 (9.03)</td>
<td>11.95 (7.30)</td>
<td>0.952</td>
</tr>
<tr>
<td></td>
<td>10 (5-15)</td>
<td>7.5 (4-14)</td>
<td>10.5 (6.63-16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-36</td>
<td>0-51</td>
<td>0-35</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.11 summarises the data for the athletes with the worst and best gingival bleeding scores. At baseline the median bleeding score was 10 (5-15) with 11 (18.0%) athletes in the lowest quartile (best score) and 14 (22.9%) in the highest (worst score). At visit two the median score was 7.5 (4-14) with 13 (23.2%) athletes in the lowest quartile and 12
(21.4%) in the highest. At visit three the median score was 10.5 (6.6-16) with 9 (16.1%) in the lowest quartile and 10 (17.9%) in the highest. Although the proportion of athletes with the worst score decreased from baseline to visit 3, Chi squared test with Yates continuity correction confirmed that this was not statistically significant (p = 0.651).

Table 7:11 Proportions of athletes with best and worst gingival bleeding scores

<table>
<thead>
<tr>
<th>Study visit</th>
<th>Proportion of the group with best scores</th>
<th>Proportion of the group with worst scores</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>11 (18.0%)</td>
<td>14 (22.9%)</td>
<td></td>
</tr>
<tr>
<td>Visit 2</td>
<td>13 (23.2%)</td>
<td>12 (21.4%)</td>
<td></td>
</tr>
<tr>
<td>Visit 3</td>
<td>9 (16.1%)</td>
<td>10 (17.9%)</td>
<td>P = 0.651</td>
</tr>
</tbody>
</table>

7.4.5 Secondary outcomes

Oral health kit replacement items

At visit 2 and visit 3, athletes were asked if they had been using each item in the oral health kit and also if they required replacement items. Table 7.12 provides a summary of the data. The study toothpaste was the most requested item and the study toothbrush the least requested item.

Table 7:12 Replacement items in the oral health kit

<table>
<thead>
<tr>
<th>Item</th>
<th>Visit 2</th>
<th></th>
<th>Visit 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Using</td>
<td>Requested</td>
<td>Using</td>
<td>Requested</td>
</tr>
<tr>
<td>Study toothbrush</td>
<td>28 (47.5%)</td>
<td>27 (45.8%)</td>
<td>23 (41.1%)</td>
<td>29 (51.8%)</td>
</tr>
<tr>
<td>(Sensodyne Search 3.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study toothpaste</td>
<td>52 (88.1%)</td>
<td>54 (91.5%)</td>
<td>53 (94.6%)</td>
<td>52 (92.9%)</td>
</tr>
<tr>
<td>(Duraphat 2800)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study flosspicks</td>
<td>36 (61.0%)</td>
<td>26 (44.1%)</td>
<td>32 (57.1%)</td>
<td>32 (57.1%)</td>
</tr>
<tr>
<td>(Oral-B Glide)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Self-reported oral health problems

Overall, there was a statistically significant decrease in the number of athletes reporting oral health problems over the course of the study as shown in table 7.13. At baseline, 8 (13.1%) athletes reported current pain or problem in their mouth whereas 1 (1.8%) athlete reported current problem at the end of the study (p = 0.015). Self-reported gingival bleeding “at least occasionally” reduced from 36.0% at baseline to 20.0% at the end of the study (p = 0.008). There was no statistically significant change in the proportion of athletes reporting sensitivity at least occasionally (p = 0.261).
Table 7.13 Changes in self-reported oral health problems

<table>
<thead>
<tr>
<th>Self-reported problem</th>
<th>Baseline N = 62</th>
<th>Visit 2 N = 59</th>
<th>Visit 3 N = 55</th>
<th>Chi squared test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current problem/pain</td>
<td>Number %</td>
<td>Number %</td>
<td>Number %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 13.1</td>
<td>7 11.7</td>
<td>1 1.8</td>
<td>0.015</td>
</tr>
<tr>
<td>Sensitivity (yes or occasionally)</td>
<td>17 27.9</td>
<td>11 18.3</td>
<td>12 21.9</td>
<td>0.261</td>
</tr>
<tr>
<td>Gingival bleeding (yes or occasionally)</td>
<td>22 36</td>
<td>16 26.6</td>
<td>11 20.0</td>
<td>0.008</td>
</tr>
</tbody>
</table>

When asked at visit two, 12 (20.3%) athletes said they had an appointment arranged to attend the dentist or hygienist. When asked the same question at visit three, 13 (23.2%) athletes said they had arranged a future dental appointment.

**Adherence with toothbrushing frequency and duration**

Both frequency of toothbrushing and duration of toothbrushing were measured using the Brushlink device if and when the athletes recorded this activity and then uploaded the information to the website. However, the device had not been programmed to record duration of brushing over 180 seconds. Therefore, it is likely that these data underestimate the actual mean time. The following section presents data collected from the Brushlink devices at six selected points during the study: baseline, immediately after the intervention (V1), the week before visit 2 (Pre V2), the week of visit 2 (V2), the week before visit 3 (Pre V3) and the week of visit 3 which represented the end of the study period (V3).

During the study, there was a steady decline in the number of athletes in all groups using the device to record brushing sessions. (Figure 7.14). Consequently, there was a steady decline in the number of episodes of brushing recorded and uploaded to the website by the athletes. However, over the study period the mean number of sessions recorded per user for each of the study periods increased from 5.2 to 11.1. The mean duration of brushing time increased from 1.93 minutes to 2.17 minutes and the frequency of brushing episodes recorded per day increased from 0.97 to 1.52 (Table 7.15). A statistical analysis of this data was not conducted as it would not be meaningful due to the large drop-out rate.
Table 7:14 Number of registered Brushlink users at specific time points during the study

<table>
<thead>
<tr>
<th>Data point</th>
<th>Group 1 (n)</th>
<th>%</th>
<th>Group 2 (n)</th>
<th>%</th>
<th>Group 3 (n)</th>
<th>%</th>
<th>Total (N)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>11 (30)</td>
<td>36.7</td>
<td>6 (18)</td>
<td>33.3</td>
<td>6 (14)</td>
<td>42.9</td>
<td>24 (62)</td>
<td>38.7</td>
</tr>
<tr>
<td>V1</td>
<td>13 (30)</td>
<td>43.3</td>
<td>8 (18)</td>
<td>44.4</td>
<td>4 (14)</td>
<td>28.6</td>
<td>25 (62)</td>
<td>40.3</td>
</tr>
<tr>
<td>Pre-V2</td>
<td>12 (30)</td>
<td>40.0</td>
<td>5 (17)</td>
<td>29.4</td>
<td>3 (14)</td>
<td>21.4</td>
<td>20 (61)</td>
<td>32.8</td>
</tr>
<tr>
<td>V2</td>
<td>8 (30)</td>
<td>26.7</td>
<td>6 (17)</td>
<td>35.3</td>
<td>1 (14)</td>
<td>7.1</td>
<td>15 (61)</td>
<td>24.6</td>
</tr>
<tr>
<td>Pre-V3</td>
<td>5 (29)</td>
<td>17.2</td>
<td>5 (17)</td>
<td>29.4</td>
<td>1 (14)</td>
<td>7.1</td>
<td>11 (60)</td>
<td>18.3</td>
</tr>
<tr>
<td>V3</td>
<td>4 (29)</td>
<td>13.8</td>
<td>2 (17)</td>
<td>11.8</td>
<td>1 (14)</td>
<td>7.1</td>
<td>7 (60)</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Table 7:15 Adherence with toothbrushing, recorded with the Brushlink device

<table>
<thead>
<tr>
<th>Data point (number of registered users)</th>
<th>Total number of brushing sessions recorded</th>
<th>Mean number of brushing sessions recorded per user</th>
<th>Mean duration of brushing time in minutes</th>
<th>Mean daily frequency of brushing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (24)</td>
<td>129</td>
<td>5.4</td>
<td>1.93</td>
<td>0.97</td>
</tr>
<tr>
<td>v 1 (25)</td>
<td>216</td>
<td>8.6</td>
<td>2.16</td>
<td>1.05</td>
</tr>
<tr>
<td>Pre-v 2 (20)</td>
<td>186</td>
<td>9.3</td>
<td>1.92</td>
<td>1.06</td>
</tr>
<tr>
<td>v 2 (15)</td>
<td>125</td>
<td>8.3</td>
<td>1.42</td>
<td>1.1</td>
</tr>
<tr>
<td>Pre-v 3 (11)</td>
<td>87</td>
<td>7.9</td>
<td>1.70</td>
<td>0.8</td>
</tr>
<tr>
<td>v 3 (7)</td>
<td>78</td>
<td>11.1</td>
<td>2.17</td>
<td>1.52</td>
</tr>
</tbody>
</table>

**Athlete feedback**

At the first study visit after the presentation was delivered, 58 athletes completed a written evaluation form. The responses are summarised in Figure 7.14. The presentation appears to have provided a good level of motivation, with each item achieving at least 75% athletes being motivated to avoid negative consequences of oral health problems, ranging from “impact on daily activities (79%)” to inflammation in the rest of the body (93%).
At the final study visit 55 athletes completed an evaluation of the utility of the oral health kit (Figure 7.15) the majority (91%) said that they found the kit useful overall, however there were elements that athletes found less useful, such as the washbag (27%), the drills card (24%) and the Brushlink device (36%). The items felt to be useful by the athletes were the PFT and the flosspicks. The manual toothbrush provided in the kit was felt to be useful by fewer than half (49%) of the athletes.

PTF = prescription fluoride toothpaste, MTB – manual toothbrush, ETB = electric toothbrush

The athletes were also asked to indicate which oral hygiene aids they intended to use in the future (Appendix BB). PFT was the item that (80%) said they intended to use. Fewer
than half (47%) of the athletes said they intended to use a manual toothbrush and 65% said they intended to use an ETB (Figure 7.16).

**Figure 7.16 Athlete feedback regarding intended future use of oral health kit items**

![](chart.png)

ETB = electric toothbrush, MTB = manual toothbrush, PFT = prescription fluoride toothpaste

### 7.4.6 RE-AIM evaluation of the study

Further consideration of these elements will be included in the discussion section of this Chapter, however Table 7.16 presents a reflective account of the study. Achieving a minimum sample size of 50 was a huge challenge. Three of the squads that were approached said that they could not give priority to this project and in the three squads that agreed to participate, the liaison person was key to successful engagement. Although this study was designed to run over a period of about four months, it took more than a year to complete. The initial focus group meeting was held in March 2018 and the final study visit completed in April 2019. In terms of reaching the target audience, good engagement with athletes occurred, however there was less success in reaching the medical and support staff in all the teams. The presentation to Squad 1 was attended by members of the physiotherapy team and nutritionists as well as the athletes. Few members of the support staff attended the presentation to Group 2 and Group 3. Support staff members were recruited to the study from Group 1 only.

The study was associated with statistically significant improvements in the use of PFT and knowledge but did not demonstrate an improvement in athlete oral health as measured by gingival bleeding score. Positive oral hygiene behaviours reported by athletes increased and there was a reduction in OSTRC scores. However, few athletes used the Brushlink device as requested to consistently record episodes of brushing.
Athlete feedback regarding the presentation was positive and feedback regarding the oral health kit indicated that they found it useful and intend to continue to use PFT and to clean interdentally. There is interest in the results of the study being reported back to the athletes and support staff and a written report will be produced. In addition, JG will arrange to present the study findings to the athletes at a specially arranged session.

Table 7:16 Evaluation of the study using the RE-AIM framework

<table>
<thead>
<tr>
<th>RE-AIM element</th>
<th>Outcome</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach</td>
<td>The intervention was delivered to the whole team and support staff of one professional squad, to athletes and support staff at one Olympic squad and to athletes only at one other Olympic squad. 62 athletes were recruited and 55 completed all three visits.</td>
<td>55 participants completed the study.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Knowledge. OSTRC score. Bleeding score.</td>
<td>Mean knowledge score improved. Mean OSTRC score improved Mean BS unchanged.</td>
</tr>
<tr>
<td>Adoption</td>
<td>The new behaviour was adopted.</td>
<td>Self-reported use of kit Request for replenishment of oral health kit items.</td>
</tr>
<tr>
<td>Implementation</td>
<td>Challenging to gain access to the athletes. Required flexibility and engagement from the provider.</td>
<td>Athletes were adherent to the recommended behaviour. Athlete feedback was positive.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Athlete evaluation indicated that they want to continue to use PFT.</td>
<td>Continued use of PFT will depend on athletes requesting or team medic prescribing.</td>
</tr>
</tbody>
</table>

OSTRC = Oslo Trauma Research Centre overuse injury questionnaire, BS = bleeding score, PTF = prescription fluoride toothpaste
7.5 Discussion

The rationale, methods and results of an oral health intervention implemented within an elite sport environment have been presented. The key findings will now be summarised and discussed in relation to contemporary literature, followed by the implications for athlete performance and future research.

7.5.1 Key findings

The process of planning, developing, implementing and evaluating this intervention was complex and involved multiple steps. The intervention was implemented in three separate elite athlete groups and in total, 55 (88.7%) athletes completed the study, conducted over 16 (+/-4) weeks per group. Overall, this intervention, based on contemporary behaviour change theory, was associated with improvements over the study period. Statistically significant improvements in the primary outcomes included: an increase in athlete oral health knowledge, an increase in athlete-reported use of 2800ppm PFT and interdental cleaning, a decrease in athlete-reported psychosocial and a decrease in athlete-reported sport performance impacts. There was, however no statistically significant change in oral health as measured with a gingival bleeding score.

7.5.2 Strengths of the study

The preventive interventions conformed with the guidance in Delivering Better Oral Health (Public Health England, 2017). Overall, the intervention was associated with measurable changes in behaviour across a number of areas.

This study was developed within research frameworks recommended for use in the field of sports and exercise medicine (SEM), namely the TRIPP model for prevention of injury (Finch, 2006) and the KTS model for implementation of interventions (Verhagen et al., 2014). It was informed by data collected from a representative sample of Olympic and professional athletes (Chapters 5 and 6) and a knowledge transfer group (KTG) comprising behaviour change experts, dental experts and key stakeholders in elite sport including athletes and members of the support team. User engagement played a pivotal role in the development, implementation and evaluation of this project.

The intervention design was based on the behaviour change wheel (BCW), a contemporary behaviour change method for characterising and designing behaviour change interventions (Michie et al., 2011) and the final “product” developed using the COM-B model of behaviour that was incorporated into the KTS as an additional stage.
The study therefore benefitted from a clear and structured approach that can be built upon in future research.

The behaviour change techniques employed during the personalised feedback opportunities at data collection visits have been recommended to enhance oral health related behaviour in the dental setting (Newton and Asimakopoulou, 2017) and, with the exception of coercion and restriction, the majority of potential links between COM-B model elements of behaviour and intervention functions were employed successfully as shown in Table 7.17.
Table 7: Links between components of COM-B and intervention functions

<table>
<thead>
<tr>
<th>Model of behaviour: sources</th>
<th>Education (Presentation)</th>
<th>Persuasion (Feedback)</th>
<th>Incentivisation (Reward)</th>
<th>Coercion (Sanction)</th>
<th>Training (Short films)</th>
<th>Restriction</th>
<th>Environmental restructuring</th>
<th>Modelling (Sport ambassador)</th>
<th>Enablement (Oral health kit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical capability</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological capability</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflective motivation</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic motivation</td>
<td>Y</td>
<td>Y</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical opportunity</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>Social opportunity</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Y = yes, X = no
The outcomes employed were a further strength. The OSTRC overuse injury questionnaire has evidence of validity for use in elite sport and has been shown to be more sensitive than measures based on a time-loss definition (Haroy et al., 2017; Clarsen et al., 2013; Gallagher et al., 2017).

The knowledge questionnaire used in this study was concise, simple for the athletes to use and crucially reflected the changes in knowledge. It had already used successfully been in a previous study (Richards et al., 2014), although a more formal validation would have been helpful.

The clinical index used to measure oral health was a simple gingival bleeding on probing score, commonly used to monitor gingival inflammation in clinical practice (Periodontology, 2016). The examination is rapid and simple to perform and record, therefore did not require an unreasonable time commitment from each athlete. The acceptability of repeating the bleeding on probing score was discussed and confirmed at the focus group.

An additional advantage was that the bleeding score provided an opportunity for personalised feedback to the athlete. Given the relatively short duration of the study it was not considered reasonable to measure changes in oral health with clinical outcomes such as dental caries and erosive tooth wear (ETW).

Despite the many barriers to conducting research in elite athlete groups, the intervention was successfully conducted at three separate elite training centres, with a meaningful sample size maintained throughout the duration of the study.

7.5.3 Limitations of the study

There were however some limitations to this study, the most important being the lack of a control group. Coaches were reluctant to make time available when there was a potential for benefit, but even less willing for athletes to participate in a control group without a potential benefit.

There is a possibility that the improvements indicated by the reduction in the mean OSTRC score and self-reported oral health problems could be attributed to the Hawthorne effect (participants improve or change their behaviour in response to being observed in a study). A control group would have helped to evaluate whether there was an intervention effect beyond this.
Although efforts were made to recruit the complete squad at each centre, not all athletes participated in the research. The athletes who agreed to participate may have been already motivated towards oral health, introducing a possible selection bias.

Resources were not available to recruit an independent person to collect the clinical data. The same researcher delivered the intervention and collected the clinical data at all three time points of the study therefore there was a potential for recorder bias. This was mitigated as the previous clinical data was not available to the researcher at each data collection visit.

Objective outcomes serve to validate self-reported outcomes and the purpose of the Brushlink device was to provide an objective measure of adherence to toothbrushing frequency and duration. However, there were limitations to the use of the Brushlink device in this research. During the course of the study the number of users decreased in each squad and it is likely that several aspects could have undermined athlete adherence to the use of the Brushlink including technical difficulties with the device such as synchronising the device with their mobile phone to upload brushing data. In addition, the researcher had not been made aware of the censoring of the duration data to three minutes by the company.

A COM-B analysis to explain why there was such a low adherence to use of the Brushlink device is presented in Table 7.18. This analysis suggests that adherence to use of Brushlink might have been enhanced by providing an incentive to use the device, such as allowing athletes to utilise its full functionality.
The study relied on self-reported use of the items in the oral health kit. Ideally, the athletes would be asked to return empty containers to be given further supplies and this would serve as an objective measure of adherence. However, this was not feasible and a prompt for the athletes to request further supplies at each visit was used instead.

A manual toothbrush was supplied with the oral health kit however it was deemed unreasonable to demand that the athletes use this brush for the duration of the study, especially if they were already using a powered brush (ETB).

### 7.5.4 Comparison with other studies

A literature search revealed no oral health behaviour change intervention studies implemented in elite sport, therefore comparisons will be made both with oral health studies in the general population and with studies in sports science and sports and exercise medicine (SEM).

### 7.5.5 Comparison with oral health studies

Two elements of this study that might have contributed to the improvements in athlete knowledge and behaviour were also identified in a systematic review (SR) of oral health promotion approaches that aimed to change individual’s knowledge attitudes or behaviours in order to influence their oral health (Kay et al., 2016). The advice was

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**Table 7:18 The COM-B model applied to the Brushlink device**

<table>
<thead>
<tr>
<th>COM-B component</th>
<th>Target behaviour</th>
<th>Intervention</th>
<th>Strategy employed</th>
<th>Achieved in every case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability</td>
<td>Knowing how to use the Brushlink to record each episode of brushing.</td>
<td>Education</td>
<td>Supply an instruction sheet to each athlete with their specific ghost email and step by step instructions.</td>
<td>Yes</td>
</tr>
<tr>
<td>Opportunity</td>
<td>Register the device with Brushlink. Download the mobile phone app to allow each brushing session to be recorded.</td>
<td>Persuasion</td>
<td>Brushlink staff member on hand to help athletes set up the device. Ensure Wi-Fi is available at the athlete training venue.</td>
<td>Yes, for Group 1 and Group 3 Not possible</td>
</tr>
<tr>
<td>Motivation</td>
<td>Attach the device to “main” toothbrush and remember to record each session.</td>
<td>Incentivisation</td>
<td>There was no incentive to use the device.</td>
<td>No</td>
</tr>
</tbody>
</table>
provided verbally and by video. The attributes of the “sender” of the oral health promotion message can influence its effectiveness. A sporting ambassador was used as a model in the information films and the presentation was delivered by an “expert” with an interest in sport.

A study that aimed to develop a structured taxonomy of behaviour change techniques (BCTs) identified 93 distinct BCTs (Michie et al., 2013) including those behaviour change techniques (BCT) employed in this intervention. Goal setting and planning were identified as useful techniques in a SR of psychological approaches to behaviour change for improved plaque control in periodontal management (Newton and Asimakopoulou, 2015).

However, there are other BCTs that have been used in a dental setting. A SR that investigated the efficacy of health behaviour change interventions/counselling to change health behaviours in adults with periodontal diseases, provided in the dental setting, found that brief interventions using BCTs such as motivational interviewing (MI) were effective (Ramseier and Suvan, 2015). The window of opportunity to provide feedback to each athlete was of necessity very brief, therefore MI was not considered as a BCT in this intervention.

A SR and meta-analysis that aimed to investigate the effectiveness of psychological interventions in adults and adolescents with poor oral health also found no statistically significant difference in gingivitis compared to traditional oral health education in adults (Werner et al., 2016). However, the meta-analysis was limited to adults aged ≥ 50 years with periodontitis. The recommendations from that SR were that psychological interventions should not yet be routinely provided in dental care for patients with poor oral health. However, this was linked to methodological limitations including target group selection and use of behavioural outcome measures, adherence and acceptability, many of which were addressed in the study presented in this chapter.

The outcome measures employed in this study are similar to those used in other oral health research. A SR investigated the effect of interventions based on social cognition models on oral health-related behaviour in individuals with periodontal diseases, (Newton and Asimakopoulou, 2015). Outcomes to measure adherence to oral hygiene included: self-reported behaviour and confirmatory objective measures, attitudes and beliefs including intention to change and clinical outcomes.

Behavioural interventions to change oral health behaviour have been reported on younger adults. A randomised controlled trial (RCT) conducted over a two-week period
aimed to evaluate the effect of a brief psychological intervention (acceptance and commitment therapy (ACT) a form of cognitive behaviour therapy), as a means to help young adult patients to make behavioural changes to improve their poor oral health. The study participants had a mean number of caries surfaces of 6.3 and 4.9 in the intervention and control group respectively, which are much greater than in this study. The intervention was delivered by a psychologist and therefore required additional resources that were not available in this study. No clear improvement in oral health behaviour was reported in the test group compared to the control group. However, this is an example of another BCT to consider in future research.

The effectiveness and acceptability of the Brushlink device was tested in an RCT conducted on patients attending general dental practice over a four week period (Kay and Shou, 2019). Plaque levels were used as a proxy measure of oral health related behaviour. The behaviour change technique linked to the Brushlink was self-efficacy supported by immediate feedback. Despite methodological weaknesses in the reporting, including a lack of clarity in the statistical testing, the results suggest that the Brushlink device was more effective in improving plaque control in the test group. Self-monitoring of behaviour is yet another BCT to consider in future studies.

7.5.6 Comparison with behaviour change studies in sport science

The behavioural intervention, described herein, was based on the behaviour change wheel (BCW) and the COM-B model to characterise and design behaviour change interventions (Michie et al., 2011). Behaviour change interventions are by definition complex and involve many interacting components (Michie et al., 2011). They are challenging to design and implement as is identifying the active components and understanding the effects and mechanisms of behaviour change interventions (Michie et al., 2013).

This study followed a step-by-step process to develop and implement the intervention study, the KTS framework for effective implementation of interventions (Verhagen et al., 2014). The addition of the BCW added to the complexity of the study. This was a common finding in other studies that describe interventions to change behaviour.

The BokSmart National Rugby Safety Programme aimed to “implement evidence-based sports medicine and exercise research to prevent injury and enhance performance at all levels of rugby union in South Africa” (Viljoen and Patricios, 2012). Like the intervention described in this chapter, it was a before/after study with no control group. It also followed a multi-stage process to describe and place in context the extent and severity of the
problem (neck injury, concussion and fatal head injury), identify evidence-based interventions and involve key stakeholders throughout.

The BokSmart programme was ambitious in the number of behaviours it sought to change. A five-year evaluation however found that (50%) of the behaviours improved significantly (p<0.005) between 2008 and 2012 and the remaining behaviours remained unchanged (Brown et al., 2015). However, it was not clear if self-reported behaviours reflected actual behaviour, and whether the observed improvements translated into changes in injury rates.

The development of FootyFirst, a preventive programme targeted at recreational adult, male Australian Football (AF) players (typically aged between 18 years and 35 years) generally training twice and playing one game of football each week has been described (Donaldson et al., 2017). The implementation activities were directed at the senior coaches because the training of these players was their responsibility. Like the study described in this chapter, it was a before/after study implemented nationally therefore without a control group. Again, similarities to the oral health intervention study involved a multi-stage process to describe the extent of the problem, place it in context, identify a planning group, what needed to change, and targets for intervention. The intervention has not yet been evaluated, however the challenges identified in the development were similar to those in the oral health intervention study, including co-ordination of all members of the planning group and the time required for the planning process. Engagement was found to be vital to create good working relationships.

The behaviour change framework used in both BokSmart and FootyFirst was intervention mapping (IM) which is a behavioural approach that draws on a range of theoretical methods, each of which independently addresses different aspects of the behaviours being investigated (Michie et al., 2011). However, it does not consider factors such as motivation to change. On the other hand, the BCW approach draws from a single unifying theory of motivation in context that predicts what aspects of the motivational system will need to be influenced (and how) to achieve a behavioural target (Michie et al., 2011).

The use of the BCW has also been described in a case study that described the development of a nutritional intervention targeted at athlete-consumption of a high-quality dietary intake, to achieve an increase in body mass across a twelve week period (Costello et al., 2018). This case study confirmed the complexity and multi-stage process of behaviour change interventions.
It has been recommended that contemporary sport injury research include qualitative studies with coaches and other members of the athlete support group as they are influential in supporting athlete health behaviours (Bolling et al., 2018b). A systematic review aimed to investigate where and how behaviour change theories and techniques have been used to inform and evaluate published coach development plans (CDPs) targeting a range of coach behaviours (Allan et al., 2017). It also concluded that future research should include behaviour science to increase effective implementation.

The COM-B model was used in a qualitative study that aimed to investigate barriers and enablers to athletes’ dietary behaviours in high-performance sport from sports nutritionists’ perspectives (Bentley et al., 2019). Although the experiences presented were not representative of the athletes’ perspectives the research provided another example of using behavioural diagnosis of what needs to change to alter future behaviour.

A systematic review that aimed to investigate the effectiveness of psychological intervention for preventing sports injuries (Gledhill et al., 2018) identified some practical implications that resonate with the challenges encountered during this study. The SR recommended that Sports Injury Practitioners (SIPs) contemplating psychologically based interventions for injury prevention need to consider how best to obtain full engagement in the type of intervention used in order to maximise impact. In other words, using BCTs such as MI, goal-setting and planned behaviour. The importance of using clearly defined terms was also emphasised and is presented in Table 7.19. As more research to test effectiveness of interventions rather than efficacy is published, greater understanding of the difference between the two types of study should lead to appropriate use of terminology.
Table 7:19 Key terms. Gledhill et al 2018

<table>
<thead>
<tr>
<th>Key term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence</td>
<td>The voluntary, collaborative and active involvement of an athlete in an injury preventive programme that is mutually acceptable to the athlete and clinician.</td>
</tr>
<tr>
<td>Compliance</td>
<td>The degree to which a participant conforms to the recommended dosage, timing and frequency of an intervention. The athlete is often passive in the process.</td>
</tr>
<tr>
<td>Efficacy</td>
<td>The performance of an intervention under controlled conditions with greater potential to claim a high degree of internal validity.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>The pragmatic considerations (e.g. time requirements, financial implications or administrative requirements) of using an intervention.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>A more “real-world” consideration, jointly determined by efficacy, efficiency, and compliance/adherence, with greater potential to claim a high degree of external validity.</td>
</tr>
</tbody>
</table>

7.5.7 Implications for wellbeing and performance

In elite sport, performance is everything (Bolling et al., 2019) and there can be differences in perspective between a performance point of view and a medical viewpoint (Levy and Delaney, 2012; Dijkstra et al., 2014). High-performance sport is a time-pressured environment where immediate results can often supersede pursuit of the most effective evidence-based practice (Costello et al., 2018). Although the International Olympic Committee and the International Sport Federations have an obligation ‘to encourage and support measures protecting the health of athletes’, oral health is an area that might still be given low priority when considering athlete performance (Ashley et al., 2015; Mountjoy et al., 2019). Ideally, youth athletes should be targeted before they become elite athletes so that good oral health is already a normal behaviour when they reach that stage.

Increasing capability to enhance oral health: The short films, educational module, Power Point presentation and script are a resource that is now available for use by any elite training squad. It is likely that if education/intervention is provided by persons or in a context that persons identify with/admire, then it may be well received (Murray et al., 2019; Gray et al., 2013). This intervention used an Olympic rower as a model however this model may have limited appeal for an athlete from other sports. Different sports could use the same basic intervention but with modifications such as more relevant...
representatives for that particular group of athletes. Expert opinion is important, therefore it may well be important that the person who delivers the presentation should be a dentist or dental care professional (DCP) with an interest in sport.

A recommendation to make oral health screening routine in professional football has been made elsewhere (Needleman et al., 2015) and personalised feedback at the screening visit can increase capability through provision of information and guidance (Newton and Asimakopoulou, 2017).

**Increasing motivation to enhance oral health:** At the screening visit, motivation to change can be enhanced through understanding likely motivators (such as performance and appearance, in this study, rather than oral health per se), emphasising the benefits of behaviour change to achieve this goal and emphasising the individual athlete’s susceptibility or risk of oral disease (Newton and Asimakopoulou, 2017). It is striking that a wish to avoid inflammation in the rest of the body was the motivation to improve oral health most frequently cited by the athletes in this study.

**Increasing opportunity to enhance oral health:** At the screening visit, motivation can be put into action through creating opportunities for the athlete to practice enhanced oral health behaviour (Newton and Asimakopoulou, 2017). Specific BCTs that have been identified as useful include planning, self-monitoring and motivational interviewing, therefore the dental care professional providing the screening should be competent in these BCTs (Gledhill et al., 2018).

Screening can be conducted by any dentist or DCP following appropriate training, as has been done for previous surveys completed for the British Association of Community Dentistry (Cameron, 2019 personal communication), potentially making this a more affordable health input into the overall care provided for elite athletes.

In this study, athlete-reported use of 2800ppm PFT increased and no adverse effects were recorded. The use of PFT has a strong evidence base to prevent dental caries (Walsh et al., 2010) and may have a protective effect against ETW (Carvalho et al., 2018). Therefore, provision of 5000ppm PFT should be offered to all elite athletes during their athletic career.

Monitoring of oral health could be facilitated by athlete self-report if an oral health question could be included in athlete wellbeing monitoring systems. The OSTRC questionnaire is useful for any pre-defined health problem as has been demonstrated in its validation study (Clarsen et al., 2013) and a follow up study to monitor athlete health (Clarsen et al., 2014).
The data did not show a change in oral health as measured by a gingival bleeding score, possibly due to poor toothbrushing and/or flossing techniques. One challenge lies in encouraging athletes to attend a dental care professional for oral hygiene advice and monitoring. The high recruitment rates seen throughout this research suggest that athletes would attend an appointment with a dental care professional (DCP) such as a dental therapist/hygienist for oral hygiene instructions, if that service were to be provided at the training centre. Personalised oral hygiene instructions and feedback are therefore advised for athletes.

7.5.8 Implications for future research

This work has shown that interventions based on sound behaviour change theory have the potential to be effective in promoting oral health in elite athletes. The Knowledge Transfer System provides a useful framework on which to base future implementation research if the Behaviour Change Wheel is incorporated into the process. A new model is proposed below in Figure 7.17 to guide implementation of interventions. It has potential for use in both the field of oral health promotion and the field of elite athlete health promotion. Therefore, this study forms a base on which to design future research.

Stakeholder engagement

An important factor in being granted access to the athletes was to link this oral health intervention study to an investigation into the elite athlete microbiome. Therefore, it is important to consider the advantages to be gained through engagement with all potential stakeholders. Two aspects are: the opportunity to put oral health at the same level as general health, through the influencing that can be achieved, and the creation of new opportunities for research and developing intervention techniques.

Future research should involve focus groups that include representatives from all stakeholders to discuss the study design, and outcome measures to be used in each implementation study (steps 3, 4, 5 and 6 of the behaviour change wheel). These groups might also generate and identify priorities for efficacy studies.

Mixed methods

The prevalence of oral disease in other sports and other countries would be a valuable source of data to strengthen the problem statement. The determinants of oral health in elite sport are not yet fully understood, and therefore such future research should also include both quantitative and qualitative data collection methods to help explain how and why elite athletes demonstrate poor oral health.
Data analysis

Systematic reviews of interventions to provide evidence of efficacy are required before designing implementation studies to test their effectiveness in the elite athlete environment. Ideally the population should include elite athletes but may need to be extended to include sub-elite athlete groups or healthy adolescent/younger adult groups to increase the relevance to elite athletes. Future systematic reviews could include other interventions to protect against dental caries and erosion such as fluoride mouthwashes and sugar free chewing gum with xylitol. Interventions to improve gingival health could investigate powered toothbrushes and interdental cleaning. Many BCTs have been shown to be effective and further research could investigate which are effective in elite athletes.

In addition to descriptive analysis of qualitative data, the COM-B model provides a useful aid for behavioural diagnosis of what needs to change (steps 1 and 2 of the BCW).

Study design

Where possible, future studies should aim to follow a more rigorous study design with the inclusion of control groups, such as randomised controlled trials (RCTs). Implementation studies that aim to evaluate effectiveness of a single intervention in elite athletes may need to follow a more pragmatic design, such as the before and after study design used in this study. However, RCTs could be used to compare the effectiveness and acceptability of other evidence-based methods to increase fluoride delivery such as prescription fluoride toothpaste and fluoride mouthwash. There is also some evidence of the efficacy of sugar free chewing gum with Xylitol to prevent caries.

Implementation studies

This intervention should be implemented in, and evaluated for, a larger sample of elite athletes. Prospective studies are required to measure the long-term effect on clinical outcomes and training, performance and prevention of illness. Future studies should be conducted in sub-elite groups including youth training squads as it is important to establish good oral health habits at an earlier age. However, these groups are not subject to the same environmental concerns associated with being an elite athlete therefore the external validity would be compromised.

One area for consideration is who should be targeted with interventions and advice regarding oral health. Oral diseases are accumulative, therefore interventions aimed at younger athletes have the potential to be more useful than at a later stage. In this study, the target group were the athletes and the support team, however due to time constraints and other commitments, very few members of the support teams were available to attend
the presentations and give feedback. Future studies could consider use of the COM-B model to target coaches, parents and other support team members.

The interdental aids provided to the athletes in this study were flosspicks, however there is no single aid that works for everyone and there is no single aid that does not work for anyone (Salzer et al., 2015). Therefore, the acceptability and adherence with other dental cleaning aids could be assessed if there is sufficient evidence to recommend them.

**Outcome measures**

Clearly defined outcomes are important to evaluate future studies, including behavioural outcomes, health outcomes, cost-effectiveness, acceptability, and adherence. A COM-B analysis could be used to explain successes and failures and inform future research. A framework such as RE-AIM could also be useful to explore strengths and limitations and inform future research.
Figure 7.17 A new model to guide implementation of preventive interventions.

Step 1
(Stakeholder engagement)
Recruit endusers, support staff, policy decision makers, experts
Establish advisory group and focus groups

Step 2
(Problem statement)
Describe the extent and severity of the problem in context
Quantitative research
Qualitative research

Step 3
(Evidence synthesis)
Systematic reviews
COM-B behavioural analysis

Step 4
(Intervention development)
Behaviour change wheel activities
Knowledge transfer group

Step 5
(Intervention implementation)
Study design
Recruitment strategies
Outcome measures

Step 6
(Evaluation)
RE-AIM
COM-B analysis
End-user feedback

Step 7
(Dissemination of information)
Academic journals
Specialist journals
Traditional media
Social media platforms
7.6 Conclusion

This study demonstrated that an oral health intervention, based on contemporary behaviour change theory (COM-B model of behaviour) implemented in three separate groups of elite athletes, was associated with improvements in athlete behaviour, knowledge and performance impacts.

Capability (knowledge and skills to perform the recommended behaviours) was increased with an educational module comprising a short (10 minute) presentation and three short (90 second) films viewed by athletes and members of the support team. Opportunity (enablement to perform the recommended behaviour) was increased with provision of an oral health kit that included prescription fluoride toothpaste (Duraphat 2800ppm, Colgate) and interdental cleaning aids (Glide Floss picks, Colgate). Motivation (reflective and automatic motivation to perform the recommended behaviour) was increased with provision of personalised feedback to each athlete following oral health screening.

In order to improve oral health and reduce performance impacts in elite athletes the following recommendations should be included in guidance documents and athlete health promotion policies.

- Regular oral health screening of elite athletes should be offered at their training venue and provided by a dental professional with an understanding of athlete lifestyle. The dental professional should be trained in the use of standard clinical screening indices to ensure consistency of information provided to the athletes.
- Dental professionals should be familiar with behaviour change techniques such as goal setting and planning as the screening visit creates a situation for a brief intervention to increase athlete motivation to adhere to recommend oral health behaviours.
- Prescription fluoride toothpaste should be offered to all elite athletes by the dentist providing the screening or the team medical officer.
- Follow up appointments with a DCP should be offered to athletes to provide personalised oral hygiene instructions.

A six-step process was described, in the form of a new model that integrates the KTS and the BCW, to guide future research that aims to implement interventions requiring behaviour change.
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8 General Discussion

The preceding chapters in this thesis have presented the results of three pieces of research that were collectively designed to investigate the oral health of elite athletes and associated self-reported impacts on performance.

Chapters 1, 2 and 3 of this thesis have presented the study hypotheses and research questions formulated to address the knowledge gaps identified in the review of the literature. The initial hypothesis proposed in this thesis was that “poor oral health in elite athletes is associated with negative impacts on quality of life, training and competition”. The second study hypothesis was that “an intervention based on contemporary behaviour change theory can improve athlete oral health and reduce performance impacts”.

Chapters 4, 5, 6 and 7 presented the research conducted to answer those research questions; the findings have contributed to the body of evidence on the association between oral health of elite athletes and self-reported impact on performance. This chapter will present an overall summary of the thesis then discuss the implications of this research for athlete health, wellbeing and performance and for future research in relation to current opinion.

8.1 Key findings

The following section presents a summary of the key findings from Chapters 4, 5, 6 and 7 in relation to the research questions and study hypotheses.

8.1.1 An athlete-reported outcome measure of impact on performance

The first research question was “is there an outcome measure with evidence of validity in sport to evaluate the impact of oral health problems on athlete performance?”

The aim of the systematic review (SR) presented in Chapter 4 was a) to identify which athlete reported outcomes have been used previously to evaluate the self-reported impact of health problems on performance in sport then b) to evaluate eligible outcome measures for evidence of validity and potential for use in both SEM and this research.

The SR concluded that the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire (Clarsen et al., 2013) was a valid AROM (athlete-reported outcome measure) to measure the consequences or impact of any pre-defined health problems on performance in sport. The OSTRC questionnaire, modified for oral health problems
was incorporated into the questionnaire used in the epidemiologic study presented in Chapter 5 and the intervention study presented in Chapter 7 of this thesis.

### 8.1.2 Oral disease and athlete-reported impact on performance

The second and third research questions were “what is the extent and severity of oral health problems in elite athletes?” and “what is the extent and severity of the impact of oral health problems on performance in elite athletes?”

The aim of the cross-sectional study presented in Chapter 5 was to measure the prevalence of common oral health problems and associated athlete-reported performance impacts in elite athletes using materials and methods that addressed the limitations of previous studies.

The results obtained from oral health screening of 352 Olympic and professional athletes confirmed the findings from other studies conducted in the UK, namely that oral diseases such as dental caries, erosive toothwear and periodontal diseases are common in elite athletes.

Evidence of moderate or severe dental caries (DT_\leq_1, ICDAS code_\leq_3) was observed in 49.1% (173) athletes. The prevalence of restored teeth (FT_\geq_1) was significantly greater in athletes _\geq_ 25 years (p < 0.001). There was no association between untreated caries and age, gender, ethnicity or education in this study, suggesting that caries is associated with being an elite athlete. Furthermore, there were differences in the prevalence of caries between sports and between sports categories. The proportion of athletes with caries in the mixed/team sport category (56%, 95% CI 48.2 to 63.5) was greater than those in endurance category (38.5%, 95% CI 31 to 46.4): this was statistically significant (p=0.009), with an odds ratio of 2.4 (95% CI 1.5-3.8).

Excellent periodontal health was rare. Evidence of gingival inflammation at one or more sites (BPE worst score 1 or 2) was present in 77.3% (95% CI 72.6-81.3) of athletes and evidence of at least moderate periodontal diseases (BPE score _\geq_ 3) was present in a further 21.6% (95% CI 17.6-26.2) of athletes. There was no association with gender, ethnicity, educational status or sport category, but there was an association with age: the prevalence of BPE score _\geq_ 3 was greater in athletes _\geq_ 25 years (p = 0.012).

The prevalence of ETW in this relatively young population was high. Evidence of obvious erosive tooth wear (ETW) in one or more teeth (BEWE score _\geq_ 7) was present in 42.0% (95% CI 37.0-47.3) of athletes. The presence of ETW was significantly associated with being male (p < 0.001): the proportion of men with evidence of ETW (48.7%) was greater
than the proportion of women (28.4%) with an odds ratio of 2.4 (95% CI 1.5-3.9). Prevalence of ETW was also associated with athletes participating in team sports (p = 0.015). The proportion of athletes in the mixed/team sport category (51.6%) with ETW was greater than the proportion of athletes in the endurance sport category (35.0%), with an odds ratio of 2.0 (95% CI 1.3 to 3.1) however this may be a reflection of the greater proportion of men in mixed sport in this study.

Overall 6% of athletes reported that in the previous year, an oral health problem had a moderate to severe impact on performance in sport. Non-zero impacts reported from the OSTRC questionnaire were: oral pain (29.9%, 95% CI 25.3-25.0), participation in normal training and competition affected (9.0%, 95% CI 6.4-12.5), performance affected (5.8%, 95% CI 3.7-8.6) and reduction in training volume (3.8%, 95% CI 2.2-6.4).

The highest OSTRC score reported was 94 out of a maximum possible score of 100 but such catastrophic impacts on performance in sport were very infrequent. Two thirds (69%) of athletes recorded no impact on performance from oral health problems and 26% of athletes scored between 1 and 29 which is unlikely to be of any clinical significance. However, 5% of athletes scored between 30 and 59 and 1% of athletes scored more than 60.

Non-zero psychosocial impacts were also reported by athletes: Difficulties with eating/drinking (34.6%, 95% CI 29.8-39.8), embarrassed to smile, laugh or show teeth (17.2%, 95% CI 13.5-21.5) and difficulty relaxing/sleeping (15.1%, 95% CI 11.7-19.3). There was an association between self-assessed poor oral health status and negative psychosocial impacts: eating/drinking (p = 0.001), relaxing including sleeping (p = 0.005) and confidence (p = 0.001). These activities of daily life are essential for athlete preparation therefore, at elite level, where the accumulation of marginal gains is critical to performance, such chronic impacts could be important.

The most likely mechanisms by which oral health problems affect performance in sport are through pain, inflammation and psychosocial factors. Oral sepsis resulting from extensive caries was associated with difficulty participating in normal training or competition (p =0.005) and self-assessed poor oral health was associated with pain (p = 0.022).

A history of wisdom tooth swelling in the previous 12 months was associated with impact on performance in sport (p < 0.001) and at least one psychosocial impact (p < 0.001). However, this is not always a condition that can be controlled by the athlete.
Together the results presented in Chapters 4 and 5 provide evidence of an association between oral diseases and self-reported negative impacts on performance in sport, general health and wellbeing in a representative sample of the elite athlete population in the UK. Therefore, it is reasonable to reject the null hypothesis of “there is no association between oral health and performance impacts in elite athletes”.

8.1.3 Oral health behaviours, risks and opportunities for change

The fourth research question was “what are the behavioural determinants of oral health in elite athletes and are they willing to consider making changes?”

The secondary aim of the cross-sectional study was to investigate oral health related and risk behaviours reported by athletes. An additional objective was to identify opportunities for behaviour change. The results were presented in Chapter 6.

Regular toothbrushing was reported to be an established habit in elite athletes: 94.2% (95% CI 91.1-96.2) said they brushed morning and night and 55.3% (95% CI 50.1-60.6) said they used an electric toothbrush (ETB). Athletes reported using other oral hygiene aids to maintain oral health: 40.9% (95% CI35.7-46.0) said they used fluoride mouthwash and 43.1% (95% CI 38.0-48.4) said they cleaned interdentally. Although regular attendance for dental checks does not necessarily predict better oral health, fewer than half of the athletes had attended a dental appointment in the previous six months.

Athletes did not report smoking or tobacco use, and the majority of athletes participating in a sport where a mouthguard is recommended reported compliance. Less than a third (28.2%) of athletes were categorised as high consumers of sugar in their regular diet. However, 85.7% reported using sports drinks at least sometimes during training/competition, 58.8% reported using energy bars and 70.3% energy gels. Therefore, overall, athletes should be considered to be high consumers of sugar.

To improve their oral health, 89% of athletes said that they would consider regular dental visits, however the factor that was most important to them when arranging a dental visit was convenience in order to fit in with training. Less than half (46%) of the athletes said they could, or probably could, reduce the use of energy gels and bars between meals, but 80.4% said they could or probably could reduce sugary drinks including sports drinks between meals. The majority of athletes said they could, or probably could, consider use of additional oral hygiene aids and a fluoride mouthwash.

In this study, the athletes with the highest self-reported consumption of sugar had the lowest prevalence of caries. However, this group of athletes also reported the highest
prevalence of oral health behaviours including: brushing before bed at night (100%), use of ETB (73.3%) and use of dental floss or other interdental aid at least occasionally (60%) which suggested that it was possible to mitigate the risks to athlete oral health through enhanced oral hygiene habits.

8.1.4 A behaviour change intervention to improve oral health

The fifth research question was “can a pragmatic oral health intervention based on contemporary behaviour change theory lead to improvements in oral health and a reduction in negative performance impacts?”

The aim of the study presented in Chapter 7 therefore was to develop, implement and evaluate an oral health intervention in a group of elite athletes.

The process of development and implementation of the intervention was a complex one. The Knowledge Transfer System (KTS) model for effective implementation of preventive interventions in sport was expanded to include the COM-B model of behaviour change that lies at the centre of the behaviour change wheel (BCW) a system that was also incorporated in the development process. Evaluation of the study was also complex: outcome measures included behavioural outcomes, a clinical outcome, a personal reflective account and athlete evaluation.

The intervention was delivered to 62 elite athletes from three separate elite squads and 55 (88%) completed the study. Statistically significant improvements were seen in athlete use of prescription fluoride toothpaste from 12.9% to 80.4% (p <0.001), use of interdental cleaning aids at least 2-3 x week from 16.2% to 34% (p = 0.013), knowledge (p<0.001), athlete-reported sport performance impacts (p<0.001). The prevalence of self-reported oral health problems also reduced (p = 0.015). An initial decrease in gingival inflammation/bleeding score was not maintained, therefore overall there was no significant change in gingival inflammation/bleeding (p = 0.952).

The results presented in Chapters 6 and 7 demonstrated that an oral health intervention developed with input from key stakeholders could be implemented in an elite sport environment and was associated with improvements. Therefore, it is reasonable to reject the null hypothesis of “Interventions based on contemporary behaviour change theory cannot improve oral health and reduce self-reported performance impacts in elite athletes”
8.2 Strengths of the PhD

Key strengths of this PhD are that the research was conducted exclusively with Olympic and professional athletes from a number of sports and that more than 75% of each team were recruited (with the single exception of track and field). Therefore, the results are generalisable to elite athletes.

This unique cross-sectional study was methodologically robust and is one of the largest studies of oral health in sport with 352 athletes recruited. These are therefore statistically significant results that strengthen the evidence base to describe oral health and associated performance impacts in elite athletes.

The accompanying questionnaire study was also representative of elite athletes and added to the knowledge base around the determinants and influences of oral health in this particular group. The questionnaire study was unique in that it was the first to identify opportunities for interventions to promote oral health in elite athletes.

The intervention study was the first to implement an oral health intervention for elite athletes and extended the current model for effective implementation of preventive interventions to include behaviour change theory. It demonstrated that an oral health intervention can be implemented in an elite athlete group and statistically significant results confirmed improvements in athlete knowledge, oral hygiene behaviours and performance impacts.

This PhD aligned well with the research priorities of International Sporting Federations (ISFs) and International Olympic Committee research centres (IOC-RC). Both groups have a strong interest, and engagement, in research to prevent injury and illness in athletes. ISFs in particular are interested in the conduct of more implementation research and studies that evaluate intervention effectiveness (Finch et al., 2016).

An advisory group was established at the outset of the PhD. This group comprised experts in oral health, oral health research, sports science, sports and exercise medicine, dentists with an interest in sport, experts in behaviour change and ex-elite athletes. Members from this group reviewed the protocols for the systematic review, the epidemiology study questionnaire and provided advice for the intervention.

A fundamental strand of the project was involving the key stakeholders throughout the study (including athletes, support staff, sport policy organisations and sport science experts). Despite the fact that access to elite athletes for research was extremely challenging, a strength of this PhD research was the remarkable level of engagement
and participation with elite athletes and elite athlete support staff both during the epidemiological study and the intervention research. They were involved in the research, as members of the advisory group, during data collection and during development of the intervention as participants in the focus group. Public involvement in research is recognised as being helpful to generating higher quality and more relevant research (Needleman, 2014). The genuine interest of the researcher (JG) in sport is also likely to have been instrumental in the successful interaction with the athletes and their support staff.

Clearly defined outcome measures with evidence of validity for use in both oral health research and sports and exercise medicine research were used throughout. The inclusion of athletes from different sports enabled comparison of oral health status within sport. In addition, athlete oral health was compared with the oral health of an age-matched group in the general population, thereby placing athlete oral health in context.

In order to strengthen the relevance to sports science and sports and exercise medicine (SEM), the research was aligned with contemporary research frameworks advocated for sport including the Translating Research in Injury Prevention into Practice (TRIPP) for developing interventions (Finch, 2006) and the Knowledge Transfer System (KTS) for effective implementation of interventions (Verhagen et al., 2014).

The intervention itself was developed using the COM-B behaviour change model that lies at the centre of the behaviour change wheel (BCW) a method to characterise and design behaviour change interventions (Michie et al., 2011). This expansion of the KTS framework, to include the BCW and COM-B, provided a new model for effective implementation of preventive interventions.

Finally, this PhD has identified a number of areas for future research into oral health in sport.

8.3 Implications for athlete health, wellbeing and performance

One of the striking findings throughout this PhD was the consistency of the prevalence of oral disease and associated self-reported negative impacts. Oral health problems can affect athlete performance therefore improved oral health has the potential to enhance performance; reduced performance due to poor oral health is unacceptable as well as preventable.
8.3.1 Oral health should be integrated into athlete development

International sporting bodies advocate a holistic approach to ensuring athlete wellbeing and performance (Dijkstra et al., 2014), however key lifestyle, relational, training and performance practices are commonly overlooked (Burns et al., 2019). Participation in sport at elite level increases the risk of oral health problems: protection of athlete health is an obligation for International Sports Federations therefore it is important to establish appropriate services to manage athlete oral health on a continuous basis and not only in association with major competitions.

Involve coaches at all levels
Elite athletes often begin their athletic career at an early age when they join youth development squads. Therefore, oral health education and advice should be incorporated into the youth system and coach development programmes.

Implement a high-risk prevention strategy
Athletes are at increased risk of both dental caries and ETW due to their use of sports nutrition/energy supplements during training and competition. Furthermore, although gingivitis and periodontitis levels were similar to population levels, they are both high and could have consequences both for athletic performance, and longer-term health and wellbeing. Although required for optimum training, performance and recovery, the use of beverages and supplements containing sugars should be discouraged where possible (Needleman et al., 2018). Since frequency of intake of sugars is likely to be high in elite sport, strong consideration and planning of risk mitigation approaches is also required.

There is a well established dose-response relationship between the concentration of fluoride in toothpaste and caries prevention (Walsh et al., 2010; Pretty, 2016) and prescription strength toothpaste may also have a protective effect against ETW (Carvalho et al., 2018) therefore provision of fluoride toothpaste 5,000ppm should be offered to all athletes.

Regular oral health screening
Like overuse injuries, oral diseases such as caries, ETW and periodontal diseases do not present with severe pain in their early stages and athletes continue to train and compete even with symptoms. Not everyone with gingivitis will go on to develop periodontitis, but gingivitis is an essential precursor to periodontitis. The athlete periodic health examination (PHE) should include a comprehensive oral health assessment to allow early detection and preventive management of dental caries, erosive tooth wear and periodontal diseases.
The main purpose of the periodic health examination (PHE) is to screen for injuries or medical conditions that may place an athlete at risk for safe participation. In addition, athletes may be affected by conditions that do not have overt symptoms including oral diseases that can only be detected by PHE (Ljungqvist et al., 2009). The oral health screening appointment also provides an opportunity for athlete feedback regarding their individual susceptibility to oral disease from the dental care professional. An appropriate brief intervention can increase athlete motivation and capability to improve oral health behaviour.

**Monitor, maintain and motivate**

Health promotion is synonymous with prevention of disease at a primary level (Brukner and Khan, 2014; Murray et al., 2007). The most important behavioural factor, affecting both dental caries and periodontal diseases, is routinely performed oral hygiene with fluoride (Jepsen et al., 2017) and encouraging everyone to do this effectively may be the most important part of the work of the dental team (Kidd and Fejerskov, 2016). In the case of excessive erosion associated with disordered eating, a dentist or DCP may be the first health care professional to identify this problem. Dentists and DCPs have an important role to play in providing oral health advice for athletes, either at the dental surgery or as part of a pre-season PHE.

**Nutritionists are influential in oral health**

Nutrition is integral to sport performance, therefore strategies incorporating oral health should be jointly developed by registered sport nutritionists, oral health experts, and other athlete support team members.

### 8.3.2 Implications for dental professionals

The clinical indices used in this study to measure dental caries (ICDAS), ETW (BEWE) and periodontal health (BPE) have been developed to link recognition of the disease at an early stage with preventive management. A “traffic lights” system of reporting oral health status to athletes and the team, similar to that used in UK Athletics in preparation for the London Olympic and Paralympic Games (Dijkstra et al., 2014) might be useful.

Adoption of these indices and associated behaviour management techniques (such as motivational interviewing) by dentists or dental care professionals (DCPs) providing screening for athletes could lead to greater consistency in the oral health promotion messages being given to athletes.
Historically, the placement of restorations has been the primary solution to manage dental caries (Featherstone and Domejean, 2012), therefore the presence of restorations may be considered not only as a reflection of past caries activity, but also as a reflection of the caries management philosophy of the dentist providing the dental care (Kidd and Fejerskov, 2013). It is important to note that caries management options at ICDAS=3 include preventive options such as application of sealants and remineralisation with increased fluoride (Innes and Schwendicke, 2017). Topical fluoride varnish application and fissure sealants are two clinical interventions that have proven efficacy but seem to be underutilised (Bonetti, 2014; Bonetti and Clarkson, 2016).

The inclusion of a question about participation sport as part of the history-taking process in the dental clinic would serve to highlight the need for enhanced prevention, particularly for youth elite athletes.

8.4 Limitations of the PhD and implications for future research

There were many avenues that could not be explored due to the constraints imposed by having only one researcher, limited time and limited access to the study population of elite athletes. However, the findings presented in this thesis forms the basis for further research. The following section will discuss the limitations and suggest opportunities for future research projects.

8.4.1 The impact of oral health on athletes

Throughout this research, the OSTRC overuse injury questionnaire was used as a basic questionnaire to measure athlete-reported impact on performance from oral health problems. The data was organised into binary categories of effect/no effect. The disadvantage of this organisation of the data is the loss of detail regarding the severity of the impact and, in fact, many of the non-zero scores might be below a minimum clinically important difference (Davidson and Keating, 2014). In other studies where the OSTRC questionnaire was used, the data has been further organised to include a “severe” category (Harøy et al., 2019). However, oral health problems that have a severe or even moderate effect are very uncommon. The OSTRC questionnaire might have had greater functionality if respondents with a non-zero score were followed up to ascertain the specific oral health problem and time lost from training or reductions in training intensity.

Oral health problems are also associated with negative impacts on those activities of daily living that are important for elite athletes lifestyle such as sleep (Roberts et al.,
2019; Fullagar et al., 2015), nutrition (Machuca et al., 2014; Jeukendrup, 2014) and confidence (White et al., 2012). Therefore, an additional three questions from the OIDP were used to measure psychosocial impacts. Although the OSTRC questionnaire has been validated for use in athletes, the OIDP questions have not. They did not use the same scale therefore were reported separately. Future research could include further development and validation of an AROM for oral health in sport.

Although the exact mechanism by which oral health problems impact on performance in sport is not fully understood: pain and inflammation appear to be key players in the process. Among the athletes in this research, gingival inflammation was common. However, it is not clear if participation in sport has a protective effect or is a risk factor for periodontal diseases in elite athletes. Athlete feedback from the intervention study indicated that avoiding the possibility of systemic inflammation linked to oral inflammation was a key motivator to improve oral health habits. Therefore, further research, to investigate the bidirectional relationship between oral inflammation and systemic inflammation, is required. Potential subject areas could include: intense effort and gingival inflammation, and prevalence and management of impacted third molars.

The opportunity for long-term follow up within the time-frame of this PhD was limited. Tooth decay, tooth wear and trauma to the teeth cause irreversible damage, as does the dental treatment required to manage these conditions, which also carries a lifetime cost. The effect of poor oral health on athletes in later life has not been researched, but is likely to have considerable impact, including a continued treatment need, tooth loss, reduced oral function and psychological effects. A longitudinal cohort study could be considered to include an investigation of the impact of dental treatment itself on performance.

### 8.4.2 Determinants of oral health in sport

The data were collected from athletes training in the UK, however an international approach with data from other countries would be valuable to strengthen the problem statement.

The data described a difference in oral disease prevalence between sports and between sports categories, however the factors contributing to those differences could not be fully explored. Qualitative research has the potential to increase understanding of the determinants of oral health in sport and guide the direction of further studies. Therefore, further research including both quantitative and qualitative methods including clinical studies to evaluate interventions and behavioural diagnostic studies are required.
Nutrition and hydration are essential components of athlete preparation and performance, however the questionnaire used to investigate dietary factors had a number of limitations. One was a lack of clarity in the definition of sports drinks and another was the fact that this was self-reported data. Therefore, further work should look at objective measures of athlete consumption of regular diet and sports supplements such as protein recovery drinks, electrolyte drinks and energy drinks.

8.4.3 Interventions

There was no association with use of sports/energy supplements and ETW, however there was an association between use of sports drinks and dental caries therefore further research is needed to investigate the effects of sports nutrition products on the dental hard tissues. Given that the mechanisms by which carbohydrate-containing or acidic supplements can affect oral health are well established, it is important to develop mitigation strategies to reduce the risk of possible adverse oral effects while maintaining the performance benefits.

Provision of dental care following oral health screening was not within the remit of this PhD, therefore athletes were not followed up to confirm if they had sought treatment or advice from their local dentist. Future research should investigate how to most effectively communicate treatment need to athletes and the most effective and acceptable way to provide dental care for elite athletes.

This PhD focused on able-bodied, adult elite athletes to provide a homogenous research group. However youth groups and recreational athletes have been identified as target groups for future research by both IOC-RCs and ISFs (Finch et al., 2016) therefore interventions should be developed, implemented and evaluated in these groups in addition to para-athlete groups.

8.4.4 Collaboration and public engagement

Dentistry and oral health care provision continue to be poor relatives in general health care and wellbeing considerations. This could result from ingrained perceptions among the medical and other healthcare professions including failure of the medical profession to promote the value of/contribution of oral healthcare/dentistry in the provision of forward-looking, value-based, preventatively-orientated, minimal-intervention, patient-centred care (Wilson, 2017). Future research should concentrate on engagement with all stakeholders in sport to identify opportunities for effective implementation of interventions. Therefore, collaboration between oral health research and sports
science/SEM research could offer the opportunity for information sharing (Gabbett et al., 2017). Application of the COM-B model could help understand behaviour and find ways to increase engagement.

8.5 Conclusions

Oral diseases, including dental caries, erosive toothwear and periodontal diseases are common in elite athletes. Although these individuals aim to have a healthy lifestyle, the demands of training and competition at elite level increase the risks of dental caries and erosive tooth wear. It is not clear if participation in sport is protective or harmful for periodontal diseases. Further research including both quantitative and qualitative methods is required to increase our understanding of the determinants of oral health in elite athletes.

Oral health problems are associated with negative self-reported performance impacts in elite athletes. The mechanisms of these impacts are not fully understood, however, oral conditions resulting in pain, swelling and infection are strongly implicated. Further research is required to explore the relationship between oral and systemic inflammation in elite athletes.

To compete at the highest level, an athlete must be well-prepared, fit and healthy; optimum oral health contributes to overall athlete health and wellbeing that aims to maximise training adaptations, reduce the risk of injury and illness and enhance competitive performance. Regular oral health screening in conjunction with targeted oral health promotion should serve to reinforce the importance of oral health as part of athlete general health, wellbeing and performance.

There is an established evidence-base of simple preventive and oral health promotion interventions that have proven efficacy under controlled conditions. However, to be effective these interventions, mainly establishing optimum oral hygiene with fluoride, are strongly dependent upon individuals adopting and maintaining these behaviours in real life and over the long term. Therefore, strategies that aim to be effective in improving oral health in elite athletes need to be developed, implemented, and evaluated following a complex model similar to that presented in this thesis.

This research contributes considerably to the growing body of evidence that supports the benefits of integrating oral health into the wider health, educational and social care agendas which aims to put the “mouth back in the body”.
In other groups, poor oral health is associated with social disadvantage, and whilst elite athletes have not been designated as such, their oral health can be considered disadvantaged. Furthermore, the lessons learned from research with this study population are relevant to other sectors of society.
9 References


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Appendix A. Systematic search strategy

Search strategy

Search for: 5 and 12

Results: 100

Database: Ovid MEDLINE(R) In-Process & Other Non-indexed Citations and Ovid MEDLINE(R) <1946 to Present> Search Strategy.

1. exp Self Report/ (13463)
2. self report* mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (105948)
3. (patient* adj 3 report*).mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (143655)
4. "patient reported outcome measure".mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (13463)
5. 1 or 2 or 3 or 4 (246412)
6. exp Athletes/ (4886)
7. (swim* or archer* or badminton or football or beach volleyball or boxing or boxerc* or canoe or kayak or cycling or cyclist* or equest* or fencing or fencer* or football or gymnastic* or handball or hockey or judo or "modern pentathl*** or rowing or rower* or sail* or shooting or taekwondo or tennis or triathl*** or volleyball or weightlift* or wreast*).mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (993389)
8. ("alpine ski"* or biathl* or bobsleigh or "cross country ski"* or curling or "figure skat"* or "free style skat"* or "short track speed skat"* or "skatboard" hob or snowboard*).mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (2406)
9. olymp* mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (314)
10. athlet* mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (23338)
11. ("professional rugby player*" or "professional cricket player*").mp. [mp-title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (77)
12. 6 or 7 or 8 or 9 or 10 or 11 (149444)
13. 5 and 12 (2129)
Appendix B. List of excluded articles


Ein-Dor, T., Reizer, A., Shaver, P. R., & Dotan, E. (2012). Standoffish perhaps, but successful as well: evidence that avoidant attachment can be beneficial in professional tennis and computer science. *Journal of Personality*, 80(3), 749-768. doi:http://dx.doi.org/10.1111/j.1467-6494.2011.00747.x


doi:http://dx.doi.org/10.1007/s00776-013-0442-x
SYSTEMATIC REVIEW

Self-Reported Outcome Measures of the Impact of Injury and Illness on Athlete Performance: A Systematic Review

Julie Gallagher¹ · Ian Needleman¹ · Paul Ashley¹ · Ruben Garcia Sanchez² · Robbie Lamdsden⁵

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Abstract
Background Self-reported outcome measures of athlete health, wellbeing and performance aid information to that obtained from clinical measures. However valid, universally accepted outcome measures are required.
Objective To determine which athlete-reported outcome measures of performance have been used to measure the impact of injury and illness on performance in sport and assess evidence to support their validity.
Methods The authors searched Ovid MEDLINE, Ovid EMBASE, CINAHL Plus, SPORTDestsus with Full Text and Cochrane library to January 2016. Predefined inclusion and exclusion criteria were applied and papers included if an outcome measure of performance, assessed in relation to illness, injury or a related intervention, was reported by an elite, adult, able-bodied athlete. A checklist was used to assess eligible outcome measures for aspects of validity. Reporting of this study was guided by PRISMA guidelines for systematic reviews.
Results Twenty athlete-reported outcome measures in 21 papers were identified. Of these 20, only four cited validation. Of these four, three reported evidence to support validity in elite athlete groups as defined by the predetermined checklist. Fifteen patient-reported outcome measures were identified, of which four demonstrated validity in young athletic populations.
Conclusions Most athlete-reported outcome measures of performance have been designed for individual studies with no reported assessment of validity. Despite some limitations, the Oslo Sports Trauma Centre overuse injury questionnaire demonstrates validity and potential utility to investigate the self-reported impact of pre-defined conditions on athletic performance across different sports.

Key Points
Valid self-reported outcome measures can contribute to a greater understanding of the impact of illness and injury on athletic performance.
There is currently no universally accepted self-reported outcome measure of athlete performance.
The Oslo Sports Trauma Research Centre overuse injury questionnaire has potential for development for use across different sports.

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1 Background

Athlete-reported measures of health, wellbeing and performance can add meaningful information to that obtained from traditional physiological and biochemical performance measures [1, 2]. Research which includes the athlete’s perspective has contributed to a greater understanding of development and performance along with issues pertaining to athlete welfare and wellbeing [1, 3].

Validity and reliability are key characteristics of self-reported outcome measures [4] and questionnaires with evidence of validity and reliability in a general population or even a younger active population have been previously used in the sporting setting. However their length, narrow focus or lack of specificity to the athlete population has led to widespread use of study-specific questionnaires within sports medicine. While this reflects an attempt to reduce the burden on the athlete and increase the relevance, it may compromise validity and reliability [2, 5].

The scores obtained from these self-reported measures should allow valid inferences to be made including hypothesis-testing, therefore they should be assessed for validity in the particular population of interest. Evidence of validity accumulates over time from multiple studies [4, 5], therefore there is a need for consensus regarding the methods used to record and measure health-related incidents and their consequences for athletes [4–6]. Used together these values describe change that can be distinguished from measurement error and is important to athletes [6].

Athletes are different from the general population [7, 8], they have higher levels of physical function, psychological function and perceived health. Physical activity is often their main employment, therefore the morbidity consequences of injury and illness tend to be high [9]. Athletes may not manifest symptoms during activities of daily living, and existing outcomes measures may not detect problems resulting from the demands of their training and competition [10]; thus, development of outcome measures that are specific to high performance sport could be important [9, 11–13].

The negative consequences of health problems include impairment, activity limitation and participation restrictions [11, 12]. Information regarding the prevalence and impact of health-related incidents is important to establish the burden of health problems and inform appropriate preventive and health promotion strategies [13–17]. However, athletes may not always seek medical care or present as patients, therefore patient-reported outcome measures (PROMs) may not be sufficient to capture all available information [9, 11, 18–21]. Additional barriers to the use of self-reported outcome measures include time to complete and lack of accessibility [2, 22].

Measures that are easy to understand, administer, score and interpret are more likely to be useful to all stakeholders in sport, including athletes, clinicians, researchers, support staff, funding bodies and policy makers [9]. We aimed to review the evidence to determine which athlete-reported outcomes have been used to evaluate the impact of health problems on performance in sport. A secondary objective was to evaluate eligible outcome measures for evidence of validity and potential for future research.

2 Methods

In order to address the first objective we conducted a systematic review to answer the focused question: “Which athlete-reported outcome measures of performance have been used to measure the impact of injury and illness on performance in sport?”

Studies were included if they met the following eligibility criteria: (1) participants were currently or had been competing at an elite level as able-bodied athletes; elite level was defined as competitive at Olympic, international, national or professional level [7], (2) any outcome measure of performance, assessed in relation to illness, injury or a related intervention, was reported by the athlete including functional and generic patient-reported outcome measures (PROMS), athlete diaries, interviews and patient satisfaction surveys; (3) the study was published in English. Studies were excluded from the review based on the following criteria: (1) participants were under the age of 16 years; (2) participants were competing at a recreational level; (3) the study was undertaken with a heterogeneous sample (e.g. elite and non-elite, able-bodied and disabled, under and over age 16 years) without reporting groups separately.

2.1 Search Methods for Identification of Studies

2.1.1 Electronic Searches

The databases of MEDLINE (Ovid version), EMBASE, CINAHL Plus, SPORTDiscus with Full Text, and Cochrane library were searched to 26 January 2016. A sensitive search strategy was devised initially in MEDLINE including the following search terms: self-report * athlete * patient reported outcome measure * and used in subsequent searches. An overview of the search strategy is available on request.
2.1.2 Searching Other Resources

The reference lists of included studies were checked for other papers that might be suitable for inclusion.

2.2 Data Extraction

Titles and abstracts were screened for eligibility by one of the authors (JG). The full text of all potentially eligible studies was assessed for inclusion by two authors in duplicate and independently (JG and RGS), resolving disagreements by discussion. Where resolution could not be achieved, a third author, experienced in conducting systematic reviews, arbitrated (IN). For included studies, data were extracted using a specially designed form (piloted before use) also in duplicate and independently by two reviewers. Where information in a paper was unclear, the corresponding author was contacted for clarification. Data extraction related to type of study, setting where the study took place, sport, population, injury or illness regardless of need for medical attention and details of the outcome measure.

2.3 Quality Assessment

In order to address our second objective, validity of development of outcome measures was assessed. Aspects of validity were evaluated using a pre-defined checklist based on the taxonomy and criteria proposed by Terwee et al. [2], [26] for evaluation of measurement properties of health status questionnaires.

2.3.1 Validity

There are many types of validity evidence [6] including face validity (the instrument actually measures the intended construct), content and construct validity. We considered evidence for content validity to include a clear description of the measurement aim, the target population, the concepts being measured and item selection. In addition the target population should have been involved in item selection. Evidence for internal consistency required factor analysis to be applied, with a Cronbach’s alpha value between 0.7 and 0.95. Ideally there should be at least 50 participants and minimal floor or ceiling effects [21].

Evidence for construct validity included reporting of values to show convergent validity (agreement in scores from other outcome measures which aim to assess similar constructs) and/or divergent validity (low correlation with scores from outcome measures which assess different constructs). Correlation coefficients such as the Spearman rho or Pearson r are most commonly reported in construct validation studies [6]. There should be at least 50 participants and at least 75% of the results should support a previously defined hypothesis [21].

2.3.2 Reproducibility (Agreement and Reliability)

The outcome measure scores should reflect changes where real change has occurred rather than changes due to measurement error. Evidence for agreement included at least 50 participants and the standard error of measurement (SEM) to be reported along with smallest detectable change (SDC) and minimal important change (MIC) or convincing arguments that agreement is acceptable. Evidence for reliability required at least 50 participants and an intra-class correlation coefficient (ICC) of at least 0.7 to be reported [21].

2.3.3 Responsiveness (Longitudinal Validity)

Evidence for the outcome measurement instrument to detect clinically important change over time included correlation with scores from other outcome measures of the same construct. Interpretability was assessed from evidence that (a change in) score was clinically meaningful along with means and standard deviations (SDs) of scores of reference populations and participant subgroups. In addition an MIC should be defined [21].

2.4 Data Synthesis and Reporting

In keeping with the aims of the review, findings from eligible studies were combined narratively using tables of evidence. The characteristics of the outcomes were used to synthesise results as well as validity outcomes. Reporting of the review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [25].

3 Results

The adopted search strategies yielded 6536 results. After removal of duplicates and titles clearly not relevant to the research question, 1358 articles were further screened by title and abstract for consideration in full text screening. The full text of 159 articles was assessed against eligibility criteria and 21 articles were finally included [26–46]. Agreement on article inclusion was high (0.8). Reasons for exclusion of full text studies are given in Fig. 1.

3.1 Characteristics of Included Studies

The studies represented a range of countries, with the USA being the most frequent. Seven categories of health
problems including hip and groin, knee, shoulder, lower back, eyes, oral health, overuse injuries and illness were represented across 34 different sports (Table 1). Ten of the 20 outcome measures were used in evaluations of medical interventions [31, 32, 34, 36–38, 41, 43–45].

3.2 Characteristics of the Athlete-Reported Outcome Measures

Athlete-reported outcome measures of performance included return to play, time to return to training/competition, level of competition, perception of performance compared to pre-injury, participation limitation, reduction in volume of training and impact on performance. A summary of the athlete-reported outcomes identified by the search is presented in Table 2.

3.3 Evaluation of Athlete-Reported Outcome Measures Used in Health Surveillance

Nine different athlete-reported outcome measures were used in ten observational (epidemiological or surveillance) studies [26, 27, 29, 30, 32, 33, 39, 40, 42, 43]. However, most were designed for use in individual studies without reference to evidence of validity. Self-reported information was used in one qualitative investigation of rugby players’ experiences following anterior cruciate ligament injury and repair, conducted over a period of rehabilitation and return to competition [28]. Quality criteria based on a pre-defined checklist [23, 24] were applied to the four questionnaires where the study had included a reference to evidence of validity of the outcome measure (Table 3).
Table 1  Characteristics of the studies

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of references</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA [31–33, 36, 41, 44, 46]</td>
<td>7</td>
</tr>
<tr>
<td>UK [54, 79, 40, 43]</td>
<td>4</td>
</tr>
<tr>
<td>Norway [27, 29, 30, 42]</td>
<td>4</td>
</tr>
<tr>
<td>Australia [28, 35]</td>
<td>2</td>
</tr>
<tr>
<td>Nigeria [26]</td>
<td>1</td>
</tr>
<tr>
<td>Switzerland [47]</td>
<td>1</td>
</tr>
<tr>
<td>Sweden [45]</td>
<td>1</td>
</tr>
<tr>
<td>Germany [37]</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sport</th>
<th>No. of references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>8</td>
</tr>
<tr>
<td>Athletics</td>
<td>7</td>
</tr>
<tr>
<td>Volleyball, aquatic, baseball, American Football, lacrosse, basketball</td>
<td>4</td>
</tr>
<tr>
<td>Equestrian, cycling, handball, skiing, swimming, wresting, hockey, tennis, ice hockey</td>
<td>3</td>
</tr>
<tr>
<td>Gymnastics, rugby, floor ball, archery, beach volleyball, shooting, taekwondo, weightlifting, table tennis</td>
<td>2</td>
</tr>
<tr>
<td>Cricket, boxing, frisbee, golf, judo, water polo, badminton, fencing</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health problem</th>
<th>No. of references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip/ groin [34, 37, 41, 44, 45, 47]</td>
<td>6</td>
</tr>
<tr>
<td>Any injury/illness [27, 30, 35, 42]</td>
<td>4</td>
</tr>
<tr>
<td>Knee [28, 29, 36, 43]</td>
<td>4</td>
</tr>
<tr>
<td>Shoulder [29, 31–33]</td>
<td>4</td>
</tr>
<tr>
<td>Oral health [26, 39, 40]</td>
<td>3</td>
</tr>
<tr>
<td>Eye [46]</td>
<td>1</td>
</tr>
<tr>
<td>Lower back [29]</td>
<td>1</td>
</tr>
</tbody>
</table>

3.4 Athlete- Versus Patient-Reported Outcomes to Evaluate Medical Intervention

None of the athlete-reported outcomes of performance used in evaluation of medical interventions cited evidence of validity, seven were used in conjunction with PROMs, not all of which cited validity in a sporting population (Table 2). However, three of the functional PROMs—International Hip and Groin Outcome Score (HAGOS) and Victorian Institute of Sport Assessment-Patellar Tendinopathy (VISA-P)—identified that this review have evidence of validity in a younger active population [44–50]. The three generic PROMs used in the studies—Short Form (12) Health Survey (SF-12), Short Form (36) Health Survey (SF-36) and EuroQol (EQ-5D) Health Questionnaire—have been reviewed by another author found to have limited validity in a sport and recreation population [9]. The Hip Sports Activity Scale (HSAS) used to identify level of sporting activity (Table 4) has evidence of validity in young patients with hip disease [47].

4 Discussion

Our key finding is that most athlete-reported outcome measures of performance to assess the impact of illness and injury on performance in sport identified in this review were developed for use in individual studies. There can never be a single study which validates an outcome measure; however, evidence of validity and reliability of the inferences drawn from the data accumulates over time with use in multiple studies, thereby allowing meaningful comparison across studies. One oral health self-reported measure of impact on performance was used in Olympic athletes and professional footballers but evidence of its validity has been assessed in a general population only. Functional PROMs such as i-HOT12, HAGOS and VISA-P, developed using the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) guidelines, demonstrate validity in young, active populations but not specifically in elite sport groups (Table 4). The HSAS self-reported measure of athletic capability has evidence of validity and reliability and could be a useful model for a tool to report the level of competition of athletes in research studies. Although rich in qualitative information, athlete interviews require a substantial time commitment from both the athlete and the researcher, as does the use of multiple PROMs. Consistent use of outcome measures with evidence of validity and reliability could help to quantify the burden of injury and illness and relative risk in athletes across different sporting activities. Researchers should aim to identify and use outcome measures with evidence of validity in the target group in which they are to be used. Three athlete-reported outcome measures of impact on performance demonstrate validity in a high performance athletic population—the OSTRC overuse injury questionnaire, the OSTRC questionnaire on health problems and the KJIC shoulder and elbow questionnaire: however, the KJIC questionnaire is specific to overhead throwing athletes. All are short and straightforward to complete and measure impact on performance in terms of athlete-reported pain/symptoms, participation, volume and quality of training/competition.

4.1 Strengths and Limitations of the Included Evidence

There are challenges to drawing robust conclusions from the included evidence. In general, the data regarding the outcome measures were drawn from their use in single
<table>
<thead>
<tr>
<th>Table 2</th>
<th>Characteristics of the self-reported outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domain/num. of items</td>
</tr>
<tr>
<td>Oral health surveillance</td>
<td>Demographics Health behaviours History of oral health problems Impact on performance (12 items)</td>
</tr>
<tr>
<td>Injury surveillance</td>
<td>History of training/playing Presence of injury</td>
</tr>
<tr>
<td>Structured interview</td>
<td>OSTiRC injury questionnaire</td>
</tr>
<tr>
<td>Knee injury and repair</td>
<td>Confidence building Anticipation Anxiety Physical preparation Psychological preparation Social support Dealing with fears</td>
</tr>
<tr>
<td>Qualitative</td>
<td>Predesigned diary and 5 semi-structured in-depth interviews</td>
</tr>
<tr>
<td>OSTiRC outcome injury questionnaire</td>
<td>History of injury Impact on performance</td>
</tr>
</tbody>
</table>
Table 2 continued

<table>
<thead>
<tr>
<th>Athlete-reported outcome measure</th>
<th>Domains/no. of items</th>
<th>Question asked to measure impact on performance</th>
<th>Scale</th>
<th>Time to complete/setting</th>
<th>Population in which measure has been validated</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSTRC questionnaire on health problems [30]</td>
<td>History of illness/ injury Impact on performance (4 items)</td>
<td>Have you had any problems participating during past week due to illness/injury/other health problem? To what extent have you reduced your training volume over the past week due to illness/injury/other health problem? To what extent have injury/illness/other problems reduced your performance during the past week? To what extent have you experienced symptoms/health complaints related to your sport during the past week?</td>
<td>As above</td>
<td>Self-administered e-mail, followed up by telephone for clarification if needed</td>
<td>During training/ pre-competition based on OSTRC overuse injury questionnaire</td>
</tr>
<tr>
<td>Shoulder injury and repair</td>
<td>Returning to pre-injury level of athletics (1 item)</td>
<td>Level of return to play</td>
<td>3 categories: Return to pre-injury level Return in a limited capacity Unable to play at all</td>
<td>Professional/self-administered</td>
<td>None (L’Acuata shoulder questionnaire ASES Validity in the general population)</td>
</tr>
<tr>
<td>Study-specific questionnaire [31]</td>
<td>Playing status Post-op complications Impact on performance (5 items)</td>
<td>Seasons played since surgery Time needed to return to competition Competitive level of return Pitch velocity compared with pre-injury levels Pitch control compared with pre-injury levels</td>
<td>3 categories: Increase in pitch quality No change in pitch quality Decrease in pitch quality</td>
<td>Telephone interview</td>
<td>None</td>
</tr>
<tr>
<td>ASHS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder injury and repair Study-specific questionnaire [32]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip groin injury and repair Study-specific questionnaire [33]</td>
<td>Demographics History of complaint Impact on daily activities Impact on sport Perception of fitness (3 items)</td>
<td>Time to return to training Time to return to sport competitively</td>
<td>Time in weeks 4 categories: Light training, full training Competition Fully match fit</td>
<td>Self-administered and telephone interview</td>
<td>None</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains/no. of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population in which measure has been validated</td>
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<tr>
<td>EIOC shoulder and elbow questionnaire [13]</td>
<td>Playing with pain Impact on performance Relationship with coach (30 items)</td>
<td>How difficult is it to get loose or warm prior to competition or practice? How much pain do you experience in your shoulder or elbow? How much fatigue do you experience? How unstable is your shoulder/elbow? How much have problems affected your relationship with coach management? How much has your velocity or power suffered? What limitation do you have in endurance? How much has your control suffered? How much do you feel your arm affects your current level of competition?</td>
<td>16-point VAS score</td>
<td>Self-administered At beginning and end of playing season</td>
<td>Overhead throwing athletes</td>
</tr>
<tr>
<td>Illness surveillance Athlete diary [15]</td>
<td>Demographics Training load Illness behaviour</td>
<td>Did you train? Are you ill or injured?</td>
<td>3 categories to score impact on training: Score 1 = minimal – normal trainingscore 2 = moderate = modified training score 3 = severe = discontinued training</td>
<td>Self-administered</td>
<td>Based on questionnaire developed by Australian Institute for Sport</td>
</tr>
<tr>
<td>Hip groin injury and repair Study-specific questionnaire [37]</td>
<td>Return to play Pain (5 items)</td>
<td>Resumption of sport within 28 days Time to resumption of sport (days) Full return to sport within 28 days Time to full return to sport (days)</td>
<td>Telephone interview</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Knee injury and repair Study-specific questionnaire [36]</td>
<td>Return to sport (3 items)</td>
<td>Self-reported time to return to sport Self-assessment of level of performance Level of competitive sport achieved after college</td>
<td>Telephone interview</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains/No. of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population in which measure has been validated</td>
</tr>
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</tr>
<tr>
<td>Hip groin injury and repair</td>
<td>Quality of performance Return to play (3 items)</td>
<td>Athlete perception of percentage of pre-injury level Time to return to play Level of play</td>
<td>Percentage of pre-injury performance</td>
<td>Self-administered</td>
<td>None SF-12 HOS HSAS Validity for use in general population</td>
</tr>
<tr>
<td>Oral health surveillance</td>
<td>Health behaviours History of oral problems Impact on performance (3 items)</td>
<td>To what extent have you been &quot;bothered&quot; by your mouth, teeth or gums over the past 12 months? To what extent have your mouth, teeth or gums affected your quality of life over the past 12 months? To what extent have your mouth, teeth or gums affected your athletic training or performance over the past 12 months?</td>
<td>5 categories: Not at all A little Somewhat A fair amount A great deal</td>
<td>Professional administered</td>
<td>During competition During training Derived from global questions Validity for use in the general population</td>
</tr>
<tr>
<td>Hip groin injury and repair</td>
<td>Return to sport Time to return to sport Level of competition (4 items)</td>
<td>Time to return to sport Level of competition</td>
<td>2 categories: Same level Not at all</td>
<td>Telephone interview</td>
<td>None MHHS HOS Validity for use in the general population</td>
</tr>
<tr>
<td>Injury surveillance</td>
<td>Time lost from training/competition (3 items)</td>
<td>How many minutes of match play did you do last week? How many hours of training did you do last week? Have you had any illness/injury that has restricted you from full participation in one or more training sessions and/or matches last week?</td>
<td>Time in minutes and/or hours Yes or no</td>
<td>Self-administered</td>
<td>Based on questionnaire developed for use in other elite sport groups</td>
</tr>
<tr>
<td>Knee injury and repair</td>
<td>Return to sport (2 items)</td>
<td>Time to return to play Level of return to play</td>
<td>3 categories: Return to same level Return to lower level Not competing</td>
<td>Professional/self-administered</td>
<td>None IKDC, Lysholm validity in general population VISA-P validity in active populations</td>
</tr>
<tr>
<td>Athlete-reported outcome measure</td>
<td>Domains/no. of items</td>
<td>Question asked to measure impact on performance</td>
<td>Scale</td>
<td>Time to complete/setting</td>
<td>Population in which measure has been validated</td>
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</tr>
<tr>
<td>Hip/groin injury and repair</td>
<td>Return to play (3 items)</td>
<td>Time to return to skating drills Number of NHL games played</td>
<td>Time is months Number of games</td>
<td>Self-administered</td>
<td>None</td>
</tr>
<tr>
<td>Study-specific questionnaire [64]</td>
<td>MHHS Patient satisfaction</td>
<td></td>
<td></td>
<td></td>
<td>MHHS Validity for use in general population</td>
</tr>
<tr>
<td></td>
<td>Hip/groin injury and repair</td>
<td>Return to play (1 item) Return or not to pre-injury sport</td>
<td>Yes or no</td>
<td>Self-administered Web-based</td>
<td>None</td>
</tr>
<tr>
<td>Study-specific questionnaire [65]</td>
<td>iHOT-12 HAGOS HSAS EQ-5D VAS for hip function</td>
<td></td>
<td></td>
<td></td>
<td>iHOT and HAGOS have validity in athletic population EQ-5D for general population</td>
</tr>
<tr>
<td></td>
<td>Eye injury surveillance</td>
<td>Playing history Circumstances of injury</td>
<td>How much playing time did you miss because of the injury? Some categories: yes, some, none</td>
<td>5 categories: 0, some of game/practice</td>
<td>Self-administered During competition</td>
</tr>
<tr>
<td>Study-specific questionnaire [66]</td>
<td>Medical behavior/ intervention Consequences of injury (34 items)</td>
<td></td>
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<td>None</td>
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</tbody>
</table>

ASSESS American Shoulder and Elbow Surgeons Shoulder Assessment, SF-12 Short Form 12 quality-of-life questionnaire, HOS Hip Outcome Score, HSAS Hip Sport Activity scale, MHHS Modified Harris Hip score, UCLA University of California Los Angeles Activity Score, IKDC International Knee Documentation Committee subjective knee evaluation form, VISA-P Victorian Institute of Sport Patellar Tendinitis questionnaire, iHOT International Hip Outcome Tool (Short Form 12), HAGOS The Copenhagen Hip and Groin Outcome score, EQ-5D EuroQol Health Status Questionnaire.

studies, although one measure of the impact of oral health on performance was used in two separate studies. Few questionnaires reported development using a structured approach and involvement of the target population, limiting their validity.

4.2 Strengths and Limitations of the Review

4.2.1 Eligibility Criteria: Performance Level

In order to limit the review we made a decision to limit the participants in the studies to high performance, able-bodied athletes. This focus resulted in several studies being excluded because the studies included participants with disabilities, participants under the age of 16 years or recreational sports people who could not be separated out from the highest level athletes.

4.2.2 Performance Versus Functional Outcomes

Return to play is dependent on a number of factors, most of which are outside an athlete’s control. Included studies had to demonstrate that a self-reported outcome measure was used to evaluate the impact upon performance in elite athletes. This resulted in exclusion of studies which included heterogeneous samples and reported on the development of functional outcome measures using the COSMIN criteria, such as the Functional Assessment Scale for Acute Hamstring Injuries (FASH) [52] and Victorian Institute of Sport Assessment—Achilles Tendinopathy (VISA-A).
Table 3: Validity checklist applied to eligible outcome measures

<table>
<thead>
<tr>
<th>Atletereported outcome</th>
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<tbody>
<tr>
<td><strong>KJOC shoulder and elbow questionnaire [16, 33]</strong></td>
<td>+ Clear description of target aim. Target population and experts involved in item selection and development</td>
<td>+ Factor analysis Cronbach’s alpha 0.861</td>
<td>+ Correlates well with established PROMs for upper limb (DASH and DASH for performing arts); Pearson r 0.84 and 0.86 respectively</td>
<td>+ Data presented and discussed regarding meaningful clinical change</td>
<td>+ Test-retest data reported</td>
<td>+ Differentiates between patients with pain and without pain; Change in scores reported for different subgroups</td>
<td>+ Maximum scores reported</td>
<td>+ Score of 100 indicates maximum function</td>
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<tr>
<td><strong>OSTRC overuse injury questionnaire [29]</strong></td>
<td>+ Clear description of target aim. Target population and experts involved in item selection and development</td>
<td>+ Factor analysis using a principle component analysis extraction method Cronbach’s alpha 0.91</td>
<td>+ Correlates with time loss recorded by conventional measures</td>
<td>0</td>
<td>0</td>
<td>+ Severity score can be plotted for each athlete</td>
<td>&gt;1.5% of respondents achieve highest or lowest scores</td>
<td>+ Severity score can be calculated out of 100</td>
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<tr>
<td><strong>OSTRC questionnaire on health problems [30]</strong></td>
<td>+ ? Developed from OSTRC overuse injury questionnaire</td>
<td>+ Factor analysis Cronbach’s alpha 0.96</td>
<td>For non-injury cases 0.97</td>
<td>0</td>
<td>0</td>
<td>+ Severity score can be plotted for each athlete</td>
<td>&gt;1.5% of respondents achieve highest or lowest scores</td>
<td>+ Severity score can be calculated out of 100</td>
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<tr>
<td><strong>Impact of oral health problems [39, 40]</strong></td>
<td>- Target group not involved in item selection</td>
<td>- No factor analysis Cronbach’s alpha not calculated</td>
<td>+ Tooth decay associated with self-reported impact on performance</td>
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*KJOC* Kerlan Jobe Orthopedic Clinic, *OSTRC* Oslo Sports Trauma Research Centre, *PROMs* patient-reported outcome measures, *DASH* Disabilities of the Arm, Shoulder and Hand. + positive rating, - negative rating, 0 no information available.
4.2.3 Risk of Bias and Quality Assurance

We attempted to minimise bias by developing the protocol a priori and employing duplicate full-text screening and data abstraction. However, initial eligibility assessment of titles and abstracts was carried out by one researcher (JG), which might have introduced bias in study selection.

4.2.4 Comparison with Other Reviews

This review supports the finding of related reviews. One systematic review of PROMs used to assess Achilles tendon rupture management [53] applied COSMIN criteria to 17 region-specific and condition-specific outcome measures; the authors found only four were presented in articles that referenced development and/or validation of that outcome measure and of these only one was developed using recognised methodology for outcome measure development. A systematic review of instruments used to assess outcomes of sport and active recreation injury [9] listed seven different health status and health-related quality-of-life measures, five different functional outcome measures and three physical activity measures; the authors stated that none have been specifically or region designed to measure injury outcomes in a general sport and active recreation population. One recent study of low back pain in international level rowers [54] recommended using the OSTRC exercise injury questionnaire, demonstrating its potential for use across all sports.

5 Conclusion

Within the limits of this review there is currently no universally accepted athlete-reported outcome measure of the impact of injury/illness on performance in sport. Most questionnaires were designed for individual studies and evidence to support their validity, reliability and...
responsiveness has not been reported. The KJOC shoulder and elbow questionnaire has evidence to support its validity, reliability and responsiveness but is specific to professional baseball players. Consistent use of self-reported outcome measures with evidence of validity, reliability and responsiveness would lead to more reliable and comparable evidence. Despite some limitations, as a potential tool to measure athlete-reported impact on performance across a variety of sports, the OSTRC questionnaire on overuse injuries forms a model that could be adapted to evaluate the impact of any pre-defined health problem on athletic performance. The addition of items related to impact on quality of life could add value in terms of understanding the negative consequences of injury and illness in sport.

Author contributions Ian Needham conceived the study. Robbie Lamsdon assisted in formulating the systematic search strategy. Julie Gallagher and Ruben Garcia Sanchez were responsible for duplicate screening and data extraction. Julie Gallagher prepared the first draft of the study protocol and the manuscript and was chiefly responsible for the conduct of the review. Ian Needham, Paul Ashley and Julie Gallagher contributed to the final draft of the protocol and manuscript.

Compliance with Ethical Standards

Funding The research project that resulted in this review was funded by an investigator-led grant from GlaxoSmithKline (Award Number: 15787) and an Impact Award from University College London.

Conflict of Interest Julie Gallagher, Paul Ashley, Ruben Garcia Sanchez, Robbie Lamsdon and Ian Needham declare that they have no conflicts of interest relevant to the content of this review.

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References


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<tr>
<td><strong>Title and abstract</strong></td>
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<tr>
<td>a) Indicate the study’s design with a commonly used term in the title or the abstract [within the title and method section of abstract]</td>
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<td>b) Provide in the abstract an informative and balanced summary of what was done and what was found [see results section of abstract]</td>
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<td><strong>Introduction</strong></td>
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<td><strong>Background/rationale</strong></td>
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<td>Explain the scientific background and rationale for the investigation being reported [page 1]</td>
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<td><strong>Objectives</strong></td>
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<td>State specific objectives, including any pre-specified hypotheses [page 1]</td>
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<td><strong>Methods</strong></td>
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<td><strong>Setting</strong></td>
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<td><strong>Participants</strong></td>
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<td>Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants [page 2]</td>
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<td><strong>Variables</strong></td>
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<td>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 3]</td>
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<td><strong>Data sources/measurement</strong></td>
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<td>For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 3,4]</td>
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<td><strong>Bias</strong></td>
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<td>Describe any efforts to address potential sources of bias [page 3]</td>
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<td><strong>Study size</strong></td>
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<td>Explain how the study size was arrived at [page 2]</td>
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<td><strong>Quantitative variables</strong></td>
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<td>Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 3]</td>
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<td><strong>Statistical methods</strong></td>
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<td>a) Describe all statistical methods, including those used to control for confounding [page 4]</td>
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<td>b) Describe any methods used to examine subgroups and interactions [page 4]</td>
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<td>c) Explain how missing data were addressed [page 4]</td>
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<td>d) If applicable, describe analytical methods taking account of sampling strategy [n/a]</td>
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<td>e) Describe any sensitivity analyses [n/a]</td>
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<td>a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4,5 tables 1,2]</td>
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Appendix E Ethics approval ID 001

11 May 2015

Professor [Name]
UCL, Faculty of Dentistry

Dear Professor [Name],

University of London Ethics Approval

To: [Name]

Subject: Approval of Proposed Research Project

I am pleased to confirm that a proposal for a research project has been approved by the University of London Ethical Review Board. The research project is entitled “[Project Title]” and is to be conducted at the [Institution Name].

Approval is subject to the following conditions:

1. You must seek each participant's consent prior to their participation in the research.
2. You must obtain permission from the Ethics Review Board before initiating any changes to the protocol.
3. You must ensure that all data collected is stored securely and is only accessible to authorized personnel.

The research project will be reviewed on an annual basis and any changes made to the protocol must be approved by the Ethics Review Board before implementation.

You are required to submit a progress report at the end of each academic year and a final report at the conclusion of the research project. These reports should include an overview of the research conducted, including any challenges faced and how they were overcome.

If you have any questions or concerns, please do not hesitate to contact me.

Yours sincerely,

[Signature]

[Name]
Chair of the UCL Research Ethics Committee

Col. [Date]
Appendix F Participant information sheet ID 001

Information Sheet for participation in Research Studies

You will be given a copy of this information sheet.

Title of Project: Oral health of Elite Athletes and Impact on Performance

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 6388/001

Lead researcher: Julie Gallagher

Work Address: UCL Eastman Dental Institute, 256 Gray’s Inn Road, London WC1X 8LD

Contact Details: julie.gallagher.14@ucl.ac.uk
Tel: 020 345 61075

We would like to invite you to take part in this research project.

Background:
Our research at the London 2012 Olympic Games, and with Professional Footballers in 2014, showed that some athletes may have problems with their mouth, teeth and gums. This could affect their sporting performance. We would like to look at this in more detail by asking you to attend for a dental check with our researcher and completing a questionnaire.

This study will only involve elite athletes and has been agreed with your team doctor and management.

You are eligible to take part in the study if you are;
- A member of the elite squad
- Aged 18 years or over
- Able to understand the questionnaire
- Able to understand the consent process

It is up to you to decide whether to take part or not; choosing not to take part will not disadvantage you in any way. If you do decide to take part you are still free to withdraw at any time and without giving a reason.

If you take part in the research, we will give you a summary of the dental check that you can take to your dentist

What does it involve?
The study will take place in your training centre. The dentist will examine your mouth, using a dental mirror and blunt probe (the same as your dentist uses). Then we have a questionnaire for you to complete. The whole thing should take about 20-30 minutes

All data will be collected and stored in accordance with the Data Protection Act 1998

Once we have analysed the data, we will write a research paper to be published in a sports medicine journal. We will also send copies of the paper to your team doctor for you so that you can see how your participation has helped the research.

Please discuss the information above with others if you wish or ask us if there is anything that is not clear or if you would like any more information.
Appendix G Participant consent form ID 001

Informed Consent Form for participation in Research Studies

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Project: Oral Health of Elite Athletes and Impact on Performance

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 6388/001

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant’s Statement

- I have read the notes written above and the Information Sheet, and understand what the study involves
- I agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.
- I understand that if I decide at any time that I no longer wish to take part in this project, I can notify the researchers involved and withdraw immediately.
- I consent to a clinical oral health screening examination
- I consent to the processing of my personal information for the purposes of this research study.
- I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- I understand that the information I have submitted will be published as a report and I will be sent a copy. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications.

Participant name: __________
Participant signature: __________ Date: __________

Researcher statement:

I have explained the above named project to the study participant and confirm their understanding of what the study involves.

Researcher name: Julie Gallagher
Researcher signature: __________ Date: __________
Appendix H Clinical record form ID 001

Dental history

<table>
<thead>
<tr>
<th>Question</th>
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<tbody>
<tr>
<td>Do you have any problems or pain in your mouth at the moment?</td>
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<td>If yes</td>
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<td>Do you think that the pain is related to your teeth?</td>
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<td>Do you have any sensitivity to hot or cold related to your teeth at the moment?</td>
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<td>Do you notice any bleeding from your gums when cleaning your teeth?</td>
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<td>Have you ever had any swelling or infections around your wisdom teeth?</td>
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<td>Have you ever had any wisdom teeth removed?</td>
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<td>Have you ever had an injury to your teeth?</td>
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<td>If you did, was this related to your sport?</td>
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<td>No = 0    Yes (always/often) = 1   N/A =2   Sometimes/occasionally =3</td>
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PUFA index (Pulp, Ulceration, Fistula, Abscess)

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<tr>
<td>Pulp</td>
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<td>Ulcer</td>
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<tr>
<td>Fistula</td>
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<td>Abscess</td>
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0=no lesions, 1=single lesion, 2=2 or more lesions

Pericoronitis

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No clinical evidence =0   Clinical evidence present (swelling) =1

Periodontal examination

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Erosion

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0= no surface loss, 1=early change, 2=<50% loss, 3=>50% loss

Total score: Posterior____________ Anterior___________ Total _______________
Caries experience, trauma experience

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</table>
Appendix I Athlete Questionnaire ID 001

Project Title: Oral Health of Elite Athletes and Impact on Performance

This project has been approved by the UCL Ethics committee: Project ID number 6388/001

This questionnaire should take no more than 15 minutes to complete. Please answer all questions. We appreciate your contribution towards this research.

First, some questions about you;
1. What is your competition sport?
2. What is your age?.............years
3. Are you?
   0. Male
   1. Female
4. What is your highest educational level to date?
   0. GCSE (or equivalent)
   1. A-level (or equivalent)
   2. FE College (or equivalent)
   3. University undergraduate degree
   4. University postgraduate degree

Now some questions about your oral health.
Compared to other people,
5. How would you describe your general health at present?
   0. Very good
   1. Good
   2. Fair
   3. Poor
   4. Very poor
6. How would you describe your oral health (mouth, teeth and gums) at present?
   0. Very good
   1. Good
   2. Fair
   3. Poor
   4. Very poor

Over the past 12 months:
7. Have you had any difficulty eating or drinking because of your mouth, teeth or gums?
   0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal
8. Have you had any difficulty relaxing (including sleeping) because of your mouth, teeth or gums?
   0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal
9. Have you had any difficulty smiling, laughing or showing your teeth without embarrassment?
0. Not at all
1. A little
2. Somewhat
3. A fair amount
4. A great deal

10. Have you had any difficulties participating in normal training or competition due to problems with your mouth, teeth or gums?
0. Full participation without mouth, teeth or gum problems
1. Full participation but with mouth, teeth or gum problem
2. Reduced participation due to mouth, teeth or gum problems
3. Could not participate due to mouth, teeth or gum problems

11. To what extent have you reduced your training volume due to mouth, teeth or gum problems over the past 12 months?
0. No reduction
1. Minor reduction
2. Moderate reduction
3. To a major extent
4. Could not participate at all

12. To what extent have problems with your mouth, teeth or gums affected your performance over the past 12 months?
0. No effect
1. To a minor extent
2. To a moderate extent
3. To a major extent
4. Could not participate at all

13. To what extent have you experienced pain from your mouth, teeth or gums over the past 12 months?
0. No pain
1. Mild pain
2. Moderate pain
3. Severe pain

14. How often do you eat a serving of any of the following; cakes, biscuits, puddings, pastries?
0. Rarely or never
1. Less than once a week
2. One to two times a week
3. Three to five times a week
4. Six or more times a week

15. How often do you eat sweets and/or chocolate?
0. Rarely or never
1. Less than once a week
2. One to two times a week
3. Three to five times a week
4. Six or more times a week

16. How often do you drink fizzy drinks or soft drinks like squash? Please do not include sports drinks in this section.
0. Rarely or never
1. Less than once a week
2. One to two times a week
3. Three to five times a week
4. Six or more times a week

17. How often do you drink water?
0. Rarely or never
1. Less than once a week
2. One to two times a week
3. Three to five times a week
4. Six or more times a week

18. Do you use tobacco or e-cigarettes? Please tick each line
   0. Have never done so   1. I used to but not now   2. Yes:
   I smoke tobacco
   I use smokeless/chewing tobacco
   I use e-cigarettes with nicotine
   I use e-cigarettes without nicotine

19. I use sports drinks   Please tick each line
    0. Never   1. Sometimes   2. Always
    Before training
    During training
    After training
    Before competition
    During competition
    After competition

20. I use energy bars   Please tick each line
    0. Never   1. Sometimes   2. Always
    Before training
    During training
    After training
    Before competition
    During competition
    After competition

21. I use energy gels   Please tick each line
    0. Never   1. Sometimes   2. Always
    Before training
    During training
    After training
    Before competition
    During competition
    After competition

22. Which of the following do you think can cause damage to your mouth, teeth or gums? Please tick each line
    0. No   1. Yes   2. Don't know
    Cakes, biscuits, puddings, pastries
    Sweets/chocolate
    Fizzy drinks and/or squash
    Sports drinks
    Energy bars
Energy gels
Smoking tobacco
Smokeless/chewing tobacco
E-cigarettes with nicotine
E-cigarettes without nicotine

23. When do you usually clean your teeth? Please tick each line

1. Yes 0.No

In the morning
Before going to sleep at night
Before sleeping during the day
After sleeping during the day
Other time in the day

24. Which of the following do you use to help keep your mouth, teeth and gums healthy? Please tick each line

1. Yes 0.No

Normal toothbrush
Electric toothbrush
Dental floss/interdental brushes
Regular (fluoride) toothpaste
Fluoride mouthwash
Other mouthwash
Sugar free chewing gum
Toothpicks
Other

25. Do you ever wear a gum shield in connection with your sport?

1. Yes
0. No

26. Have you ever been given advice from a dentist or dental hygienist about the following? Please tick each line

1. Yes 0. No 2. Can’t remember

How to look after your mouth, teeth and gums
What to eat and/or drink

27. About how long ago was your last visit to the dentist?

0. Within the past six months
1. Six to 12 months ago
2. One to two years ago
3. More than two years ago

28. For your most recent dental visit, what type of service did you use?

0. NHS dentist
1. Private dentist
2. Private dental hygienist
3. Other

29. Which of the following is most important to you when arranging a dental appointment?

0. Cost
1. Convenience
2. Reputation of the dentist
30. What of the following do you think you could do if you thought it would help keep your mouth, teeth and gums healthy? Please tick each line

Reduce snacking between meals (including energy bars/gels)
Reduce sugary drinks (including sports drinks) between meals
Brush teeth before sleeping
Only spit out toothpaste, don’t rinse with water
Use fluoride mouthwash at a different time to brushing
Use dental floss/interdental brushes every day
Use sugar free chewing gum
Regular visits to a dentist/hygienist for advice and monitoring

31. Finally, what is your ethnic group?
Please tick one option that best describes your ethnic group or background.
White  1 English/Welsh/Scottish/Northern Irish/British
       2 Irish
       3 Gypsy or Irish traveller
       4 Any other white background- please describe
Mixed/Multiple Ethnic Group  5 White and Black Caribbean
       6 White and Black African
       7 White and Asian
       8 Any other mixed/multiple ethnic background- please describe
Asian/Asian British  9 Indian
       10 Pakistani
       11 Bangladeshi
       12 Chinese
       13 Any other Asian background, please describe
Black/African/Caribbean/Black British  14 African
       15 Caribbean
       16 Any other Black/African/Caribbean background, please describe
Other ethnic group  17 Arab
       18 Any other ethnic background, please describe

32. If you use them, what brand of sports nutrition products do you use?

The questionnaire is now complete. Thank you.
## Oral Health Report

**Athlete name:** …………………………………………………………………………………………………………………

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>You have a healthy mouth:</td>
<td></td>
</tr>
<tr>
<td>You have evidence of early stage dental decay (ICDAS code 1 or 2)</td>
<td></td>
</tr>
<tr>
<td>You have evidence of established dental decay (ICDAS code 3 or 4)</td>
<td></td>
</tr>
<tr>
<td>You have evidence of severe dental decay (ICDAS code 5 or 6)</td>
<td></td>
</tr>
<tr>
<td>You have evidence of gingival (gum) inflammation periodontal (gum) disease</td>
<td>BPE:</td>
</tr>
<tr>
<td>You have evidence of dental erosion (tooth wear)</td>
<td>BEWE:</td>
</tr>
<tr>
<td>You have evidence of infection associated with a wisdom tooth</td>
<td></td>
</tr>
<tr>
<td>You have evidence of: any other problems</td>
<td></td>
</tr>
</tbody>
</table>

**Prescription:** Sodium Fluoride Toothpaste 0.619 % 1 tube.  

**Supplied**

**Signed:** …………………………………………………………………………………………………………………

**Date:** …………………………………………………………………………………………………………………

**Name of Dentist:** Julie Gallagher BDS, MSc
Appendix K Examiner training and repeatability, calibration exercises ID 001

Dental caries and erosive tooth wear

Prior to initiation of the study the examiner participated in training and repeatability exercises for classifying both dental caries and erosive tooth wear. Following a detailed review of the criteria, the examiner practised scoring using two separate series of ten clinical slides. Repeatability was assessed using a series of ten extracted teeth for dental caries and a different series of ten extracted teeth for dental erosion.

Dental caries; ICDAS scoring system

For the purposes of this survey, caries will be reported as one of three categories; no caries (ICDAS code 0), enamel caries (ICDAS code 1, 2 or 3) or dentine caries (ICDAS code 4, 5 or 6)

To calibrate against a “gold standard” caries in dentine

A series of slides is presented as a quiz following completion of the on line training programme, with the correct score made available after the assessment has been completed. The examiner completed the quiz on three separate occasions and a kappa statistic was calculated for agreement at the threshold of caries into dentine, caries in enamel only and all caries (enamel caries and caries into dentine). Kappa values were 1 (perfect agreement), 0.714 (good agreement) and 1 (perfect agreement).

Examiner reliability

A series of 10 extracted teeth were examined on an initial occasion, together with a teaching colleague and agreement on the ICDAS code reached through separate coding followed by discussion. The same series of teeth was scored by the examiner in a random order four days later to avoid possible recall of scores. As these scores are categorical, agreement was assessed by calculating a Kappa value (1).

Initial scoring: Caries agreed with colleague

<table>
<thead>
<tr>
<th>tooth</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
<td>code</td>
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<td>0</td>
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<td>4</td>
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</table>

Second scoring 6 days later: Caries repeatability

<table>
<thead>
<tr>
<th>tooth</th>
<th>9</th>
<th>8</th>
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<th>3</th>
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<td>0</td>
<td>3</td>
<td>6</td>
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</table>

Kappa value = 1 Perfect agreement

Dental erosion; BEWE scoring system

For the purposes of this survey, erosive tooth wear will be recorded for the most affected tooth surface in each sextant. There are three categories; 0, 1, 2, 3.
To calibrate against a “gold standard”
Although there is an online training programme for dental erosion using the BEWE index, there is no formal assessment using clinical slides as there is for ICDAS.

Examiner reliability
A series of 10 extracted teeth were examined on an initial occasion, together with a teaching colleague and agreement on the BEWE code was reached through separate coding followed by discussion. The same series of teeth was scored by the examiner in a random order four days later to avoid possible recall of scores. As these scores are categorical, agreement was assessed by calculating a Kappa value (1).

Initial scoring: Erosion agreed with colleague

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Second scoring 6 days later: Erosion repeatability

<table>
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<th>1</th>
<th>4</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>2</th>
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<th>8</th>
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<tr>
<td>code</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
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Prefect agreement

Periodontal health
For the purposes of this study periodontal health will be recorded using the Basic Periodontal Examination. A ball ended WHO probe is used and each sextant is scored into a treatment need category; 0,1,2,3,4- the * which indicates furcation involvement will not be used.

To calibrate against a “gold standard”
In studies of patients with periodontal disease, calibration and examiner reliability is carried out using repeatability of measurement of pocket probing depths. However this is not appropriate for patients who have not been diagnosed with periodontal disease. There may be ethical concerns about repeating what is considered to be an uncomfortable procedure therefore calibration for BPE is not often carried out for epidemiological surveys. In order to calibrate against a “gold standard”, the examiner completed a BPE for a series of patients who were attending for periodontal treatment as part of an ongoing clinical trial. The BPE code was then compared with the 6 point pocket charting measured by the previously calibrated study clinician. Agreement was measured by calculating a Kappa value (0.865) which is considered to be “very good”.
Appendix L Fieldwork procedures ID 001

Conduct of the examination

The athlete is greeted by the examiner, the study explained and consent gained. The purpose of the study will be explained to each participant along with provision of a written information sheet. Consent will be gained by the examiner. A copy of the information sheet will be initialled by the participant and kept with the study records. One signed copy of the consent form will be given to the participant and the top copy kept with the study records. The dental examination will take place with the participant reclined on an examination couch or similar. Lighting is provided from a portable examination light (DARAY model NviroLED X100) providing illumination of light intensity 6,000 ± 500 lux at 0.5 metre. The teeth will be dried using compressed air from a portable dental unit (Portable Dental Unit PDU II Standard Quayle Dental). A fresh set of disposable instruments (Medi Dent Disposable International Mirror and Ball-Tip probe Kit Code 52BT-1) and a new 3-in-1 syringe will be used for each participant. These will be opened once the participant is reclined. The dental examiner will wear fresh gloves and mask for each examination. Barrier film will be used to cover the light handle and the 3-in-1 syringe.

The recorder then asks the set of questions on the clinical recording form (CRF) and records the athlete’s answer while the examiner dons gloves, mask, eye protection and places the triple syringe and cover in the PDU. The assistant will ask the questions about current symptoms and history of trauma and wisdom tooth problems and record the responses. Clinical data will be then be recorded onto the same clinical record form by the assistant. The examiner will call out codes for each category in the following order upper left, upper right, lower right, lower left.

Once the clinical examination is complete, the participant will be given the questionnaire to complete while the examiner transfers information to the oral health report form. During this time the assistant will don a clean pair of gloves, dispose of the used instruments and personal protective equipment (PPE) into a sharps container and clinical waste bag as appropriate, wipe down all surfaces and protective glasses and lay out a fresh set of instruments and PPE for the next participant.

Once the questionnaire is completed the examiner will check that responses have been recorded where indicated and give the athlete a verbal and written summary of the examination along with specific recommendations to seek care where indicated.

Equipment set up
The examinations will be carried out in the medical facilities of the training centres used by the athletes. The athlete is examined supine on an examination couch with the examiner seated at the head and the recorder seated to the left of examiner. Illumination is provided by the DARAY lamp set up on the examiner’s right. Compressed air is supplied from a PDU also set up on the examiner’s right. Dark glasses are supplied to be worn by the athlete during the clinical examination. An unopened instrument pack, gloves, mask, glasses, triple syringe and cover are laid out on a clean dental napkin on a suitable surface to the left or right of the examiner.

**Clinical examination**

The clinical examination is then conducted. Throughout the examination the convention is to score low (i.e. least disease) if in doubt. The mouth is examined in the following sequence: upper left, upper right, lower right, lower left. The recorder will record as called by the examiner the following conditions and codes.
### Appendix M Derived variables

<table>
<thead>
<tr>
<th>Derived variable</th>
<th>Categories</th>
<th>Original variable type</th>
<th>Original data</th>
</tr>
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<tbody>
<tr>
<td>Age category</td>
<td>&lt; 24, &gt; 25</td>
<td>Continuous</td>
<td>Age in years</td>
</tr>
<tr>
<td>Educational status</td>
<td>Degree, No degree</td>
<td>Categorical</td>
<td>5 categories: GCSE, A-level, FE college, university undergraduate, university postgraduate</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>White British, Other</td>
<td>Categorical</td>
<td>18 categories</td>
</tr>
<tr>
<td>Sport category</td>
<td>Strength &amp; power, Endurance, Mixed</td>
<td>Categorical</td>
<td>11 sports</td>
</tr>
<tr>
<td>General health status</td>
<td>Good/very good, Fair/poor/very poor</td>
<td>Categorical</td>
<td>5 categories: very poor, poor, fair, good, very good</td>
</tr>
<tr>
<td>Oral health status</td>
<td>Good/very good, Fair/poor/very poor</td>
<td>Categorical</td>
<td>5 categories: very poor, poor, fair, good, very good</td>
</tr>
<tr>
<td>Psychosocial impacts</td>
<td>No impact, Non-zero impact</td>
<td>Categorical</td>
<td>5 categories: not at all, a little, somewhat, a fair amount, a great deal</td>
</tr>
<tr>
<td>OSTRC</td>
<td>No impact, Non-zero impact</td>
<td>Categorical</td>
<td>4 or 5 categories, none, minor, moderate, severe</td>
</tr>
<tr>
<td>Sugar consumption</td>
<td>Low sugar &lt; 6 x week, High sugar &lt; 6 x week</td>
<td>Categorical</td>
<td>Rarely, &lt;1 week, 1-2x week, 3-5x week, &gt;6x week</td>
</tr>
<tr>
<td>Sports drinks</td>
<td>Never, Sometimes/always</td>
<td>Categorical</td>
<td>3 categories: Never, sometimes, always</td>
</tr>
<tr>
<td>Energy bars</td>
<td>Never, Sometimes/always</td>
<td>Categorical</td>
<td>3 categories: Never, sometimes, always</td>
</tr>
<tr>
<td>Energy gels</td>
<td>Never, Sometimes/always</td>
<td>Categorical</td>
<td>3 categories: Never, sometimes, always</td>
</tr>
<tr>
<td>Received advice</td>
<td>Yes, No/can’t remember</td>
<td>Categorical</td>
<td>3 categories: yes, no, can’t remember</td>
</tr>
<tr>
<td>Behaviour change</td>
<td>Yes/probably, No/with difficulty</td>
<td>Categorical</td>
<td>4 categories: no, with difficulty, probably, yes</td>
</tr>
<tr>
<td>Dental caries</td>
<td>Caries ICDAS ≥ 3, No caries ICDAS &lt; 2</td>
<td>Continuous</td>
<td>ICDAS 0,1,2,3,4,5,6</td>
</tr>
<tr>
<td>Erosive toothwear</td>
<td>ETW BEWE &gt; 7, No ETW BEWE &lt; 6</td>
<td>Continuous</td>
<td>BEWE 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18</td>
</tr>
<tr>
<td>Item No.</td>
<td>Title and abstract</td>
<td></td>
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</tbody>
</table>
| 1       | a) Indicate the study’s design with a commonly used term in the title or the abstract [within the title and method section of abstract]  
|         | b) Provide in the abstract an informative and balanced summary of what was done and what was found [see results section of abstract] |

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Explain the scientific background and rationale for the investigation being reported [page 1]</td>
</tr>
<tr>
<td>3</td>
<td>State specific objectives, including any pre-specified hypotheses [page 1]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Present key elements of study design early in the paper [page 1]</td>
</tr>
<tr>
<td>5</td>
<td>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection [page 1]</td>
</tr>
<tr>
<td>6</td>
<td>Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants [page 2]</td>
</tr>
<tr>
<td>7</td>
<td>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable [page 2]</td>
</tr>
<tr>
<td>8</td>
<td>For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group [page 2, 3]</td>
</tr>
<tr>
<td>9</td>
<td>Describe any efforts to address potential sources of bias [page 2]</td>
</tr>
<tr>
<td>10</td>
<td>Explain how the study size was arrived at [page 1]</td>
</tr>
<tr>
<td>11</td>
<td>Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why [page 2]</td>
</tr>
</tbody>
</table>
| 12       | a) Describe all statistical methods, including those used to control for confounding [page 3]  
|         | b) Describe any methods used to examine subgroups and interactions [page 3]  
|         | c) Explain how missing data were addressed [page 3]  
|         | d) If applicable, describe analytical methods taking account of sampling strategy [n/a]  
|         | e) Describe any sensitivity analyses [n/a] |
| 13       | a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed [page 4, 5 tables 1, 2] |
b) Give reasons for non-participation at each stage [p5]

c) Consider use of a flow diagram [n/a see table1]

Descriptive data 14

a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders [page 4 Supplementary table1]

b) Indicate number of participants with missing data for each variable of interest [page5 Supplementary tables]

Outcome data 15

Cross-sectional study—Report numbers of outcome events or summary measures [page 5 Supplementary tables]

Give information separately for exposed and unexposed groups in cohort and cross-sectional studies [supplementary tables].

Main results 16

a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included [page 5 and supplementary tables]

b) Report category boundaries when continuous variables were categorized [page 7 supplementary tables]

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period [n/a]

Other analyses 17

Report other analyses done [page 7,9 tables 1,2]

Discussion Key results 18

Summarise key results with reference to study objectives [page 10]

Limitations 19

Discuss limitations of the study, taking into account sources of potential bias or imprecision. [page 11]

Discuss both direction and magnitude of any potential bias [page 11]

Interpretation 20

Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence [page 10]

Generalisability 21

Discuss the generalisability (external validity) of the study results [page 11]

Other information Funding 22

Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based [p12]
Appendix P Oral health kit ID 001

Oral health kit based on the “bed in a bag” used by Team SKY. The kit consists of a UCL Eastman Dental Institute branded washbag with a label listing the advice to achieve good oral health. It contained

- Manual toothbrush (Sensodyne 3.5 GSK)
- Prescription toothpaste “Duraphat” 2,800 ppm fluoride
- Pre-threaded flossers (Boots oral health expert)
- Fluoride mouthwash 0.5% fluoride 0 alcohol (Superdrug expert)
- Instructions about brushing
- Patient information leaflet for Duraphat toothpaste
### Frequency of toothbrushing by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Clean teeth am</th>
<th>Clean teeth pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N = 344)</td>
<td>334 (97.1%)</td>
<td>333 (96.8%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years</td>
<td>163 (97.6%)</td>
<td>160 (96.4%)</td>
</tr>
<tr>
<td>≥ 25 years</td>
<td>171 (96.6%)</td>
<td>173 (97.7%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>218 (95.6%)</td>
<td>221 (97.4%)</td>
</tr>
<tr>
<td>Female</td>
<td>116 (100%)</td>
<td>112 (96.6%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>266 (96.7%)</td>
<td>270 (98.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>66 (98.5%)</td>
<td>61 (92.4%)</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree</td>
<td>177 (98.3%)</td>
<td>160 (98.8%)</td>
</tr>
<tr>
<td>No degree</td>
<td>155 (95.7%)</td>
<td>171 (95.5%)</td>
</tr>
</tbody>
</table>

### Frequency of reported water consumption by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Drink water &gt; 6 x week</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>312/344 (90.7%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>≤ 24 years</td>
<td>149/167 (89.2%)</td>
</tr>
<tr>
<td>≥ 25 years</td>
<td>163/177 (92.1%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>208/228 (91.2%)</td>
</tr>
<tr>
<td>Female</td>
<td>104/116 (89.7%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>251/275 (91.3%)</td>
</tr>
<tr>
<td>Other</td>
<td>59/67 (88.1%)</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree</td>
<td>147/162 (90.7%)</td>
</tr>
<tr>
<td>No degree</td>
<td>163/180 (90.6%)</td>
</tr>
</tbody>
</table>
## Frequency of use of additional oral hygiene aids by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Electric toothbrush</th>
<th>Dental floss/Interdental brushes</th>
<th>Fluoride mouthwash</th>
<th>Sugar free chewing gum</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N =344)</td>
<td>190 (55.9%)</td>
<td>148 (43.7%)</td>
<td>139 (40.9%)</td>
<td>120 (35.1%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years</td>
<td>89/164 (54.3%)</td>
<td>58/164 (35.4%)</td>
<td>81/164 (49.4%)</td>
<td>47/164 (28.5%)</td>
</tr>
<tr>
<td>≥ 25 years</td>
<td>101/176 (57.4%)</td>
<td>90/176 (51.4%)</td>
<td>58/176 (33%)</td>
<td>73/176 (41.2%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>130/226 (57.5%)</td>
<td>84/226 (37.5%)</td>
<td>96/226 (42.5%)</td>
<td>73/226 (32.2%)</td>
</tr>
<tr>
<td>Female</td>
<td>60/114 (52.6%)</td>
<td>64/114 (55.7%)</td>
<td>43/114 (37.7%)</td>
<td>47/114 (40.9%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>155/272 (57% )</td>
<td>120/272 (44.3%)</td>
<td>43/272 (39.3%)</td>
<td>103/272(37.6%)</td>
</tr>
<tr>
<td>Other</td>
<td>33/66 (50% )</td>
<td>27/66 (40.9%)</td>
<td>31/66 (47%)</td>
<td>17/66 (25.8%)</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree</td>
<td>96/159 (60.4%)</td>
<td>82/159 (51.2%)</td>
<td>64/159 (40.3%)</td>
<td>67/159(41.6%)</td>
</tr>
<tr>
<td>No degree</td>
<td>94/179 (52.5%)</td>
<td>65/179 (36.7%)</td>
<td>74/179 (41.3%)</td>
<td>53/179 (29.6%)</td>
</tr>
<tr>
<td>Characteristics of athletes</td>
<td>Cakes, biscuits, pastries, puddings (a)</td>
<td>Sweets/chocolate (b)</td>
<td>Soft/fizzy drinks (c)</td>
<td>High Sugar consumer (one or more of a, b or c)</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------------------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>All (N=344)</td>
<td>36 (10.5%)</td>
<td>25 (7.3%)</td>
<td>74 (21.5%)</td>
<td>97 (28.2%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years (167)</td>
<td>10 (6%)</td>
<td>9 (5.4%)</td>
<td>21% (35)</td>
<td>41/167 (24.6%)</td>
</tr>
<tr>
<td>&gt; 25 years (177)</td>
<td>26 (14.7%)</td>
<td>16 (9%)</td>
<td>22% (39)</td>
<td>56/177 (31.6%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>25 (11%)</td>
<td>18 (7.9%)</td>
<td>45 (19.7%)</td>
<td>60/228 (26.3%)</td>
</tr>
<tr>
<td>Female (116)</td>
<td>11 (9.5%)</td>
<td>7 (6%)</td>
<td>29 (25%)</td>
<td>37/116 (31.9%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>29 (10.5%)</td>
<td>18 (6.5%)</td>
<td>65 (23.6%)</td>
<td>82/275 (29.8%)</td>
</tr>
<tr>
<td>Other (69)</td>
<td>7 (10.4%)</td>
<td>7 (10.4%)</td>
<td>9 (13.4%)</td>
<td>15/67 (22.4%)</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>19 (11.7%)</td>
<td>11 (6.8%)</td>
<td>40 (24.7%)</td>
<td>51/162 (31.5%)</td>
</tr>
<tr>
<td>No degree (182)</td>
<td>17 (9.4%)</td>
<td>14 (7.8%)</td>
<td>34 (18.9%)</td>
<td>46/180 (25.6%)</td>
</tr>
</tbody>
</table>
## Athlete-reported use of Sports Nutrition Products

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Any use of sports drink during training/competition</th>
<th>Any use of energy bars during training/competition</th>
<th>Any use of energy gels during training/competition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All (N=344)</strong></td>
<td>288/336 (85.7%)</td>
<td>198/337 (58.8%)</td>
<td>239/340 (70.3%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years</td>
<td>137/167 (83.5%)</td>
<td>91/162 (56.2%)</td>
<td>103/167 (61.7%)</td>
</tr>
<tr>
<td>≥ 25 years</td>
<td>151/172 (87.8%)</td>
<td>68/175 (61.1%)</td>
<td>136/173 (78.6%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>196/223 (87.9%)</td>
<td>132/224 (58.9%)</td>
<td>161/226 (71.2%)</td>
</tr>
<tr>
<td>Female</td>
<td>92/113 (81.4%)</td>
<td>66/113 (58.4%)</td>
<td>78/114 (68.4%)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>228/264 (85.4%)</td>
<td>156/269 (58%)</td>
<td>193/271 (71.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>59/67 (88.1%)</td>
<td>41/66 (62.1%)</td>
<td>45/67 (67.2%)</td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree</td>
<td>136/158 (86.1%)</td>
<td>88/161 (52.8%)</td>
<td>115/161 (71.4%)</td>
</tr>
<tr>
<td>No degree</td>
<td>150/176 (85.2%)</td>
<td>111/174 (63.8%)</td>
<td>123/177 (69.5%)</td>
</tr>
</tbody>
</table>
### Most recent attendance by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Most recent dental visit &lt; 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (344)</td>
<td>136 (39.5%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (167)</td>
<td>69 (41.3%)</td>
</tr>
<tr>
<td>≥ 25 years (177)</td>
<td>67 (37.9%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Male (236)</td>
<td>96 (42.1%)</td>
</tr>
<tr>
<td>Female (116)</td>
<td>40 (34.5%)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
</tr>
<tr>
<td>White British (275)</td>
<td>111 (40.4%)</td>
</tr>
<tr>
<td>Other (69)</td>
<td>23 (34.3%)</td>
</tr>
<tr>
<td><strong>Education to date</strong></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree 9162)</td>
<td>73 (45.1%)</td>
</tr>
<tr>
<td>No degree (182)</td>
<td>61 (33.9%)</td>
</tr>
</tbody>
</table>

### Provider of care received at most recent dental visit by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>NHS Dentist</th>
<th>Private Dentist</th>
<th>Private hygienist</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>141 (41.2%)</td>
<td>157 (45.9%)</td>
<td>34 (9.9%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (165)</td>
<td>71 (43%)</td>
<td>71 (43%)</td>
<td>17 (10.3%)</td>
</tr>
<tr>
<td>≥ 25 years (177)</td>
<td>70 (39.5%)</td>
<td>96 (48.6%)</td>
<td>17 (9.6%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (226)</td>
<td>86 (38.1%)</td>
<td>108 (47.8%)</td>
<td>26 (11.5%)</td>
</tr>
<tr>
<td>Female (116)</td>
<td>55 (47.4%)</td>
<td>49 (42.2%)</td>
<td>8 (6.9%)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (274)</td>
<td>119 (43.4%)</td>
<td>125 (45.6%)</td>
<td>24 (8.8%)</td>
</tr>
<tr>
<td>Other (66)</td>
<td>21 (31.8%)</td>
<td>31 (47%)</td>
<td>10 (15.2%)</td>
</tr>
<tr>
<td><strong>Educational status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P = 0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (162)</td>
<td>52 (50.6%)</td>
<td>62 (38.3%)</td>
<td>13 (8%)</td>
</tr>
<tr>
<td>No degree (178)</td>
<td>59 (33.1%)</td>
<td>93 (52.2%)</td>
<td>21 (11.8%)</td>
</tr>
</tbody>
</table>
## Advice received from dental care professional by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Oral hygiene</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (N=344)</td>
<td>262 (76.2%)</td>
<td>206 (59.9%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 24 years</td>
<td>120/167 (71.9%)</td>
<td>94/167 (56.3%)</td>
</tr>
<tr>
<td>&gt; 25 years</td>
<td>142/177 (80.2%)</td>
<td>112/177 (63.6%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>173/236 (75.9%)</td>
<td>142/236 (62.3%)</td>
</tr>
<tr>
<td>Female</td>
<td>89/116 (76.7%)</td>
<td>64/116 (55.7%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British</td>
<td>215/275 (78.2%)</td>
<td>171/275 (62.4%)</td>
</tr>
<tr>
<td>Other</td>
<td>45/69 (67.2%)</td>
<td>34/69 (50.7%)</td>
</tr>
<tr>
<td>Education to date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree</td>
<td>130/162 (80.2%)</td>
<td>102/162 (63.4%)</td>
</tr>
<tr>
<td>No degree</td>
<td>131/182 (72.8%)</td>
<td>103/182 (57.2%)</td>
</tr>
</tbody>
</table>

## Most important factor when arranging a dental appointment by characteristics of the group

<table>
<thead>
<tr>
<th>Characteristics of athletes</th>
<th>Convenience</th>
<th>Reputation of dentist</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (344)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (153)</td>
<td>100 (65.4%)</td>
<td>37 (24.2%)</td>
<td>16 (10.5%)</td>
</tr>
<tr>
<td>≥ 25 years (161)</td>
<td>95 (59%)</td>
<td>48 (29.8%)</td>
<td>18 (11.2%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (208)</td>
<td>124 (59.6%)</td>
<td>62 (29.8%)</td>
<td>22 (10.6%)</td>
</tr>
<tr>
<td>Female (106)</td>
<td>71 (67%)</td>
<td>23 (21.7%)</td>
<td>12 (11.3%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White British (250)</td>
<td>162 (64.8%)</td>
<td>64 (25.6%)</td>
<td>24 (9.6%)</td>
</tr>
<tr>
<td>Other (62)</td>
<td>32 (51.6%)</td>
<td>20 (32.3%)</td>
<td>10 (16.1%)</td>
</tr>
<tr>
<td>Educational status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have/studying for degree (150)</td>
<td>98 (65.3%)</td>
<td>32 (21.3%)</td>
<td>20 (13.3%)</td>
</tr>
<tr>
<td>No degree (162)</td>
<td>96 (59.3%)</td>
<td>52 (32.1%)</td>
<td>14 (8.6%)</td>
</tr>
</tbody>
</table>

*includes only those who chose just one option
### Opportunities for behaviour change

<table>
<thead>
<tr>
<th></th>
<th>Reduce snacking</th>
<th>Reduce sport/soft drinks</th>
<th>Use F m/wash</th>
<th>Clean daily interdental</th>
<th>Use SFG</th>
<th>Regular dental visits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong> (N=344)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46% (157)</td>
<td>80.4% (274)</td>
<td>90.6% (308)</td>
<td>83.4% (282)</td>
<td>84.4% (287)</td>
<td></td>
<td>89.2% (306)</td>
</tr>
<tr>
<td><strong>Age (N=344)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 24 years (167)</td>
<td>46.7% (78)</td>
<td>81.9% (9136)</td>
<td>87.4% (146)</td>
<td>81.9% (136)</td>
<td>81.9% (136)</td>
<td>89.8% (150)</td>
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<td>≥ 25 years (177)</td>
<td>45.4% (79)</td>
<td>93.6% (162)</td>
<td>84.9% (146)</td>
<td>86.8% (151)</td>
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<td>88.6% (156)</td>
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<td>Male (236)</td>
<td>54.2% (123)</td>
<td>79.6% (180)</td>
<td>89.8% (203)</td>
<td>82.2% (188)</td>
<td>86.6% (194)</td>
<td>90.7% (206)</td>
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<td>29.8% (34)</td>
<td>81.7% (94)</td>
<td>92.1% (105)</td>
<td>85.8% (97)</td>
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<td>White British (275)</td>
<td>40.5% (111)</td>
<td>79.2% (217)</td>
<td>91.6% (250)</td>
<td>84.2% (230)</td>
<td>84.6% (230)</td>
<td>90.2% (248)</td>
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<td>Other (69)</td>
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<td>87.7% (57)</td>
<td>79.4% (50)</td>
<td>83.3% (55)</td>
<td>84.8% (56)</td>
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<tr>
<td><strong>Educational status (N=344)</strong></td>
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<tr>
<td>Have/studying for degree (162)</td>
<td>32.7% (53)</td>
<td>75.8% (122)</td>
<td>90.1% (145)</td>
<td>83.9% (135)</td>
<td>83.2% (134)</td>
<td>88.3% (143)</td>
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<tr>
<td>No degree (182)</td>
<td>57.6% (102)</td>
<td>84.8% (151)</td>
<td>91% (161)</td>
<td>83% (146)</td>
<td>85.3% (151)</td>
<td>88.9% (161)</td>
</tr>
</tbody>
</table>
Storyboard 2 Strength and conditioning for gums

- **Be the best**
  - Effective brushing
  - Athletes need to be healthy

- **Going to the Olympics?**
  - Get your kit!
  - Don't forget your toothbrush

- **Reducing inflammation**
  - ![Image of a muscle]

- **You can use a manual or an electric toothbrush**
  - ![Image of toothbrushes]
  - But replace it every 3 months

- **Angle your brush at 45° to the gums**
  - • Short gentle strokes
  - ![Image of toothbrush angle]

- **Electric toothbrush**
  - • Let the brush do the work
  - • Count for 2-5 seconds each tooth
  - ![Image of electrical toothbrushes]
Start at the back- inside

Then the outside

Finally the chewing surfaces

Remember
- Spit don’t rinse for the fluoride effect

See you on the podium!
Storyboard 3 Going the extra mile

**Be the best**
Interdental cleaning

**Going to the Olympics?**
You don't want anything to hold you back
Need to be well prepared
• Attention to detail
• Marginal gains

Dental plaque sticks to all tooth surfaces

**Germs can cause decay**

and contribute to poor gum health

If you don’t floss you are missing 40% of tooth surface

**Aim to floss 1 x day**
• Before brushing

**make sure you have time**
Arm’s length of floss

Wind around your middle finger

Make a c-shape around the tooth

It takes practice to get it right
  • Like all techniques

If you can’t manage floss

Ask your dental professional about other ways
  • Single tufted brush
  • Interdental brush
  • Superfloss

• Race ready- well prepared
Appendix T Power point presentation

Aiming for Excellence

www.ucl.ac.uk/cohp

Oral health affects performance
What does an unhealthy mouth look like?
How does it affect performance?
What can you do about it?

Tooth decay
Abscess
Pain

Gum disease
Inflammation
Bleeding
Swelling
Circulation

Acid erosion
Thin enamel

Our research
London 2012 Olympic Games – 18%
English Professional Football – 7%
Rio 2016 Olympic Games – 9%

Impact on training

SPORT ATHLETICS

Related to this story
The Olympic Games

"I had a tooth taken out and it got infected. I went for a run, came back and collapsed," said 31-year-old Farah.
Infection
E-mail: Footballers poor teeth — please read

Inflammation
Triggered by bacteria or gums too

Research from athletes shows
- Pain and discomfort - 30%
- Sleep/relaxing - 15%
- Eating/drinking - 35%
- Embarrassment - 17%

Oral health affects performance
What does an unhealthy mouth look like?
How does it affect performance?
What can you do about it?

Over to you.....

Script
Slide 1 Hello I’m Julie, I’m a dentist and I’m here to talk about teeth. As elite athletes your aim is to get to competition well prepared fit and healthy and that includes having healthy teeth and gums.

Slide 2 Over the next 10 minutes or so I’m going to show you what an unhealthy mouth looks like, I’m going to tell you how it affects performance and we’re going to see what you can do to make your mouth as healthy as it can be.

Slide 3 This is a photo of tooth decay. Tooth decay is linked to sugar in drinks and snacks. The more often you have them the more the chances are of having decay. These are large cavities which are close to the nerve of the tooth. They cause pain, when eating and drinking. And it doesn’t look very good either.

Slide 4 This is quite severe gum disease. Inflamed gums and Gum diseases are linked to dental plaque not being removed regularly. It is also linked to immune deficiency such as after hard effort. You can see swelling, inflammation and even bleeding gums. What you can’t see is that the bone has been affected. Some of the teeth have started to drift from their original positions because they are loose. Inflammation in the mouth can be linked to inflammation elsewhere in the body. It certainly does not look good.

Slide 5 Acid erosion is caused by excessive consumption of acidic food and drinks—especially energy drinks which have acid added to make them taste refreshing. We also see it people who control their weight by vomiting. Look how thin the teeth have become. At an early stage the teeth may look quite yellow. This is really difficult to fix. Once you’ve lost the enamel it’s gone for good. Treatment is time consuming, challenging and expensive.

Slide 6 How does it affect performance?

Slide 7 Our research shows that athletes do report that oral health problems have an impact on performance in sport.

Slide 8 For example, in 2014, Mo Farrah had a bad year. He didn’t perform well in the marathon and he missed the Commonwealth games.

Slide 9 9 percent of the athletes in our survey also reported difficulties with training associated with oral health problems.

Slide 10 Infection in the mouth can spread through the bloodstream to other parts of the body and cause infection elsewhere. This series of slides was sent to us by an ex-footballer who developed osteomyelitis affecting the tibia and fibia following a dental abscess. And I’ve come across similar tales from athletes in other Olympic and professional sports.

Slide 11 Inflammation in the mouth can spread through the bloodstream to other parts of the body and cause inflammation elsewhere.

Slide 12 Oral health problems can also have an impact on daily life.
Slide 13 A healthy mouth is important, not just for health and wellbeing, but also to look good when you’re picking up that gold medal or world cup or making an appearance on question of sport

Slide 14 What can you do to make your mouth as healthy as it can be

Slide 15 This is our oral health kit inspired by Team Sky “bed in a bag”. We will provide one to each of you. It contains the elements to keep your mouth teeth and gums in excellent condition if you do it and do it right. You don’t need to change much

Slide 16 The following three films will show you exactly what to do then it’s over to you…
Appendix U Focus group plan
Focus group questions (5-6 questions) for 23.03.18

Ice-breaker
Thank you for giving up your time this morning. Introduce myself and ask each person to introduce themselves by name and role within the team. I’m going to record this on my phone then delete it once I’ve transcribed it if that’s OK

Set the goal of the meeting
Our research has found that half of athletes have an oral health problem such as decay or erosion or gum inflammation and about a third report an impact on performance. We believe that improving oral health will lead to fewer performance impacts so we have developed a simple intervention based on best evidence and our most recent project. This focuses on what you already do rather than introducing anything new. The design of the study was informed by discussion with EIS and we have secured funding from BASEM. The whole study will involve 3 visits over 4 months
Any questions so far?
The intervention consists of two stages.
Stage one
The first is to everyone in the team working together. It consists of a short presentation of about 10 minutes supported by 3 x 30 second demonstration videos. We will also give you an oral health kit and ask everyone to complete a brief questionnaire.
Stage two
The second stage is for athletes only and involves a dental check and personalised advice.
I’d like to get your ideas and opinions on various aspects of the intervention and your ideas and suggestions on how to improve the study
Over the next 40 minutes, I’d like to discuss stage 1 which applies to everybody then look at stage 2 which applies to the athletes.

1st Question
Regarding stage one, all members of the team have a part to play in any performance intervention and this should be part of a whole team culture so how do we get everyone together? (have we missed anyone out) When is the best time? (after the commonwealth games)

2nd Question
Thinking of the presentation, what information would provide the best hook for your interest? (Size of the problem? Risks from sport? Duty of care? Ease of preventive measures?)

3rd Question
Who would you prefer to deliver the presentation in an ideal situation? (JG or train another team member)

4th Question (Show each storyboard for the films)
The films are based on the principles of strength, conditioning and attention to detail. Is the sporting analogy useful?
Overall would you find this helpful as an individual or for the team? How could we improve it/ what else would you like to see?

The short films are to be shared on social media- what do you think is the best approach?

5th Question (show the oral health kit)

This is the oral health kit. What do you think about this? The intervention will improve your oral hygiene and amount of fluoride through effective toothbrushing 2x daily, specifically last thing at night and first thing in the morning (before first training session)

The toothbrush is manual, as it can be transported anywhere. The toothpaste will be special fluoride toothpaste for athletes, standard for other team members. Do you prefer floss or floss wands?

6th Question

Stage 2 is for the athletes. We want you to clean your teeth more effectively, use special toothpaste and we will provide the kit and the coaching. How will we work out if this has been successful for you and the team?

We can measure how you brush your teeth using a small Bluetooth device- what do you think?

We have a questionnaire to ask how you are doing through the study

We can assess plaque and inflammation using a fluorescent dye which shows up under UV light- this takes about 5-10 minutes to record – you need to lie down to be examined as in the dental screening. Ideally we would do this at the beginning, middle and end of the study but we understand that this could take up too much time- what do you think?

How can we keep you on task during the study? Do you have any hand hygiene, nutritional protocols to stick to?

How would you like to be reminded about the study during participation?

Round up

Thank you very much for your time. Does anyone have anything else to add?

I will leave you my card and there is an email address if you wish to contact me.
Appendix V Ethics approval ID 002

UCL RESEARCH ETHICS COMMITTEE
OFFICE FOR THE VICE PROVOST RESEARCH

23 January 2019

Professor Ian Needleman
Eastman Dental Institute
UCL

Dear Professor Needleman

Notification of Ethics Approval with Provisos

Project ID/Title: 6388/002: Oral health to enhance elite athletes performance

Further to your satisfactory responses to my comments on your application, I am pleased to confirm in my capacity as Joint Chair of the UCL Research Ethics Committee (REC) that I have ethically approved the data collection element of your study until 23rd January 2019.

Ethical approval is subject to the following conditions:

Notification of Amendments to the Research

You must seek Chair’s approval for proposed amendments (to include extensions to the duration of the project) to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing an “Amendment Approval Request Form”
http://ethics.grad.ucl.ac.uk/responsibilities.php

Adverse Event Reporting – Serious and Non-Serious

It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Joint Chairs will decide whether the study should be terminated pending the opinion of an independent expert. For non-serious adverse events the Joint Chairs of the Ethics Committee should again be notified via the Ethics Committee Administrator within ten days of the incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Joint Chairs will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

Final Report

At the end of the data collection element of your research we ask that you submit a very brief report (1-2 paragraphs will suffice) which includes in particular issues relating to the ethical implications of the research i.e. issues obtaining consent, participants withdrawing from the research, confidentiality, protection of participants from physical and mental harm etc.

In addition, please:
• ensure that you follow all relevant guidance as laid out in UCL’s Code of Conduct for Research: http://www.ucl.ac.uk/srs/governance-and-committees/resgov/code-of-conduct-research

• note that you are required to adhere to all research data/records management and storage procedures agreed as part of your application. This will be expected even after completion of the study.

With best wishes for the research.

Yours sincerely

Dr Lynn Ang
Joint Chair, UCL Research Ethics Committee

Cc: Julie Gallagher
Appendix W Participant information form ID 002

UCL EASTMAN DENTAL INSTITUTE
CENTRE FOR ORAL HEALTH AND PERFORMANCE

Participant Information Sheet (Athlete): UCL Research Ethics Committee ID Number: 1388/002

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Title of Study: Oral Health to Enhance Elite Athlete Performance (the “Study”)
Department: Unit of Periodontology, Centre for Oral Health and Performance
Lead Researcher: Julie Gallagher, juliagallagher.14@ucl.ac.uk
Principal Researcher: Professor Ian Needleman, i.needleman@ucl.ac.uk
Data Protection Officer: data.protection@ucl.ac.uk

You are being invited to take part in a research project. Before you decide about participation, it is important for you to understand why the research is being done and what participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

Our research, involving more than 800 elite and professional athletes, provides a clear and consistent message – poor oral health is common in elite sport with common self-reported performance impacts. There are well-recognised, simple and effective approaches to preventing poor oral health outside of sport but we need to identify effective strategies for elite athletes. This Study will only involve elite athletes and has been agreed with your team doctor and management. You are eligible to take part in the Study if you are:

• A member of this elite squad
• Aged 18 years or over
• Able to understand the questionnaire
• Able to understand the consent process

The Study is for research purposes only and is not intended to treat any medical conditions. There is no personal health benefit to you taking part in this Study and you will not be given or asked to take any medical product as part of your participation in the Study.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. You can withdraw at any time without giving a reason by contacting the lead researcher (her email address is given above) and without it affecting any benefits that you are entitled to. If you decide to withdraw you will be asked what you wish to happen to the data you have provided up to that point.

This Study has been reviewed and approved by a Research Ethics Committee.

The study will take place in your training centre. We have a questionnaire for you to complete before attending an oral health education presentation. The dentist will then examine your mouth, using a dental mirror and blunt probe (the same as your dentist uses during routine check-ups). You will be given an oral health report and an oral health kit with instructions for use during the duration of the study. The dental examination will take place in a private area and you can change your mind at any time if you feel uncomfortable. We will repeat the questionnaire and dental exam after 3 months. We will also collect data from your routine health and performance surveillance carried out by your team during the length of the Study. If you agree, we will also ask you to provide a swab from your nose and a sample of your saliva and stool. A second sample will be collected during the study to examine how the bacteria are affected by your oral health and their relationship to your wellbeing and performance.

All the information that we collect about you during the course of the research will be kept strictly confidential and store securely. You will not be able to be identified in any ensuing reports or publications. All personal data will be collected and stored in accordance with the Data Protection Act 2018 and the General Data Protection Regulations 2018. Your personal data will be processed solely as it is required for the research project. We will de-identify the personal data you provide and will endeavour to minimise the processing of personal data wherever possible. The legal basis that would be used to process your personal data will be a task in the Public Interest. You can provide your consent for the use of your personal data in this project by completing the consent form that has been provided to you.

PTO
UCL may send your samples to Vedanta Biosciences Inc ("Vedanta"), based in Cambridge, Massachusetts, USA. Vedanta will sequence the DNA of bacteria present in your samples and compare this to bacterial databases in order to identify the bacterial strains present in the samples. Vedanta will share this bacterial sequencing information with UCL. All data which could identify you will have been removed before your samples are provided to Vedante. Effectively, Vedante will only receive anonymised data from UCL and will not process any personal data relating to you. In addition, Vedante may isolate microorganisms from your samples. Any microorganisms isolated from samples in this study may be used as source material for new therapeutics and/or commercialisation of new therapies including (but not limited to) small molecules, combinations of microorganisms and probiotics (e.g. food additives).

Once we have analysed the data, we will write a research paper to be published in a sports medicine/dental journal. We will also send copies of the paper to your team doctor for you so that you can see how your participation has helped the research. Your data will not be presented or published in any way that might identify you as a volunteer in this study. Your consent record relating to this study may be inspected by a Research Ethics Committee for the purpose of quality control or regulatory inspection, but your personal data cannot be associated with any sample.

Thank you for reading this information sheet and for considering participation in this study.
Appendix X Participant consent form ID 002

**UCL EASTMAN DENTAL INSTITUTE**  
**CENTRE FOR ORAL HEALTH AND PERFORMANCE**

**INFORMED CONSENT FORM FOR PARTICIPATION IN RESEARCH STUDIES**

Please complete this form after you have read the information sheet and/or listened to an explanation about the research.

**Title of Study:** Oral Health to Enhance Elite Athlete Performance (the "Study")
**Department:** Centre for Oral Health and Performance, Unit of Periodontology
**Lead Researcher:** Dr Julie Gallagher; julie.gallagher.1@ucl.ac.uk
**Principal Investigator:** Professor Ian Bickham; ian.bickham@ucl.ac.uk
**Data Protection Officer:** data-protection@ucl.ac.uk
**UCL Research Ethics Committee:** Project ID Number: 1808/002

Thank you for your interest in taking part in this study. Before you agree to take part, the person organising the study must explain the project to you. If you have any questions arising from the information sheet or explanation already given to you, please ask the researcher before you decide whether to join. You will be given a copy of this informed consent form to keep and refer to at any time.

<p>| | |</p>
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<tr>
<td>1</td>
<td>I confirm that I have read and understood the information sheet for the above study. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction and would like to take part in.</td>
</tr>
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</table>
| 2 | I confirm and would like to take part in the study and agree to:  
|   |  • Undergo the oral health assessment;  
|   |  • Complete the questionnaire provided to me;  
|   |  • Provide saliva, saliva and stool samples requested at the beginning and one other time during the study;  
|   |  • UCL being given access to the performance data and other data held by my team doctors. |
| 3 | I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, without the care I receive from my team doctors or any legal rights being affected. I understand that if I decide to withdraw, any personal data stored by UCL in relation to the study will be deleted unless I agree otherwise and any sample being held by UCL shall be destroyed. I understand that I will be able to withdraw my data at any time during the study. |
| 4 | I understand that any sample provided to Yeda and Dicrances on an anonymous basis may be used to isolate microorganisms which may be used as source material for new therapeutic and/or commercialisation of new therapies (including dentistry and not limited to) small molecules, combinations of microorganisms and probiotics (e.g. food additives). |
| 5 | I consent to the processing of my personal information (name, age, gender, ethnicity, educational status), information collected by team doctors, the questionnaire and performance data for the purposes explained to me in the information sheet. I understand that all personal information and data samples will be anonymised. I understand that such information will be handled in accordance with all applicable data protection legislation, namely the Data Protection Act 2018 and General Data Protection Regulations 2018. |
| 6 | Use of the information for the project only:  
|   |  • I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified. I understand that my data gathered in this study will be stored anonymously and securely. It will not be possible to identify me in any publications. |
| 7 | I agree that my anonymised research data may be used by others for future research [to one will be able to identify you when this data is shared] |
| 8 | I understand that the information I have submitted will be published as a report and I wish to receive a copy of it. Yes/No |

**Name of participant**

**Date**

**Signature**

---

**Researcher**

**Date**

**Signature**

---

320
Appendix Y Baseline questionnaire ID 002

UCL EASTMAN DENTAL INSTITUTE

CENTRE FOR ORAL HEALTH AND PERFORMANCE

Project ID……………………………..

Project Title: Oral Health to Enhance Elite Athlete Performance

This project has been approved by the UCL Ethics committee: Project ID number 6388/002

This questionnaire should take no more than 15 minutes to complete. Please answer all questions. We appreciate your contribution towards this research.

1. What is your competition sport and role (e.g. athlete, support staff)?

................................................................................................................................................................................................................................................................................
.................................................................................................................................................................................................

2. What is your age?

............................................

3. What is your gender?

Male

Female

4. Over the past year have you had any difficulty: (Please tick)

1. Eating or drinking because of your mouth, teeth or gums?

0. Not at all

1. A little

2. Somewhat

3. A fair amount
4. A great deal

2. Relaxing (including sleeping) because of your mouth, teeth or gums
   0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal

3. Smiling, laughing or showing your teeth without embarrassment?
   0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal

5. Over the past year: (Please tick)

1. Have you had any difficulties participating in normal training or competition due
   to problems with your mouth, teeth or gums?
   0. Full participation without mouth, teeth or gum problems
   1. Full participation but with mouth, teeth or gum problem
   2. Reduced participation due to mouth, teeth or gum problems
   3. Could not participate due to mouth, teeth or gum problems

2. To what extent have you reduced your training volume due to mouth, teeth or
   gum problems?
   0. No reduction
   1. Minor reduction
2. Moderate reduction
3. To a major extent
4. Could not participate at all

3. To what extent have problems with your mouth, teeth or gums affected your performance?
0. No reduction
1. Minor reduction
2. Moderate reduction
3. To a major extent
4. Could not participate at all

4. To what extent have you experienced pain from your mouth teeth or gums?
0. No pain
1. Mild pain
2. Moderate pain
3. Severe pain

6. Which of the following do you use to help keep your mouth, teeth and gums healthy?

1 x Day 2 x day 3 x day 2-3 x week < 1 x week

Manual toothbrush
Electric toothbrush
Dental floss/interdental brushes
Normal fluoride toothpaste
Prescription fluoride toothpaste
Fluoride mouthwash

7. Please answer the following questions

True  False  Don't know

If I want to stop my teeth decaying, it is more important to cut down how much sugar I eat/ drink, than to cut down how often I have it.

If a drink says ‘no added sugar’ on the packaging, this means that it has no sugar in it, and that it is safe for my teeth.

I should rinse out my mouth after brushing to remove all the toothpaste.

Mouthwashes are just as effective as flossing at preventing gum disease.

If I brush my teeth for 3-5 minutes twice a day, I won’t get any tooth decay

If my gums bleed, I should avoid brushing and flossing in these areas.

Brushing my teeth straight after drinking a fizzy drink will protect them.

When brushing my teeth, it is more important to brush the teeth themselves than around the gums.

8. Finally, what is your ethnic group? Please tick one option that best describes your ethnic group or background.

White  1 English/Welsh/Scottish/Northern Irish/British

2 Irish

3 Gypsy or Irish traveller

4 Any other white background- please describe

Mixed/Multiple Ethnic Group  5 White and Black Caribbean

6 White and Black African
7 White and Asian

8 Any other mixed/multiple ethnic background- please describe

Asian/Asian British 9 Indian

10 Pakistani

11 Bangladeshi

12 Chinese

13 Any other Asian background, please describe

Black/African/Caribbean/Black British 14 African

15 Caribbean

16 Any other Black/African/Caribbean background, please describe

Other ethnic group 17 Arab

18 Any other ethnic background, please describe
Appendix Z Follow up questionnaire ID 002

UCL EASTMAN DENTAL INSTITUTE

CENTRE FOR ORAL HEALTH AND PERFORMANCE

Participant ID……………………………..

Project Title: Oral Health to Enhance Elite Athlete Performance

This project has been approved by the UCL Ethics committee: Project ID number 6388/002

Please answer all questions. We appreciate your contribution towards this research.

1. Since our last visit: (Please tick)

1. Have you had any difficulty eating or drinking because of your mouth, teeth or gums? 0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal

2. Have you had any difficulty relaxing (including sleeping) because of your mouth, teeth or gums 0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal

3. Have you had any difficulty smiling, laughing or showing your teeth without embarrassment? 0. Not at all
   1. A little
   2. Somewhat
   3. A fair amount
   4. A great deal
2. Over the past month, which of the following have you used to help keep your mouth, teeth and gums healthy?

   1 x Day      2 x day      3 x day  2-3 x week  < 1 x week

   Manual toothbrush
   Electric toothbrush
   Dental floss/interdental brushes
   Normal fluoride toothpaste
   Prescription fluoride toothpaste
   Fluoride mouthwash
   PTO

3. Over the past month: (Please tick)

   1. Have you had any difficulties participating in normal training or competition due to problems with your mouth, teeth or gums  0. Full participation without mouth, teeth or gum problems
      1. Full participation but with mouth, teeth or gum problems
      2. Reduced participation due to mouth, teeth or gum problems
      3. Could not participate due to mouth, teeth or gum problems

   2. To what extent have you reduced your training volume due to mouth, teeth or gum problems  0. No reduction
      1. Minor reduction
      2. Moderate reduction
      3. To a major extent
      4. Could not participate at all

   3. To what extent have problems with your mouth, teeth or gums affected your performance  0. No reduction
      1. Minor reduction
      2. Moderate reduction
      3. To a major extent
      4. Could not participate at all
4. To what extent have you experienced pain from your mouth teeth or gums  

0. No pain  

1. Mild pain  

2. Moderate pain  

3. Severe pain  

4. Please answer the following questions  

True  False  Don’t know  

If I want to stop my teeth decaying, it is more important to cut down how much sugar I eat/ drink, than to cut down how often I have it.  

If a drink says ‘no added sugar’ on the packaging, this means that it has no sugar in it, and that it is safe for my teeth.  

I should rinse out my mouth after brushing to remove all the toothpaste.  

Mouthwashes are just as effective as flossing at preventing gum disease.  

If I brush my teeth for 3-5 minutes twice a day, I won’t get any tooth decay  

If my gums bleed, I should avoid brushing and flossing in these areas.  

Brushing my teeth straight after drinking a fizzy drink will protect them.  

When brushing my teeth, it is more important to brush the teeth themselves than around the gums.
Appendix AA Baseline CRF ID 002

Participant ID: ___________________________ Date: ___________________________

Dental history

| Do you have any problems or pain in your mouth related to your teeth at the moment? |
| Do you have any sensitivity to hot or cold related to your teeth at the moment? |
| Do you notice any bleeding from your gums when cleaning your teeth? |
|_________|_________|
| No : 0  | Yes (always/often) : 1  | Sometimes/occasionally : 2 |

PUFA Index (Pulp, Ulceration, Fistula, Abscess)

<table>
<thead>
<tr>
<th>Code</th>
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</thead>
<tbody>
<tr>
<td>Pulp</td>
</tr>
<tr>
<td>Ulcer</td>
</tr>
<tr>
<td>Fistula</td>
</tr>
<tr>
<td>Abscess</td>
</tr>
</tbody>
</table>

0 = no lesions, 1 = single lesion, 2 = 2 or more lesions

<table>
<thead>
<tr>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>periapicalitis</td>
</tr>
</tbody>
</table>

Periodontal examination

<p>| |</p>
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<thead>
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<tbody>
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</table>

Erosion

| 0  | 1  | 2  | 3  |
|    |    |    |    |

0 = no surface loss, 1 = early change, 2 = <50% loss, 3 = >50% loss

Total score: Posterior ___________ Anterior ___________ Total ___________

Worst score: Posterior ___________ Anterior ___________
## Caries experience, trauma experience

<table>
<thead>
<tr>
<th>Tooth</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
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<th>28</th>
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<td>Total score</td>
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</tbody>
</table>

## Bleeding, score

<table>
<thead>
<tr>
<th>CALCULUS</th>
<th>8</th>
<th>7</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOOD</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>PLAQUE</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>BLOOD</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>PLAQUE</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>BLOOD</td>
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<tr>
<td>PLAQUE</td>
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<td>7</td>
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<tr>
<td>PLAQUE</td>
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<tr>
<td>BLOOD</td>
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<tr>
<td>PLAQUE</td>
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</tr>
<tr>
<td>BLOOD</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
Appendix BB Follow up CRF ID 002

Participant ID: ___________________________ Date: ___________________________

Dental history

<table>
<thead>
<tr>
<th>Question</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have any problems or pain in your mouth related to your teeth at the moment?</td>
<td></td>
</tr>
<tr>
<td>Do you have any sensitivity to hot or cold related to your teeth at the moment?</td>
<td></td>
</tr>
<tr>
<td>Do you notice any bleeding from your gums when cleaning your teeth?</td>
<td></td>
</tr>
</tbody>
</table>

No = 0    Yes (always/often) = 1    Sometimes/occasionally = 2

Antibiotic use since last visit  Yes    No

Replacement items for oral health kit dispensed

<table>
<thead>
<tr>
<th>Item</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toothbrush</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toothpaste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floss picks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trip to dentist/hygienist arranged?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bleeding score

% Score = \(((\text{number of surfaces with BoF})/ (\text{number of teeth} \times 4)) \times 100\)
Appendix CC Athlete evaluation form presentation

Thinking about the Oral Health Presentation (power point slides)
How much did this motivate you to want to avoid?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little</th>
<th>A fair amount</th>
<th>A lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth decay</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Gum disease</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Acid erosion</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Unattractive appearance</td>
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<tr>
<td>Inflammation elsewhere in the body</td>
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<tr>
<td>Impact on performance in sport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact on daily activities</td>
<td></td>
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</tbody>
</table>
### Appendix DD Athlete evaluation form oral health kit

**Oral health to enhance athlete performance: Evaluation of the oral health kit**

Thinking about the oral health kit

1. **How useful was it?**

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little</th>
<th>A fair amount</th>
<th>A lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found the kit useful</td>
<td></td>
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</tbody>
</table>

2. **The most useful items were....**

<table>
<thead>
<tr>
<th>Item</th>
<th>Not at all</th>
<th>A little</th>
<th>A fair amount</th>
<th>A lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wash bag itself</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The oral health drills card</td>
<td></td>
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<tr>
<td>The toothpaste</td>
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<tr>
<td>The toothbrush</td>
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<td></td>
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<tr>
<td>The flosspicks</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The brushlink device</td>
<td></td>
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</tbody>
</table>

3. **In the future I intend to use ....**

<table>
<thead>
<tr>
<th>Item</th>
<th>Not at all</th>
<th>Occasionally</th>
<th>1 x day</th>
<th>2 x day</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wash bag itself</td>
<td></td>
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<tr>
<td>The oral health drills card</td>
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<tr>
<td>Duraphat toothpaste (on prescription)</td>
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<tr>
<td>Regular fluoride toothpaste</td>
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<tr>
<td>Non-fluoride toothpaste</td>
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<tr>
<td>A manual toothbrush</td>
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<tr>
<td>An electric toothbrush</td>
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<tr>
<td>The flosspicks</td>
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<tr>
<td>Regular dental floss</td>
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<tr>
<td>Interdental brushes</td>
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<tr>
<td>The brushlink device</td>
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</table>