What are the psychological mechanisms that underlie the positive effects of exercise on mental health?

Jessica Lewis

DClinPsy Thesis (Volume 1), 2022

University College London

UCL Doctorate in Clinical Psychology

Thesis declaration form

I 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.

Signature: REMOVED FROM PUBLIC VERSION

Name: Jessica Lewis

Date: 16/06/2022

Overview

It has been established that exercise is beneficial for mental health and wellbeing. However, the mechanisms underlying the effect of exercise on mental health are not fully understood. Much research into mechanisms focuses on physiological and neurological effects, but less focuses on psychological processes that occur during exercise. This thesis explores possible psychological mechanisms for the effect of exercise on mental health, along with barriers and facilitators to increasing exercise, with a view to informing more effective exercise interventions for mental wellbeing.

Part one is a conceptual introduction exploring what is currently known about the effect of exercise on mental wellbeing including possible mechanisms. It also explores literature on barriers and facilitators of increasing exercise in general and clinical populations.

Part two is an empirical research paper. It describes a survey-based study where exercise level, mental wellbeing, and a range of psychological factors that might underlie the relationship between the two, were assessed across three time points. The paper presents the results of mediation analyses exploring which factors may explain the association between exercise and mental wellbeing as well as additional exploratory analysis to support interpretation. Additionally, predictors of increasing exercise are analysed and reported. The results are discussed with particular emphasis on clinical applications.

Part three is a critical appraisal of the research process including the literature review and empirical study. It includes detailed analysis of potential threats to validity of the findings and conclusions and personal reflections on the experience of completing the research project.

Impact Statement

This research project has a number of academic and clinical implications including generating new theories, creating areas for further research, and informing future provision of exercise as an intervention for mental wellbeing.

Previous research has identified a need to better understand the mechanisms that underlie the effects of exercise on mental wellbeing (Craft & Perna, 2004; Schuch et al., 2016). While the majority of research on mechanisms considers biological processes, this project focuses on possible psychological mechanisms. In this way the research addresses a gap in the literature.

Both the literature review and empirical paper suggest that psychological mechanisms underlie the relationship between exercise and mental wellbeing. More specifically, distress tolerance, unconditional self-acceptance, self-efficacy and self-esteem are likely to be important processes. This research was exploratory "theory-generating" research, and therefore more focussed "theory-testing" research to investigate specific hypotheses about the role of these psychological processes is recommended.

Currently, follow-up qualitative analysis is being conducted with participants from the study as part of a second clinical doctorate research project. This aims to investigate whether the individual experiences of people increasing exercise aligns with the patterns suggested by the data.

In the United Kingdom, exercise is recommended as an intervention for low to moderate depression (NICE, 2009). This is usually offered via exercise referral schemes. However, individuals referred to exercise referral schemes for mental health reasons are less likely to attend than those referred for physical health reasons (Crone et al., 2008). Previously it has been suggested that mental health difficulties themselves are a barrier to exercise (Vancampfort et al., 2015). In contrast, this project finds that individuals with greater psychological distress or depression are more likely to maintain a plan to increase exercise when they have made this plan themselves. This suggests that the barrier for individuals

with mental health difficulties using exercise referral schemes may be related to initial motivation to exercise, rather than maintenance. A more tailored exercise intervention, specifically for mental health, might more effectively manage this barrier.

Findings throughout the literature review and empirical paper suggest a combined exercise psychology intervention may be beneficial. This intervention would focus on motivational strategies to support exercise maintenance, psychological mechanisms of change that occur during exercise, and monitoring and preventing exercise dependence. “Exercise therapy” may appeal to different populations than talking therapies or creative therapies such as dance, drama and music, and therefore improve accessibility of psychological support. This project also finds that individuals with lower distress tolerance are more likely to maintain a plan to increase exercise. This suggests that an exercise-based therapy would be appropriate for individuals with low distress tolerance who may find other forms of therapy overwhelming.

More research is required to develop and evaluate these ideas. However, there has already been interest in the dissemination of key findings and suggestions from this project within academic networks and clinical services. It is hoped that the findings in this project may support funding applications for further research in this area, or the commissioning of pilot exercise interventions within clinical services.

References:

Craft, L. L., & Perna, F. M. (2004). The benefits of exercise for the clinically depressed. *Primary care companion to the Journal of clinical psychiatry*, *6*(3), 104.

Crone, D., Johnston, L. H., Gidlow, C., Henley, C., & James, D. V. (2008). Uptake and participation in physical activity referral schemes in the UK: an investigation of patients referred with mental health problems. *Issues in mental health nursing*, *29*(10), 1088-1097.

National Institute for Health and Care Excellence. (2009a). *Depression in Adults: Recognition and Management* (Clinical Guideline CG90). Retrieved from https://www.nice.org.uk/guidance/cg90

Schuch, F. B., Deslandes, A. C., Stubbs, B., Gosmann, N. P., da Silva, C. T. B., & de Almeida Fleck, M. P. (2016). Neurobiological effects of exercise on major depressive disorder: a systematic review. *Neuroscience & Biobehavioral Reviews*, *61*, 1-11.

Vancampfort, D., Stubbs, B., Sienaert, P., Wyckaert, S., De Hert, M., Rosenbaum, S., & Probst, M. (2015). What are the factors that influence physical activity participation in individuals with depression? A review of physical activity correlates from 59 studies. *Psychiatria Danubina, 27(3), 0-224.*

Contents

Tables

Acknowledgements

I would like to thank Prof John King, who not only gave me the chance to research an area I am passionate about by listening to my ideas for a project and agreeing to supervise it, but who then provided continuous education and reassurance throughout the process. Opportunities to reflect and discuss findings with John over the course of this project have left me with curiosity and excitement about how research might fit into my future career as a clinical psychologist.

I am also grateful to Dr. Victoria Lawson, who consulted on the initial development of survey questions from a health psychology perspective. I would like to thank the “Adventure Psychology Network” who have offered continued insight and opportunities to present my research in the future.

I want to thank the participants who took the time to complete the surveys that allowed for this research to be completed. Special gratitude goes to those who were generous enough to offer even more time by agreeing to be contacted for follow-up interviews. I also want to acknowledge Olga Jelkina, who took on those interviews as part of a second qualitative research project, and in doing so is continuing to develop this research area.

Finally, I want to acknowledge the contributions of my friends and family. In particular, I am grateful to my parents for teaching me to believe in myself and to see challenges as opportunities, as well as believing in me themselves and being there for me throughout the entire process of getting to this point in my psychology career. I would also like to acknowledge my sister, Alicia, whose natural talent with words often helped me to find the vocabulary to do justice to my ideas and to phrase things in a more readable way. Her interest in the subject maintained my own through discussions with her. I would also like to thank Dan, for being a constant throughout the ups and downs of this thesis. From always

making time and space for me to work when needed, to joining me for my own exercise therapy, to reminding me that it is ok to do nothing sometimes, he has been a voice of calm and compassion when I have forgotten to prioritise those things myself.

Part 1: Conceptual Introduction

What is our current understanding of the role of exercise in mental health and how can this be applied to support better mental health?

Abstract:

There is a large body of evidence supporting the notion that exercise is beneficial for several different mental health presentations across the lifespan. Too much exercise can result in relative energy deficiency syndrome and exercise addiction. There is therefore an 'optimum' dose of exercise, although this will differ by individual depending on body weight, gender, and mental health history.

Mental health difficulties, along with pain, physical illness, finance and time, may be barriers to engaging in exercise. However, exercise counselling incorporating technology, incentives, motivational interviewing or cognitive behavioural techniques can overcome some of these. There are biological, social and psychological explanations for the impact of exercise on mental health, but also a bias among academics and researchers to compare exercise to pharmacological interventions.

This review encourages a shift to viewing exercise as a psycho-social rather than biological intervention, and considers how combined exercise psychology interventions could lead to maximum mental health benefits by overcoming barriers to engagement and reinforcing psychological mechanisms of change through exercise.

Longitudinal research into barriers to exercise as well as more research into psychological mediators of the relationship between exercise and mental health would inform the design of such interventions. The plan for a study aiming to address these areas is described.

1. Introduction

The importance of exercise and activity in developing and maintaining good mental health is widely commented upon in the media, in wellbeing resources, and by health professionals. Exercise is a suggested treatment for low to moderate severity depression in the National Institute for Health and Care Excellence (NICE) guidelines (2009a), which draw together best evidence for healthcare in the United Kingdom (UK). As a result, many areas of the UK prescribe exercise groups or a pass for free gym access to individuals struggling with their mental health. Some mental health services run specific exercise groups as an intervention to improve mental wellbeing. There are also numerous third sector organisations using exercise as the basis for mental wellbeing support.

Despite a growing body of evidence supporting the importance of exercise for mental health, the reason why it is beneficial is still not fully understood. Initial theories were based on biological mechanisms such as endorphins, neurotransmitters, neurogenesis, and related neuroanatomical changes. Until recently, there has been less attention given to social and psychological changes that occur during exercise. These involve social identity, comparison and connection, as well as things people learn about themselves and their capacity for strength and achievement through exercise.

Understanding the social and psychological role of exercise in improving mental health could help exercise programmes better target key mechanisms for change, and therefore improve their therapeutic effectiveness. Additionally, understanding the role of exercise in promoting psychological health could allow for the development of combined exercise and psychological approaches as opposed to treating exercise as a stand-alone alternative to mainstream interventions. A combined approach might be especially beneficial for people struggling to engage with psychological therapy or exercise, as psychological approaches support engagement with exercise (Krebs et al., 2019), and exercise improves cognitive flexibility (Roig-Coll et al., 2020).

This review will discuss literature on the impact of exercise on mental health and wellbeing, both in the general population and clinical mental health settings. It will consider the effect of exercise on different mental health difficulties, and in different populations. Different approaches to exercise intervention will be considered along with accessibility, engagement and outcomes. The chapter will also review the currently available literature looking at possible mechanisms behind the benefits of exercise on mental health from biological, social and psychological perspectives. Finally, it will identify gaps in the current literature, and describe the key aims and methodology of a research study aiming to address some of these gaps.

2. Current context: How exercise is being used as a mental health or wellbeing intervention

NICE guidelines refer to exercise as an intervention for mental health difficulties in two contexts: within guidance for treating mild to moderate depression (NICE, 2009a), and within guidance around exercise referral schemes for individuals whose inactivity and health conditions make them susceptible to further health difficulties (NICE, 2014). This acknowledges that physical activity is an effective treatment for mild to moderate depression (Hansen et al., 2001) and that people with mental health conditions are more at risk of inactivity-related health conditions.

For mild to moderate depression, NICE recommends a 10-14 week programme of structured and supervised exercise, with three sessions a week ranging from 45 minutes to an hour. While NICE guidelines for other mental health conditions do not incorporate exercise, evidence suggests it may be an effective intervention for anxiety (LeBouthillier & Asmundson, 2017), Post Traumatic Stress Disorder (Rosenbaum et al., 2015), Obsessive Compulsive Disorder (Rector et al., 2015), and Serious Mental Illness (Alexandratos et al., 2012).

NICE guidelines recommend that exercise referral schemes are commissioned and provided by all primary care services as part of social prescribing. Social prescribing is an aspect of Universal Personalised Care (NHS England, 2019) where individuals vulnerable to health problems are referred for holistic social support including vocational, educational, creative and physical opportunities (Kinsella, 2016). Mental health difficulties are one of several areas of health being targeted by exercise referral schemes, which should include assessment by an exercise specialist and access to a physical activity programme. Evidence suggests that exercise referral schemes are effective in increasing physical activity and that they are 51-88% cost effective overall (Rowley et al., 2018; Rowley et al., 2020).

However, exercise referrals may not be as effective an intervention for people with mental health difficulties. The dropout rate for mental-health-related referrals to exercise programmes in South Tyneside was 57.7% (Kelly et al., 2017). In another location, when motivational interviewing techniques were utilised, the dropout rate was only slightly lower at 44.7% (Wade et al., 2020). This dropout rate is higher than for individuals referred to exercise programmes for physical health reasons, and the uptake rate for people with mental health difficulties is also lower (Crone et al., 2008). This may be due to the impact of mental health difficulties on motivation, social engagement and planning capacity. Blake (2012) suggests clinicians might be hesitant to prescribe or recommend exercise to depressed service users for worry they would lack motivation to engage. As different mental health conditions have different characteristics and mechanisms, and many mental health conditions may be barriers to engaging with exercise (Vancampfort et al., 2015), it is clear that providing a ‘one size fits all’ approach to exercise interventions is not adequate. Mental health service users would benefit from exercise programmes that are sensitive to their specific and individual needs. These might be best provided by specialist mental health services.

Some NHS mental health teams do offer exercise groups as a part of their service. In primary care physical activity has been incorporated into group cognitive behavioural therapy (CBT) (iCope Camden and Islington Psychological Therapies Service, 2021). In one

trust, a mental health nurse who is a qualified physical trainer has been employed to deliver a full exercise programme (Devon Partnership Trust, 2019). A CAMHS (Children and Adolescent Mental Health Services) team collaborates with local football teams to provide football programmes for young people with mental health needs (NELFT NHS Foundation Trust, 2020) and several Early Intervention in Psychosis Services have had physical intervention programmes commissioned based on evidence to suggest there are benefits to health in this population (Smith et al., 2020). However, despite physical activity being demonstrated as beneficial for several mental health disorders, programmes like these are still rare. With current economic strains on the NHS and limited evidence to support the use of physical activity programmes within mental health services, it remains challenging to have such programmes commissioned.

To fill this gap in provision, there are numerous third sector organisations providing physical activity opportunities to support individuals with mental health difficulties. Activities include surfing, martial arts, football and climbing, and report beneficial impact (Strong, 2009; Salari, 2009; Morgan, 2010; Hynes, 2010; Leech et al., 2018; Schwarz et al., 2020). While many of these initiatives report positive outcomes through testimonials, there is currently a lack of published empirical evidence to support their efficacy.

Overall, more research is needed into the impact of tailored exercise interventions for individuals with mental health conditions.

3. Current knowledge about the association between exercise and mental health

There is a large body of evidence demonstrating that physical exercise is associated with better mental wellbeing both in the general population, and in individuals diagnosed with a mental health condition (Goodwin, 2003; Kim et al., 2012, Rebar et al., 2015; Harris, 2018, Fluetsch; Levy & Tallon, 2019; Vancampfort et al., 2020). This is a bidirectional relationship,

where increasing exercise results in improved mental health, and those with better mental health are more likely to engage in exercise (Da Silva et al., 2012).

3.1. Exercise and different Mental Health Presentations

3.1.1. Depression

The majority of research on the positive impact of exercise on mental health has looked at mood and depression (Paluska & Schwenk, 2000; Goodwin, 2003; Reed & Buck, 2009; Pasco et al., 2011). Most studies compare individuals who exercise at or above the recommended amount to those who do not. However, with observational designs it is hard to identify the direction of causation, as it may be that depressed people are less likely to exercise, rather than that exercise improves mood.

Kanning & Schlicht (2010) found there is also a within-subjects relationship between mood and exercise, with mood improving after an episode of physical activity. This suggests that mood varies as a function of exercise, and therefore exercise could be used as an intervention for mood.

A Cochrane review examining exercise and depression found that high-quality evidence shows only a small effect size, but when lower-quality evidence was included exercise appeared an effective intervention (Cooney et al., 2013). Ekkekakis (2015) pointed out that the inclusion and exclusion criteria used in the review were inconsistent, and re-analysed the same data using revised inclusion and exclusion criteria. This analysis found a large significant effect size for exercise on depression. Netz (2017) reassessed the data which was used to generate the American Psychological Association guidelines for treating depression (which do not include exercise), and found similar bias with regards studies on exercise and depression.

This suggests guidelines may be biased against the use of exercise as treatment for depression, perhaps because of assumptions by authors about it being more difficult to implement, or less of a specialised service, than medication or psychotherapy. Reluctance to

engage in the concept of exercise as treatment means there is little funding for researching it, so evidence quality remains poorer than for well-funded pharmacological randomised control trials (RCTs).

Other research has focused on exercise as an adjunctive rather than stand-alone treatment. Exercise has been found beneficial for individuals with clinical depression when combined with antidepressant use (Siqueira et al., 2016; Danielsson et al., 2013), and high-intensity exercise with antidepressants appears to result in faster and more probable remission than low-intensity exercise with antidepressants, or antidepressants alone (Murri et al., 2015).

In a meta-analysis of meta-analyses, Rebar et al. (2015) found a medium effect size of exercise on reduced depressive symptoms across 94 studies cumulatively. Kvam et al. (2016) conclude that exercise is an effective treatment for depression, and that it may also be beneficial as an adjunctive therapy to medication. However, evidence is generally of poor quality and more funding is required to generate a body of higher quality evidence.

3.1.2. Anxiety

There is a growing body of research looking at the impact of exercise on anxiety disorders and stress. Goodwin (2003) found that exercise was associated with decreased prevalence of social anxiety, panic attacks, specific phobias, and agoraphobia, including when socio-demographic factors and other physical and mental health disorders are controlled for. Paluska & Schwenk (2000) found exercise to be more effective for acute anxiety than chronic. Resistance exercise may also be more effective for reducing anxiety than aerobic exercise (Stonerock et al., 2015). However, a review of the research on exercise and anxiety shows only a small number of studies addressing this area, and most of those have small samples and poor control measures (Asmundson et al., 2013).

While panic disorder is considered an anxiety disorder, exercise appears to affect it differently. Exercise resulted in increased anxiety during and immediately after exercise for individuals with panic disorder (Rief & Hermanutz, 1996), but after a ten-week exercise

programme, a significant reduction in panic and anxiety symptoms was found (Broocks et al., 1998). People with panic disorder often misinterpret internal stimuli (heart racing, breathing heavily) as signs of serious illness, so exercise may be beneficial as part of exposure therapy in this instance. Over time, people may learn that these sensations are not dangerous and become less sensitive to them. However, exercise was found to be only as effective as medication for panic disorder, but medication was faster acting and had a lower dropout rate (Broocks et al., 1998).

In the non-clinical population, research has found that working adults who engaged in leisure time physical activity at or above recommended levels report half as much perceived stress as those who did not (Aldana et al., 1996). However, another study on a sample of over 18-year-old college students found no association between physical activity and perceived stress (Hubbs et al., 2012). In a review, Chu et al. (2014) conclude that exercise and yoga programmes delivered in the workplace are effective for reducing symptoms of depression or anxiety, but that the impact on stress is less evident. While exercise seems to be an effective intervention for anxiety disorders, it appears to be limited as a method for reducing stress in the general population.

3.1.3. Serious Mental Illness (SMI)

Research is more limited for the impact of exercise on SMI, which refers to psychotic illnesses, bipolar disorder and treatment-resistant major depression. Exercise has been shown to improve negative symptoms and physical health for those with schizophrenia, but there is no clear impact on positive symptoms (Gorczynski & Faulkner, 2010; Korman et al., 2018). A review of evidence concluded that mood, concentration, sleep, and psychotic symptoms all improved with exercise for individuals with SMI (Alexandratos et al., 2012). However, another study with a sample of 18 inpatients with SMI found no relationship between physical activity and quality of life (Bonsaksen & Lerdal, 2012).

Stubbs et al. (2018) broke SMI down into diagnostic categories and found that exercise is most helpful for treatment-resistant depression, and somewhat helpful for

psychosis. There is not yet enough literature to conclude whether it is helpful for bipolar disorder.

A meta-analysis found that while SMI inpatient exercise programmes resulted in moderate increases in activity, this was not reflected in changes in mental health symptoms (Pearsall et al., 2014). It appears therefore that exercise as a mental health intervention is more limited in this population. This is likely due to the many barriers that individuals with SMI face in terms of initiating physical activity, although social support from a trusted source is found to help address some of these (Quirk et al., 2020).

3.1.4. Post Traumatic Stress Disorder (PTSD)

One study on the impact of exercise on PTSD following sexual trauma found that while exercise or meditation alone did not lead to a reduction in PTSD symptoms, the combination of meditation and exercise did (Shors et al., 2018). Meditation combined with physical exercise has also been found to be beneficial to the mental health of medical students who witness traumatic incidents as part of training (Henning et al., 2018).

A review of four studies suggests that physical activity is most effective at reducing depressive symptoms for individuals with PTSD, but does have some effect on trauma symptoms too (Rosenbaum et al., 2015). Another more recent review concluded that physical exercise is a viable treatment option for military and community populations with PTSD (Hegberg et al., 2019). Hall et al. (2020) ran a randomised control trial looking at the impact of an exercise programme compared to waitlist for older veterans with PTSD and found that PTSD symptoms were significantly reduced in the exercise condition. However, the main symptom area affected was again low mood.

3.1.5. Summary

While exercise is beneficial in the treatment of PTSD, SMI and anxiety, its primary impact appears to be on depression, and secondary depression resulting from these other disorders.

3.2. Exercise in different populations

The majority of research on exercise and mental health uses university student or working-age adult samples. However, research shows these findings generalise to older adults, children, adolescents and individuals with disabilities or long-term conditions (LTCs), whose relationships with physical exercise and ability to partake in it may differ.

3.2.1. Older Adults

Much research on older adults focuses on cognition. A number of studies have shown that regular exercise in mid-to-later life is protective against development of cognitive impairment and dementia (Larson et al., 2006; Geda et al., 2010; Sofi et al., 2011; Liu et al., 2018). While cognitive ability and mental wellbeing are thought to be strongly inter-related, Awick et al. (2017) found that moderate to vigorous exercise directly predicts improved psychological health outcomes in older adults, which in turn predicts improved quality of life. This demonstrates that exercise is beneficial for older adults' mental wellbeing, as well as cognitive and physical health.

Farioli-Vecchioli et al. (2018) suggest that inactivity could cause the higher rates of depression in older adults, given research demonstrating that active older adults with healthy diets are less likely to become depressed. Research from the context of the Covid-19 pandemic found that exercise increased psychological resilience (Carriedo et al., 2020) and reduced depressive symptoms in older adults experiencing isolation and stress, but did not have an effect on anxiety (Callow et al., 2020).

The implications of this research are summarised in a United States taskforce report which concluded that older adults should engage in pleasurable physical activity twice a week in order to decrease risk of depression as well as falls, frailty and cognitive decline (de Souto Barreto et al., 2016).

3.2.2. Children and Young People

At the other end of the lifespan, reviews find a consistent relationship between physical activity and better mental health for children and young people, with most evidence concerning mood (Briddle & Asare, 2011; Camero et al., 2012; Hagell, 2016; Piñeiro-Cossio et al., 2021; Hale et al., 2021). However, much of this research only demonstrates small-to-moderate effects, and there is a lack of research with longitudinal follow-up, so it is hard to establish causation.

Despite the weak evidence base, there are consistent indicators that physical activity is beneficial to the mental wellbeing of children and young people, and no research evidence to suggest that organised sport or exercise does harm (Hagell, 2016). Exercise therefore appears a viable intervention for supporting the mental health of young people.

Of course, there is no 'one size fits all' approach, and several demographic factors have been shown to interact with the effect of exercise on wellbeing in this group. Age has been shown to moderate the effect of exercise on wellbeing, with a stronger positive effect the older the child (Andermo et al., 2020), and exercise only becoming impactful on wellbeing in adolescence (Rodriguez-Ayllon et al., 2019). An Australian study on Kindergarten children found that physical activity had no impact on indicators of mental wellbeing, but socioeconomic status and belonging to an ethnic minority did (O'Brien et al., 2020).

Research also examines how physical activity interacts with other lifestyle factors that could impact mental health in young people such as academic performance, social support and screen time. Physical activity and fitness are associated with academic achievement in adolescents (Rodriguez et al., 2020), which could contribute to improved mental wellbeing. Social support has been found to mediate and moderate the inverse relationship between physical activity and social anxiety in children in rural China (Ren & Li, 2020). Physical activity is also associated with reduced screen time, and screen time is associated with poor mental health (Nigg et al., 2021). A combination of reduced screen time

and increased physical activity is best associated with good mental health (Hrafnkelsdottir et al., 2018).

3.2.3. Individuals with Additional Support Needs

Participation in physical activity has been shown to be beneficial for the mental health of adults with physical disabilities (Bakhshayesh et al., 2013) as well as adults and children with intellectual disabilities (Borland et al., 2021; Bondár et al., 2020).

One study on children with 'special educational needs' (SEN), which includes intellectual disability, learning difficulties and neurodiversity, found that physical activity was associated with better psychological wellbeing including enjoyment, self-worth, self-competence, mental wellness and quality of life (Yang et al., 2021).

Research into the impact of physical activity on mental health for individuals with LTCs has focussed on chronic pain, cancer and HIV. A review of research focussed on chronic pain found that while exercise appears to reduce pain and improve quality of life, evidence for its direct impact on mental health is variable between studies (Geneen et al., 2017). Physical activity has been related to improved mental health outcomes for some forms of cancer (Kang et al., 2017; Kim et al., 2020), and is an effective intervention for depression in individuals with HIV (Guo et al., 2020; Ibeneme et al., 2020).

3.2.4. Gender

Amongst children and young people, girls seem to benefit more from exercise (Guddal et al., 2019; Bunketorp Käll et al., 2015). This might occur because boys tend to be more physically active overall (Brooks et al., 2015), so interventions that increase activity in females have more of an effect. Another possible explanation is that the link between exercise and mental health relates to changes in physical perception and self-esteem (Lubans et al., 2016; McNamee et al., 2017), which are more common concerns for girls, especial post-puberty.

However, in university students the opposite is found with a stronger effect of exercise on all measures of mental health for men (Grasdalsmoen et al., 2020). This might be related to motivation, as it has been found that for men exercise benefits mental wellbeing regardless of motivation to exercise, but for women exercise is only beneficial to mental health when it is for reasons unrelated to altering body shape (Craft et al., 2014). Women were found to be more likely to exercise for body image reasons.

Another possible explanation is that men may engage in more exercise than women, which in turn results in better mental health, rather than gender moderating the effect of exercise on mental health (Halliday et al., 2019). A more recent study found that when split by gender exercise was equally beneficial for reducing depressive symptoms for men and women, but had a greater beneficial impact on affect, sleep and anger for women (Glavin et al., 2021).

There is currently no published research on the benefits of exercise for non-binary or transgender individuals specifically, although there are known barriers to participation for this group, which will be discussed later.

3.2.5. Summary

It appears that exercise is beneficial for the mental health of not only working age adults, but for older adults, children and adolescents. Moreover, exercise maintains its benefits when people have additional needs such as disability, SEN, or LTCs. While effect sizes for many of these groups are small, there is little to no evidence of adverse effects of exercise, and therefore given the amount of evidence pointing towards use of exercise as an intervention to support mental health across the lifespan, it should be made available to all of these groups.

It is worth noting that with the exception of research demonstrating the helpfulness of traditional culturally-specific physical activity options for adolescents (Akbar et al., 2020), there is still a scarcity of research looking at the impact of exercise across cultures. It is important to recognise that many of the identities discussed in this section related to age,

additional needs, or gender also intersect with one another, as well as with minoritised or disadvantaged identities not explicitly referenced. While there is little research looking at the effectiveness of exercise in individuals who identify as specific ethnicities or LGBTQA+, some research has focussed on participation in exercise within these groups, which will be discussed later.

4. Negative impact of exercise on mental health

While there is a large body of evidence demonstrating the positive impact of exercise on mental health for different populations, it is important to acknowledge that excessive exercise can have a negative impact. Excessive exercise can result in relative energy deficiency syndrome (RED-S), or exercise addiction. Excessive exercise has also been linked to eating disorders, increased alcohol use, and violence, although most research into this has been in college student samples where sports teams may promote drinking and risk-taking (Sønderlund et al., 2014).

While eating disorder rates are shown to be higher in elite athletes than the general population (Sundgot-Borgen & Torstveit, 2004; Martinsen & Sundgot-Borgen, 2013), other research finds that exercise may be beneficial for treating eating disorders by improving general quality of life (Levine et al., 1996; Cook & Hausenblas, 2011). One study finds that exercise is only related to disordered eating when the motive for exercising is to alter body shape, or when postponing exercise results in feelings of guilt (Mond et al., 2004).

A recent review suggests that 1.5-6.7% of female athletes have all three main symptom areas of RED-S (Rogers et al., 2021) which are insufficient energy consumption, amenorrhea, and osteoporosis (Mountjoy et al., 2014). However 42% of female high school athletes had at least two risk factors (Brown et al., 2014), and 80% of elite and pre-elite female athletes in Australia had at least one symptom (Rogers et al., 2021). RED-S is common in male athletes also (Burke et al., 2018). RED-S is more common in ‘lean’ sports,

where it is beneficial to be light, or in ‘aesthetic’ sports such as gymnastics or synchronised swimming (Logue et al., 2018). There is an absence of evidence directly examining the impact of RED-S on mental wellbeing, but it is known to increase cortisol (stress hormone) and reduce oxytocin, which reduces stress and anxiety (Elliott-Sale et al., 2018).

RED-S is often hard to identify because both eating and exercise behaviour may appear within an acceptable range, but not proportional to one another. RED-S therefore often goes unrecognised, and because in its early stages the symptoms (steadier hormone levels for females and lower weight) can be beneficial for performance, it often goes undisclosed by athletes.

Exercise can also become an unhealthy behaviour when people become addicted. This may result in RED-S, but the diagnosis is based on psychological rather than physical impact. Exercise addiction is not included in the Diagnostic Statistics Manual 5th edition (American Psychiatric Association, 2013), although its presentation fits descriptions of other addictions: people become tolerant and require more exercise over time to achieve the same sense of satisfaction; withdrawal results in distress; there is perceived lack of control over the behaviour; people continue even when they understand the detrimental impact; and exercise interferes with other activities and routines (Freimuth et al., 2011). Exercise addiction often occurs when exercise is used as a ‘socially acceptable’ way to control body shape (Johnston et al., 2011), or to regulate emotion (Davis, 2000).

It is estimated that 3.6% of the population (Szabo & Griffiths, 2007) and 7.1-9.7% of fitness club members or sports club players (Lichtenstein et al., 2014) are addicted to exercise. This is more common in younger athletes (Simon-Grima et al., 2018). Exercise addiction in itself can be considered a mental health problem, and people with it are also over three and a half times more likely to develop an eating disorder (Trott et al., 2021). It has been shown to result in poorer quality of life (Simon-Grima et al., 2018). However, there is no evidence that exercise addiction results in mood disturbance (Hausenblas & Downs, 2002; Gapin et al., 2009). This fits with the idea that exercise addiction occurs when exercise is used excessively to manage emotions.

5. Optimum Exercise 'Dose'

Because excessive exercise can be damaging for overall quality of life, it is important to have an understanding of the optimum 'dose' of exercise for mental wellbeing. Early research notes a dose-response relationship between frequency of exercise and mental health (Goodwin, 2003). However, this is not a simple linear relationship. Mental health improves with physical activity up until 50 minutes a day, where it starts to decrease, or 5000 steps a day where mental health benefits plateau (Bernard et al., 2018). Because of this pattern, researchers have tried to discover the optimum frequency, duration and intensity of exercise for mental wellbeing. Kim et al. (2012) found that 2.5-7.5 hours of exercise a week was optimal for general mental health.

Another way of conceptualising the 'amount' of exercise individuals do is energy expenditure. One study found that for adults with mild to moderate depression, burning 17.5kcal/kg/week had a positive impact on self-reported depression scores, whereas only 7kcal/kg/week did not (Dunn et al., 2005). This suggests a threshold for minimum energy expenditure required for mental health to benefit from exercise. Another study looking at energy consumption in individuals with nonremitted depression found that burning 16kcal/kg/week was more beneficial for mental health than burning 4kcal/kg/week, but this difference was not as clear for women with a family history of mental illness (Trivedi et al., 2011). This suggests that there might not be one optimum 'amount' of exercise, as it depends on weight, gender, and family history of mental illness.

More research has focussed on the question of exercise intensity, finding no clear association between low-intensity physical exercise and improved mental wellbeing (Felez-Nobrega et al., 2021). Similarly, a meta-analysis found that those doing moderate to high-intensity activity benefitted most in terms of anxiety outcomes (Conn, 2010), and one study found that intensity of exercise was inversely associated with depression (Porras-Segovia et al., 2019). However, in females with depression being able to select exercise intensity resulted in better scores for self-esteem, depression and anxiety than being prescribed a

particular intensity (Callaghan et al., 2011). Ekkekakis et al. (2011) reviewed the literature and found that lower-intensity exercise (below the lactate threshold) was generally rated as more enjoyable. However, personal choice is important- when people were allowed to select their own intensity they rated high-intensity exercise as more enjoyable than when they were assigned to it. They argue, based on behavioural economics, that enjoyment means that people are more likely to repeat the behaviour. Enjoyment of exercise is therefore crucial to increasing the physical or mental health benefits over time, suggesting that lower-intensity exercise or self-selected intensity may be more beneficial as a mental health intervention than prescribed moderate to high-intensity activity.

Some statistical research has aimed to identify the optimum 'dose' of exercise across all of these domains (duration, intensity and frequency) for mental health. Overall, lower intensity exercise (60-80% of maximum heart rate) for 30-35 minutes three times a week appears to be the most beneficial 'dose' of exercise for the general population (Reed & Buck, 2009; Perraton et al., 2010). However, other research found that the relationship between physical activity 'dosage' and mental health is moderated by sedentary time, and therefore these estimations are only useful when there are also low levels of sedentary time (Bernard et al., 2018).

Most of these studies focus on aerobic exercise, which appears to have a stronger relationship with mental wellbeing than strength-based exercise (Fluetsch et al., 2019). Whether or not strength-based exercise counts towards the suggested dose of exercise is unclear. It is also unclear whether 'lifestyle physical activity', which includes leisure, occupational and household activities that are moderate to vigorous in intensity (Farris & Abrantes, 2020), counts towards these totals.

There are a few physical health conditions where exercise may be contra-indicated, at least temporarily during flare-ups or following surgical management, and others whereby the type and amount of exercise may need to be adapted to accommodate the condition (Hoffman et al., 2016)

Overall, the exact amount of exercise that will benefit an individual depends on the type of exercise, as well as their gender, weight, fitness, physical or mental health conditions, family history of mental illness, and sedentary time. The above estimations act as a useful starting point for services wishing to deliver an exercise intervention focussed on improving mental health, but evidently adapting a programme to individual needs based on the above criteria, and giving individuals the option to choose their preferred exercise intensity, would improve benefits further.

6. Participation

Despite the benefits of exercise for mental and physical health, many people do not participate in regular physical activity. Numerous factors can make it difficult to engage in exercise as a habit or lifestyle choice. This has been studied both in the general population and individuals with mental health difficulties.

6.1. Demographic Factors

In the general population, poverty and unemployment are known barriers to engaging in sport (Edwards et al., 2015; Sport England, 2018). While long term unemployment is a barrier to physical activity, being retired is an enabler of engagement with exercise programmes (Johnson et al., 2018), which suggests that it is not having a job which facilitates physical activity, but other aspects of employment such as financial stability and reduced stress.

Overall, girls and women at all ages do less physical activity per week compared to boys or men (Health Survey England, 2009; Brooks et al. 2015; Sport England, 2018). There is also an interaction between gender and socioeconomic status, whereby women with high socioeconomic status are the most physically active, and women with low socioeconomic

status the least active (Ford et al., 1991). In contrast there is little difference for men or young children with different socioeconomic situations (Ford et al., 1991; Kelly et al., 2006).

Being transgender has also been linked to difficulties engaging in physical activity as many sport facilities and teams are set up to accommodate binary genders only (Jones et al., 2017). While there is speculation that sport environments may have higher levels of trans and homophobic abuse, which would also present a barrier to LGBTQA+ individuals (Hagell, 2016), statistics suggest that physical activity levels differ very little between people with different sexualities (Sport England, 2018).

People with a disability or LTCs are much less physically active in general (Sport England, 2018), and one reason for this might be that school and youth sports programmes are still not disability inclusive (Fitzgerald & Bailey, 2009). Physical activity also decreases in older age (Sport England, 2018), likely due to an increased probability of experiencing LTCs or pain (Crab et al., 2015).

There are only very small differences seen in activity levels between different ethnicities in England (Sport England, 2018). However, the Faculty of Sport and Exercise Medicine (N.D.) states that individuals from minority ethnicities do experience specific barriers to participation so should be given additional provisions to overcome barriers.

Interventions to support individuals to engage in physical activity need to consider their individual identities and circumstances, and the provision of financial support to access facilities or coaching.

6.2. Facilitators of exercise in the general population

Interventions aimed at increasing physical activity often target motivation, using technology, incentives, or exercise counselling.

A review found that overall use of technology to change health behaviours has mixed results (Milne-Ives et al., 2020). Amongst studies aiming to increase physical activity with mobile-based apps, only five out of thirteen found a significant effect. There is some evidence that technology results in increased physical activity in the short-term, but that this

is not maintained beyond 20 weeks (Maher et al., 2015). Other research suggests that while physical activity may not change, confidence and sense of the importance of exercise can be increased through technology (Taylor et al., 2020).

Physical activity sessions combined with psychological coaching have been shown to be more effective than physical activity alone for increasing physical activity levels six weeks after the intervention (Krebs et al., 2019). After 12 months there was still a difference between groups, but it did not reach statistical significance. Motivational interviewing when integrated with CBT appears to be acceptable and feasible for adults with chronic illness, and results in increased physical activity (Scott et al., 2019). Harland et al. (1999) however, found that six sessions of motivational interviewing, with or without a £30 voucher incentive, made no difference to physical activity in the long-term. This suggests that CBT may have been the active aspect in the integrated intervention. CBT alone, focussed on exercise goals, has also been shown to result in increased physical activity (Strid et al., 2016). Psychological inoculation techniques (where individuals repeatedly refute arguments for not exercising) have also been found to effectively increase exercise engagement (Dorling et al., 2018).

Enjoying exercise has been found to be an important part of it becoming a regular habit (Ekkekakis et al., 2011). Therefore the intensity, type of exercise, and access to motivational enablers such as technology, need to be individually tailored to ensure people gain maximum enjoyment (Public Health England, 2018). Exercise counselling using motivational techniques and CBT may help ensure an individual's needs and preferences are incorporated into their exercise plan, thus increasing the likelihood they will maintain the behaviour (Stonerock & Blumenthal, 2017).

6.3. Barriers and facilitators for individuals with mental health difficulties

As individuals with mental health difficulties may have specific needs related to engagement and motivation they may require additional support to participate in exercise (Farholm & Sørensen, 2016). Low mood, stress and mental health difficulties have been

cited as barriers to physical activity (Cole, 2010; Vancampfort et al., 2015), but also key motivators for taking it up (Firth et al., 2016). In one survey, 90% of mental health service users stated that they thought they would benefit from increased physical activity. Of those only 12% were meeting the minimum physical activity guidelines, and 50% said that they thought increasing physical activity would be difficult (Crabb et al., 2015).

The most commonly reported barriers to engaging in exercise were pain, physical health conditions, lack of time and lack of social support, but specialist input and a regular activity schedule were identified as enablers (Crabb et al., 2015). Conn (2010) found that supervised sessions and exercising at a facility resulted in better engagement than at home, but having to go to a gym to exercise can be a barrier to uptake for people with mental health conditions (Morgan et al., 2016).

Using a series of interviews and focus groups, Wheeler et al. (2018) co-designed recommendations for mental health services to increase engagement in physical activity. One recommendation was to ask about service users' social networks and make plans with them to utilise their network for support, reminders and accountability to exercise. Additionally, provision of specialist knowledge and financial support to attend groups were recommended. They suggested that clients should be educated, supported with integrating activity into their existing lifestyle, and that their GP and psychiatrist should be made aware of their exercise plan.

7. Mechanisms explaining the effect of exercise on mental health

Once the global impact of exercise on mental health was established, research became focussed on the mechanisms underpinning this relationship. A number of biological, social and psychological mechanisms have been proposed.

7.1. Biological mechanisms

Potential biological mechanisms for the relationship between exercise and mental health include broader aspects of physical health including improved sleep, reduced BMI and reduced inflammation as well as processes such as hypothylamic-pituitary-axis (HPA) regulation, the role of endorphins, and neuroanatomical and neurochemical changes.

7.1.1. Sleep and overall health

Physical activity has been shown to improve sleep quality and wakefulness during the day both in the general population (Loprinzi & Cardinal, 2011) and for those with insomnia (Wendt et al., 2018). This has been demonstrated in the short-term following one exercise session (Passos et al., 2010), and the long-term following a six-month exercise programme (Passos et al., 2011). Sleep is strongly associated with quality of life, especially when moderated by physical activity (Yuan et al., 2020). Therefore the positive impact of exercise on mental health could be mediated by sleep quality.

7.1.2. Body Mass Index (BMI)

Exercise can contribute to lower BMI due to its fat-burning effects. Individuals with lower BMI have better mental health (Eddolls et al., 2018; Porras-Segovia et al., 2019), so exercise may improve mental health by reducing BMI. This could be because lower BMI reduces risk of other health difficulties that reduce wellbeing, or because lower BMI is associated with increased self-esteem, which in one study was shown to be sufficient to explain the antidepressant effects of exercise (Ryan, 2008).

Some research found that the relationship between exercise and self-esteem is bidirectional. This suggests that rather than exercise affecting BMI, BMI improving self-esteem, and self-esteem improving mental health, those with better self-esteem to begin with are more likely to exercise (Raudsepp et al., 2013).

7.1.3. Inflammation

Inflammation has been associated with depression (Zunszain et al., 2012), as well as with injury and long-term physical health conditions (Antonelli & Kushner, 2017). Exercise has been found to have anti-inflammatory effects in several LTCs (Petersen & Pedersen, 2005), and to reduce inflammatory markers in general (Beavers et al., 2010). It is therefore possible that exercise, by reducing inflammation, improves mood.

7.1.4. Endorphins and Endocannabinoids

Endorphins are natural opioids which increase during exercise, potentially resulting in a relaxed euphoric state similar to that experienced when using synthesised opioids (Adams, 2009). However, endorphin levels are higher in athletes who report greater anxiety and lower mood, and do not increase during low-intensity exercise although mood still does (Dishman & O'Connor, 2009; Saanijoki et al., 2018). Further evidence against the popular theory that endorphins improve mood after exercise includes the fact that they do not cross the blood-brain barrier (Dishman & O'Connor, 2009; Fuss et al., 2015), they are associated with stress response (Harber & Sutton, 1984), and when opioid receptors are blocked exercise still results in improved mood (Markoff et al., 1982). Endocannabinoids have been proposed as a more likely mechanism for the analgesic, sedative and anxiolytic effects of exercise, previously attributed to endorphins (Dietrich & McDaniel, 2004).

7.1.5. Hypothalamic-Pituitary Axis

Another theory behind exercise improving mental health is that exercise increases cortisol and catecholamine levels, which over time results in decreased HPA sensitivity, reducing the somatic experience of stress (Freimuth et al., 2011; Huang et al., 2013).

7.1.6. Neurochemicals

Another proposed mechanism is the production and release of neurotransmitters essential in regulating mood. Rat studies have shown that serotonin and dopamine, two

neurotransmitters associated with depression, increase following exercise (Blomstrand et al., 1989).

In the short term, high serotonin levels result in depression-like behaviours in rats, but over time cause down-regulation of the serotonergic system and less depressed behaviour (Greenwood & Fleshner, 2008). As antidepressants (which increase serotonin levels) often result in short-term reduced mood, followed by long-term improvement, it is possible that a similar mechanism underlies the effect of exercise on mental heath. Exercise may increase serotonin levels, eventually resulting in serotonergic down-regulation and improved mood.

The relationship between dopamine and exercise is bidirectional, with exercise increasing dopamine levels and higher dopamine increasing motivation to exercise (Marques et al., 2021).

7.1.7. Neuroanatomy

Exercise leads to increased brain derived neurotrophic factor (BDNF) levels, which stimulate neuronal and synaptic growth (Pilc & Zoladz, 2010; Takahashi et al., 2019; Heinze et al., 2021; De Sousa et al., 2021). Low BDNF levels are associated with depression and increase with antidepressants (Lee & Kim, 2010).

Increased BDNF results in hippocampal neurogenesis in depressed people (Campbell & MacQueen, 2004). Herting & Chu (2017) report that the hippocampus volume of exercisers was greater than non-exercisers. As the hippocampus plays important roles in memory and problem solving, changes in hippocampal volume could explain the role of exercise in mental health.

7.1.8. Summary

Schuch et al. (2016) conclude that a combination of short-term physiological, and long-term neurological changes co-occur following exercise to result in improved mental health. It is evident that these processes are highly inter-related, so it is hard to ascertain

exactly which process drives the others. More research looking at these processes in relation to one another is required.

7.2. Social Mechanisms

Several social explanations for the impact of exercise on mental wellbeing have been proposed. These include social connection, social identity, social comparison, and the role of the environment.

7.2.1. Social connection

Social connection is considered crucial for maintaining good mental health (Cacioppo & Patrick, 2008). One explanation for the impact of exercise on wellbeing is that it increases social connection from belonging to a team, club or group (Edmunds et al., 2013). Support for this comes from findings that exercising with others is more effective for improving mental health than exercising alone (Harada et al., 2019). An evaluation of walking groups also found that social inclusion and reduced isolation appeared to play a significant role in the impact the groups had on people's mental wellbeing (South et al., 2013).

7.2.2. Social identity theory

Social identity theory (Tajfel & Turner, 1979) describes how people see themselves as belonging to particular groups and gain pride and self-esteem from these. One theory is that when we exercise, we gain a social identity, be it a team identity or a broader identity such as 'runner' or 'athlete' (Haslam et al., 2020). We then feel a sense of connection to others who fit the same identity label, and share in their pride and self-esteem. For example, amateur runners feel proud when watching elite runners race. In turn this sense of 'belonging' and communal achievement drives improved mood and better mental health.

Qualitative research found that 'identity' associated with exercise was a key theme related to the impact of exercise on mental health (Mason & Holt, 2012). It has also been suggested that changes in self-schemata (such as thinking of self as capable or energetic),

which are highly linked to identity, appear to explain the benefits of exercise on work stress (Long & Flood, 1993). Hausenblas et al. (2004) suggest that self-presentation may play an important part in how exercise affects people's mental health, and their motivation. For example, people might exercise to appear healthy, adventurous or capable to others.

7.2.3. Social comparison theory

Social comparison theory (Festinger, 1954) suggests that people evaluate themselves in comparison to others. This has been shown to occur in exercise classes, and to be associated with participation in exercise (Frederick et al., 1994). Downwards social comparisons (believing you are fitter than others) result in greater duration of exercise and more positive self-ratings (Wasilenko et al., 2007). However, upwards social comparisons (believing you are less fit than others) result in increased exercise intensity, due to ambition to be like others, but does not improve mood (Plante et al., 2010). Individuals who exercise regularly are therefore likely to enjoy exercise for longer at lower intensities and feel better about themselves when they compare themselves to those who do not exercise, which may explain the association between exercise and mental health. Social media might reinforce the impact of social comparisons, as people may be more exposed to information about other people's fitness and exercise patterns.

7.2.4. Environment and Nature

Another possible link between exercise and improved mental health is that exercise makes people more likely to spend time outside in green or blue spaces, i.e. spaces with lots of vegetation or water. An association between nature and improved mental health outcomes has been established, although bias in the literature makes it hard to conclude about the strength of this relationship (Natural England, 2016; Lahart et al., 2019; Coventry et al., 2021). Despite this, NICE guidelines refer to the importance of making green and blue spaces accessible and appealing (NICE, 2009b). A twin study found that while access to green space was associated with lower depression scores, when genetics, physical activity

and socioeconomic status were controlled for, it did not have an impact on anxiety (Cohen-Cline et al., 2015).

Specific positive effects on mental health have been associated with so-called “green and blue exercise” compared to indoor exercise (Pretty et al., 2005; Thompson Coon et al., 2011; Thompson & Wilkie, 2021). One study found that outdoor exercise predicted reduced somatic anxiety, whereas indoor exercise predicted increased somatic anxiety, although they did not find a difference between indoor and outdoor exercise for general wellbeing (Lawton et al., 2017). However, some studies have found no relationship between physical activity and time in green spaces (Hillsdon et al., 2006; Maas et al., 2008), and others have found that access to green spaces may result in increased physical activity rather than the other way around (Bélanger et al., 2019; Van den Berg et al., 2019). More longitudinal research into the interaction between exercise, green space and mental health would be beneficial in establishing causal relationships.

There is also a large body of evidence concerning the particular benefits of cold-water swimming for mental and brain health. This is thought to result from the impact of the environment on physiology (e.g. cold-shock response and mammalian dive reflex), rather than exercise (Tipton et al., 2017; Speciale, 2020). Thus another mechanism by which exercise improves mental health is exposing people to environments that cause mentally beneficial physiological adaptations.

7.3. Psychological Mechanisms

Psychological mechanisms that may explain the effect of exercise on mental health include improved executive function, behavioural activation, self-efficacy, self-esteem, improved body relationship and distress tolerance.

7.3.1. Executive Function

It has been demonstrated that exercise results in improved brain health throughout the lifespan (Public Health England, 2018), and that this in turn improves executive functions such as problem solving, memory, attention and inhibition (Roig-Coll et al., 2020) and reduces the likelihood of older adults developing cognitive impairment (Sofi et al., 2011). Exercise has even been shown to be better than specific cognitive training for enhancing executive function (Roig-Coll et al., 2020).

Low mood and anxiety reduce cognitive capacity (Fossati et al., 2002; Shield et al., 2016), and cognitive therapy uses guided problem solving, attention control, and learning alternative perspectives as interventions. It has been suggested that depression may result from problem-solving deficits (Nezu, 1987). Exercise may therefore improve mental health by improving cognitive flexibility and ability to problem-solve emotional difficulties.

7.3.2. Behavioural Activation (BA)

BA is an important aspect of CBT for depression, and has been demonstrated to be effective as a standalone treatment (Jacobson et al., 1996). It involves increasing activity to create more opportunity for positive experiences of mastery, and less opportunity for rumination (Kanter et al., 2012). Exercise has been theorised to support mental health through distraction from ruminative concerns (Craft & Perna, 2004; Craft, 2005), and through mastery experiences and sense of purpose and achievement (Mason & Holt, 2012; Edmunds et al., 2013). It has therefore been proposed that exercise programmes create a good structure for BA, as they often involve specific training schedules, similar to the activity schedules and goal-setting used in BA therapy.

This suggests that exercise is a form of BA, but that other forms such as hobbies or creative activities would be as effective (Veale, 2008). Several studies have tried to compare exercise to other forms of BA, and have found no differences between the two on depression scores (Pentecost et al., 2015; Soucy et al., 2017; Nyström et al., 2017). This implies that exercise is purely a form of BA and does not add any other mental health

benefits. However, in the general population sport and exercise have been shown to have a stronger effect on mental health than physically inactive activities (Hamer et al., 2009; Hallgren et al. 2020). Thus in the general population at least, exercise does seem to have additional beneficial effects on mental health compared to other forms of activation, so BA cannot explain the entire effect of exercise on mental wellbeing.

7.3.3. Self-Efficacy

Self-efficacy is the degree to which someone believes they are capable of achieving certain tasks in life (Bandura, 1977). Exercise interventions have been shown to increase self-efficacy (Craft, 2005; Knapen et al., 2015; Carriedo et al., 2020). Carriedo et al. (2020) consider self-efficacy a component of psychological resilience, and find that exercise increases resilience. A review by Medrano-Ureña et al. (2020) found that while several studies show that fitness and self-efficacy are correlated and quality of life and self-efficacy are separately correlated, none so far have studied self-efficacy as a mediating factor between fitness and quality of life. This warrants further research to understand whether self-efficacy explains the impact of exercise on mental health.

7.3.4. Self-Esteem

While self-efficacy describes someone's beliefs about their capability, self-esteem describes their beliefs about their worth. This is likely impacted by self-efficacy, but also includes evaluations according to a person's own values, for example morality, loyalty, attractiveness or successfulness. Sonstroem & Morgan (1989) proposed that exercise improves self-esteem through physical work expenditure, physical self-efficacy, physical competence and physical acceptance. A more recent review of mechanisms explaining the relationship between physical activity and mental health found that the strongest evidence was for self-perception and self-esteem (Lubans et al., 2016).

Both studies allude to the importance of physical worth, which as discussed in the biological mechanisms section could be influenced by changes in body shape. However,

mental health improves with exercise regardless of changes in BMI (Sani et al., 2016), and a study focussing on educational, familial, social, and general self-esteem found that all of these increase with exercise, showing that increased self-esteem is not just about physical worth (Mousavi Gilani & Dashipour, 2017). This suggests that it is not actual shape, or even perception of size and shape that changes when people exercise, but instead the relationship individuals have with their bodies.

7.3.5. Distress Tolerance

A less-researched mechanism by which exercise could improve mental health is through distress tolerance. Asmundson et al. (2013) suggested that exercise may reduce sensitivity to internal stimuli associated with negative mood states such as anxiety. By becoming tolerant to sensations associated with distress, exercise may improve people's distress tolerance, which has been strongly implicated as a protective factor against a huge variety of mental health concerns (Zvolemky et al., 2011).

It is also likely that exercise increases tolerance (as well as perception) of pain and discomfort, which start to be perceived as natural and acceptable as individuals push themselves in pursuit of a goal. This distress tolerance to anxiety, pain and discomfort may translate to psychological experiences, increasing coping with regard to difficult emotions. As well as supporting mental health generally, this may also help individuals to engage in therapy (which often involves anxiety and opening up to emotional pain or discomfort), suggesting that exercise could be an effective offer for individuals seeking support form mental health services but struggling to engage in therapy, by providing a form of exposure therapy to the difficult experiences they are avoiding.

8. Conclusions:

8.1. Limitations of the evidence:

It is important to acknowledge that almost all of the reviews and meta-analyses cited have acknowledged a high degree of bias and low quality of research. In part this is because exercise and mental health are both difficult constructs to study. Both tend to rely on self-report, which is affected by social desirability and memory bias. When exercise is measured objectively using an accelerometer, adults record much lower levels of exercise than they self-report (Health Survey England, 2009). This calls into question the validity of evidence on exercise and mental health, which tends to use self-reported measures of exercise.

Additionally, even in randomised control trials, it is impossible to double-blind exercise, and as the mood-enhancing effects of exercise are widely discussed in popular culture, placebo effect cannot be controlled for. Another issue with the evidence is that the vast majority is from Western countries, with a growing body of evidence from East Asia. One study has found that a particular self-report measure of exercise is valid globally (Rosenbaum et al., 2020), but there are no cross-cultural studies of the impact of exercise on mental health. Conceptualisations of mental health and mental illness differ a great deal between cultures, so findings of current literature cannot be generalised globally.

There are limited longitudinal studies of the impact of exercise on mental health, making it difficult to draw conclusions with regards the long-term impact of exercise. However, Callaghan (2004) states that the methodological weaknesses in the study of exercise and mental health do not invalidate the argument that exercise is beneficial for improving the mental health of the majority of individuals of different ages, with different life experiences, and different mental health histories.

8.2. Exercise as a treatment for mental health difficulties

Evidence suggests that exercise is an effective intervention for mental health and wellbeing (Czosnek et al., 2016). As a result of this widely-accepted and well-evidenced

idea, academics have recommended that exercise should be used as a ‘first-line treatment’ for depression (Nahas & Sheikh, 2011), that exercise prescriptions should be routinely offered to individuals with mental health difficulties (Stanton et al., 2015), and that the benefits of exercise for physical and mental health should be explained to all mental health service users as part of standard care (Sharma et al., 2006).

As well as directly improving mental health itself, exercise may help people who are not ready to engage in psychological treatments for mental health difficulties by equipping them with certain cognitive and psychological abilities. Evidence suggests that exercise improves working memory, planning and attention, all of which are required to engage in psychological therapies. Depression and anxiety are both associated with impaired cognitive processes (Fossati et al., 2002; Shields et al., 2016; Mirza et al., 2017), which can be a barrier for seriously anxious or depressed individuals to engage in therapy.

Self-efficacy, which has been demonstrated to increase as a result of consistent exercise, has also been shown to be an important predictor of engagement with therapy (Delsignore et al. 2008). It is also possible that exercise may improve distress tolerance, which is important for therapies that involve engaging with difficult emotions and experiences.

It is therefore likely that exercise would be a beneficial first step in the treatment of mental health difficulties. As well as directly improving mood, it may improve ability to engage in psychological therapies by increasing cognitive capacity, self-efficacy, and distress tolerance.

8.3. Overcoming Barriers: Exercise as Part of Mental Health Care

Despite this body of evidence, when exercise referrals are made for individuals with mental health difficulties, their uptake is generally low (Crone et al., 2008). This is likely due to barriers which occur more commonly for individuals with mental health difficulties like low motivation, anxiety, lack of social support, and increased pain mediated by emotional

factors, as well as demographic variables including socioeconomic barriers, disability, or holding minority identities (Crabb et al., 2015).

As a result, the exercise intervention individuals with mental health difficulties would benefit from might look different to those provided to individuals with purely physical conditions. Activity scheduling, psychological pain management, motivational interviewing, and building social networks have all been suggested as important aspects of overcoming barriers to exercise for mental health service users (Crabb et al., 2015).

In a survey 93% of mental health staff said it was important to support service users to increase physical activity, but 74% said this would be difficult due to service user motivation and financial barriers (Crabb et al., 2015). However, clients are often not motivated to take medication, but this remains the dominant treatment (Netz, 2017). If exercise services were commissioned and staff were allocated time to support exercise interventions, this could overcome motivational and financial barriers. Mental health staff are also used to working with other issues of identity and intersectionality that have been found to impact exercise participation.

Dropout rates from exercise interventions are lower when they are run by highly-qualified staff such as physiotherapists or exercise psychologists (Stubbs et al., 2016). Mental health services would benefit from commissioning a specialist physiotherapist, exercise psychologist or physical trainer who works within the team and is supported by other staff. Currently physiotherapists receive little training on using psychological strategies to support rehabilitation (Annear et al., 2019), so additional mental health training in the techniques described above would be useful.

It is also important that any exercise or sport-based mental health intervention has designated safeguarding staff and referral pathways to specialist support (Faculty of Sport and Exercise Medicine, N.D.). While several charities currently fill the gap left by mental health services in providing these interventions, and many do an excellent job of assessing risk or signposting, these are rarely formal processes with direct referral pathways. By moving these services into mental health teams, these processes could be made much

clearer and safer. Sancassiani et al. (2018) explain that exercise programmes for psychosocial rehabilitation need to take place within mental health teams, with mental health practitioners who understand barriers to motivation, as well as the impact of previous exercise history and effort intensity experience.

8.4. Combined Exercise Psychology Interventions

While exercise programmes are shown to have value as an adjunct, or perhaps preparatory activity for other treatments, individuals with mental health difficulties may benefit from exercise that is actively integrated with psychological therapy. Several aspects of psychological therapy have been shown to support engagement with exercise, and some of the benefits of exercise on mental health appear to be amplified by opportunities to reflect.

One study found that while exercise on its own did not result in improved self-esteem, exercise followed by group counselling did (Hilyer & Mitchell, 1979). No similar research has been conducted since, making it unclear whether these results are reliable. If so, they infer that psychological mechanisms by which exercise supports mental health might result from reflections on exercise - for example, beliefs about overcoming adversity, resilience, and achieving goals. Psychological therapies using narrative approaches could support individuals to construct new, more helpful narratives based on exercise.

Additionally, support and psycho-education about exercise as a treatment for depression have been cited as crucial factors in making physical activity an effective treatment (Nyström et al., 2017). Therapists would be able to support this understanding by providing psycho-education about the likely mechanisms by which exercise improves mental health. This is reinforced by findings that physical activity is as effective as psychological therapy for treating common mental health disorders, so long as psychological approaches are incorporated into the design of the exercise programme (Thomas et al., 2020).

Such interventions were found to result in increased activity levels over time, thereby also contributing to improvements in physical health (which interacts with mental health, as well as being important to manage in its own right). This shows exercise to be a cost

effective mental health intervention, as it reduces the burden of both mental and physical illness simultaneously (Public Health England, 2018), and unlike pharmacological interventions does not result in side-effects (Netz, 2017).

However, so far there has been very little or no cost effectiveness analysis into the impact of exercise on mental health (Czosnek et al., 2016). The area of combined exercise psychology approaches therefore warrants much more research to confirm that a) psychological input increases engagement with exercise, b) psychological input alongside exercise improves outcomes more than exercise alone and c) the intervention is cost effective.

8.5. Requirements for further research

Before combined exercise psychology interventions can be researched further, a clear evidence and theory-based model for the intervention needs to be devised. To do this, the psychological mechanisms underlying the relationship between exercise and mental health need to be better understood. Currently there is a tendency to compare exercise to pharmacological treatments in terms of possible effects on the brain and body (Netz, 2017), which may reflect the dominance of the medical model as a way of approaching mental health. In order to design a psycho-social exercise intervention, it may be more helpful to compare the effects of exercise to psychological treatments in terms of the aspects of psychological wellbeing being targeted. These might include self-esteem, self-efficacy, body relationship, distress tolerance, emotional regulation, and sense of identity and belonging. Additionally, most research into barriers to engaging in exercise is qualitative and takes place at one time point. A longitudinal study of barriers and motivators for exercise would support the design of more effective exercise interventions.

In response to these gaps in the literature, and in order to inform potential future combined exercise psychology interventions, an exploratory analysis will be run on a series of survey responses from members of the general population who are increasing regular exercise. Individuals who are beginning or markedly increasing regular exercise (e.g. as part

of a training programme) will be recruited online and through sports or gym groups. They will complete online surveys at three time points: at the start of their new exercise regime, after three months, and after six months. The surveys will include measures of mental health and wellbeing, as well as specific psychological constructs that could underlie mental wellbeing (self-esteem, self-efficacy, body satisfaction, distress tolerance, and unconditional self-acceptance). Participants will record their frequency, duration and intensity of exercise, and some basic measures of physical health at each time point. The data will then be analysed to see whether any of the named psychological constructs mediate the relationship between exercise and mental wellbeing over time. It will also be analysed for predictors of exercise maintenance over time.

This information will allow for better understanding how psychological factors and exercise impact one another to result in mental health benefits. In turn, this should support an understanding of how the benefits of exercise can be maximised by using psychological principles to support engagement and to amplify the key psychological mechanisms affected by exercise.

References:

Adams, J. (2009). Understanding exercise dependence. *Journal of Contemporary Psychotherapy*, *39*(4), 231-240.

Akbar, L., Zuk, A. M., & Tsuji, L. J. (2020). Health and wellness impacts of traditional physical activity experiences on indigenous youth: A systematic review. *International journal of environmental research and public health*, *17*(21), 8275.

Aldana, S. G., Sutton, L. D., Jacobson, B. H., & Quirk, M. G. (1996). Relationships between leisure time physical activity and perceived stress. *Perceptual and Motor skills*, *82*(1), 315-321.

Alexandratos, K., Barnett, F., & Thomas, Y. (2012). The impact of exercise on the mental health and quality of life of people with severe mental illness: A critical review. *British Journal of Occupational Therapy*, *75*(2), 48-60.

American Psychiatric Association (2013). Diagnostic and statistical manual of mental disorders, Fifth Edition. *Am Psychiatric Assoc*, *21*, 591-643.

Andermo, S., Hallgren, M., Nguyen, T. T. D., Jonsson, S., Petersen, S., Friberg, M., Romqvist, A., Stubbs, B., & Elinder, L. S. (2020). School-related physical activity interventions and mental health among children: a systematic review and meta-analysis. *Sports medicine-open*, *6*(1), 1-27.

Annear, A., Sole, G., & Devan, H. (2019). What are the current practices of sports physiotherapists in integrating psychological strategies during athletes' return-to-play

rehabilitation? Mixed methods systematic review. *Physical Therapy in Sport*, *38*, 96-105.

Antonelli, M., & Kushner, I. (2017). It's time to redefine inflammation. *The FASEB Journal*, *31*(5), 1787-1791.

Asmundson, G. J., Fetzner, M. G., DeBoer, L. B., Powers, M. B., Otto, M. W., & Smits, J. A. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depression and anxiety*, *30*(4), 362-373.

Awick, E. A., Ehlers, D. K., Aguiñaga, S., Daugherty, A. M., Kramer, A. F., & McAuley, E. (2017). Effects of a randomized exercise trial on physical activity, psychological distress and quality of life in older adults. *General hospital psychiatry*, *49*, 44-50.

Bakhshayesh, H., Bahmani, F., & Kamali, M. (2013). Comparative of mental health disabled people of athletic and non-athletic. *Iranian Journal of War and Public Health*, *5*(1), 22-26.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191.

Beavers, K. M., Brinkley, T. E., & Nicklas, B. J. (2010). Effect of exercise training on chronic inflammation. *Clinica chimica acta*, *411*(11-12), 785-793.

Bélanger, M., Gallant, F., Doré, I., O'Loughlin, J. L., Sylvestre, M. P., Abi Nader, P., Larouche, R., Gunnell, K., & Sabiston, C. M. (2019). Physical activity mediates the relationship between outdoor time and mental health. *Preventive medicine reports*, *16*, 101006.

Bernard, P., Doré, I., Romain, A. J., Hains-Monfette, G., Kingsbury, C., & Sabiston, C. (2018). Dose response association of objective physical activity with mental health in a representative national sample of adults: A cross-sectional study. *PloS one*, *13*(10), e0204682.

Blake, H. (2012). Physical activity and exercise in the treatment of depression. *Frontiers in Psychiatry*, *3*, 106.

Blomstrand, E., Perrett, D., Parry-Billings, M., & Newsholme, E. A. (1989). Effect of sustained exercise on plasma amino acid concentrations and on 5-hydroxytryptamine metabolism in six different brain regions in the rat. *Acta Physiologica Scandinavica*, *136*(3), 473-482.

Bondár, R. Z., Di Fronso, S., Bortoli, L., Robazza, C., Metsios, G. S., & Bertollo, M. (2020). The effects of physical activity or sport-based interventions on psychological factors in adults with intellectual disabilities: A systematic review. *Journal of Intellectual Disability Research*, *64*(2), 69-92.

Bonsaksen, T., & Lerdal, A. (2012). Relationships between physical activity, symptoms and quality of life among inpatients with severe mental illness. *British Journal of Occupational Therapy*, *75*(2), 69-75.

Borland, R. L., Cameron, L. A., Tonge, B. J., & Gray, K. M. (2021). Effects of physical activity on behaviour and emotional problems, mental health and psychosocial wellbeing in children and adolescents with intellectual disability: A systematic review. *Journal of Applied Research in Intellectual Disabilities*.

Broocks, A., Bandelow, B., Pekrun, G., George, A., Meyer, T., Bartmann, U., Hillmer-Vogel, U., & Rüther, E. (1998). Comparison of aerobic exercise, clomipramine, and placebo in the treatment of panic disorder. *American Journal of Psychiatry*, *155*(5), 603-609.

Brooks, F., Magnusson, J., Klemera, E., Chester, K., Spencer, N., & Smeeton, N. (2015). HBSC England National Report: Health behaviour in school-aged children (HBSC): World Health Organization collaborative cross national study.

Brown, K. N., Wengreen, H. J., & Beals, K. A. (2014). Knowledge of the female athlete triad, and prevalence of triad risk factors among female high school athletes and their coaches. *Journal of pediatric and adolescent gynecology*, *27*(5), 278-282.

Bunketorp Käll, L., Malmgren, H., Olsson, E., Lindén, T., & Nilsson, M. (2015). Effects of a curricular physical activity intervention on children's school performance, wellness, and brain development. *Journal of school health*, *85*(10), 704-713.

Burke, L. M., Close, G. L., Lundy, B., Mooses, M., Morton, J. P., & Tenforde, A. S. (2018). Relative energy deficiency in sport in male athletes: a commentary on its presentation among selected groups of male athletes. *International journal of sport nutrition and exercise metabolism*, *28*(4), 364-374.

Cacioppo, J. T., & Patrick, W. (2008). *Loneliness: Human nature and the need for social connection.* WW Norton & Company.

Callaghan, P. (2004). Exercise: a neglected intervention in mental health care?. *Journal of psychiatric and mental health nursing*, *11*(4), 476-483.

Callaghan, P., Khalil, E., Morres, I., & Carter, T. (2011). Pragmatic randomised controlled trial of preferred intensity exercise in women living with depression. *BMC public health*, *11*(1), 1-8.

Callow, D. D., Arnold-Nedimala, N. A., Jordan, L. S., Pena, G. S., Won, J., Woodard, J. L., & Smith, J. C. (2020). The mental health benefits of physical activity in older adults survive the COVID-19 pandemic. *The American Journal of Geriatric Psychiatry*, *28*(10), 1046-1057.

Camero, M., Hobbs, C., Stringer, M., Branscum, P., & Taylor, E. L. (2012). A review of physical activity interventions on determinants of mental health in children and adolescents. *International Journal of Mental Health Promotion*, *14*(4), 196-206.

Campbell, S., & MacQueen, G. (2004). The role of the hippocampus in the pathophysiology of major depression. *Journal of Psychiatry and Neuroscience*, *29*(6), 417-426.

Carriedo, A., Cecchini, J. A., Fernandez-Rio, J., & Méndez-Giménez, A. (2020). COVID-19, psychological well-being and physical activity levels in older adults during the nationwide lockdown in Spain. *The American journal of geriatric psychiatry*, *28*(11), 1146-1155.

Chu, A. H. Y., Koh, D., Moy, F. M., & Müller-Riemenschneider, F. (2014). Do workplace physical activity interventions improve mental health outcomes?. *Occupational Medicine*, *64*(4), 235-245.

Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *J Epidemiol Community Health*, *69*(6), 523-529.

Cole, F. (2010). Physical activity for its mental health benefits: conceptualising participation within the Model of Human Occupation. *British Journal of Occupational Therapy,* 73(12), 607-615.

Conn, V. S. (2010). Anxiety outcomes after physical activity interventions: meta-analysis findings. *Nursing research*, *59*(3), 224.

Cook, B. J., & Hausenblas, H. A. (2011). Eating disorder-specific health-related quality of life and exercise in college females. *Quality of Life Research*, *20*(9), 1385-1390.

Cooney, G. M., Dwan, K., Greig, C. A., Lawlor, D. A., Rimer, J., Waugh, F. R., McMurdo, M., & Mead, G. E. (2013). Exercise for depression. *Cochrane database of systematic reviews*, (9).

Coventry, P. A., Brown, J. E., Pervin, J., Brabyn, S., Pateman, R., Breedvelt, J., Gilbody, S., Stancliffe, R., McEachan, R., & White, P. L. (2021). Nature-based outdoor activities for mental and physical health: Systematic review and meta-analysis. *SSM-population health*, *16*, 100934.

Crabb, J., Milne, L., Conway, L., Fulton, M., Dewar, C., McHugh, B., Speed, L., Tourish, P., & McKinnon, M. (2015). A population-based survey of barriers and enablers to physical activity in people using, and working in a mental health service in Scotland. *International Journal of Mental Health Promotion, 17*(4), 234-246.

Craft, B. B., Carroll, H. A., & Lustyk, M. K. B. (2014). Gender differences in exercise habits and quality of life reports: assessing the moderating effects of reasons for exercise. *International journal of liberal arts and social science*, *2*(5), 65.

Craft, L. L. (2005). Exercise and clinical depression: examining two psychological mechanisms. *Psychology of sport and exercise*, *6*(2), 151-171.

Craft, L. L., & Perna, F. M. (2004). The benefits of exercise for the clinically depressed. *Primary care companion to the Journal of clinical psychiatry*, *6*(3), 104.

Crone, D., Johnston, L. H., Gidlow, C., Henley, C., & James, D. V. (2008). Uptake and participation in physical activity referral schemes in the UK: an investigation of patients referred with mental health problems. *Issues in mental health nursing*, *29*(10), 1088-1097.

Czosnek, L., Lederman, O., Cormie, P., Zopf, E., Stubbs, B., & Rosenbaum, S. (2019). Health benefits, safety and cost of physical activity interventions for mental health conditions: A meta-review to inform translation efforts. *Mental Health and Physical Activity*, *16*, 140-151.

Da Silva, M. A., Singh-Manoux, A., Brunner, E. J., Kaffashian, S., Shipley, M. J., Kivimäki, M., & Nabi, H. (2012). Bidirectional association between physical activity and symptoms of anxiety and depression: the Whitehall II study. *European journal of epidemiology*, *27*(7), 537-546.

Danielsson, L., Noras, A. M., Waern, M., & Carlsson, J. (2013). Exercise in the treatment of major depression: a systematic review grading the quality of evidence. *Physiotherapy theory and practice*, *29*(8), 573-585.

Davis, C. (2000). Exercise abuse. *International journal of sport psychology*.

De Sousa, R. A. L., Rocha-Dias, I., de Oliveira, L. R. S., Improta-Caria, A. C., Monteiro-Junior, R. S., & Cassilhas, R. C. (2021). Molecular mechanisms of physical exercise on depression in the elderly: a systematic review. *Molecular Biology Reports*, *48*(4), 3853-3862.

de Souto Barreto, P., Morley, J. E., Chodzko-Zajko, W., Pitkala, K. H., Weening-Djiksterhuis, E., Rodriguez-Mañas, L., Barbagallo, M., Rosendahl, E., Sinclair, A., Landi, F., & Izquierdo, M. (2016). Recommendations on physical activity and exercise for older adults living in long-term care facilities: a taskforce report. *Journal of the American Medical Directors Association*, *17*(5), 381-392.

Delsignore, A., Carraro, G., Mathier, F., Znoj, H., & Schnyder, U. (2008). Perceived responsibility for change as an outcome predictor in cognitive-behavioural group therapy. *British Journal of Clinical Psychology*, *47*(3), 281-293.

Devon Partnership Trust (2019). *New Sole2Soul exercise project.* Retrieved from: https://www.dpt.nhs.uk/news/new-sole2soul-exercise-project

Dietrich, A., & McDaniel, W. F. (2004). Endocannabinoids and exercise. *British journal of sports medicine*, *38*(5), 536-541.

Dishman, R. K., & O'Connor, P. J. (2009). Lessons in exercise neurobiology: the case of endorphins. *Mental Health and Physical Activity*, *2*(1), 4-9.

Dorling, H., Blervacq, J., & Gidron, Y. (2018). Effects of psychological inoculation versus health education on physical activity: Two randomized controlled studies. *Journal of Physical Activity and Health*, *15*(4), 295-302.

Dunn, A. L., Trivedi, M. H., Kampert, J. B., Clark, C. G., & Chambliss, H. O. (2005). Exercise treatment for depression: efficacy and dose response. *American journal of preventive medicine*, *28*(1), 1-8.

Eddolls, W. T., McNarry, M. A., Lester, L., Winn, C. O., Stratton, G., & Mackintosh, K. A. (2018). The association between physical activity, fitness and body mass index on mental well-being and quality of life in adolescents. *Quality of Life Research*, 27(9), 2313-2320.

Edmunds, S., Biggs, H., Goldie, I., Cyhlarova, E., Lawton-Smith, S., & McCulloch, A. (2013). Let's get physical: The impact of physical activity on wellbeing. *Mental Health Foundation*, *38*, 1-47.

Edwards, G., Grubb, B., Power, A., & Serle, N. (2015). *Moving the goal posts: poverty and access to sport for young people.*

Ekkekakis, P. (2015). Honey, I shrunk the pooled SMD! Guide to critical appraisal of systematic reviews and meta-analyses using the Cochrane review on exercise for depression as example. *Mental health and physical activity*, *8*, 21-36.

Ekkekakis, P., Parfitt, G., & Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities. *Sports medicine*, *41*(8), 641-671.

Elliott-Sale, K. J., Tenforde, A. S., Parziale, A. L., Holtzman, B., & Ackerman, K. E. (2018). Endocrine effects of relative energy deficiency in sport. *International Journal of Sport Nutrition and Exercise Metabolism*, *28*(4), 335-349.

Faculty of Sport and Exercise Medicine (N.D.). *The Role of Physical Activity and Sport in Mental Health: A Faculty of Sport and Exercise Medicine UK Joint Position Statement with the Sports and Exercise Psychiatry Special Interest Group of the Royal College of Psychiatrists.* Retrieved from: https://www.fsem.ac.uk/position_statement/the-role-of-physical-activity-and-sport-in-mental-health/

Farholm, A., & Sørensen, M. (2016). Motivation for physical activity and exercise in severe mental illness: A systematic review of cross-sectional studies*. International journal of mental health nursing,* 25(2), 116-126.

Farioli-Vecchioli, S., Sacchetti, S., di Robilant, N. V., & Cutuli, D. (2018). The role of physical exercise and omega-3 fatty acids in depressive illness in the elderly. *Current neuropharmacology*, *16*(3), 308-326.

Farris, S. G., & Abrantes, A. M. (2020). Mental health benefits from lifestyle physical activity interventions: A systematic review. *Bulletin of the Menninger Clinic,* 84(4), 337-372.

Felez-Nobrega, M., Bort-Roig, J., Ma, R., Romano, E., Faires, M., Stubbs, B., Stamatakis, E., Olaya, B., Haro, J.M., Smith, L. and Shin, J.I., Kim, M.S., & Koyanagi, A. (2021). Light-intensity physical activity and mental ill health: a systematic review of observational studies in the general population. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 1-15.

Festinger, L. (1954). A theory of social comparison processes. *Human relations*, *7*(2), 117-140.

Firth, J., Rosenbaum, S., Stubbs, B., Gorczynski, P., Yung, A. R., & Vancampfort, D. (2016). Motivating factors and barriers towards exercise in severe mental illness: a systematic review and meta-analysis. *Psychological medicine*, *46*(14), 2869-2881.

Fitzgerald, H., & Bailey, R. (2009). Disability and youth sport. London: Routledge.

Fluetsch, N., Levy, C., & Tallon, L. (2019). The relationship of physical activity to mental health: A 2015 behavioral risk factor surveillance system data analysis. *Journal of Affective Disorders*, *253*, 96-101.

Ford, E. S., Merritt, R. K., Heath, G. W., Powell, K. E., Washburn, R. A., Kriska, A., & Haile, G. (1991). Physical activity behaviors in lower and higher socioeconomic status populations. *American journal of epidemiology*, *133*(12), 1246-1256.

Fossati, P., Ergis, A. M., & Allilaire, J. F. (2002). Executive functioning in unipolar depression: a review. *L'encéphale*, *28*(2), 97-107.

Frederick, C. J., Havitz, M. E., & Shaw, S. M. (1994). Social comparison in aerobic exercise classes propositions for analyzing motives and participation. *Leisure Sciences*, *16*(3), 161-176.

Freimuth, M., Moniz, S., & Kim, S. R. (2011). Clarifying exercise addiction: Differential diagnosis, co-occurring disorders, and phases of addiction. *International journal of environmental research and public health*, *8*(10), 4069-4081.

Fuss, J., Steinle, J., Bindila, L., Auer, M. K., Kirchherr, H., Lutz, B., & Gass, P. (2015). A runner's high depends on cannabinoid receptors in mice. *Proceedings of the National Academy of Sciences*, *112*(42), 13105-13108.

Gapin, J., Etnier, J. L., & Tucker, D. (2009). The relationship between frontal brain asymmetry and exercise addiction. *Journal of Psychophysiology*, *23*(3), 135-142.

Geda, Y. E., Roberts, R. O., Knopman, D. S., Christianson, T. J., Pankratz, V. S., Ivnik, R. J., Boeve, B.F., Tangalos, E.G., Petersen, R.C. & Rocca, W. A. (2010). Physical exercise, aging, and mild cognitive impairment: a population-based study. *Archives of neurology*, *67*(1), 80-86.

Geneen, L. J., Moore, R. A., Clarke, C., Martin, D., Colvin, L. A., & Smith, B. H. (2017). Physical activity and exercise for chronic pain in adults: an overview of Cochrane Reviews. Cochrane Database of Systematic Reviews, (4).

Glavin, E. E., Matthew, J., & Spaeth, A. M. (2021). Gender differences in the relationship between exercise, sleep, and mood in young adults. *Health Education & Behavior*.

Goodwin, R. D. (2003). Association between physical activity and mental disorders among adults in the United States. *Preventive medicine*, *36*(6), 698-703.

Gorczynski, P., & Faulkner, G. (2010). Exercise therapy for schizophrenia. *Cochrane database of systematic reviews*, (5).

Grasdalsmoen, M., Eriksen, H. R., Lønning, K. J., & Sivertsen, B. (2020). Physical exercise, mental health problems, and suicide attempts in university students. *BMC psychiatry*, 20(1), 1-11.

Greenwood, B. N., & Fleshner, M. (2008). Exercise, learned helplessness, and the stress-resistant brain. *Neuromolecular medicine*, *10*(2), 81-98.

Guddal, M. H., Stensland, S. Ø., Småstuen, M. C., Johnsen, M. B., Zwart, J. A., & Storheim, K. (2019). Physical activity and sport participation among adolescents: associations with mental health in different age groups. Results from the Young-HUNT study: a cross-sectional survey. *BMJ open*, *9*(9), e028555.

Guo, Y., Hong, Y. A., Cai, W., Li, L., Hao, Y., Qiao, J., Xu, Z., Zhang, H., Zeng, C., Liu, C., Li, Y., Zhu, M., Zeng, Y., & Penedo, F. J. (2020). Effect of a weChat-based intervention (Run4Love) on depressive symptoms among people living with HIV in China: randomized controlled trial. Journal of medical Internet research, 22(2), e16715.

Hagell, A. (2016). The connections between young people's mental health and sport participation: Scoping the evidence. *Association for Young People's Health*.

Hale, G. E., Colquhoun, L., Lancastle, D., Lewis, N., & Tyson, P. J. (2021). Physical activity interventions for the mental health and wellbeing of adolescents–a systematic review. *Child and Adolescent Mental Health*, *26*(4), 357-368.

Hallgren, M., Nguyen, T.T.D., Owen, N., Stubbs, B., Vancampfort, D., Lundin, A., Dunstan, D., Bellocco, R., & Lagerros, Y. T. (2020). Cross-sectional and prospective relationships of passive and mentally active sedentary behaviours and physical activity with depression. *The British Journal of Psychiatry*, *217*(2), 413-419.

Halliday, A. J., Kern, M. L., & Turnbull, D. A. (2019). Can physical activity help explain the gender gap in adolescent mental health? A cross-sectional exploration. *Mental Health and Physical Activity*, 16, 8-18.

Hamer, M., Stamatakis, E., & Steptoe, A. (2009). Dose-response relationship between physical activity and mental health: the Scottish Health Survey. *British journal of sports medicine*, *43*(14), 1111-1114.

Hansen, C. J., Stevens, L. C., & Coast, J. R. (2001). Exercise duration and mood state: How much is enough to feel better?. *Health Psychology*, *20*(4), 267.

Harada, K., Masumoto, K., & Kondo, N. (2019). Exercising alone or exercising with others and mental health among middle-aged and older adults: longitudinal analysis of cross-lagged and simultaneous effects. *Journal of Physical Activity and Health,* 16(7), 556-564.

Harber, V. J., & Sutton, J. R. (1984). Endorphins and exercise. *Sports Medicine*, *1*(2), 154-171.

Harland, J., White, M., Drinkwater, C., Chinn, D., Farr, L., & Howel, D. (1999). The Newcastle exercise project: a randomised controlled trial of methods to promote physical activity in primary care. *BMJ*, *319*(7213), 828-832.

Harris, M. A. (2018). The relationship between physical inactivity and mental wellbeing: Findings from a gamification-based community-wide physical activity intervention. *Health psychology open*, *5*(1).

Haslam, S. A., Fransen, K., & Boen, F. (2020). *The new psychology of sport and exercise: The social identity approach*. Sage.

Hausenblas, H. A., & Downs, D. S. (2002). How much is too much? The development and validation of the exercise dependence scale. *Psychology and health*, *17*(4), 387-404.

Hausenblas, H. A., Brewer, B. W., & Van Raalte, J. L. (2004). Self-presentation and exercise. *Journal of applied sport psychology*, *16*(1), 3-18.

Health Survey England (2009). *Health Survey for England - 2008: Physical activity and fitness.* Retrieved from: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/health-survey-for-england-2008-physical-activity-and-fitness

Hegberg, N. J., Hayes, J. P., & Hayes, S. M. (2019). Exercise intervention in PTSD: A narrative review and rationale for implementation. *Frontiers in psychiatry*, *10*, 133.

Heinze, K., Cumming, J., Dosanjh, A., Palin, S., Poulton, S., Bagshaw, A. P., & Broome, M. R. (2021). Neurobiological evidence of longer-term physical activity interventions on mental health outcomes and cognition in young people: A systematic review of randomised controlled trials. *Neuroscience & Biobehavioral Reviews*, *120*, 431-441.

Henning, M. A., Park, T. J., Moir, F., Krägeloh, C., Mysko, C., Hobson, J., & Webster, C. (2018). Integrating mindfulness and physical exercises for medical students: A systematic review. *OBM Integrative and Complementary Medicine*, *3*(4), 1-1.

Herting, M. M., & Chu, X. (2017). Exercise, cognition, and the adolescent brain. *Birth defects research*, *109*(20), 1672-1679.

Hillsdon, M., Panter, J., Foster, C., & Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. *Public health*, *120*(12), 1127-1132.

Hilyer, J. C., & Mitchell, W. (1979). Effect of systematic physical fitness training combined with counseling on the self-concept of college students. *Journal of Counseling Psychology,* 26(5), 427.

Hoffmann, T. C., Maher, C. G., Briffa, T., Sherrington, C., Bennell, K., Alison, J., Singh, M. F., & Glasziou, P. P. (2016). Prescribing exercise interventions for patients with chronic conditions. *Canadian Medical Association journal*, *188*(7), 510–518.

Hrafnkelsdottir, S. M., Brychta, R. J., Rognvaldsdottir, V., Gestsdottir, S., Chen, K. Y., Johannsson, E., Guðmundsdottir, S.L., & Arngrimsson, S. A. (2018). Less screen time and more frequent vigorous physical activity is associated with lower risk of reporting negative mental health symptoms among Icelandic adolescents. *PloS one*, *13*(4).

Huang, C. J., Webb, H. E., Zourdos, M. C., & Acevedo, E. O. (2013). Cardiovascular reactivity, stress, and physical activity. *Frontiers in physiology*, *4*, 314.

Hubbs, A., Doyle, E. I., Bowden, R. G., & Doyle, R. D. (2012). Relationships among self-esteem, stress, and physical activity in college students. *Psychological reports*, *110*(2), 469-474.

Hynes, J. (2010). Changing lives through sport: the story of the Positive Mental Attitude Sports Foundation Trust. *Advances in Dual Diagnosis,* 3(1), 26-31.

Ibeneme, S. C., Uwakwe, V. C., Myezwa, H., Irem, F. O., Ezenwankwo, F. E., Ajidahun, T. A., Ezuma, A.D., Okonkwo, U.P., & Fortwengel, G. (2020). Effectiveness of Exercise Training on Mental Health, Physical Activity Level and Social Participation in People Living with HIV/AIDS: A Systematic Review and Meta-Analysis.

iCope Camden and Islington Psychological Therapies Service (2021). *New IAPT pilot aims to help service users 'Move more, feel better'.* Retrieved from: https://www.candi.nhs.uk/sites/default/files/211012%20IAPT%20flyer.pdf

Jacobson, N. S., Dobson, K. S., Truax, P. A., Addis, M. E., Koerner, K., Gollan, J. K., Gortner, E., & Prince, S. E. (1996). A component analysis of cognitive-behavioral treatment for depression. *Journal of consulting and clinical psychology*, *64*(2), 295.

Johnson, N. A., Ewald, B., Plotnikoff, R. C., Stacey, F. G., Brown, W. J., Jones, M., Holliday, E.G. & James, E. L. (2018). Predictors of adherence to a physical activity counseling intervention delivered by exercise physiologists: secondary analysis of the NewCOACH trial data. *Patient preference and adherence*, *12*, 2537.

Johnston, O., Reilly, J., & Kremer, J. (2011). Excessive exercise: From quantitative categorisation to a qualitative continuum approach. *European Eating Disorders Review*, *19*(3), 237-248.

Jones, B. A., Arcelus, J., Bouman, W. P., & Haycraft, E. (2017). Sport and transgender people: a systematic review of the literature relating to sport participation and competitive sport policies. *Sports Medicine*, *47*(4), 701-716.

Kang, K. D., Bae, S., Kim, H. J., Hwang, I. G., Kim, S. M., & Han, D. H. (2017). The relationship between physical activity intensity and mental health status in patients with breast cancer. Journal of Korean Medical Science, 32(8), 1345-1350.

Kanning, M., & Schlicht, W. (2010). Be active and become happy: an ecological momentary assessment of physical activity and mood. *Journal of Sport and Exercise Psychology*, *32*(2), 253-261.

Kanter, J. W., Puspitasari, A. J., Santos, M. M., & Nagy, G. A. (2012). Behavioural activation: history, evidence and promise. *The British Journal of Psychiatry*, *200*(5), 361-363.

Kelly, L. A., Reilly, J. J., Fisher, A., Montgomery, C., Williamson, A., McColl, J. H., Paton, J.Y.,
& Grant, S. (2006). Effect of socioeconomic status on objectively measured physical activity. *Archives of disease in childhood*, *91*(1), 35-38.

Kelly, M. C., Rae, G. C., Walker, D., Partington, S., Dodd-Reynolds, C. J., & Caplan, N. (2017). Retrospective cohort study of the South Tyneside Exercise Referral Scheme 2009–14: predictors of dropout and barriers to adherence. *Journal of Public Health*, *39*(4), e257-e264.

Kim, J., Kim, J., & Han, A. (2020). The impact of leisure time physical activity on mental health and health perception among people with cancer. Health Promotion Perspectives, 10(2), 116.

Kim, Y. S., Park, Y. S., Allegrante, J. P., Marks, R., Ok, H., Cho, K. O., & Garber, C. E. (2012). Relationship between physical activity and general mental health. *Preventive medicine*, *55*(5), 458-463.

Kinsella, S. (2016). Social prescribing: a review of the evidence. *SCIE Social Care Online.*

Knapen, J., Vancampfort, D., Moriën, Y., & Marchal, Y. (2015). Exercise therapy improves both mental and physical health in patients with major depression. *Disability and rehabilitation*, *37*(16), 1490-1495.

Korman, N. H., Shah, S., Suetani, S., Kendall, K., Rosenbaum, S., Dark, F., Nadareishvili, K., & Siskind, D. (2018). Evaluating the feasibility of a pilot exercise intervention implemented within a residential rehabilitation unit for people with severe mental illness: GO HEART:(Group Occupational Health Exercise and Rehabilitation Treatment). *Frontiers in psychiatry*, *9*, 343.

Krebs, S., Baaken, A., Wurst, R., Goehner, W., & Fuchs, R. (2019). Effects of a worksite group intervention to promote physical activity and health: The role of psychological coaching. *Applied Psychology: Health and Wellbeing*, *11*(3), 584-605.

Kvam, S., Kleppe, C. L., Nordhus, I. H., & Hovland, A. (2016). Exercise as a treatment for depression: a meta-analysis. *Journal of affective disorders*, *202*, 67-86.

Lahart, I., Darcy, P., Gidlow, C., & Calogiuri, G. (2019). The effects of green exercise on physical and mental wellbeing: A systematic review. *International journal of environmental research and public health*, *16*(8), 1352.

Larson, E. B., Wang, L. I., Bowen, J. D., McCormick, W. C., Teri, L., Crane, P., & Kukull, W. (2006). Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. *Annals of internal medicine*, *144*(2), 73-81.

Lawton, E., Brymer, E., Clough, P., & Denovan, A. (2017). The relationship between the physical activity environment, nature relatedness, anxiety, and the psychological well-being benefits of regular exercisers. *Frontiers in psychology*, *8*, 1058.

LeBouthillier, D. M., & Asmundson, G. J. (2017). The efficacy of aerobic exercise and resistance training as transdiagnostic interventions for anxiety-related disorders and constructs: A randomized controlled trial. *Journal of anxiety disorders*, *52*, 43-52.

Lee, B. H., & Kim, Y. K. (2010). The roles of BDNF in the pathophysiology of major depression and in antidepressant treatment. *Psychiatry investigation*, *7*(4), 231.

Leech, C., Harrison, R. & Timpson, H. (2018). An exploration of the social value and impact of community projects delivered by Widnes Vikings Sports Foundation. *PHI, Liverpool John Moores University*.

Levine, M. D., Marcus, M. D., & Moulton, P. (1996). Exercise in the treatment of binge eating disorder. *International Journal of Eating Disorders*, *19*(2), 171-177.

Lichtenstein, M. B., Larsen, K. S., Christiansen, E., Støving, R. K., & Bredahl, T. V. G. (2014). Exercise addiction in team sport and individual sport: Prevalences and validation of the exercise addiction inventory. *Addiction Research & Theory*, *22*(5), 431-437.

Liu, Z., Hsu, F. C., Trombetti, A., King, A. C., Liu, C. K., Manini, T. M., Fielding, R.A., Pahor, M., Newman, A.B., Kritchevsky, S., & Gill, T. M. (2018). Effect of 24-month physical activity on cognitive frailty and the role of inflammation: the LIFE randomized clinical trial. *BMC medicine*, *16*(1), 1-10.

Logue, D., Madigan, S. M., Delahunt, E., Heinen, M., Mc Donnell, S. J., & Corish, C. A. (2018). Low energy availability in athletes: a review of prevalence, dietary patterns, physiological health, and sports performance. *Sports Medicine*, *48*(1), 73-96.

Long, B. C., & Flood, K. R. (1993). Coping with work stress: Psychological benefits of exercise. *Work & Stress*, *7*(2), 109-119.

Loprinzi, P. D., & Cardinal, B. J. (2011). Association between objectively-measured physical activity and sleep, NHANES 2005–2006. *Mental Health and Physical Activity*, *4*(2), 65-69.

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. Pediatrics, 138(3).

Maas, J., Verheij, R. A., Spreeuwenberg, P., & Groenewegen, P. P. (2008). Physical activity as a possible mechanism behind the relationship between green space and health: a multilevel analysis. *BMC public health*, *8*(1), 1-13.

Maher, C., Ferguson, M., Vandelanotte, C., Plotnikoff, R., De Bourdeaudhuij, I., Thomas, S., Nelson-Field, K. & Olds, T. (2015). A web-based, social networking physical activity intervention for insufficiently active adults delivered via Facebook app: randomized controlled trial. Journal of medical Internet research, 17(7), e4086.

Markoff, R. A., Ryan, P. A. U. L., & Young, T. (1982). Endorphins and mood changes in long-distance running. *Medicine and science in sports and exercise*, *14*(1), 11-15.

Marques, A., Marconcin, P., Werneck, A. O., Ferrari, G., Gouveia, É. R., Kliegel, M., Peralta, M., & Ihle, A. (2021). Bidirectional Association between Physical Activity and Dopamine Across Adulthood—A Systematic Review. *Brain sciences*, *11*(7), 829.

Martinsen, M., & Sundgot-Borgen, J. (2013). Higher prevalence of eating disorders among adolescent elite athletes than controls. *Med Sci Sports Exerc*, *45*(6), 1188-1197.

Mason, O. J., & Holt, R. (2012). Mental health and physical activity interventions: a review of the qualitative literature. *Journal of Mental Health*, *21*(3), 274-284.

McNamee, J., Timken, G. L., Coste, S. C., Tompkins, T. L., & Peterson, J. (2017). Adolescent girls' physical activity, fitness and psychological well-being during a health club physical education approach. *European Physical Education Review*, 23(4), 517-533.

Medrano-Ureña, M. D. R., Ortega-Ruiz, R., & Benítez-Sillero, J. D. D. (2020). Physical fitness, exercise self-efficacy, and quality of life in adulthood: a systematic review. *International Journal of Environmental Research and Public Health*, *17*(17), 6343.

Milne-Ives, M., Lam, C., De Cock, C., Van Velthoven, M. H., & Meinert, E. (2020). Mobile apps for health behavior change in physical activity, diet, drug and alcohol use, and mental health: systematic review. JMIR mHealth and uHealth, 8(3), e17046.

Mirza, S. S., Ikram, M. A., Bos, D., Mihaescu, R., Hofman, A., & Tiemeier, H. (2017). Mild cognitive impairment and risk of depression and anxiety: A population-based study. *Alzheimer's & Dementia*, *13*(2), 130-139.

Mond, J. M., Hay, P. J., Rodgers, B., Owen, C., & Beumont, P. J. V. (2004). Relationships between exercise behaviour, eating-disordered behaviour and quality of life in a community sample of women: when is exercise 'excessive'?. *European Eating*

Disorders Review: The Professional Journal of the Eating Disorders Association, *12*(4), 265-272.

Morgan, F., Battersby, A., Weightman, A. L., Searchfield, L., Turley, R., Morgan, H., Jagroo, J., & Ellis, S. (2016). Adherence to exercise referral schemes by participants–what do providers and commissioners need to know? A systematic review of barriers and facilitators. *BMC public health*, *16*(1), 1-11.

Morgan, P. (2010). 'Get Up. Stand Up.' Riding to resilience on a surfboard. *Child and Family Social Work,* 15(1), 56-65.

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., Meyer, N., Sherman, R., Steffen, K., Budgett, R. & Ljungqvist, A. (2014). The IOC consensus statement: beyond the female athlete triad—relative energy deficiency in sport (RED-S). *British journal of sports medicine*, *48*(7), 491-497.

Mousavi Gilani, S. R., & Dashipour, A. (2017). The effects of physical activity on self-esteem: A comparative study. *International Journal of High Risk Behaviors and Addiction*, *6*(1).

Murri, M. B., Amore, M., Menchetti, M., Toni, G., Neviani, F., Cerri, M., Rocchi, M.B.L., Zocchi, D., Bagnoli, L., Tam, E. and Buffa, A., Ferrara S., Neri, M., Alexopoulos, G.S., & Zanetidou, S. (2015). Physical exercise for late-life major depression. *The British Journal of Psychiatry*, *207*(3), 235-242.

Nahas, R., & Sheikh, O. (2011). Complementary and alternative medicine for the treatment of major depressive disorder. *Canadian Family Physician*, *57*(6), 659-663.

National Institute for Health and Care Excellence. (2009a). *Depression in Adults: Recognition and Management* (Clinical Guideline CG90). Retrieved from https://www.nice.org.uk/guidance/cg90

National Institute for Health and Care Excellence. (2009b). *Physical activity and the environment.* (NICE Guideline NG90). Retrieved from https://www.nice.org.uk/guidance/ng90

National Institute for Health and Care Excellence. (2014). *Physical activity: exercise referral schemes* (Public Health Guideline PH54). Retrieved from https://www.nice.org.uk/guidance/ph54

Natural England (2016). *Links between natural environments and mental health: evidence briefing. Natural England Access to Evidence Information Note EIN018*. Natural England. Retrieved from: http://publications.naturalengland.org.uk/publication/5748047200387072.

NELFT NHS Foundation Trust (2020). *NELFT partners with local football teams to launch youth mental health initiative.* Retrieved from: https://www.nelft.nhs.uk/camhs-news/nelft-partners-with-local-football-teams-to-launch-youth-mental-health-initiative-4117/

Netz, Y. (2017). Is the comparison between exercise and pharmacologic treatment of depression in the clinical practice guideline of the American College of Physicians evidence-based?. *Frontiers in Pharmacology,* 8, 257.

Nezu, A. M. (1987). A problem-solving formulation of depression: A literature review and proposal of a pluralistic model. *Clinical Psychology Review*, *7*(2), 121-144.

NHS England (2019). *Universal personalised care: implementing the comprehensive model.* Retrieved from: https://www.england.nhs.uk/wp-content/uploads/2019/01/universal-personalised-care.pdf

Nigg, C. R., Wunsch, K., Nigg, C., Niessner, C., Jekauc, D., Schmidt, S. C., & Woll, A. (2021). Are physical activity, screen time, and mental health related during childhood, preadolescence, and adolescence? 11-year results from the German Motorik-Modul longitudinal study. *American journal of epidemiology*, *190*(2), 220-229.

Nyström, M. B., Stenling, A., Sjöström, E., Neely, G., Lindner, P., Hassmén, P., Andersson, G., Martell, C., & Carlbring, P. (2017). Behavioral activation versus physical activity via the internet: A randomized controlled trial. *Journal of affective disorders*, *215*, 85-93.

O'Brien, K., Agostino, J., Ciszek, K., & Douglas, K. A. (2020). Physical activity and risk of behavioural and mental health disorders in kindergarten children: Analysis of a series of cross-sectional complete enumeration (census) surveys. *BMJ open*, *10*(3).

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports medicine*, *29*(3), 167-180.

Pasco, J. A., Jacka, F. N., Williams, L. J., Brennan, S. L., Leslie, E., & Berk, M. (2011). Don't worry, be active: Positive affect and habitual physical activity. *Australian & New Zealand Journal of Psychiatry*, *45*(12), 1047-1052.

Passos, G. S., Poyares, D., Santana, M. G., D'Aurea, C. V. R., Youngstedt, S. D., Tufik, S., & de Mello, M. T. (2011). Effects of moderate aerobic exercise training on chronic primary insomnia. *Sleep medicine*, *12*(10), 1018-1027.

Passos, G. S., Poyares, D., Santana, M. G., Garbuio, S. A., Tufik, S., & Mello, M. T. (2010). Effect of acute physical exercise on patients with chronic primary insomnia. *Journal of Clinical Sleep Medicine*, *6*(3), 270-275.

Pearsall, R., Smith, D. J., Pelosi, A., & Geddes, J. (2014). Exercise therapy in adults with serious mental illness: a systematic review and meta-analysis. *BMC psychiatry*, *14*(1), 1-17.

Pentecost, C., Farrand, P., Greaves, C. J., Taylor, R. S., Warren, F. C., Hillsdon, M., Green, C., Welsman, J.R., Rayson, K., Evans, P.H., & Taylor, A. H. (2015). Combining behavioural activation with physical activity promotion for adults with depression: findings of a parallel-group pilot randomised controlled trial (BAcPAc). *Trials*, *16*(1), 1-15.

Perraton, L. G., Kumar, S., & Machotka, Z. (2010). Exercise parameters in the treatment of clinical depression: a systematic review of randomized controlled trials. *Journal of evaluation in clinical practice*, *16*(3), 597-604.

Petersen, A. M. W., & Pedersen, B. K. (2005). The anti-inflammatory effect of exercise. *Journal of applied physiology*, *98*(4), 1154-1162.

Pilc, J., & Zoladz, A. (2010). The effect of physical activity on the brain derived neurotrophic factor: from animal to human studies. *Journal of physiology and pharmacology*, *61*(5), 533-41.

Piñeiro-Cossio, J., Fernández-Martínez, A., Nuviala, A., & Pérez-Ordás, R. (2021). Psychological wellbeing in physical education and school sports: a systematic review. *International Journal of Environmental Research and Public Health*, *18*(3), 864.

Plante, T. G., Madden, M., Mann, S., & Lee, G. (2010). Effects of perceived fitness level of exercise partner on intensity of exertion.

Porras-Segovia, A., Rivera, M., Molina, E., López-Chaves, D., Gutiérrez, B., & Cervilla, J. (2019). Physical exercise and body mass index as correlates of major depressive disorder in community-dwelling adults: results from the PISMA-ep study. *Journal of Affective Disorders*, *251*, 263-269.

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. International journal of environmental health research, 15(5), 319-337.

Public Health England (2018a). *Knowledge & Library Services (KLS) Evidence Briefing: How can primary care interventions increase the uptake of physical activity for people at different stages of life?.* Retrieved from: https://ukhsa.koha-ptfs.co.uk/cgi-bin/koha/opac-retrieve-file.pl?id=412f2553d62f51e34cfdd6ab1103a2ba

Public Health England (2018b). *Knowledge & Library Services (KLS) Evidence Briefing: What evidence is there that physical activity builds or supports brain health?* Retrieved from: https://ukhsa.koha-ptfs.co.uk/cgi-bin/koha/opac-retrieve-file.pl?id=af514a99e1e789501295860e3ac9a251

Quirk, H., Hock, E., Harrop, D., Crank, H., Peckham, E., Traviss-Turner, G., Machaczek, K., Stubbs, B., Horspool, M., Weich, S. & Copeland, R. (2020). Understanding the

experience of initiating community-based group physical activity by people with serious mental illness: A systematic review using a meta-ethnographic approach. *European Psychiatry*, *63*(1).

Raudsepp, L., Neissaar, I., & Kull, M. (2013). A longitudinal assessment of the links between physical activity and physical self-worth in adolescent females. *European journal of sport science*, *13*(6), 716-722.

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health psychology review*, *9*(3), 366-378.

Rector, N. A., Richter, M. A., Lerman, B., & Regev, R. (2015). A pilot test of the additive benefits of physical exercise to CBT for OCD. *Cognitive behaviour therapy*, *44*(4), 328-340.

Reed, J., & Buck, S. (2009). The effect of regular aerobic exercise on positive-activated affect: A meta-analysis. *Psychology of Sport and Exercise*, *10*(6), 581-594.

Ren, Y., & Li, M. (2020). Influence of physical exercise on social anxiety of left-behind children in rural areas in China: The mediator and moderator role of perceived social support. *Journal of Affective Disorders*, *266*, 223-229.

Rief, W., & Hermanutz, M. (1996). Responses to activation and rest in patients with panic disorder and major depression. *British journal of clinical psychology*, *35*(4), 605-616.

Rodriguez, C. C., Camargo, E. M. D., Rodriguez-Añez, C. R., & Reis, R. S. (2020). Physical activity, physical fitness and academic achievement in adolescents: a systematic review. *Revista Brasileira de Medicina do Esporte*, *26*, 441-448.

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-García, P., Henriksson, H., Mena-Molina, A., Martínez-Vizcaíno, V., Catena, A. Löf, M., Erickson, K., Lubans, D., Ortega, F., & Esteban-Cornejo, I. (2019). Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. *Sports medicine*, *49*(9), 1383-1410.

Rogers, M. A., Appaneal, R. N., Hughes, D., Vlahovich, N., Waddington, G., Burke, L. M., & Drew, M. (2021). Prevalence of impaired physiological function consistent with Relative Energy Deficiency in Sport (RED-S): an Australian elite and pre-elite cohort. *British Journal of Sports Medicine*, *55*(1), 38-45.

Roig-Coll, F., Castells-Sánchez, A., Lamonja-Vicente, N., Torán-Monserrat, P., Pera, G., García-Molina, A., Tormos, J.M., Montero-Alía, P., Alzamora, M.T., Dacosta-Aguayo, R. and Soriano-Raya, J.J., Cáceres, C., Erickson, K., & Mataró, M. (2020). Effects of Aerobic Exercise, Cognitive and Combined Training on Cognition in Physically Inactive Healthy Late-Middle-Aged Adults: The Projecte Moviment Randomized Controlled Trial. *Frontiers in aging neuroscience*, 376.

Rosenbaum, S., Morell, R., Abdel-Baki, A., Ahmadpanah, M., Anilkumar, T. V., Baie, L., Bauman, A., Bender, S., Boyan Han, J., Brand, S. Bratland-Sanda, S., Bueno-Antequera, J., Camaz Deslandes, A., Carneiro, L., Carraro, A., Castañeda, C.P., Castro Monteiro, F., Chapman, J., ...

& Ward, P. B. (2020). Assessing physical activity in people with mental illness: 23-country reliability and validity of the simple physical activity questionnaire (SIMPAQ). *BMC psychiatry*, *20*(1), 1-12.

Rosenbaum, S., Vancampfort, D., Steel, Z., Newby, J., Ward, P. B., & Stubbs, B. (2015). Physical activity in the treatment of post-traumatic stress disorder: a systematic review and meta-analysis. *Psychiatry research*, *230*(2), 130-136.

Rowley, N., Mann, S., Steele, J., Horton, E., & Jimenez, A. (2018). The effects of exercise referral schemes in the United Kingdom in those with cardiovascular, mental health, and musculoskeletal disorders: a preliminary systematic review. *BMC public health*, *18*(1), 1-18.

Rowley, N., Steele, J., Wade, M., Copeland, R. J., Mann, S., Liguori, G., Horton, E. & Jimenez, A. (2020). Are exercise referral schemes associated with an increase in physical activity? Observational findings using individual patient data meta-analysis from the National Referral Database. *Journal of Physical Activity and Health*, *17*(6), 621-631.

Ryan, M. P. (2008). The antidepressant effects of physical activity: Mediating self-esteem and self-efficacy mechanisms. *Psychology & Health*, *23*(3), 279-307.

Saanijoki, T., Tuominen, L., Tuulari, J. J., Nummenmaa, L., Arponen, E., Kalliokoski, K., & Hirvonen, J. (2018). Opioid release after high-intensity interval training in healthy human subjects. *Neuropsychopharmacology*, *43*(2), 246-254.

Salari, N. (2009, April). The Martial Plan. *Community Care.* 28-29

Sancassiani, F., Machado, S., & Preti, A. (2018). Physical activity, exercise and sport programs as effective therapeutic tools in psychosocial rehabilitation. *Clinical practice and epidemiology in mental health: CP & EMH*, *14*, 6.

Sani, S. H. Z., Fathirezaie, Z., Brand, S., Pühse, U., Holsboer-Trachsler, E., Gerber, M., & Talepasand, S. (2016). Physical activity and self-esteem: testing direct and indirect relationships associated with psychological and physical mechanisms. *Neuropsychiatric disease and treatment*, *12*, 2617.

Schuch, F. B., Deslandes, A. C., Stubbs, B., Gosmann, N. P., da Silva, C. T. B., & de Almeida Fleck, M. P. (2016). Neurobiological effects of exercise on major depressive disorder: a systematic review. *Neuroscience & Biobehavioral Reviews*, *61*, 1-11.

Schwarz, L., Dorscht, L., Book, S., Stelzer, E. M., Kornhuber, J., & Luttenberger, K. (2019). Long-term effects of bouldering psychotherapy on depression: benefits can be maintained across a 12-month follow-up. *Heliyon*, *5*(12), e02929.

Scott, S. E., Breckon, J. D., & Copeland, R. J. (2019). An integrated motivational interviewing and cognitive-behavioural intervention promoting physical activity maintenance for adults with chronic health conditions: A feasibility study. *Chronic illness*, *15*(4), 276-292.

Sharma, A., Madaan, V., Petty, F. (2006). Exercise for mental health. *The Primary Care Companion for CNS Disorders*, *8*(2), 24919.

Shields, G. S., Moons, W. G., Tewell, C. A., & Yonelinas, A. P. (2016). The effect of negative affect on cognition: Anxiety, not anger, impairs executive function. *Emotion*, *16*(6), 792.

Shors, T. J., Chang, H. Y., & Millon, E. M. (2018). MAP Training My Brain™: meditation plus aerobic exercise lessens trauma of sexual violence more than either activity alone. *Frontiers in neuroscience*, *12*, 211.

Simon-Grima, J. S., Estrada-Marcen, N., & Montero-Marín, J. (2018). Exercise addiction measure through the Exercise Addiction Inventory (EAI) and health in habitual exercisers. A systematic review and meta-analysis. *Adicciones*, *990*.

Siqueira, C. C., Valiengo, L. L., Carvalho, A. F., Santos-Silva, P. R., Missio, G., de Sousa, R. T., Di Natale, G., Gattaz, W.F., Moreno, R.A., & Machado-Vieira, R. (2016). Antidepressant efficacy of adjunctive aerobic activity and associated biomarkers in major depression: a 4-week, randomized, single-blind, controlled clinical trial. *Plos one*, *11*(5).

Smith, J., Griffiths, L. A., Band, M., Hird-Smith, R., Williams, B., Bold, J., Bradley, E., Dilworth, R. & Horne, D. (2020). Early intervention in psychosis: effectiveness and implementation of a combined exercise and health behavior intervention within routine care. *Frontiers in Endocrinology*, *11*, 825.

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *Journal of internal medicine*, *269*(1), 107-117.

Sønderlund, A. L., O'Brien, K., Kremer, P., Rowland, B., De Groot, F., Staiger, P., Zinkiewicz, L., & Miller, P. G. (2014). The association between sports participation, alcohol use and aggression and violence: A systematic review. *Journal of science and medicine in sport*, *17*(1), 2-7.

Sonstroem, R. J., & Morgan, W. P. (1989). Exercise and self-esteem: rationale and model. *Medicine & Science in Sports & Exercise*.

Soucy, I., Provencher, M., Fortier, M., & McFadden, T. (2017). Efficacy of guided self-help behavioural activation and physical activity for depression: a randomized controlled trial. *Cognitive behaviour therapy*, *46*(6), 493-506.

South, J., Giuntoli, G., & Kinsella, K. (2013). An evaluation of the walking for wellness project and the befriender role.

Speciale, A. (2020). Can the mammalian dive response override posttraumatic stress disorder?. *Journal of Evolution and Health: A joint publication of the Ancestral Health Society and the Society for Evolutionary Medicine and Health*, *5*(1).

Sport England. (2018). *Active lives adult survey.* Retrieved from: https://activelives.sportengland.org/

Stanton, R., Rosenbaum, S., Kalucy, M., Reaburn, P., & Happell, B. (2015). A call to action: exercise as treatment for patients with mental illness. *Australian journal of primary health*, *21*(2), 120-125.

Stonerock, G. L., & Blumenthal, J. A. (2017). Role of counseling to promote adherence in healthy lifestyle medicine: strategies to improve exercise adherence and enhance physical activity. *Progress in cardiovascular diseases*, *59*(5), 455-462.

Stonerock, G. L., Hoffman, B. M., Smith, P. J., & Blumenthal, J. A. (2015). Exercise as treatment for anxiety: systematic review and analysis. *Annals of behavioral medicine*, *49*(4), 542-556.

Strid, C., Andersson, C., Forsell, Y., Öjehagen, A., & Lundh, L. G. (2016). Internet-based cognitive behaviour therapy and physical exercise–Effects studied by automated telephone assessments in mental ill-health patients; a randomized controlled trial. *British Journal of Clinical Psychology*, *55*(4), 414-428.

Strong, S. (2009, May). Football Mad. *Mental Health Today,* 14-15.

Stubbs, B., Vancampfort, D., Hallgren, M., Firth, J., Veronese, N., Solmi, M., Brand, S., Cordes, J., Malchow, B., Gerber, M., Schmitt, A., Correll, C. U., De Hart, M., Gaughran, F., Schneider, F., Kinnafick, F., Falkai, P., Moller, H. J., & Kahl, K. G. (2018). EPA guidance on physical activity as a treatment for severe mental illness: a meta-review of the evidence and Position Statement from the European Psychiatric Association (EPA), supported by the International Organization of Physical Therapists in Mental Health (IOPTMH). *European Psychiatry*, *54*, 124-144.

Stubbs, B., Vancampfort, D., Rosenbaum, S., Ward, P. B., Richards, J., Soundy, A., Veronese, N., Solmi, M., & Schuch, F. B. (2016). Dropout from exercise randomized controlled trials among people with depression: a meta-analysis and meta regression. *Journal of affective disorders*, *190*, 457-466.

Sundgot-Borgen, J., & Torstveit, M. K. (2004). Prevalence of eating disorders in elite athletes is higher than in the general population. *Clinical journal of sport medicine*, *14*(1), 25-32.

Szabo, A., & Griffiths, M. D. (2007). Exercise addiction in British sport science students. *International Journal of Mental Health and Addiction*, *5*(1), 25-28.

Tajfel, H., & Turner, J. C. (1979). An integrative theory of inter-group conflict. In W. G. Austin & S. Worchel (Eds.), *The social psychology of inter-group relations* (pp. 33–47). Monterey, CA: Brooks/Cole.

Takahashi, M., Lim, P. J., Tsubosaka, M., Kim, H. K., Miyashita, M., Suzuki, K., Tan, E.L. & Shibata, S. (2019). Effects of increased daily physical activity on mental health and depression biomarkers in postmenopausal women. *Journal of Physical Therapy Science*, *31*(4), 408-413.

Taylor, A. H., Taylor, R. S., Ingram, W. M., Anokye, N., Dean, S., Jolly, K., Mutrie, N., Lambert, J., Yardley, L., Greaves, C., King, J., McAdam, C., Stelle, M., Price, L., Streeter, A., Charles, N., Terry, R., Webb, D., Campbell, J., ... & Cavanagh, C. (2020). Adding web-based behavioural support to exercise referral schemes for inactive adults with chronic health conditions: the e-coachER RCT. Health Technology Assessment (Winchester, England), 24(63), 1.

Thomas, J., Thirlaway, K., Bowes, N., & Meyers, R. (2020). Effects of combining physical activity with psychotherapy on mental health and well-being: A systematic review. *Journal of Affective Disorders*, *265*, 475-485.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M. H. (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environmental science & technology*, *45*(5), 1761-1772.

Thompson, N., & Wilkie, S. (2021). 'I'm just lost in the world': the impact of blue exercise on participant well-being. *Qualitative Research in Sport, Exercise and Health*, *13*(4), 624-638.

Tipton, M. J., Collier, N., Massey, H., Corbett, J., & Harper, M. (2017). Cold water immersion: kill or cure?. *Experimental physiology*, *102*(11), 1335-1355.

Trivedi, M. H., Greer, T. L., Church, T. S., Carmody, T. J., Grannemann, B. D., Galper, D. I., Dunn, A.L., Earnest, C.P., Sunderajan, P., Henley, S.S. & Blair, S. N. (2011). Exercise as an augmentation treatment for nonremitted major depressive disorder: a randomized, parallel dose comparison. *The Journal of clinical psychiatry*, *72*(5), 6911.

Trott, M., Jackson, S. E., Firth, J., Jacob, L., Grabovac, I., Mistry, A., Stubbs, B., & Smith, L. (2021). A comparative meta-analysis of the prevalence of exercise addiction in adults with and without indicated eating disorders. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*, *26*(1), 37-46.

Van den Berg, M. M., van Poppel, M., van Kamp, I., Ruijsbroek, A., Triguero-Mas, M., Gidlow, C., Nieuwenhuijsen, M.J., Gražulevičiene, R., van Mechelen, W., Kruize, H., & Maas, J. (2019). Do physical activity, social cohesion, and loneliness mediate the association between time spent visiting green space and mental health?. *Environment and behavior*, *51*(2), 144-166.

Vancampfort, D., Scheewe, T., van Damme, T., & Deenik, J. (2020). The efficacy of physical activity on psychiatric symptoms and physical health in people with psychiatric disorders: a systematic review of recent meta-analyses. *Tijdschrift Voor Psychiatrie*, *62*(11), 936-945.

Vancampfort, D., Stubbs, B., Sienaert, P., Wyckaert, S., De Hert, M., Rosenbaum, S., & Probst, M. (2015). What are the factors that influence physical activity participation in

individuals with depression? A review of physical activity correlates from 59 studies. *Psychiatria Danubina, 27(3), 0-224.*

Veale, D. (2008). Behavioural activation for depression. *Advances in Psychiatric Treatment*, *14*(1), 29-36.

Wade, M., Brown, N., Dancy, B., Mann, S., Gissane, C., & Majumdar, A. (2020). Identification of dropout predictors to a community-based physical activity programme that uses motivational interviewing. *Journal of Public Health*, *42*(1), 3-11.

Wasilenko, K. A., Kulik, J. A., & Wanic, R. A. (2007). Effects of social comparisons with peers on women's body satisfaction and exercise behavior. *International Journal of Eating Disorders*, *40*(8), 740-745.

Wendt, A., Flores, T. R., Silva, I. C. M., & Wehrmeister, F. C. (2018). Association of physical activity with sleep health: a systematic review. *Revista Brasileira de Atividade Física & Saúde*, *23*, 1-26.

Wheeler, A. J., Roennfeldt, H., Slattery, M., Krinks, R., & Stewart, V. (2018). Codesigned recommendations for increasing engagement in structured physical activity for people with serious mental health problems in Australia. *Health & Social Care in the Community, 26*(6), 860-870.

Yang, W., Wong, S. H. S., Sum, R. K. W., & Sit, C. H. P. (2021). The association between physical activity and mental health in children with special educational needs: A systematic review. *Preventive medicine reports*, *23*, 101419.

Yuan, Y., Li, J., Jing, Z., Yu, C., Zhao, D., Hao, W., & Zhou, C. (2020). The role of mental health and physical activity in the association between sleep quality and quality of life among rural elderly in China: A moderated mediation model. *Journal of affective disorders*, *273*, 462-467.

Zunszain, P. A., Hepgul, N., & Pariante, C. M. (2012). Inflammation and depression. *Behavioral neurobiology of depression and its treatment*, 135-151.

Zvolemky, M. J., Leyro, T. M., Bernstein, A. E., & Vujanovic, A. A. (2011). *Historical perspectives, theory, and measurement of distress tolerance.*

Part 2: Empirical Paper

What are the psychological mechanisms that underlie the positive effects of exercise on mental health?

Abstract:

Aims:

A large body of evidence has demonstrated that exercise has a positive effect on mental health and wellbeing. The majority of research on mechanisms for this effect focuses on biological mechanisms, but more recently several psychological mechanisms have been proposed. This study aims to examine the validity of several psychological mechanisms, as well as explore barriers to participation in exercise.

Methods:

80 participants completed an online survey at three time points. It included measures of exercise frequency, duration and intensity, as well as standardised measures assessing mental wellbeing (CORE-10, BDI, BAI) and proposed psychological mechanisms for the possible psychological factors that might underlie the impact of exercise on wellbeing (self-efficacy, self-esteem, unconditional self-acceptance, distress-tolerance, body satisfaction and openness to experience).

Results

Cross-sectional mediation analysis demonstrated that distress tolerance, unconditional self-acceptance, and self-esteem significantly mediated the relationship between weekly exercise frequency and duration and all measures of wellbeing (p<.05). Distress tolerance (F(2,87.1)=5.35, p=.006) and self-acceptance (F(2,87.5)=3.83, p=.025) were shown to increase significantly over the six months, after participants increased exercise. As anticipated, depression (F(2,87.4)=3.35, p=.04) and anxiety (F(2,77.8)=3.99, I=.022) scores significantly decreased over the six months. Low distress tolerance at Time 1 was the strongest predictor of increasing exercise frequency (p=.002) and duration (p=.003) by Time 3.

Conclusions

Distress tolerance appears to be an important mechanism in the relationship between exercise and mental wellbeing, which until now has received very little research attention. Implications of these findings for the use of exercise as a mental wellbeing intervention are discussed, along with recommendations for further research.

Introduction:

Despite large amounts of evidence suggesting that exercise is an efficacious intervention for depression (Paluska & Schwenk, 2000; Goodwin, 2003; Reed & Buck, 2009; Pasco et al., 2011) and several other mental health difficulties (Alexandratos et al., 2012; Rector et al., 2015; Rosenbaum et al., 2015; LeBouthillier & Asmundson, 2017) across the lifespan (Piñeiro-Cossio et al., 2021; Hale et al., 2021; Awick et al., 2017), very few people with mental health difficulties engage in regular exercise (Da Silva et al., 2012).

In the United Kingdom (UK) exercise is prescribed for people with low to moderate depression, because its benefits are so proven (NICE, 2009). However, people who are referred to exercise programmes for mental health reasons are less likely to take up the referral, and more likely to drop out of the programme (Crone et al., 2008). This suggests that the way exercise is currently being offered as an intervention is not as effective as it could be.

In order to better understand how exercise can be used as a mental health intervention, we need to first understand why exercise supports mental health, and what the main barriers and facilitators of exercise are. While the literature often refers to ‘physical activity’ and ‘exercise’ interchangeably, this paper will primarily use the term ‘exercise’ in order to indicate the intentional nature of exercise activities and programmes as a way of improving or maintaining health or fitness, as opposed to physical activity as part of commuting, work, or daily chores.

So far, research examining explanations for the impact of exercise on mental wellbeing has focussed mainly on biological mechanisms. One of the most popular theories is that endorphins, which are natural opioids released during exercise, create a natural ‘high’ (Adams, 2009). However, much research has debunked this as a useful explanation for the impact of exercise on mental wellbeing, given that endorphins do not cross the blood brain barrier and are actually associated with increased anxiety during exercise and injury (Dishman & O’Connor, 2009).

More recently other theories have received more support, including the role of exercise in increasing serotonin levels (Greenwood & Fleshner, 2008), brain derived neurotrophic factor (BDNF) levels (Heinze et al., 2021; De Sousa et al., 2021), and hippocampal volume (Herting & Chu, 2017). Overall, the neurological effect of exercise appears similar to that of selective serotonin reuptake inhibitors (SSRIs), which are the most commonly prescribed family of antidepressants (Greenwood & Fleshner, 2003).

It has also been suggested that the effect of exercise on physical health results in better quality of life overall, and thus better mental health. Exercise is associated with better sleep quality (Loprinzi & Cardinal, 2011), and sleep is associated with improved mental health (Yuan et al., 2020). Exercise is also associated with lower rates of non-infectious health conditions including cardiovascular disease (Kramer, 2020), diabetes (Savikj & Zierath, 2020) and cancer (Hojman et al., 2018). Therefore people who exercise regularly have reduced odds of developing these conditions, protecting them from additional mental health stressors.

Exercise results in reduced inflammation (Beavers et al., 2010), and inflammation is associated with depression (Zunszain et al., 2012), so reduced inflammation is another process by which exercise may improve mental health. However, people who exercise more have also been found to be more likely to eat vegetables, wear seatbelts, and engage in many other health-promoting and risk-averse behaviours (Dinger, Brittain & Hutchinson, 2014). Therefore, rather than exercise directly causing improved health, it may just be that people who are health-conscious are more likely to do exercise as well as other behaviours that improve overall quality of life.

More recently, attention has been paid to social and psychological mechanisms by which exercise may improve mental health. People who exercise in a team or class may have more social connection (Edmunds et al., 2013) and gain a ‘social identity’ from which they gain cumulative self-esteem (Haslam et al., 2020). People who exercise outdoors may benefit from the therapeutic effects of nature (Lahart et al., 2019).

People may also benefit from exercise by learning things about themselves and their capabilities. They might develop increased self-efficacy and self-esteem by realising that they can set goals and achieve things that would have once been impossible for them (Knapen et al., 2015; Lubans et al., 2016). Exercise creates structure for activity, reducing the time people spend ruminating or worrying (Craft & Perna, 2004). Exercise may result in improved distress tolerance, as people learn they can overcome discomfort and pain (LeBouthillier & Asmundson, 2017). People may also become more appreciative of their bodies, by becoming focussed on what their body does, rather than what it looks like (Hausenblas & Fallon, 2006).

Despite several plausible psychological theories for the impact of exercise on mental health, there is much less research looking at these than biological mechanisms. Exercise, potentially because of similarities between its effects on the brain and those of SSRIs, is repeatedly compared to pharmacological treatments, and less so with psychological treatments (Netz, 2017). This limits both the way people access exercise as an intervention (as a 'prescription' rather than therapy), and the way exercise is used in mental health services (as an adjunct, rather than an integrated aspect of care).

Unsurprisingly exercise, which requires significant initial motivation to engage, and which does not have clearly defined processes for 'titrating' the correct 'dose', has a smaller effect on mental health than pharmacological treatments (Broocks et al., 1998; Cooney et al., 2013). However, unlike pharmacological intervention, exercise (at an appropriate frequency and intensity) does not have additional side-effects, is cheaper or free, has additional physical health benefits, and perhaps most importantly is acceptable to individuals for whom pharmacology is not (Netz, 2017). It may therefore be more helpful to conceptualise exercise for mental health as a form of 'therapy', but to do this, a stronger understanding of the psychological and therapeutic processes occurring when people increase exercise is required.

While exercise is known to be beneficial for mental health, individuals with mental health difficulties are less likely to engage in free exercise programmes offered via referral

(Crone et al., 2008). This suggests that people with mental health difficulties experience specific barriers to exercise. Clinicians cite low motivation as the main reason why mental health service users may not engage in exercise, although service users themselves state that pain, financial barriers and poor social support are more problematic (Crabb et al., 2015). Additionally, people with marginalised or minoritised identities are more likely to experience mental health conditions (Turner & Turner, 2004; Robinson et al., 2011; Grant et al., 2014), and are less likely to participate in exercise (Jones et al., 2017; Sport England, 2018). For exercise to be an effective intervention for mental health difficulties, the barriers and facilitators of exercise need to be better understood, and additional support around engagement provided.

Exercise counselling, using either motivational interviewing techniques or cognitive behavioural therapy techniques, has been found to effectively facilitate engagement in exercise (Scott et al., 2019; Strid et al., 2016). Access to exercise facilities, social support, and specialist information have also been recommended (Wheeler et al., 2018). This, along with the findings that exercise is most beneficial for mental health when followed by group counselling reflecting on the experience (Hilyer & Mitchell, 1979), suggests that a combination of facilitated exercise and psychological therapy focussed on exercise may be most beneficial for individuals with mental health difficulties. This has the additional benefit that, for people to whom conventional ‘therapy’, or the creative alternatives (art, music or drama therapy) which are offered in parts of the National Health System (NHS) do not appeal, exercise therapy may provide a more accessible alternative.

However, for an effective exercise therapy intervention to be designed, there needs to be a better understanding of the psychological and therapeutic processes involved in exercise. Additionally, a better understanding of the likely barriers to exercise engagement is required, so that interventions can directly address these.

Here, I describe a study to investigate each of these areas in turn. People who had just increased, or were just about to increase, their exercise (e.g. start exercise for the first time, or start a new training programme), were recruited via social media or sports group

mailing lists. They then completed a survey at three time points over six months which assessed their exercise levels, mental wellbeing, and a number of psychological constructs that may underlie the relationship between exercise and mental health. Exploratory statistical analysis was then performed to answer these research questions:

1. Do psychological processes mediate the relationship between exercise and improved mental wellbeing?
2. What are the main barriers to, and facilitators of, increasing exercise?

The results of the analysis are reported and interpreted within this paper, and implications both for clinical practice and further research are discussed.

Methods:

Participants:

80 participants took part in this study with a relatively even spread of ages (Table 1). 66% of participants identified as female, and 21% as male. None identified as non-binary, though 13% opted not to answer this question. 77% of the sample identified as White (British or Other), 4% as Asian (British or Other), and 4% as Mixed or Multiple ethnicities. The remaining 15% chose not to answer or answered 'Other'.

Table 1

Frequencies and percentages of participants in different age groups

Age group	Frequency	Percentage (%)
18-24	7	9
25-29	14	17
30-34	13	16
35-39	10	13
40-44	9	11
45-49	10	13
50+	12	15
Missing	5	6

There was dropout between Time 1 and 2 with only 49 participants completing the second survey. No further participants dropped out between Time 2 and 3. While the initial sample exceeded the recommended sample size of 77, calculated using G*Power for multiple linear regression (assuming medium effect size (f=.15) and using .05 alpha and .2 beta value as is conventional for non-intervention studies in psychology), the final sample did not.

This was a volunteer sample, recruited online using social media and mailing lists to send an advert (Appendix A) to members of sport clubs, gyms, or interest groups. As incentive, participants were offered entries into a prize draw to win running trainers or a fitness tracker. As the study involved completing a survey at three time points, they would receive one entry for the first survey, three for the second and five entries for the third survey, to encourage completion.

Materials:

Qualtrics was used to create the surveys and collect data initially. Nine different standardised measures were included in the surveys:

Clinical Outcomes in Routine Evaluation- ten items (CORE-10), Barkham et al. (2013):

The CORE-10 has ten items which are rated on a five-point likert scale scored from "0=Not at all" to "4=Most or all of the time". Items two and three are reverse-scored and then item scores summed to achieve overall CORE-10 score. A higher score indicates greater distress. An example item is; "I have felt panic or terror". The internal consistency (Cronbach's alpha) is .90, and it has been found to correlate with the established 34-item Clinical Outcome Measures in Routine Evaluation- Outcome Measure (CORE-OM) at .92 in a non-clinical population.

Beck's Anxiety Inventory (BAI), Beck et al. (1988a):

The BAI is a self-report measure of anxiety. It consists of 21 common symptoms of anxiety, such as "hands trembling", which are rated for how much they have bothered the respondent during the past month on a four-point likert scale from "0=Not at all" to "3=Severely - It bothered me a lot". The sum of items gives the BAI total score. A higher score indicates greater anxiety. The internal consistency is .92, and test retest validity is .75. It has been found to be moderately correlated with the Hamilton Anxiety Rating Scale (.51).

Beck's Depression Inventory (BDI), Beck et al. (1988b):

The BDI is a measure of depression. It consists of 21 items. For each item there are four statements, allocated a score of 0-3. The person completing it should choose the statement that best describes them. An example item is:

0: I make decisions about as well as I ever could

1: I put off making decisions more than I used to

2: I have greater difficulties in making decisions than I used to

3: I can't make decisions at all anymore

The sum of all scores provides the overall BDI score. A higher score indicates greater depression. The internal consistency is .81 for a non-clinical sample. It has been found to correlate strongly with the Hamilton Rating Scale for Depression (.73).

The Rosenberg Self-Esteem Scale (RSES), Rosenberg (1965):

The RSES is a measure of self-esteem. It has ten items including statements like "I feel that I have a number of good qualities", which are rated on a four-point likert scale from "1=Strongly Disagree" to "4=Strongly Agree". Five items are reverse scored. The sum of scores is the overall RSES score, with higher scores indicating greater self-esteem. It has an internal consistency of .88 and 1-week test-retest reliability of .82 (Fleming & Courtney, 1984). There is a moderate (.44) correlation between the RSES and Academic Self-Concept Scale (Reynolds, 1988).

The New General Self-Efficacy Scale (NGSE), Chen et al. (2001):

The NGSE is a 8-item measure of self-efficacy. Items such as "Compared to other people, I can do most tasks very well" are rated from "1=strongly disagree" to "5=strongly agree" on a five-point likert scale. The average score is the overall NGSE score, with a higher score indicating greater self-efficacy. Internal consistency was >.86, and test-retest validity was found to be >.62 across several different samples. There is a strong correlation

(.78) between the NGSE and already established 17-item GSE (Sherer et al., 1982), though the NGSE demonstrates greater reliability.

Distress Tolerance Scale (DTS), Simons & Gaher (2005):

The DTS has 15 items such as “I can’t handle feeling distressed or upset”, which are rated on a five-point likert scale from “1=Strongly Agree” to “5=Strongly Disagree”. Item six is reverse scored. The average of scores is the overall DTS score. While there are four subscales (tolerance, absorption, appraisal and regulation), these were not used for this analysis as the aim was to understand the role of overall distress tolerance in the relationship between exercise and wellbeing. A higher score reflects greater distress tolerance. Internal consistency was .89, and the measure is moderately correlated with the Negative Mood Regulation scale (.54).

Unconditional Self-Acceptance Questionnaire (USAQ), Chamberlain & Haaga (2001):

The USAQ consists of 20 statements, 11 of which are reverse-scored. Each statement is rated on a seven-point likert scale from “1=Almost always untrue” to “7=Almost always true”. The sum of all scores gives overall USAQ score. A higher score indicates greater unconditional self-acceptance. Internal consistency was moderate (.72). When self-esteem was controlled for, USAQ score was inversely correlated with BAI score, and Narcissistic Personality score, suggesting it measures a distinct construct from self-esteem (non-evaluation rather than positive self evaluation).

NEO-Five Factor Inventory (NEO-FFI) -Openness subscale, Costa & McCrae (1992):

The NEO-FFI is a 60-item measure of the “Big Five” personality domains. One of these domains is “openness to experience”. This research used only the 12 items from the openness domain, as a way of investigating the impact of openness to new experiences on the relationship between exercise and mental wellbeing. The items are rated on a 5-point likert scale from “0=Strongly Disagree” to “4=Strongly agree”. Seven items on the openness

subscale are reverse scored. The sum of items in each domain then gives the domain score. Despite the NEO-FFI being widely used, there is only moderate internal consistency (.50) for the openness domain alone (Sneed et al., 2002). The NEO-FFI has been externally validated against the subscales of the Adolescent Risk-taking Questionnaire (Gullone & Moore, 2000) which provided some support for its external validity.

Body Satisfaction Scale (BSS), Slade et al. (1990):

The BSS lists 16 body parts, which are then rated on a 7-point likert scale from "1=Very satisfied" to "7=Very unsatisfied". There are two subscales; head parts satisfaction and body parts satisfaction, consisting of seven items each. The overall and subscale scores are found by summing the items within them. A higher score indicates lower body satisfaction. Internal consistency is >.78 across three samples. There was a moderate correlation (.44) between BSS score and Body Shape Questionnaire score (Cooper et al., 1987).

Procedures:

A link and QR code on the study advertisement took participants to a Qualtrics Survey including the information page and consent form for the study (Appendix B). Participants were asked to fill in their e-mail address and create a unique identifier code at this stage. Once they had completed the consent form they were automatically redirected to a second survey where they would re-enter their unique identifier code and then complete a series of questions and questionnaires about demographics, exercise, wellbeing, and other psychological factors (Appendix C). Finally, at the end of this survey they would have the option to click a link to a third survey which asked them if they would like to enter the prize-draw, and receive results of the research once complete. If they clicked yes to either they would be asked again for their e-mail address. By having three separate surveys this ensured that all sensitive information collected from the surveys was not stored in the same

file as identifiable information such as e-mail addresses. The survey took participants 26 minutes to answer on average.

After three months, participants were sent an e-mail with a link to the second survey, which was nearly identical but with slight changes to phrasing to accommodate the passing of time. If they did not complete this within three weeks they were sent a reminder e-mail. At six months, they were sent the final survey link, and again received a reminder if this had not been completed within three weeks.

Data analysis:

SPSS statistics software was used to analyse data. Initially exploratory Pearson correlation analyses and linear mixed models (Howell, 2016) were run to check for patterns in the data that may suggest mediation effects. Next mediation analyses were run using PROCESS macro (Hayes, 2022), acknowledging that this analysis would be underpowered. Finally, to test the second hypothesis, binary logistic regression analyses were conducted.

Ethics:

Ethical and information governance approval was obtained from the University College London ethics board before any recruitment or data collection began; approval reference 19677/001 (Appendix D). Participants all gave informed consent before participation and had the right to withdraw up until the close of data collection. Signposting to appropriate support services was provided on the survey (Appendix C). Data management was conducted according to UCL policies and the Data Protection Act 2018.

Results

Associations between changes in exercise, wellbeing, and potential mediating factors

Change scores were generated by calculating the difference between Times 1 and 3. Correlation analyses were then conducted using the change scores.

First, correlations between change in different measures of exercise and change in different measures of wellbeing were run, to confirm the association between exercise and wellbeing. An increase in exercise frequency was significantly associated with a decrease in CORE-10 (distress) score ($r(37)=-.339$, $p=.035$) and BDI (depression) score ($r(36)=-.370$, $p=.022$), but not with BAI (anxiety) score ($r(35)=.074$, $p=.665$). An increase in hours per week spent exercising was associated with a decrease in BDI (depression) score ($r(36)=-.334$, $p=.04$) but was not associated with BAI (anxiety) score (r(35)=.117, p=.491) or CORE-10 (distress) score ($r(37)=-.182$, $p=.269$). An increase in exercise intensity was not significantly associated with any wellbeing measures (Appendix E).

Next, correlations between change in exercise and change in potential mediating factors were run to see which might plausibly explain this relationship. An increase in NGSE (self-efficacy) score was associated with an increase in exercise frequency ($r(38)=.387$, $p=.014$) and hours spent exercising ($r(38)=.341$, $p=.031$), but not with increased exercise intensity ($r(38)=.273$, $p=.088$). No measures of exercise correlated with RSES (self-esteem) score, USAQ (self-acceptance) score, BSS (body dissatisfaction) score, DTS (distress tolerance) score, NEO-FFI openness score, BMI, pain, or tiredness (Appendix E).

Then, correlations between change in potential mediating factors and change in wellbeing measures were run, again to check the plausibility of the mediating factors. A decrease in CORE-10 score, indicating reduced distress, was significantly correlated with an increase in NGSE (self-efficacy) score ($r(36)=-.337$, $p=.038$), USAQ (unconditional self-acceptance) score (r(36)=-.442, $p=.005$), and DTS (distress tolerance) score ($r(35)=.334$, $p=.043$), and negatively correlated with BSS (body dissatisfaction) score ($r(35)=.456$, $p=.005$). When BSS score was broken down into its subscales the association was only

present for body related dissatisfaction (r(36)=.540, p=.<.001) and not head related dissatisfaction (r(35)=.149, p=.378).

A decrease in CORE-10 (distress) score was also associated with reduced BMI (r(37)=.396, p=.012) and tiredness (r(36)=.476, p=.003). There was no association between decreased CORE-10 score and change in RSES (self-esteem) score (r(40)=-.198, p=.208), NEO-FFI openness score (r(36)=.199, p=.230), pain frequency rating (r(37)=.284, p=.080) or pain intensity rating (r(37)=.183, p=.266).

A decrease in BAI score (indicating reduced anxiety) was significantly associated with an increase in USAQ (unconditional self-acceptance) score (r(33)=-.361, p=.033), and a decrease in pain intensity rating (r(.483), p=.003), but was not associated with any other potential mediators (Appendix E).

A decrease in BDI score (indicating reduced depression) was significantly associated with decreased BSS (body dissatisfaction) score (r(35)=.364, p=.027). When split into sub-scales, this association was only present for body-related satisfaction (r(36)=.401, p=.013), and not head-related satisfaction (r(35)=.212, p=.208). Reduced BDI score was not associated with any other potential mediating factors (Appendix E).

This suggests that exercise frequency and duration, and not intensity, are relevant to mental wellbeing. Self-efficacy and distress tolerance appear to be the most likely mediators of the relationship between exercise and wellbeing, impacting overall distress rather than anxiety or depression on their own.

Changes over time

A linear mixed model was conducted using the suggested syntax (Appendix F) from Howell (2016). This meant that all data was taken into account, rather than cases being excluded from analysis if one set of data were missing, as would be the case in a traditional ANOVA (analysis of variance). For each model the test was run with forced sphericity (compound symmetry) and with an unstructured model. In all cases compound symmetry resulted in the smallest Shwarz Bayesian Information Criterion (BIC), which indicates lower

penalty terms and a better model. Therefore all analyses reported below use compound symmetry. Where means are reported these are estimated marginal means.

There was a significant main effect of time on BDI (depression) score ($F(2,87.4)=3.35$, $p=.04$) and BAI (anxiety) score ($F(2,77.8)=3.99$, $p=.022$), but not CORE (distress) score ($F(2,89.0)=2.43$, $p=.094$).

For BDI, pairwise comparisons (using Bonferroni correction for multiple comparisons) show that there was no significant difference between Time 1 ($M=11.26$) and 2 ($M=12.48$, p=.997), or between Time 1 and 3 ($M=9.07$, $p=.255$), but there was a significant difference between Time 2 and 3 ($p=.038$). This demonstrates that BDI scores remained fairly constant from Time 1 to 2, and then decreased significantly between Time 2 and 3. This suggests that depression decreases as a result of increased exercise, but that it takes 3-6 months for the effects to become significant.

For BAI, pairwise comparisons show that there was no significant difference between Time 1($M=11.73$) or 2 ($M=11.13$, $p=1.00$), or between Time 2 and 3 ($M=9.29$, $p=.150$), but the overall change between Time 1 and 3 was significant ($p=.021$). BAI score therefore stayed the same between Time 1 and 2 and then decreased by Time 3. Again, this suggests that the beneficial effect of increased exercise on anxiety takes 3-6 months to become significant.

There was a significant main effect of time on DTS (distress tolerance) score ($F(2,87.1)=5.34$, $p=.006$) and USAQ (unconditional self-acceptance) score ($F(2,87.5)=3.83$, $p=.025$), but not with any of the other potential mediating factors (Table 2).

For DTS, pairwise comparisons (using Bonferroni correction) show that while there was no significant difference between DTS score at Time 1 ($M=3.23$) and 2 ($M=3.35$, $p=.373$), or between Time 2 and 3 ($M=3.49$, $p=.283$), there was an overall significant difference from Time 1 to 3 ($p=.005$). This suggests that distress tolerance increased over time after increasing exercise.

The same pattern was seen for unconditional self-acceptance, with no significant difference between USAQ score at Time 1 ($M=78.4$) and 2 ($M=80.2$, $p=.599$) or between

Time 2 and 3 (*M*=82.3, *p*=.49), but a significant overall change from Time 1 to 3 (*p*=.021). This suggests that unconditional self-acceptance increased over time following an increase in exercise.

Table 2

Changes in variable means over time and linear mixed model results

	Time 1		Time 2		Time 3		*F*	*Df* time	*Df* error	*p*
	M	*SE*	*M*	*SE*	*M*	*SD*				
Exercise Frequency	2.15	.13	2.03	.15	2.08	.15	.373	2	92.06	.690
Exercise Hours	1.91	.14	1.65	.16	1.70	.16	1.904	2	94.10	.155
Exercise Intensity	.84	.07	.86	.08	.89	.08	.139	2	103.00	.870
CORE-10 score	11.89	.74	11.09	.84	10.22	.84	2.434	2	89.04	.094
BDI score	11.26	1.26	12.48	1.43	9.07	1.41	3.352	2	87.43	.040*
BAI score	11.73	1.09	11.13	1.20	9.29	1.20	3.992	2	77.83	.022*
RSES score (self-esteem)	16.50	.25	16.47	.29	16.37	.29	.101	2	93.56	.904
NGSE score (self-efficacy)	3.65	.08	3.68	.08	3.76	.08	1.588	2	87.12	.210
USAQ score (unconditional self-acceptance)	78.37	1.67	80.18	1.85	82.31	1.84	3.834	2	87.48	.025*
BSS score (body satisfaction)**	45.35	2.02	45.79	2.20	45.64	2.20	.037	2	89.88	.963
DTS score (distress tolerance)	3.23	.10	3.35	.11	3.49	.11	5.348	2	87.08	.006*
NEO-FFI O-subscale score (Openness to experience)	33.30	.72	33.28	.78	34.10	.78	1.363	2	81.93	.262
BMI	24.29	.607	24.77	.673	24.80	.683	.564	2	98.65	.571
Pain frequency (0-10)	2.22	.29	2.50	.35	2.68	.35	.827	2	103.91	.440
Pain intensity (0-10)	2.33	.26	2.53	.31	2.71	.30	.665	2	103.25	.516
Tiredness (0-10)	5.77	.27	5.22	.33	4.85	.34	2.934	2	106.04	.058

[a]A higher score on the BSS indicates lower body satisfaction

*Indicates a significant result at *p*<.05 level

Mediation Analysis

Mediation analyses were run using PROCESS (Hayes, 2022). Measures of exercise (frequency, hours and intensity) were used as the predictor variables, measures of wellbeing (CORE-10, BDI or BAI) as the outcome variable, and other factors (self-esteem, self-efficacy, unconditional self-acceptance, distress tolerance, openness to experience, body satisfaction, tiredness, pain and BMI) as mediating variables. Analyses were run systematically looking at all possible relationships in turn.

Maxwell & Cole (2007) explain that using cross-sectional mediation to look at longitudinal effects is biased, as one cannot accurately infer causation from cross-sectional data and mediation analysis is necessarily a test of causation. As a result, a longitudinal mediation model described by Hayes (2022) was used in the first instance (Appendix G for syntax). This looks at the effect of the predictor variable at Time 1, on the mediating variable at Time 2, on the outcome variable at Time 3, and thus is a stronger analysis for implying causal relationships. Bootstrapping estimation, at the 95% confidence interval using 5000 bootstrapping samples, was used to test for a significant indirect effect compared to the direct effect. No significant indirect effects were found for any measure of exercise, on any measure of wellbeing, when mediated by any of the proposed mediating variables (Appendix H).

Because longitudinal mediation analysis uses three different variables, at different time points, as well as three covariate variables, this analysis required that participants had completed every item in six different questionnaires across the three time points. Due to dropout between time points, missing data within survey responses, and a relatively small sample to start with, this meant that sample sizes used for this longitudinal mediation analysis ranged from 28 to 36, which meant that the mediation analyses were very underpowered, given that G*power recommends a sample of 77 for multiple linear regression with medium effect sizes and mediation analyses are typically less powerful than regression alone. As a result, cross-sectional analyses were run on the data from Time 1, which had the largest sample size of the three time points. While causal relationships cannot

be inferred from cross-sectional analysis, this still indicates some relationships which future research using longitudinal mediation analysis with a larger sample size may be able to build on.

Using PROCESS, a single cross-sectional mediation analysis was run using data only from Time 1. The bootstrapping method was used to determine significance.

The effect of exercise frequency on BDI score was significantly mediated by; DTS (distress tolerance) score (β=-1.42, 95% CI [-3.51, -0.247]), RSES (self-esteem) score (β=-2.22, 95% CI [-4.08, -0.861]), NGSE (self-efficacy) score (β=-1.20, 95% CI [-2.67, -0.168]), and USAQ (unconditional self-acceptance) score (β=-1.81, 95% CI [-3.78, -0.550]). Bootstrapping limits at the 95% confidence interval showed that indirect effect could not be 0, and the direct effect was reduced to non-significant. There were no significant indirect effects of exercise frequency on BDI score when mediated by NEO-FFI openness score, BSS (body dissatisfaction) score or self-reported pain frequency, pain intensity, tiredness or BMI (Appendix I).

The effect of exercise frequency on BAI score was significantly mediated by; DTS (distress tolerance) score (β=-1.23, 95% CI [-2.61, -0.28]), RSES (self-esteem) score (β=-1.42, 95% CI [-2.79, -0.44]), USAQ (unconditional self-acceptance) score (β=-1.23, 95% CI [-2.65, -0.34]), and NEO-FFI openness score (β=-0.53, 95% CI [-1.32, -0.03]). Direct effects became nonsignificant. NGSE (self-efficacy), BSS (body dissatisfaction), pain frequency, pain intensity, tiredness and BMI did not have a significant mediation effect (Appendix I).

The effect of exercise frequency on CORE-10 was significantly mediated by; DTS (distress tolerance) score (β=-0.60, 95% CI [-1.46, -0.06]), RSES (self-esteem) score (β=-0.89, 95% CI [-1.75, -0.26]), NGSE (self-efficacy) score (β=-0.74, 95% CI [-1.67, -0.11]) and USAQ (unconditional self-acceptance) score (β=-0.88, 95% CI [-1.72, -0.29]). However, for all of these the direct effect between exercise frequency and CORE-10 score remained significant also, demonstrating only partial mediation. There were no significant mediation effects for NEO-FFI openness score, BSS (body dissatisfaction) score, or self-reported pain frequency, pain intensity, tiredness or BMI (Appendix I).

The relationship between exercise hours on BDI score was significantly mediated by; DTS (distress tolerance) score (β=-1.27, 95% CI [-3.11, -0.10]), RSES (self-esteem) score (β=-1.72, 95% CI [-3.52, -0.54]), NGSE (self-efficacy) score (β=-1.22, 95% CI [-2.82, -0.13]), and USAQ (unconditional self-acceptance) score (β=-1.96, 95% CI [-4.09, -0.61]). The direct effects of exercise hours on BDI became non-significant in these analyses. No other factors mediated the effect of exercise hours on BDI score (Appendix I).

For the effect of exercise hours on BAI score, DTS (distress tolerance) score (β=-0.92, 95% CI [-2.19, -0.07]), RSES (self-esteem) score (β=-0.98, 95% CI [-2.26, -0.19]) USAQ score (unconditional self-acceptance) (β=-1.28, 95% CI [-2.69, -0.35]), and NEO-FFI Openness score (β=-0.51, 95% CI [-1.33, 0.02]) significantly mediated the relationship. Direct effects of exercise hours on BAI score reduced to non-significance. No other factors mediated the effect of exercise hours on BAI score (Appendix I).

The effect of exercise hours on CORE-10 score was significantly mediated by; DTS (distress tolerance) score (β=-0.51, 95% CI [-1.33, -0.01]), RSES (self-esteem) score (β=-0.72, 95% CI [-1.50, -0.15]), NGSE (self-efficacy) score (β=-0.74, 95% CI [-1.60, -0.13]), and USAQ (unconditional self-acceptance) score (β=-0.97, 95% CI [-1.86, -0.36]). When USAQ score was a mediator, the direct effect of exercise hours on CORE-10 became nonsignificant, but when DTS, RSES and NGSE scores mediated the relationship the direct effect remained significant, suggesting that these were only partially mediating the relationship.

Self-efficacy significantly mediated the effect of exercise intensity on BDI (β=-1.83, 95% CI [-4.22, -0.07]), and on CORE-10 (β=-1.46, 95% CI [-3.21, -0.23]). These were both full mediations. No other factors mediated the relationship between exercise intensity on any of the measures of wellbeing (Appendix I).

Predictors of participation in exercise

The second hypothesis was that psychological factors would significantly predict exercise participation. As a recent or upcoming increase in exercise was an inclusion criterion for participants to take part in the study, it was expected that participants who successfully engaged with their exercise plan would show an increase in weekly exercise from Time 1 to 3. To test this, three additional variables were created which stated whether or not exercise frequency, hours and intensity had increased between Time 1 and 3. Logistic binary regression analyses were then run to see which variables at Time 1 predicted increased exercise by Time 3.

Due to the small sample size and large number of possible predictor variables, it was not possible to put all factors into one regression model as this resulted in a near perfect fit. Instead each variable was regressed onto the three different measures of increased exercise on its own, and then in a follow-up analysis controlling for other variables that significantly predicted exercise maintenance.

Predictors of increased exercise frequency

The likelihood of increasing exercise by Time 3 was significantly predicted by exercise frequency per week (n=41, p=.009), exercise hours per week (n=41, p=.031), CORE-10 (distress) score (n=40, p=.008), BDI (depression) score (n=39, p=.018), USAQ (unconditional self-acceptance) score (n=40, p=.033) and DTS (distress tolerance) score (n=40, p=.002) at Time 1. When combined as factors in one regression equation, only DTS score remained a significant predictor (36, p=.044), although USAQ score (n=36, p=.053), exercise frequency (n=36, p=.055), and NEO-FFI openness score (n=36, p=.057) were all almost significant predictors. Age, gender, BMI, LTCs, pain frequency and intensity, tiredness, exercising with or without others, motive, past or current experience of mental health difficulties and support, anxiety (BAI), self-esteem (RSES), self-efficacy (NGSE), and body dissatisfaction (BSS) at Time 1 did not significantly predict increased exercise frequency (Table 3).

Estimated odds ratios demonstrate that greater exercise frequency (*OR*=0.282, 95% CI [0.109, 0.726], *p*=.009) and exercise hours (*OR*=0.372, 95% CI [0.151, 0.916], *p*=.031) at Time 1 predicted reduced odds of increasing exercise frequency by Time 3. In contrast, greater CORE-10 (distress) score (*OR*=1.248, 95% CI [1.061, 1.468], *p*=.008) and BDI (depression) score (*OR*=1.171, 95% CI [1.027, 1.336], *p*=.018) at Time 1 predicted increased odds of increasing exercise frequency by Time 3. Greater USAQ (unconditional self-acceptance) score (*OR*=0.932, 95% CI [0.873, 0.994], *p*=.033) and DTS (distress tolerance) score (*OR*=0.181, 95% CI [0.060, 0.546], *p*=.002) at Time 1 predicted reduced odds of increasing exercise frequency by Time 3, whereas greater NEO-FFI openness score at Time 1 predicted increased odds of increasing exercise frequency by Time 3 (*OR*=1.207, 95% CI [1.013, 1.438], *p*=.036).

Predictors of increased exercise hours

The likelihood of increasing exercise hours per week by Time 3 was significantly predicted by exercise hours per week (*n*=41, *p*=.026), NGSE (self-efficacy) score (*n*=40, *p*=.017), USAQ (unconditional self-acceptance) score (*n*=40, *p*=.015) and DTS (distress tolerance) score (*n*=40, *p*=.003) at Time 1. When combined in one regression analysis, none of these factors remained significant. Age, gender, BMI, LTCs, pain frequency and intensity, tiredness, exercise frequency and intensity, exercising with or without others, motive, past or current mental health difficulties and support, distress (CORE-10), anxiety (BAI), depression (BDI), self-esteem (RSES), body satisfaction (BSS), and NEO-FFI openness to experience at Time 1 did not significantly predict increased exercise hours (Table 3).

Estimated odds ratios demonstrate that greater exercise hours at Time 1, reduced the odds of increased exercise hours by Time 3 (*OR*=0.106, 95% CI [0.015, 0.761], *p*=.026). Greater NGSE (self-efficacy) score (*OR*=0.112. 95% CI [0.019, 0.674], *p*=.017), USAQ (unconditional self-acceptance) score (*OR*=0.911, 95% CI [0.845, 0.982], *p*=.015), and DTS (distress tolerance) score (*OR*=0.185, 95% CI [0.061, 0.565], *p*=.003) at Time 1 also reduced odds of increased exercise hours by Time 3.

Predictors of increased exercise intensity

No variables at Time 1 significantly predicted increased exercise intensity by Time 3 (Table 3).

Table 3

Binary Logistic Regression results for predicting exercise increase at Time 3, from variables at Time 1

	Exercise frequency										Exercise Hours										Exercise Intensity				
Predictor variables from Time 1	Model 1					Model 2					Model 1					Model 2					Model 1				
	Odds Ratio	CI LB	CI UB	*p*	*N*	Odds Ratio	CI LB	CI UB	*p*	*N*	Odds Ratio	CI LB	CI UB	*p*	*N*	Odds Ratio	CI LB	CI UB	*p*	*N*	Odds Ratio	CI LB	CI UB	*p*	*N*
Age	.815	.561	1.184	.283	41						.751	.503	1.122	.162	41						.929	.654	1.320	.683	41
Gender	.525	.094	2.940	.464	40						.629	.110	3.582	.601	41						.975	.188	4.080	.865	41
Ethnicity[a]	-	-	-	-	-						-	-	-	-	-						-	-	-	-	-
BMI	.986	.871	1.117	.828	41						.981	.859	1.119	.773	41						.915	.781	1.071	.268	41
LTCs	1.232	.255	5.944	.795	41						1.500	.303	7.432	.619	41						.519	.093	2.895	.454	41
Pain frequency	.803	.558	1.156	.238	40						.885	.635	1.233	.470	40						.804	.577	1.120	.197	40
Pain intensity	.707	.432	1.159	.169	39						.925	.615	1.390	.707	39						.781	.515	1.185	.245	39
Tiredness	1.232	.852	1.782	.267	40						1.155	.801	1.666	.441	40						1.086	.782	1.508	.624	40
Exercise frequency	.282	.109	.726	.009*	41	.030	.001	1.077	.055	36	.530	.256	1.096	.087	41						.841	.462	1.532	.572	41
Exercise hours	.372	.151	.916	.031*	41	.319	.024	4.258	.387	36	.106	.015	.761	.026*	41	.124	.006	2.411	.168	38	.753	.419	1.351	.341	41
Exercise intensity	.398	.103	1.545	.183	41						.554	.141	2.175	.398	41						.095	.019	.461	.004*	41
Exercising with others	.973	.383	2.472	.954	41						.858	.315	2.337	.765	41						.872	.345	2.201	.772	41
Motive: physical health	1.406	.331	5.983	.644	41						.622	.140	2.757	.532	41						1.750	.422	7.253	.440	41
Motive: To lose weight/ maintain appearance	2.444	.566	10.549	.231	41						3.194	.696	14.664	.135	41						1.143	.270	4.843	.856	41
Motive: mental health	1.818	.430	7.685	.416	41						1.333	.298	5.957	.706	41						2.400	.587	9.819	.223	41
Motive: challenge	.319	.035	2.933	.313	41						<.001	<.001	.	.999	41						.275	.030	2.505	.252	41
Motive: fun	.381	.041	3.546	.397	41						1.238	.204	7.526	.817	41						.889	.151	5.241	.896	41
Barriers experienced	2.200	.396	12.228	.368	41						1.833	.324	10.367	.493	41						.436	.104	1.835	.258	41
Mental health difficulties	.955	.201	4.538	.953	41						4.190	.463	37.938	.202	41						5.789	.651	51.505	.115	41
Mental health support	1.685	.365	7.776	.504	41						2.722	.488	15.198	.254	41						3.937	,725	21.377	.112	41

CORE-10	1.248	1.061	1.468	.008*	40	1.196	.768	1.861	.428	36	1.135	.988	1.304	.073	40						1.085	.956	1.233	.207	40
BAI	1.033	.937	1.138	.514	40						1.055	.955	1.166	.290	40						.949	.849	1.061	.358	40
BDI	1.171	1.027	1.336	.018*	39	1.212	.916	1.604	.178	36	1.108	.997	1.231	.058	39						.972	.889	1.064	.543	39
RSES	.631	.385	1.034	.068	41						.562	.316	.999	.050	41						.928	.658	1.307	.667	41
NGSE	.341	.083	1.403	.136	40						.112	.019	.674	.017*	40	.221	.024	2.006	.180	38	.635	.174	2.320	.492	40
USAQ	.932	.873	.994	.033*	40	1.345	.997	1.816	.053	36	.911	.845	.982	.015*	40	1.005	.923	1.093	.917	38	1.002	.950	1.056	.948	40
BSS[b]	1.027	.985	1.072	.210	40						1.039	.992	1.087	.106	40						.988	.950	1.029	.568	40
DTS	.181	.060	.546	.002*	40	.030	.001	.906	.044*	36	.185	.061	.565	.003*	40	.214	.038	1.200	.080	38	.782	.359	1.704	.536	40
NEO-FFI (O)	1.207	1.013	1.438	.036*	41	2.668	.969	7.342	.057	36	1.112	.947	1.306	.195	41						.927	.800	1.075	.314	41

Note. CORE-10= clinical outcomes in routine evaluation, 10 items; BAI=Beck Anxiety Inventory; BDI=Beck Depression Inventory, RSES=Rosenberg self-esteem scale; NGSE=New general self-efficacy scale; USAQ=Unconditional self-acceptance questionnaire; BSS=Body satisfaction scale; DTS=Distress tolerance scale; NEO-FFI (o)=NEO-FFI Openness to experience subscale

[a]There were not enough cases in different ethnicities to run valid regression analysis for this variable; [b]Larger score= greater body dissatisfaction

*Indicates significant contribution to the model

Discussion

Do psychological processes mediate the relationship between exercise and improved mental wellbeing?

Mediation analysis was used to investigate this first research question. The sample size did not allow enough power to demonstrate effects using longitudinal mediation, so cross-sectional mediation analysis was used.

At Time 1, distress tolerance, self-esteem, and unconditional self-acceptance were found to significantly mediate the effect of exercise frequency and exercise hours on all measures of wellbeing (depression, anxiety and distress). Additionally, self-efficacy mediated the effect of exercise frequency and exercise hours on depression and distress, but not anxiety. However, openness to experience mediated the effect of exercise frequency and hours on anxiety.

This suggests that distress tolerance, self-esteem and unconditional self-acceptance are important factors in explaining the impact of exercise on mental wellbeing. Additional psychological processes (self-efficacy and openness to experience) may also explain the benefits of exercise for specific aspects of mental wellbeing. Self-efficacy (feeling able to achieve something) does not appear to explain the effect of exercise on reduced anxiety, but openness to experience, which may include being open to doing something regardless of whether or not you will achieve it, does.

Self-efficacy was the only psychological process that mediated the effect of exercise intensity on any wellbeing scores. It mediated the effect of exercise intensity on depression and distress scores, but not anxiety. Again, this suggests that self-efficacy does not explain the beneficial effects of exercise on anxiety, but may mediate exercise's impact on other aspects of wellbeing. It also demonstrates that psychological processes do not explain the effect of exercise intensity on mental health as well as the effect of exercise frequency and hours. Therefore exercise intensity may affect mental wellbeing via more physiological

processes which this study did not measure. The effect of exercise frequency and hours, however, may plausibly be explained by psychological factors.

BMI and self-rated pain frequency, pain intensity and tiredness did not appear to mediate the effect of exercise on mental wellbeing in the short-term. However, as the mediation analysis was completed at Time 1, only shortly after participants increased their regular exercise, it is possible that these may have become mediators in the longer-term or been observable mediators in a larger sample.

Because only cross-sectional rather than longitudinal mediation analysis was performed, conclusions about causal effects cannot be made from these mediation results alone. However, further analysis taking into account data from across time points suggests that these patterns may exist across time also.

Increased exercise frequency from Time 1 to Time 3 was associated with decreased depression and distress scores, but not anxiety scores. Increased exercise hours per week were associated with decreased depression scores, but not distress or anxiety. This fits with the evidence, suggesting that the strongest effect of exercise on mental wellbeing is for depression (Rebar et al., 2015), with weaker or inconsistent effects seen for anxiety (Asmundson et al., 2013). It also suggests that increased exercise frequency and duration may improve mental wellbeing more than increased intensity. This fits with Ekkekakis' theory that while higher intensity exercise appears to have short-term benefits on mental wellbeing (Conn, 2010; Porras-Segovia et al., 2019), it is less enjoyable and therefore less likely to be maintained, so less beneficial for wellbeing in the long-term (Ekkekakis et al., 2011).

Increased exercise frequency and hours were associated with increased self-efficacy over the 6-month study, but no other psychological factors. This suggests that self-efficacy may mediate the effect of exercise on wellbeing in the longer term, as well as the short-term. However, longitudinal mediation analysis, with a larger sample, is required to confirm this.

While increases in several psychological processes (self-efficacy, unconditional self-acceptance, distress tolerance, body satisfaction) between Time 1 and 3 were associated with reduced distress, only unconditional self-acceptance was associated with reduced

anxiety, and only body satisfaction with reduced depression. This suggests that distress occurs separately to symptoms of anxiety and depression, and that the psychological factors being studied are more relevant to general distress than depression or anxiety alone.

Interestingly, changes in exercise over time did not correlate with changes in BMI, body satisfaction, or self-esteem. This contradicts suggestions that self-esteem (possibly related to body image) is sufficient to explain the impact of exercise on wellbeing (Ryan, 2008). Changes in exercise also showed no associations with changes in pain frequency, pain intensity or tiredness. This is counter to arguments that improved sleep quality and thus reduced fatigue (Loprinzi & Cardinal, 2011), or reduced inflammation, which is associated with both pain and depression (Kojima et al., 2009) may underlie the effect of exercise on mental wellbeing.

Changes in BMI, tiredness and pain frequency were not associated with changes in any wellbeing measures either. Reductions in pain intensity however, were associated with reductions in anxiety. This might demonstrate the effect of reduced pain intensity (resulting from increased exercise) on anxiety, or indeed the effect of reduced anxiety (resulting from increased exercise) on reduced pain up-regulation, as pain and anxiety have been suggested to mutually maintain one another (Asmundson & Katz, 2009).

Another way of exploring trends in data over time was to look at the change in different scores across the three time points, using linear mixed model analysis. There was a significant reduction in depression and anxiety scores over time, with both remaining relatively constant from Time 1 to Time 2, and then reducing significantly by Time 3. This suggests that it takes 3-6 months from increasing exercise for the impacts on mood and anxiety to become apparent.

Distress tolerance and unconditional self-acceptance scores were found to increase significantly between Time 1 and 3, although the changes between Time 1 and 2 and Time 2 and 3 were nonsignificant. This shows that distress tolerance and unconditional self-acceptance increase gradually over time after increasing exercise, and take about six

months to become significant. No other psychological or biological factors showed significant changes over time.

Overall, this analysis suggests that certain psychological factors (in particular distress tolerance, unconditional self-acceptance, self-efficacy and self-esteem) may mediate the relationship between exercise and mental wellbeing both in the short-term, and possibly also the long-term.

What are the main barriers to, and facilitators of, increasing exercise?

The second research question was analysed using binary logistic regression predicting whether participants had or had not increased their weekly exercise frequency, duration, or intensity between Time 1 and Time 3.

Greater exercise frequency and exercise hours at Time 1 predicted significantly reduced odds of increasing exercise frequency by Time 3. Greater exercise hours at Time 1 also predicted reduced odds of increasing exercise hours during the six months. These patterns can be explained by ceiling effects; those who began the study already reporting the highest level of exercise frequency (7+ times) or hours (10+ hours) would not have been able to record an increase in exercise even if it had occurred. Equally, those already doing lots of exercise and hoping to increase it further, may have been less able to increase exercise levels compared with those who began the study doing very little exercise due to time constraints, increased risk of injury, or over-exertion.

In contrast, greater distress and depression scores at Time 1 predicted significantly increased odds of increasing exercise frequency by Time 3. This suggests not only that distress and depression are not barriers to increasing exercise in the general population, but that those who are more distressed or depressed are more likely to maintain a plan to increase exercise. This contradicts previous suggestions that depression itself is a core barrier to taking up exercise (Vancampfort et al., 2015), and instead supports literature that suggests that exercise has strong emotion-regulating effects (Davis, 2000). However, using exercise to regulate emotions is a risk factor for exercise addiction (Davis, 2000), which has

implications for clinical applications of exercise (discussed later in this section). It is also important to remember that this study took place on a sample from the general population, so those reporting high depression scores were unlikely to be experiencing as severe depression as those in clinical settings, for whom depression and distress may create a legitimate barrier to engaging in exercise.

Greater distress tolerance scores at Time 1 predicted reduced odds of increasing exercise frequency and exercise hours by Time 3. This suggests that individuals with lower distress tolerance are more likely to increase exercise over the six months, again possibly due to the emotion-regulating effects of exercise. Interestingly, the linear mixed model analyses showed that overall distress tolerance scores increased over the six months following increased exercise. This suggests that while individuals with low distress tolerance might be more likely to increase exercise to start with, exercise might then increase their distress tolerance over time.

Greater unconditional acceptance score at Time 1 also predicted reduced odds of increasing exercise frequency and exercise hours by Time 3. As with distress tolerance, linear mixed model analysis also showed that unconditional self-acceptance increased over time after increasing exercise. Therefore those who might benefit from the effects of exercise the most (e.g. who have low distress tolerance and unconditional acceptance to start with) appear more likely to increase their exercise levels over time. This might be because exercise is reinforced by the experience of distress tolerance and self-acceptance increasing.

A higher openness to experience score at Time 1 predicted increased odds of increasing exercise frequency by Time 3. This suggests that being open to the new experiences and sensations related to exercise is an important facilitator of increased exercise.

A higher self-efficacy score at Time 1 predicted increased likelihood of increasing exercise hours per week by Time 3. This suggests that self-efficacy facilitates increasing exercise duration, rather than intensity or frequency.

When the different factors that significantly predicted exercise frequency were run in one regression model to control for one another, only distress tolerance remained significantly predictive. This suggests that some of the other factors (such as higher distress and depression, or lower unconditional self-acceptance) may be explained by distress tolerance. Low distress tolerance is therefore, perhaps counter-intuitively, one of the strongest facilitators of increasing exercise frequency.

The only variable that predicted the likelihood of increasing exercise intensity over time was exercise intensity at Time 1. It was shown to predict reduced odds of increasing intensity, likely due to ceiling effects. This suggests that increasing exercise intensity is less influenced by psychological factors than increasing exercise frequency or duration. Instead, intensity may be more influenced by choice of sport or the fitness level of one's team or group.

Age and gender did not significantly predict the likelihood of increasing exercise frequency, hours or intensity, and there were not enough participants from different ethnic groups to use ethnicity as a predictor. BMI, having a long-term condition, pain frequency, pain intensity and tiredness did not predict the likelihood of increasing exercise by Time 3. Motive for exercising, along with self-esteem, self-efficacy and body satisfaction also did not predict whether or not exercise increased by Time 3. It is worth noting however, that the study used a volunteer sample, who had already committed to increasing their exercise themselves and therefore may have had higher levels of self-efficacy than is representative of the population.

Overall, these findings suggest that low distress tolerance is one of the strongest facilitators of increasing exercise over time. Low unconditional self-acceptance, low baseline exercise levels, and higher depression or distress levels also facilitate increasing exercise. This suggests that exercise can be effectively increased and maintained by less active individuals struggling with low to moderate depression, low distress tolerance, low unconditional self-acceptance, or distress caused by other mental health conditions or circumstances.

Evaluation

There are a number of limitations to this study. Firstly, there was a high dropout rate meaning that the final sample was too small to run longitudinal mediation analysis. Longitudinal mediation analysis would have allowed for causal effects to be demonstrated if present, unlike cross-sectional mediation (Maxwell & Cole, 2007). Instead patterns in the data point towards a number of potential mechanisms, but no causal inferences can be made. Additionally, while the sample size at Time 1 exceeded the recommended sample of 77 required for multiple linear regression (calculated using G*Power, see methods section), Fritz & MacKinnon's (2007) analysis suggests that an even larger sample is required to detect mediation effects. Therefore even the cross-sectional mediation may have been underpowered. A larger initial sample, or methods of reducing dropout would have been necessary to prevent this.

The dropout between Time 1 and 2 may also have caused attrition bias. It is possible that the 31 participants who did not compete follow up surveys did not find exercise as beneficial for their mental wellbeing, or did not engage in their planned exercise increase, so were less motivated to complete the study. This could bias the results of the linear mixed models and correlation analyses towards demonstrating an effect of exercise. However, the mediation analysis, which also indicated beneficial effects of exercise for mental wellbeing, only used data from Time 1 so was not affected by attrition bias.

One factor impacting ability to recruit a larger sample, and possibly contributing to the high dropout rate, was the Covid-19 pandemic. Additionally, this may have compromised the temporal validity of results due to the number of extraneous variables impacting people's mental wellbeing and exercise participation during this time. The impact of the pandemic on both the process and validity of the research is discussed further in Chapter 3.

Another limitation of the sample is that it was a volunteer sample from the general population. This may result in biased responses as participants may already have views about exercise and mental wellbeing if they were interested enough to read and respond to the advert. Additionally, because the sample was from the general population, and only

about half of participants reported having experienced mental health difficulties or used mental health services, the findings cannot be directly generalised to clinical populations. The sample was also not diverse in terms of ethnicity, nor was it balanced for gender. The findings therefore apply best to White females, and cannot be generalised to the whole population.

The study relies heavily on self-report, which is always somewhat biased, especially when it comes to reporting exercise levels (Health Survey England, 2009). This reduces the reliability of findings, although this is an issue throughout much psychological literature.

Another limitation is that certain measures such as the RSES, NGSE, and NEO-FFI are designed to measure stable 'trait-like' constructs, rather than state-like constructs which change over time, which was how they were used in this study. However, it is understood that personality does change over the lifespan (Caspi et al., 2005), and it is possible that exercise is one factor that may influence such changes.

This study also has a number of strengths. It uses longitudinal data to address the issue of mechanisms underlying the effect of exercise on mental health and wellbeing, which has not been done before. It also uses quantitative analysis to explore facilitators and barriers of increasing exercise, which yields quite different results from studies that relied on qualitative data (Crabb et al., 2015), possibly by reducing some social desirability bias. While the relatively small sample size meant that tests were underpowered, the fact that significant effects were found suggests that, with a larger sample, these effects would persist.

Participants were also asked if they would be willing to be contacted for follow-up phone interviews, which will be completed as part of a second research project. The data from the two studies can then be used together to gain a clearer idea of what underlies improvements in wellbeing for individuals who take up or increase their exercise, benefitting from the merits of both qualitative and quantitative research.

The study used nine different standardised and validated measures, which reduces the bias related to self-report as much as possible within a survey-based study. By delivering

the survey online, participants remained completely anonymous throughout, which also likely reduced social desirability bias.

Finally, despite not using a clinical sample, the findings have clinical implications in terms of informing currently available exercise offers for mental health. Additionally there are multiple clear implications for future research, which could go on to confirm patterns found in this research and inform the delivery of more effective exercise interventions in the future.

Implications for clinical practice

The results confirm that anxiety and depression decrease after taking up or increasing exercise. However, it also suggests that these effects take three to six months to become measurable. The implication of this is that current exercise referral schemes, which offer 12-14 sessions, may not be long enough to be effective for mental wellbeing.

Secondly, the results show that unconditional self-acceptance and distress tolerance increase within six months of increasing exercise. As previous research suggests that exercise is most beneficial when individuals have the chance to discuss their experience afterwards (Hilyer & Mitchell, 1979), exercise interventions that focus on noticing changes in distress tolerance and self-acceptance, and generalising them to other aspects of life, may be even more effective.

As well as distress tolerance and unconditional self-acceptance, this study suggests that self-esteem and self-efficacy may also explain the effect of exercise on mental wellbeing. Therefore, providing opportunities to notice and develop these areas may also increase the effectiveness of exercise interventions for mental health.

Individuals with low distress tolerance and unconditional self-acceptance, as well as greater depression and distress scores, are more likely to succeed in increasing exercise over time. This suggests that depression may not be a barrier to engaging with exercise as previously thought (Vancampfort et al., 2015). If so, this suggests that the barrier for people with depression to engage in exercise referrals is related more to the way the exercise programmes are delivered, rather than exercise itself. These findings also imply that

exercise interventions may be particularly effective for individuals with depression, complex post-traumatic stress disorder, cluster-B personality disorders, or obsessive-compulsive disorder, as these are often characterised by high levels of self-evaluation and low tolerance for unpleasant emotions or sensations.

However, given that using exercise for emotion-regulation is associated with increased risk of exercise dependence (Davis, 2000), providing exercise interventions to distressed individuals could result in dependency. Therefore, exercise interventions for mental health must make service users aware of this risk, monitor signs of exercise dependence, and have a process for supporting people to overcome dependence if it occurs.

This study demonstrates that exercise improves distress tolerance over time, which is important for engaging in many psychological therapies. Exercise is also known to improve cognitive flexibility and problem solving (Roig-Coll et al., 2020), which may also support engagement in psychological therapy. Counselling and CBT both support engagement in exercise (Krebs et al., 2019; Strid et al., 2016). Therefore, the relationship between exercise and psychological therapy may be symbiotic. A combined exercise psychology intervention may be the most effective way of providing exercise interventions for mental health, in the same way that art, music and drama therapy include aspects of psychotherapy. The additional benefit of this is that for people who find talking, art, dance or music therapy unappealing, exercise therapy may feel more accessible.

Implications for future research

Further analysis would be beneficial regarding distress tolerance, unconditional self-acceptance, self-esteem and self-efficacy as mediators of the relationship between exercise and mental wellbeing. Future research should aim to recruit a much larger sample and reduce dropout across time points in order to allow for longitudinal mediation analysis which would confirm causal effects.

To confirm that these findings are applicable within clinical settings it would be beneficial for future studies in this area to recruit a clinical sample, preferably with more representative demographics in terms of gender and ethnicity.

Additionally it would be useful to complete an acceptability and feasibility study for a combined exercise psychology intervention that takes into account the above recommendations (longer than three months, focussed on psychological mechanisms of change, aims to monitor and prevent dependence). This is to ensure that mental health service users would want and be able to engage in this sort of intervention, although current evidence suggests that they would (Crabb et al., 2015).

Additionally, qualitative analysis to explore whether the interpretations made in this study are reflected by the individual experiences of those increasing their exercise would support an understanding of how best to apply findings. Participants in this study were invited to provide their contact details if they wished to take part in a follow-up interview for this purpose. This qualitative research is currently being conducted as part of a second clinical doctorate research project at University College London.

References:

Adams, J. (2009). Understanding exercise dependence. *Journal of Contemporary Psychotherapy*, *39*(4), 231-240.

Alexandratos, K., Barnett, F., & Thomas, Y. (2012). The impact of exercise on the mental health and quality of life of people with severe mental illness: A critical review. *British Journal of Occupational Therapy*, *75*(2), 48-60.

Asmundson, G. J., Fetzner, M. G., DeBoer, L. B., Powers, M. B., Otto, M. W., & Smits, J. A. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depression and anxiety*, *30*(4), 362-373.

Asmundson, G. J., & Katz, J. (2009). Understanding the co-occurrence of anxiety disorders and chronic pain: state-of-the-art. *Depression and anxiety*, *26*(10), 888-901.

Awick, E. A., Ehlers, D. K., Aguiñaga, S., Daugherty, A. M., Kramer, A. F., & McAuley, E. (2017). Effects of a randomized exercise trial on physical activity, psychological distress and quality of life in older adults. *General hospital psychiatry*, *49*, 44-50.

Barkham, M., Bewick, B., Mullin, T., Gilbody, S., Connell, J., Cahill, J., Mellor-Clark, J., Richards, D., Unsworth, G. & Evans, C. (2013). The CORE-10: A short measure of psychological distress for routine use in the psychological therapies. *Counselling and Psychotherapy Research*, *13*(1), 3-13.

Beavers, K. M., Brinkley, T. E., & Nicklas, B. J. (2010). Effect of exercise training on chronic inflammation. *Clinica chimica acta*, *411*(11-12), 785-793.

Beck, A. T., Steer, R. A., & Carbin, M. G. (1988b). Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. *Clinical psychology review*, *8*(1), 77-100.

Beck, A.T., Epstein, N., Brown, G., & Steer, R.A. (1988a). An inventory for measuring clinical anxiety: Psychometric properties. Journal of Consulting and Clinical Psychology, 56, 893-897.

Broocks, A., Bandelow, B., Pekrun, G., George, A., Meyer, T., Bartmann, U., Hillmer-Vogel, U., & Rüther, E. (1998). Comparison of aerobic exercise, clomipramine, and placebo in the treatment of panic disorder. *American Journal of Psychiatry*, *155*(5), 603-609.

Caspi, A., Roberts, B. W., & Shiner, R. L. (2005). Personality development: Stability and change. *Annu. Rev. Psychol.*, *56*, 453-484.

Chamberlain, J. M., & Haaga, D. A. (2001). Unconditional self-acceptance and psychological health. *Journal of Rational-Emotive and Cognitive-Behavior Therapy*, *19*(3), 163-176.

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational research methods*, *4*(1), 62-83.

Conn, V. S. (2010). Anxiety outcomes after physical activity interventions: meta-analysis findings. *Nursing research*, *59*(3), 224.

Cooney, G. M., Dwan, K., Greig, C. A., Lawlor, D. A., Rimer, J., Waugh, F. R., McMurdo, M., & Mead, G. E. (2013). Exercise for depression. *Cochrane database of systematic reviews*, (9).

Cooper, P. J., Taylor, M. J., Cooper, Z., & Fairbum, C. G. (1987). The development and validation of the Body Shape Questionnaire. *International Journal of eating disorders*, *6*(4), 485-494.

Costa, P. T., & McCrae, R. R. (1992). Revised NEO Personality Inventory (NEO-PIR) and NEO Five Factor Inventory (NEO-FFI) professional manual. Odessa, FL: Psychological Assessment Resources.

Crabb, J., Milne, L., Conway, L., Fulton, M., Dewar, C., McHugh, B., Speed, L., Tourish, P., & McKinnon, M. (2015). A population-based survey of barriers and enablers to physical activity in people using, and working in a mental health service in Scotland. *International Journal of Mental Health Promotion, 17*(4), 234-246.

Craft, L. L., & Perna, F. M. (2004). The benefits of exercise for the clinically depressed. *Primary care companion to the Journal of clinical psychiatry*, *6*(3), 104.

Crone, D., Johnston, L. H., Gidlow, C., Henley, C., & James, D. V. (2008). Uptake and participation in physical activity referral schemes in the UK: an investigation of patients referred with mental health problems. *Issues in mental health nursing*, *29*(10), 1088-1097.

Da Silva, M. A., Singh-Manoux, A., Brunner, E. J., Kaffashian, S., Shipley, M. J., Kivimäki, M., & Nabi, H. (2012). Bidirectional association between physical activity and symptoms of anxiety and depression: the Whitehall II study. *European journal of epidemiology*, *27*(7), 537-546.

Davis, C. (2000). Exercise abuse. *International journal of sport psychology*.

De Sousa, R. A. L., Rocha-Dias, I., de Oliveira, L. R. S., Improta-Caria, A. C., Monteiro-Junior, R. S., & Cassilhas, R. C. (2021). Molecular mechanisms of physical exercise on depression in the elderly: a systematic review. *Molecular Biology Reports*, *48*(4), 3853-3862.

Dinger, M. K., Brittain, D. R., & Hutchinson, S. R. (2014). Associations between physical activity and health-related factors in a national sample of college students. *Journal of American College Health*, *62*(1), 67-74.

Dishman, R. K., & O'Connor, P. J. (2009). Lessons in exercise neurobiology: the case of endorphins. *Mental Health and Physical Activity*, *2*(1), 4-9.

Edmunds, S., Biggs, H., Goldie, I., Cyhlarova, E., Lawton-Smith, S., & McCulloch, A. (2013). Let's get physical: The impact of physical activity on wellbeing. *Mental Health Foundation*, *38*, 1-47.

Ekkekakis, P., Parfitt, G., & Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities. *Sports medicine*, *41*(8), 641-671.

Fleming, J. S., & Courtney, B. E. (1984). The dimensionality of self-esteem: II. Hierarchical facet model for revised measurement scales. *Journal of personality and social psychology*, *46*(2), 404.

Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychological science*, *18*(3), 233-239.

Goodwin, R. D. (2003). Association between physical activity and mental disorders among adults in the United States. *Preventive medicine*, *36*(6), 698-703.

Grant, J. E., Odlaug, B. L., Derbyshire, K., Schreiber, L. R., Lust, K., & Christenson, G. (2014). Mental health and clinical correlates in lesbian, gay, bisexual, and queer young adults. *Journal of American College Health*, *62*(1), 75-78.

Greenwood, B. N., & Fleshner, M. (2008). Exercise, learned helplessness, and the stress-resistant brain. *Neuromolecular medicine*, *10*(2), 81-98.

Gullone, E., & Moore, S. (2000). Adolescent risk-taking and the five-factor model of personality. *Journal of adolescence*, *23*(4), 393-407.

Hale, G. E., Colquhoun, L., Lancastle, D., Lewis, N., & Tyson, P. J. (2021). Physical activity interventions for the mental health and wellbeing of adolescents–a systematic review. *Child and Adolescent Mental Health*, *26*(4), 357-368.

Haslam, S. A., Fransen, K., & Boen, F. (2020). *The new psychology of sport and exercise: The social identity approach*. Sage.

Hausenblas, H. A., & Fallon, E. A. (2006). Exercise and body image: A meta-analysis. *Psychology and health*, *21*(1), 33-47.

Hayes, A. F. (2022). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. *Third Edition.* Guilford publications.

Health Survey England (2009). *Health Survey for England - 2008: Physical activity and fitness.* Retrieved from: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/health-survey-for-england-2008-physical-activity-and-fitness

Heinze, K., Cumming, J., Dosanjh, A., Palin, S., Poulton, S., Bagshaw, A. P., & Broome, M. R. (2021). Neurobiological evidence of longer-term physical activity interventions on mental health outcomes and cognition in young people: A systematic review of randomised controlled trials. *Neuroscience & Biobehavioral Reviews*, *120*, 431-441.

Herting, M. M., & Chu, X. (2017). Exercise, cognition, and the adolescent brain. *Birth defects research*, *109*(20), 1672-1679.

Hilyer, J. C., & Mitchell, W. (1979). Effect of systematic physical fitness training combined with counseling on the self-concept of college students. *Journal of Counseling Psychology,* 26(5), 427.

Hojman, P., Gehl, J., Christensen, J. F., & Pedersen, B. K. (2018). Molecular mechanisms linking exercise to cancer prevention and treatment. *Cell metabolism*, *27*(1), 10-21.

Howell, D. C. (2016). *Mixed models for missing data with repeated measures Part 1.* https://www.uvm.edu/~statdhtx/StatPages/Mixed-Models-Repeated/Mixed-Models-for-Repeated-Measures1.html

Jones, B. A., Arcelus, J., Bouman, W. P., & Haycraft, E. (2017). Sport and transgender people: a systematic review of the literature relating to sport participation and competitive sport policies. *Sports Medicine*, *47*(4), 701-716.

Knapen, J., Vancampfort, D., Moriën, Y., & Marchal, Y. (2015). Exercise therapy improves both mental and physical health in patients with major depression. *Disability and rehabilitation*, *37*(16), 1490-1495.

Kojima, M., Kojima, T., Suzuki, S., Oguchi, T., Oba, M., Tsuchiya, H., Sugiura, F., Kanayama, Y., Furukawa, T.A., Tokudome, S. & Ishiguro, N. (2009). Depression, inflammation, and pain in patients with rheumatoid arthritis. *Arthritis Care & Research*, *61*(8), 1018-1024.

Kramer, A. (2020). An overview of the beneficial effects of exercise on health and performance. *Physical Exercise for Human Health*, 3-22.

Krebs, S., Baaken, A., Wurst, R., Goehner, W., & Fuchs, R. (2019). Effects of a worksite group intervention to promote physical activity and health: The role of psychological coaching. *Applied Psychology: Health and Wellbeing*, *11*(3), 584-605.

Lahart, I., Darcy, P., Gidlow, C., & Calogiuri, G. (2019). The effects of green exercise on physical and mental wellbeing: A systematic review. *International journal of environmental research and public health*, *16*(8), 1352.

LeBouthillier, D. M., & Asmundson, G. J. (2017). The efficacy of aerobic exercise and resistance training as transdiagnostic interventions for anxiety-related disorders and constructs: A randomized controlled trial. *Journal of anxiety disorders*, *52*, 43-52.

Loprinzi, P. D., & Cardinal, B. J. (2011). Association between objectively-measured physical activity and sleep, NHANES 2005–2006. *Mental Health and Physical Activity*, *4*(2), 65-69.

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. Pediatrics, 138(3).

Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological methods*, *12*(1), 23.

National Institute for Health and Care Excellence. (2009). *Depression in Adults: Recognition and Management* (Clinical Guideline CG90). Retrieved from https://www.nice.org.uk/guidance/cg90

Netz, Y. (2017). Is the comparison between exercise and pharmacologic treatment of depression in the clinical practice guideline of the American College of Physicians evidence-based?. *Frontiers in Pharmacology,* 8, 257.

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports medicine*, *29*(3), 167-180.

Pasco, J. A., Jacka, F. N., Williams, L. J., Brennan, S. L., Leslie, E., & Berk, M. (2011). Don't worry, be active: Positive affect and habitual physical activity. *Australian & New Zealand Journal of Psychiatry*, *45*(12), 1047-1052.

Piñeiro-Cossio, J., Fernández-Martínez, A., Nuviala, A., & Pérez-Ordás, R. (2021). Psychological wellbeing in physical education and school sports: a systematic review. *International Journal of Environmental Research and Public Health*, *18*(3), 864.

Porras-Segovia, A., Rivera, M., Molina, E., López-Chaves, D., Gutiérrez, B., & Cervilla, J. (2019). Physical exercise and body mass index as correlates of major depressive disorder in community-dwelling adults: results from the PISMA-ep study. *Journal of Affective Disorders*, *251*, 263-269.

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health psychology review*, *9*(3), 366-378.

Rector, N. A., Richter, M. A., Lerman, B., & Regev, R. (2015). A pilot test of the additive benefits of physical exercise to CBT for OCD. *Cognitive behaviour therapy*, *44*(4), 328-340.

Reed, J., & Buck, S. (2009). The effect of regular aerobic exercise on positive-activated affect: A meta-analysis. *Psychology of Sport and Exercise*, *10*(6), 581-594.

Reynolds, W. M. (1988). Measurement of academic self-concept in college students. *Journal of personality assessment*, *52*(2), 223-240.

Robinson, M., Keating, F., & Robertson, S. (2011). Ethnicity, gender and mental health. *Diversity in Health & Care*, *8*(2).

Roig-Coll, F., Castells-Sánchez, A., Lamonja-Vicente, N., Torán-Monserrat, P., Pera, G., García-Molina, A., ... & Mataró, M. (2020). Effects of Aerobic Exercise, Cognitive and Combined Training on Cognition in Physically Inactive Healthy Late-Middle-Aged Adults: The Projecte Moviment Randomized Controlled Trial. *Frontiers in aging neuroscience*, 376.

Rosenbaum, S., Vancampfort, D., Steel, Z., Newby, J., Ward, P. B., & Stubbs, B. (2015). Physical activity in the treatment of post-traumatic stress disorder: a systematic review and meta-analysis. *Psychiatry research*, *230*(2), 130-136.

Rosenberg, M. (1965). Rosenberg self-esteem scale. *Journal of Religion and Health*.

Ryan, M. P. (2008). The antidepressant effects of physical activity: Mediating self-esteem and self-efficacy mechanisms. *Psychology & Health*, *23*(3), 279-307.

Savikj, M., & Zierath, J. R. (2020). Train like an athlete: applying exercise interventions to manage type 2 diabetes. *Diabetologia*, *63*(8), 1491-1499.

Scott, S. E., Breckon, J. D., & Copeland, R. J. (2019). An integrated motivational interviewing and cognitive-behavioural intervention promoting physical activity maintenance for adults with chronic health conditions: A feasibility study. *Chronic illness*, *15*(4), 276-292.

Simons, J. S., & Gaher, R. M. (2005). The Distress Tolerance Scale: Development and validation of a self-report measure. *Motivation and emotion*, *29*(2), 83-102.

Slade, Peter D., et al. "Development and preliminary validation of the Body Satisfaction Scale (BSS)." *Psychology and Health* 4.3 (1990): 213-220.

Sneed, C. D., Gullone, E., & Moore, S. (2002). Reliability and factor structure of the NEO-five-factor inventory for Australian adolescents. *Behaviour Change*, *19*(2), 121-126.

Sport England. (2018). *Active lives adult survey.* Retrieved from: https://activelives.sportengland.org/

Strid, C., Andersson, C., Forsell, Y., Öjehagen, A., & Lundh, L. G. (2016). Internet-based cognitive behaviour therapy and physical exercise–Effects studied by automated telephone assessments in mental ill-health patients; a randomized controlled trial. *British Journal of Clinical Psychology*, *55*(4), 414-428.

Turner, J. B., & Turner, R. J. (2004). Physical Disability, Unemployment, and Mental Health. *Rehabilitation Psychology*, *49*(3), 241.

Vancampfort, D., Stubbs, B., Sienaert, P., Wyckaert, S., De Hert, M., Rosenbaum, S., & Probst, M. (2015). What are the factors that influence physical activity participation in individuals with depression? A review of physical activity correlates from 59 studies. *Psychiatria Danubina, 27(3), 0-224.*

Wheeler, A. J., Roennfeldt, H., Slattery, M., Krinks, R., & Stewart, V. (2018). Codesigned recommendations for increasing engagement in structured physical activity for people with serious mental health problems in Australia. *Health & Social Care in the Community, 26*(6), 860-870.

Yuan, Y., Li, J., Jing, Z., Yu, C., Zhao, D., Hao, W., & Zhou, C. (2020). The role of mental health and physical activity in the association between sleep quality and quality of life among rural elderly in China: A moderated mediation model. *Journal of affective disorders*, *273*, 462-467.

Zunszain, P. A., Hepgul, N., & Pariante, C. M. (2012). Inflammation and depression. *Behavioral neurobiology of depression and its treatment*, 135-151.

Part 3: Critical Appraisal

Critical Appraisal Of Research Process and Findings

Introduction

This critical appraisal draws together a number of reflections on the process of completing this thesis. These include critical reflections on the research including its validity and things that could have been done differently, as well as personal reflections on the experience of conducting the research, including difficulties and growth.

What led me to this research area

I have had a personal interest in the role of exercise in mental wellbeing for some time, given my own interest in endurance sport. I have experienced the benefits of exercise for my own mental health on numerous occasions. By getting to know others through sports, I have heard of many others experiencing these benefits too. I began to notice that what people shared about why exercise helped them did not seem to fit with the literature I was reading in my own time. Rather than describing short-term euphoric physiological sensations, better sleep, changes to physique or improved physical health being the route to their improved mental health, people would describe more complex psychological processes.

People spoke to me about how training for a race after a difficult life event had shown them they could overcome adversity. This, they explained, would empower them to manage greater adversities in life. People would tell me how through exercising they started to appreciate their bodies' capabilities and functions. As a result they would become less concerned by things they previously resented or worried about such as size, shape, or health conditions. People also described finding a "community" of people who shared values of health and self-improvement. These conversations made me start to ask, "do psychological mechanisms underlie the relationship between exercise and mental health?".

Additionally, I had the privilege to work in a psychosis service where exercise groups were provided as part of routine care. I was able to see the impact that exercise was having

on service users' mental as well as physical health. I also became aware of the difficulty these groups had in gaining funding, and of the gap between people knowing that exercise is important for mental wellbeing, and collecting research data to demonstrate this to commissioners. As I started to look into the way exercise is "prescribed" in primary care, and realised how poor the outcomes are for people referred for mental health difficulties, I started to think about what those groups, delivered in conjunction with clinicians, had offered to service users which the more generic exercise referral schemes did not.

Potential threats to internal validity

A key threat to the validity of any research is researcher bias. While this is acknowledged as a larger threat in qualitative research (Chenail, 2011), with processes such as bracketing interviews designed to raise awareness of personal bias (Tufford & Newman, 2012), it does still impact both internal and external validity of quantitative research (Onwuegbuzie, 2000). I therefore made an effort throughout the process to be aware of my personal perspective and attachment to the research topic, and how these could be influencing my interpretations and decisions.

This was one of the reasons I preferred to do a quantitative rather than qualitative study, as this reduced the amount of bias I could bring. Additionally, because I was not providing an intervention but instead participants were deciding to increase exercise for themselves, and because the survey was made up of primarily standardised measures, this reduced researcher bias further.

Because this was such a novel area of research, there was no data on which to base specific hypotheses, so instead the analysis and interpretation were guided by two research questions:

1. Do psychological processes mediate the relationship between exercise and improved mental wellbeing?
2. What are the main barriers to, and facilitators of, increasing exercise?

However, despite not having specific hypotheses, I did hold my own expectations and hopes about what might be found. I expected that some of the psychological mechanisms that arose in conversations with peers (e.g. improved body relationship and self-efficacy) might be mediators of the relationship between exercise and mental wellbeing. I also hoped that psychological mechanisms would mediate the relationship between exercise and mental wellbeing, as this along with research demonstrating that counseling increases the effectiveness of exercise interventions (Hilyer & Mitchell, 1979), and recommendations that exercise interventions should be delivered within mental health settings (Sancassiani et al., 2018), would support my idea that exercise as a mental health intervention may be best offered within mental health services, where psychological mechanisms of change might be better understood and facilitated. These hopes and expectations may have resulted in confirmation bias when interpreting results. However, as Greenwald et al., (1986) point out, confirmation bias is not necessarily a problem when there are no opposing hypotheses, and it is less likely in theory-generating research such as this, than theory-testing research.

Another source of bias that any longitudinal study is vulnerable to is attrition bias. Almost 39% of the original sample dropped out between Time 1 and 2 (although there was no further dropout between Time 2 and 3). While the assumption within the research is that this dropout was random, there may have been a pattern behind who dropped out. For example, people for whom exercise was less beneficial might have been more likely to drop out. If this is the case, the final sample may have been biased towards the beneficial impact of exercise for mental health. As the mediation analysis was only performed using data from Time 1 (due to the final sample-size being too small for longitudinal effects to reach significance), this would not have affected the mediation analyses. However, the linear mixed model and correlation analyses did use data from Time 3 so may be biased by attrition.

Another form of bias that could have been present is placebo effect, whereby believing one is undergoing an intervention results in reported improvement. In an attempt to

avoid this, the survey title participants saw was “What underlies the long-term impact of exercise on mental health and wellbeing?” and did not specifically mention psychological mechanisms. However, it did make clear an expectation that increasing exercise (which all participants had recently done, or were about to do) would improve wellbeing, which could have resulted in placebo effect. Again, this would not have influenced the cross-sectional mediation analyses, but may have affected the linear mixed model and correlation analyses which used data across time points.

Another threat to internal validity is the likelihood of Type I or Type II error. Due to the exploratory nature of this research many variables, and therefore many different statistical tests, were used. An alpha value of $p<.05$ means there is a less than 95% probability that the result represents a genuine effect, and therefore less than 5% probability it does not. Therefore 1 in 20 significant results could, statistically, not represent an actual effect. This is why research that uses a large number of statistical tests can be accused of “p-hacking”, because the more statistical tests run, the greater likelihood of getting a significant result by chance. Thus more tests increases Type I error. This is one of the reasons why exploratory research, such as this study, must be interpreted cautiously. Follow-up research testing specific hypotheses would be important for increasing the validity of the findings.

With any time point analysis, regression towards the mean is another phenomena which could compromise internal validity. Regression to the mean refers to the fact that when a variable is sampled repeatedly, extreme values tend to be followed by more moderate ones. Therefore, for participants who appeared to have high depression scores at Time 1, which then reduced by Time 3, this could be representing regression to the mean rather than the effect of exercise. Similarly, for those experiencing very low depression scores at Time 1, we would expect this to increase to nearer the mean by the next time point. This is one reason why a large sample is important for ensuring internal validity, as extreme high and low values tend to balance out. Because this sample was relatively small, effects of regression to the mean could have biased overall results.

Potential threats to external validity

This sample had relatively poor population validity due to its demographic make-up. Because the majority of participants were White females, the findings cannot be generalised to other members of the population. Additionally, the research was conducted with an interest in how exercise can be used as a mental health or wellbeing intervention. Given that the sample was from the general population, rather than mental health service users, findings cannot be directly generalised to clinical situations.

The ecological validity of the study however was strong. Participants had already decided to increase their exercise before being recruited, and they were entirely in control of what that increased exercise looked like. The only factor that was specific to the research study was the opportunity to reflect on changes in wellbeing and other psychological domains every few months. This however, probably would occur as part of a targeted exercise intervention for mental health (whether by the use of outcome measures, or more structured discussion about change), so does not compromise the ecological validity of the study in terms of informing exercise interventions.

The temporal validity of the study may also be low, due to the study happening during the Covid-19 pandemic. As a result, there were more external factors acting on people's wellbeing than there would be usually. Whether or not people had to isolate, lost loved ones, were experiencing Long-Covid symptoms, or had travel plans cancelled for example, was not recorded in the survey. Additionally, restrictions, as well as more general factors such as weather and daylight hours, differed between each time point. Time 1 occurred during summer 2021, when Covid-19 restrictions were being reduced, and mass sports events were occurring for the first time in a couple of years. Time 2 occurred in Autumn, as things were increasingly returning to normal and many sports and exercise groups were back to usual capacity. Time 3 occurred early in the new year of 2022, when the Omicron variant of Covid-19 was causing mass isolation and concern again. There was also less daylight and colder temperatures by Time 3, both of which may act as barriers to exercise, or could affect mental wellbeing. The findings of this study may therefore not be

fully generalisable to other times of the year, or years to come once the Covid-19 pandemic is more fully resolved.

The impact of the Covid-19 pandemic

The pandemic had other affects on the research process than affecting the temporal validity of the study. The Covid-19 pandemic began very shortly after I chose this research area. I had already planned to use an online study, but the pandemic affected my planned recruitment. I had hoped to approach gyms, physical trainers and sports coaches, and ask them to advertise to people taking up or significantly increasing their exercise. Because all gyms closed down during the lockdowns, and there were restrictions on group size for exercise groups, I was not able to do this during the time I otherwise would have been recruiting.

An additional impact of the pandemic was a rush on submissions of ethics proposals, and reduced staffing within the university ethics team. As a result, it took a full three months to receive university level ethics approval, instead of the estimated three to five weeks. This also impacted my ability to recruit as I had a shorter time period in which to do it. These things together meant that I had a smaller starting sample than hoped for the analysis. With the inevitable dropout between time points, this unfortunately impacted on the types of analysis I was able to use, as longitudinal mediation in particular was very underpowered.

What could have been done differently

One of the greatest limitations of this research is its sample size. One reason for this was dropout between time points. While entry into a prize draw was used as incentive, with an increased chance of winning after completing each time point, a smaller but guaranteed reward might have resulted in more consistent responding. However, dropout in psychological studies is a common phenomena, and another way of protecting against its impact is to recruit a larger sample to begin with. Recruiting gyms and personal trainers first, and offering an incentive to them for asking their clients to complete the research, might

have supported recruitment of a larger initial sample given that finding organisations willing to advertise the study was a barrier to recruitment.

Another thing that might have helped to recruit a larger sample was running the study at a different time of year. Unfortunately in July and August, when this study began, most sports events that people might have ben training for had already happened, and athletes might have been more focussed on recovery and maintenance than increasing exercise. By running the study from January to July instead, I might have been able to access a larger number of people who were training towards a summer event. A larger sample would also increase the likelihood of a more demographically diverse sample, which would have been beneficial for improving the population validity of the study. However, gyms and physical trainers can be expensive, so recruiting through free or charitable exercise provisions would also have been important to increase the representativeness of the sample.

Personal experience of the research process

Overall, I found the process of designing, conducting and writing up a research project very fulfilling. As I chose my own topic, I necessarily accepted a high degree of autonomy around the project. At times, especially during the peaks of the pandemic, feeling like a “solo-researcher” could feel lonely and make it difficult to motivate myself. However, I learned a new way of working, and actually began to really enjoy the freedom of being able to manage the tasks of the thesis, and my ideas around it, myself.

I had never considered myself a “researcher” before this project. I started the clinical doctorate with much more clinical than research experience, and given I had not studied mathematics at A-level I already felt a little behind some of my peers with strong backgrounds in statistics, or with published research. However, as I engaged in the process of conducting my own research about something I felt passionate about, I came to increasingly see the necessity of research skills for the profession. The points of both the literature review and empirical paper which I found most exciting were the points where I was able to link research to recommendations for practice. By speaking about this research

with colleagues, I started to learn about how useful this research, and further research in the area could be. For example, one colleague in a specialist service informed me that they have struggled to demonstrate to commissioners why their service should keep the gym machines they provide for service users. I became so much of an advocate for clinical research that in my final year placement I even completed an additional research project within my service, and supervised placement students in the team with their undergraduate dissertations.

The aspect of the research I found most difficult was the literature review. I chose to complete a conceptual introduction rather than a systematic review, on the basis that a lot of the rationale for the research was based on guidelines and current practice rather than published evidence. However, as this meant there was no clear limit to the scope of the literature I was reviewing, I ended up reading a huge amount of articles. I also realised that I was struggling to take in information as I read, which started to make me doubt my own abilities and research skills. However, after speaking to my course tutor I was recommended to get an assessment to better understand this difficulty. The outcome was a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD), something which, once it was explained to me seemed to make sense, but which I had never considered before.

I got some helpful advice on how to use my computer and other software to make reading more interactive and manageable, which helped me to complete the reading I wanted to do and finish my literature review. While it was an adjustment to accept the diagnosis, I have since reflected on how certain aspects of ADHD have actually facilitated parts of the thesis process. For example, I was able to switch quickly between working on different sections of my thesis, and hold several different elements of the research in mind at once.

Thoughts for future directions

As I researched this area I started to form links with organisations that run sports and exercise groups for mental health. I now feel more attached to the area than ever, and am

excited about future opportunities to conduct follow-up research and start to apply some of my findings.

My final year placement was in a specialist veterans' mental health team, and as I discussed my research with colleagues I started to see the opportunities for application within these services in particular. Many service users present with emotional avoidance, either as a learned response that made it possible to perform in high-threat environments, or because of post-traumatic stress disorder (PTSD). As a result, many service users feel ambivalent about psychological treatment and prefer pharmacological approaches, despite their limited efficacy for PTSD. Therapeutic exercise groups might provide something in between, given that exercise can be understood both in terms of its neurological and psychological impact. Additionally, veterans often have a lot of experience of doing exercise as part of their military service, so this sort of approach might feel more accessible to them than "talking therapy". As my first qualified post will also be in a veterans' mental health team, I hope to carry over some of these ideas and potentially look for opportunities for completing follow-up research within a clinical population.

Another direction of research I would be interested in pursuing, or seeing pursued, is research considering how biological and psychological mechanisms suggested to underlie the impact of exercise on mental health might interact. My focus on psychological mechanisms is not intended to discredit the evidence for biological mechanisms in any way, and I believe both would make more sense together. For example, exercise results in a short-term stress response in the body (Harber & Sutton, 1984), which it has been suggested leads to reduced cortisol sensitivity over time (Huang et al., 2013), and thus increased resilience to stress. This process might be partly responsible for increasing distress tolerance, as the unpleasant physical sensations related to stressful experiences reduce with exercise. Additionally changes in the hippocampus appear to result in improved problem-solving (Herting & Chu, 2017) which could underlie some of the improvements in self-efficacy resulting from exercise.

Another development from this research project is a second clinical doctorate research project being conducted in relation to it. When I applied for ethics I included follow-up phone interviews with participants to understand their experiences of increasing exercise with regards their mental health. I was aware that I might not have time to complete these, but included them in the ethics application in case I did. Between delays with ethical approval and difficulties recruiting it quickly became clear that I would not have time to, but several participants had already given consent to be phoned for follow-up interviews. As a result, a qualitative research project on the same topic, with pre-arranged ethical approval, was offered to the next cohort. Someone chose to take on the project, which means that this research area is already being developed further. I am very pleased about this as I am aware that this way the qualitative element of the research will be much more thorough than it otherwise would have been, and it also allowed me more time to dig deeper into the quantitative analysis.

Summary

Due to the constraints of the doctorate, and of the Covid-19 pandemic, there are several elements of this research that could be improved upon. However, understanding and improving upon previous research is vital to the development of models and theories. Research that explores new areas and raises interest and questions for other researchers is therefore still valuable. As colleagues, both within my placement and the university, have already asked me about dissemination, I am hopeful that this study might catalyse further interest in this area.

While many aspects of completing the thesis have been challenging, I have gained huge amounts of confidence and enthusiasm about research, and clinically applicable research in particular. I will leave the doctorate actively searching for further opportunities both to apply the skills I learned during the thesis, and to learn new ones.

References

Chenail, R. J. (2011). Interviewing the investigator: Strategies for addressing instrumentation and researcher bias concerns in qualitative research. *Qualitative Report*, *16*(1), 255-262.

Greenwald, A.G., Pratkanis, A.R., Leippe, M.R., & Baumgardner, M.H. (1986). Under what conditions does theory obstruct research progress. Psychological Review, 93,216-229.

Herting, M. M., & Chu, X. (2017). Exercise, cognition, and the adolescent brain. *Birth defects research*, *109*(20), 1672-1679.

Hilyer, J. C., & Mitchell, W. (1979). Effect of systematic physical fitness training combined with counseling on the self-concept of college students. *Journal of Counseling Psychology,* 26(5), 427.

Huang, C. J., Webb, H. E., Zourdos, M. C., & Acevedo, E. O. (2013). Cardiovascular reactivity, stress, and physical activity. *Frontiers in physiology*, *4*, 314.

Onwuegbuzie, A. J. (2000). Expanding the Framework of Internal and External Validity in Quantitative Research.

Sancassiani, F., Machado, S., & Preti, A. (2018). Physical activity, exercise and sport programs as effective therapeutic tools in psychosocial rehabilitation. *Clinical practice and epidemiology in mental health: CP & EMH*, *14*, 6.

Tufford, L., & Newman, P. (2012). Bracketing in qualitative research. *Qualitative social work*, *11*(1), 80-96.

Appendices

Appendix A

Recruitment Advert

- **Have you recently increased the amount of exercise you're doing or are you about to?**
- **Are you thinking about taking up a new sport or type of exercise?**
- **Would you like to contribute to a better understanding of the relationship between exercise and the way we think?**

We are running a new survey investigating the links between exercise and wellbeing.

Scan the QR or go to this link to find out more about taking part!
https://uclpsych.eu.qualtrics.com/jfe/form/SV_1MOPMz47Pp3rc1w

As a thank you, you will be entered into a prize draw to win a new pair of trainers or a fitness tracker

Contact: jessica.lewis.19@ucl.ac.uk
Project supervisor: Prof John King, john.king@ucl.ac.uk

This survey is part of a UCL Clinical Psychology Doctorate research study looking at the impact of exercise on people's mental and emotional wellbeing, as well as things that make it easier or harder for people to engage in exercise. The study involves completing a survey at three time points (you get more optional entries to the prize draw at each time point) including questions about your exercise habits, physical health, and mental and emotional wellbeing including how you feel about yourself and your body. The study has UCL REC ethical approval. Please click on the link above for more information and to take part, or e-mail jessica.lewis.19@ucl.ac.uk with any questions.

To take part you need to have just taken up, or be about to take up, a marked increase in activity. You cannot take part if you have been diagnosed with or think you may have an eating disorder, problematic exercise behaviour (over-exercising or relative energy deficiency syndrome), a current acute injury or have been advised to rest by a doctor or physiotherapist.

Appendix B

Text from information Page and Consent Form

[UCL logo]

Which cognitive mechanisms underlie the long-term positive impact of exercise on mental health wellbeing?

This study is being run by Jessica Lewis (REMOVED FROM PUBLIC VERSION) , under the supervision of Dr. John King (REMOVED FROM PUBLIC VERSION).

[Picture of two runners in park]

Who is it for?

If you have recently, or are about to, increase the amount of exercise you do, and do not have an eating disorder, any problematic exercise behaviour (e.g. over-exercising, relative energy deficiency syndrome), a current acute injury, or have otherwise been told to rest by your doctor, then you are eligible to take part!

An 'increase in exercise' can be anything from starting walking or running for the very first time, or joining a gym or yoga class, to training for a marathon or other new race/event, progressing to a more intense gym class, or taking up a new sport in addition to your usual exercise.

If this is you, then you are eligible to take part in this study!

As a thank you, you will have the chance to enter into a prize draw to win one of two pairs of new *Asics* running trainers (also great for general gym/sport use!) or one of three *Teminice* multi-function fitness-tracking watches (colours and styles may differ from below based on availability at time of draw).

[Picture of shoes/fitness trackers]

What is it about?

This study is looking at the impact of exercise on people's mental and emotional wellbeing, as well as things that make it easier or harder for people to engage in exercise.

What does it involve?

Participation involves completing a survey including a series of questions about yourself, and the exercise you do, and then several questionnaires looking at different aspects of mental and emotional functioning. These should take 20-30 minutes to complete.

Once you have completed the survey today, your e-mail address will be stored (separately to your survey answers to ensure that your answers remain anonymous) and you will be sent a link to complete the same survey again in 3, and then 6 months time. Please note, some of the questionnaires ask your relationship with your body, and symptoms of anxiety or low mood including thoughts of harming yourself. Please consider whether you feel comfortable answering these questions before completing the consent form. You do not have to take part in this study, and can withdraw at any time.

What do I get out of it?

By taking part you will be contributing to some really important research about physical and mental health. Completing the survey every 3 months will also give you an opportunity to notice for yourself any changes in your fitness and mental health, and what things make it easier and harder to keep to your planned exercise.

Additionally:

- Completing the first survey gets you 1 entry into the prize draw.
- Completing the second gets you 3 more entries.
- Completing the third and final survey gets you another 5 entries

This means that, as well as helping with some important research, you have 9 times the chance of winning if you do all three surveys compared to just one! E-mails adressed will be allocated numbers (like raffle numbers) according to the order they are submitted and in early 2022, data for all participants has been collected, and a random number generator will be used to select the five winners. You will be contacted by e-mail if you have won.

You will not benefit directly from this study, in terms of pay or compensation. We do not anticipate any harm or distress caused by this study to individuals taking part. If you do experience distress, please contact REMOVED FROM PUBLIC VERSION

PRIVACY NOTICE:

The lawful basis of data processing is Public Task. Sensitive data will be stored anonymously and separate to identifiable information (e-mail address, which is required to link follow-up surveys). You will receive your reminder messages to complete the second and third survey by e-mail, and your contact details will be used only for the purposes of sending the follow-up surveys, and for prize draw entry and being sent the results of the study, if you opt in to this.

If for any reason you wish to withdraw your data once you have submitted it, or if you have any questions before you start, you can e-mail your request and unique ID number (which you will create in a few steps time) to: REMOVED FROM PUBLIC VERSION

The data controller for this project is University College London (UCL). The UCL Data Protection Office provides oversight of UCL activities involving the processing of personal data, and can be contacted at REMOVED FROM PUBLIC VERSION. UCL's research privacy notice can be read ***here***. [Link to privacy notice]

If you have any concerns or complaints about the study you should contact the principal investigator in the first instance: REMOVED FROM PUBLIC VERSION, and then REMOVED FROM PUBLIC VERSION if you require further support.

If you have any questions about the study before you begin please e-mail REMOVED FROM PUBLIC VERSION. If not, please click the arrow below.

[Arrow]

Page 2:

[UCL logo]

Please tick each box below to consent to the study. If you leave any boxes un-ticked it will be assumed that you do not consent to that part of the study and you will not be able to continue to the study.

	Select box to consent
I confirm that I have read and understood the Information on the previous page and would like to take part in this survey.	☐
I am aware that I can e-mail any questions or concerns to REMOVED FROM PUBLIC VERSION before I begin or at any time during the study	☐
I understand that the information I provide about myself and my exercise will be used for research purposes.	☐
I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified, including in any publications.	☐
I understand that my data will be stored securely, and that my contact details will not be shared with any third parties or be used for any purposes except for those to which I explicitly agree in the survey.	☐
I confirm that my anonymous data can be used for future related research completed within UCL	☐
I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.	☐
I understand that while the survey is open for new responses, I will be able to withdraw my data without giving a reason by e-mailing my request and unique ID code to REMOVED FROM PUBLIC VERSION	☐
I confirm that I have recently or am about to notably increase my exercise levels	☐
I confirm that I do not currently experience any problematic exercise (such as over-exercising or REDS) or do not have a diagnosed eating disorder.	☐
I understand that if my exercising behaviour becomes excessive or problematic I should discontinue the study and contact my GP.	☐
I consent to voluntarily take part in this study.	☐

[Arrow]

Page 3:

Thank you very much for consenting to take part!

The last thing you need to do before you progress to the study is to create a unique ID and link it to your e-mail address. This is so that we can keep your responses to the

survey anonymous, but still be able to send reminders to complete the second and third survey.

To create a unique ID please write in one string of text:

- The second letter of your surname
- The day of the month of your birthday
- The last letter of your first name
- The last two numbers of your phone number

For example, Usai**n** B**o**lt's birthday is **21** August. If his mobile number was 07439687**23**, the his unique ID would be o21n23.

Enter yours below:

_____

Now please let us know your e-mail address. We will use this to send you reminders to fill in the second and third survey. This will not be stored in the same file as your survey responses to ensure anonymity.

_____

Appendix C

Text from survey

Page 1:

Thank you for completing the consent form and generating a unique participant ID on the previous page. Please enter your unique participant ID again here before you begin the survey.

As a reminder, your unique id is:

- The second letter of your surname
- The day of the month of your birthday
- The last letter of your first name
- The last two numbers of your phone number

For example, Usain Bolt's birthday is 21 August. If his mobile number was 07439687223, the his unique ID would be o21n23.

Page 2:

Let's get started...

First please tell us a bit about yourself. This will help us to understand who else your data might generalise to.

What age group are you in?

- 18-24
- 25-29
- 30-34

- 35-39
- 40-44
- 45-49
- 50+

What gender do you identify as?

- Male
- Female
- Non-binary/other
- Prefer not to say

Which group below best described your ethnicity?

- Asian or Asian British
- Black, African, Carribean or Black British
- Mixed or Multiple Ethnicities
- White
- Other Ethnic Group

Below are a few questions about your health and fitness at current. These help us to understand the physical health aspects that might relate to mental health.

What is your height in cm: _____

What is your current weight in kg: _____

Do you have any long-term health conditions? Yes/No

If you feel comfortable to, please describe the condition. _____

How often have you been in pain over the last week, where 0 is never and 10 is constantly? 0-10

How intense has any pain you've experiences in the last week been, where 0 is no pain and 10 is very severe pain? 0-10

How tired have you felt in the last week, where 0 is not tired at all and 10 is extremely tired?

0-10

Page 3:

Now you will see a couple of questionnaires. Don't spend too long on these- often your immediate response is most useful!

Below is list of statements dealing with your general feelings about yourself. Please tick the box that indicates how strongly you agree or disagree with each statement. *(2 minutes)*

	Strongly Agree	Agree	Disagree	Strongly Disagree
On the whole, I am satisfied with myself.	☐	☐	☐	☐
At times I think I am no good at all.	☐	☐	☐	☐
I feel that I have a number of good qualities.	☐	☐	☐	☐
I am able to do things as well as most other people.	☐	☐	☐	☐
I feel I do not have much to be proud of.	☐	☐	☐	☐
I certainly feel useless at times.	☐	☐	☐	☐
I feel that I'm a person of worth, at least on an equal plane with others	☐	☐	☐	☐
I wish I could have more respect for myself.	☐	☐	☐	☐
All in all, I am inclined to feel that I am a failure.	☐	☐	☐	☐
I take a positive attitude toward myself.	☐	☐	☐	☐

Page 4:

This page has 10 statements about how you have been **OVER THE LAST WEEK.** Please read each statement and think how often you felt that way last week. Then select the option which is closest to this. *(2 minutes)*

Some of these questions might not feel relevant. That is because this is a standardised measure used across many contexts. These questions may also feel quite emotive. Please feel free to skip questions that you do not want to answer.

	Not at all	Only occasionally	Sometimes	Often	Most or all of the time
I have felt tense, anxious or nervous	☐	☐	☐	☐	☐
I have felt I have someone to turn to for support when needed	☐	☐	☐	☐	☐
I have felt able to cope when things go wrong	☐	☐	☐	☐	☐
Talking to people has felt too much for me	☐	☐	☐	☐	☐
I have felt panic or terror	☐	☐	☐	☐	☐
I made plans to end my life*	☐	☐	☐	☐	☐
I have had difficulty getting to sleep or staying asleep	☐	☐	☐	☐	☐
I have felt despairing or hopeless	☐	☐	☐	☐	☐
I have felt unhappy	☐	☐	☐	☐	☐
Unwanted images or memories have been distressing me	☐	☐	☐	☐	☐

**If you answered 'often' or 'most or all of the time' to this question please make an appointment to see your GP to get support with this.*

You can also call the samaritans on 116 123 for support, or e-mail REMOVED FROM PUBLIC VERSION *or* REMOVED FROM PUBLIC VERSION *for further advice and signposting.*

Page 5:

This next questionnaire is to understand a bit more about how you feel about yourself.

Please indicate how often you feel each statement below is true or untrue of you. *(3 minutes)*

REMOVED FROM PUBLIC VERSION

REMOVED FROM PUBLIC VERSION

Page 6:

Great work. You're about a third of the way through. Now a few more questions about you...

Please tell us a bit about your exercise habits based on **THE LAST THREE WEEKS**. Please be honest and tell us about what you **have done** rather than what you planned or hoped to do.

How many times did you do exercise a week?

- None
- 1-2
- 3-4
- 5-6
- 7+

How many hours a week do you spend exercising?

- Less than an hour
- 1-3
- 4-6
- 7-10
- 10+

At what intensity do you exercise mostly?

- Low (can hold a conversation during- weights, yoga etc.)
- Medium (difficult to hold a conversation, but steady breathing- jogging, breaststroke swimming etc.)
- High (Out of breath- HIIT, sprinting etc.)

Page 7:

Do you exercise on your own or with others (online classes count as 'with others')?

- Mostly on my own
- Mostly with others

- As much on my own as with others

What is your main motivation for exercising?

- Physical health
- Sport
- Personal Improvement
- Challenge
- To lose weight/maintain a body shape
- Fun
- Mental health
- Other (please comment below) _____

Over the next few pages you will see a few more questionnaires. Some questions might feel similar to ones you have already answered, but they all give us really helpful information so please keep going!

Now you have a list of statements about how you feel in relation to things you do. Please tick the box that indicates how much you agree or disagree with each statement. *(2 minutes)*

REMOVED FROM PUBLIC VERSION

Page 9:

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during **the past month**, including today, by selecting the option that corresponds to your answer for each symptom. *(1-2 minutes)*

REMOVED FROM PUBLIC VERSION

Page 10:

This questionnaire is about your recent mood. For each item, please select the option that best describes how you have been feeling **OVER THE LAST WEEK.** *(3-4 minutes)*

Some of these questions might not feel relevant. That is because this is a standardised measure used across many contexts. These questions may also feel quite emotive. Please feel free to skip questions that you do not want to answer.

REMOVED FROM PUBLIC VERSION

REMOVED FROM PUBLIC VERSION

**If you selected this answer please make an appointment to see your GP to get support with this. You can also call the samaritans on 116 123 for support, or email* REMOVED FROM PUBLIC VERSION *or* REMOVED FROM PUBLIC VERSION *for further advice and signposting.*

Page 11:

Great work! You are now over 2/3 through the study. Feel free to take a quick break- just don't lose the answers you've given so far!

The next section asks about barriers to exercise and your emotional wellbeing. Please answer in relation to the **LAST THREE WEEKS.**

Have you noticed an effect of exercise on your mental and emotional wellbeing in the last few weeks?

_____

Have you learned anything about yourself from engaging in exercise over the last few weeks?

_____

Have you experienced any barriers to engaging in exercise? **Yes/No**

What barriers have you experienced?

_____

Have you experienced mental health difficulties currently or in the past (diagnosed or otherwise)? **Yes/no**

Have you accessed mental health support currently or in the past? **Yes/no**

Page 12

Now for your last set of questionnaires...

This next questionnaire is asking how you feel about your body. Below is a list of body parts. Please rate how satisfied you are with each of these body parts. *(1 minute)*

REMOVED FROM PUBLIC VERSION

Page 13:

This is the second to last questionnaire. You're almost done!

Think of times that you feel distressed or upset. Select the item that best describes your beliefs about feeling distressed or upset. *(2-3 minutes)*

REMOVED FROM PUBLIC VERSION

Page 14:

And for your final questionnaire...

This questionnaire looks at how you feel about new or abstract ideas. For each statement select the response that best represents your opinion. *(2 minutes)*

REMOVED FROM PUBLIC VERSION

Page 15:

You're done!

Thank you for taking part in this research study. Your answers are incredibly valuable to us.

To enter into the prize draw, or to sign up to receive a copy of the findings once they have been written up, please click or copy the following link:

REMOVED FROM PUBLIC VERSION

What next?

In 3 months time you will receive another link by e-mail to complete these questionnaires again to see if anything has changed while you've been exercising!

If you are concerned about your exercising behaviour, or changes in mood, weight, or physical health, please contact your GP in the first instance.

If you are experiencing ongoing emotional distress you may want to refer yourself to your local talking therapies service.

If you have any further concerns you can contact REMOVED FROM PUBLIC VERSION for signposting to alternative support.

If you have any concerns or complaints about the study you should contact the principal investigator in the first instance: REMOVED FROM PUBLIC VERSION, and then REMOVED FROM PUBLIC VERSION if you require further support.

Appendix D

Ethical approval letter

UCL RESEARCH ETHICS COMMITTEE
OFFICE FOR THE VICE PROVOST RESEARCH

17/05/2021

Dr John King

Clinical, Educational & Health Psychology

UCL

Cc: Jessica Lewis

Dear Dr King,

Notification of Ethics Approval

Project ID/Title: 19677/001 Which cognitive mechanisms underlie the long-term positive impact of exercise on mental health wellbeing?

Further to your satisfactory responses to the reviewer's comments, I am pleased to confirm that your study has been ethically approved until **17/05/2022.**

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. 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 (REMOVED FROM PUBLIC VERSION) 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: www.ucl.ac.uk/srs/governance-and-committees/research-governance
- 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

REMOVED FROM PUBLIC VERSION

Joint Chair, UCL Research Ethics Committee

REMOVED FROM PUBLIC VERSION University College London

Tel: REMOVED FROM PUBLIC VERSION

Email: REMOVED FROM PUBLIC VERSION

http://ethics.grad.ucl.ac.uk/

Appendix E

Correlation Matrix

Table E-1

Correlation Matrix for change in all variables between Time 1 and Time 3

Change in:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.Exercise Frequency	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.																		
	N																		
2.Exercise Hours	R	.574	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.000*																	
	N	41																	
3.Exercise Intensity	R	.267	.198	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.091	.216																
	N	41	41																
4.CORE-10	R	-.339	-.182	-.274	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.035*	.269	.092															
	N	39	39	39															
5.BDI	R	-.370	-.334	-.228	.515	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.022*	.040*	.168	.001*														
	N	38	38	38	36														
6.BAI	R	.074	.117	-.032	.379	.132	-	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.665	.491	.851	.025*	.450													
	N	37	37	37	35	35													
7.RSES	R	.079	.104	.124	-.198	-.122	-.148	-	-	-	-	-	-	-	-	-	-	-	-
	p.	.624	.517	.441	.208	.464	.381												
	N	41	41	41	42	38	37												
8.NGSE	R	.387	.341	.273	-.337	-.195	-.163	.317	-	-	-	-	-	-	-	-	-	-	-
	p.	.014*	.031*	.088	.038*	.248	.343	.046*											
	N	40	40	40	38	37	36	40											
9.USAQ	R	.087	.159	.032	-.443	-.122	-.361	.193	.521	-	-	-	-	-	-	-	-	-	-
	p.	.598	.334	.848	.005*	.478	.033*	.239	.001*										
	N	39	39	39	38	36	35	39	38										
10.BSS total	R	-.046	-.019	.005	.456	.364	.238	-.269	-.335	-.215	-	-	-	-	-	-	-	-	-
	p.	.782	.908	.976	.005*	.027*	.162	.097	.040*	.201									
	N	39	39	39	37	37	36	39	38	37									
11.BSS (body parts)	R	-.111	-.027	-.064	.540	.401	.287	-.286	-.314	-.197	.899	-	-	-	-	-	-	-	-
	p.	.495	.868	.697	<.001*	.013*	.085	.073	.052	.237	<.001								
	N	40	40	40	38	38	37	40	39	38	39								
12.BSS (head parts)	R	.035	.019	.052	.149	.212	.199	-.202	-.246	-.180	.756	.416	-	-	-	-	-	-	-
	p.	.835	.909	.752	.378	.208	.244	.217	.137	.287	<.001*	.008*							
	N	39	39	39	37	37	36	39	38	37	39	39							
13.DTS	R	-.154	-.306	.054	.334	.239	.311	-.185	-.417	-.399	.304	.366	.098	-	-	-	-	-	-
	p.	.351	.058	.744	.043*	.155	.061	.259	.009*	.014*	.064	.022*	.560						
	N	39	39	39	37	37	37	39	38	37	38	39	38						
14.NEO-FFI O domain	R	-.175	-.053	-.097	.199	.037	.119	.145	-.011	-.053	.067	1.89	-.154	.171	-	-	-	-	-
	p.	.280	.743	.552	.230	.827	.482	.372	.947	.752	.684	.243	.348	.297					
	N	40	40	40	38	38	37	40	39	38	39	40	39	39					
15.BMI	R	-.282	-.093	.035	.396	.198	.195	-.168	-.400	-.278	.516	.350	5.88	.183	.144	-	-	-	-
	p.	.087	.577	.834	.012*	.246	.269	.294	.014	.101	.001*	.034*	<.001	.285	.397				
	N	38	38	38	39	36	34	41	37	36	37	37	37	36	37				
16.Pain frequency	R	-.077	-.081	-.080	.284	.088	.207	-.022	-.155	-.204	.277	.268	.186	.157	.209	.273	-	-	-
	p.	.647	.631	.634	.080	.616	.234	.891	.352	.234	.102	.109	.279	.360	.214	.092			
	N	38	38	38	39	35	35	41	38	36	36	37	36	36	37	39			
17.Pain Intensity	R	-.009	.136	-.059	.183	-.100	.483	.031	-.058	-.272	.232	.311	.090	.117	.309	.154	.636	-	-
	p.	.958	.410	.723	.266	.562	.003*	.846	.726	.103	.167	.058	.598	.492	.059	.350	<.001*		
	N	39	39	39	39	36	36	41	39	37	37	38	37	37	38	39	40		
18. Tiredness	R	-.263	-.184	-.118	.476*	.302	.126	-.296	-.095	-.339	.220	.288	.095	.270	.386	.345	.364	-.001	-
	p.	.115	.275	.488	.003	.078	.486	.064	.583	.046*	.204	.088	.587	.116	.020*	.034*	.025*	.995	
	N	37	37	37	38	35	33	40	36	35	35	36	35	35	36	38	38	38	

Note. Un-corrected correlations are presented due to the exploratory nature of this analysis, and aim to inform future models which may use corrected correlations to further analyse patterns; CORE-10=Clinical Outcomes in Routine Evaluation- 10 items; BDI=Back's Depression Inventory; BAI= Beck's Anxiety Inventory; RSES=Rosenberg Self-esteem Scale; NGSE= New General Self-Efficacy Scale; USAQ=Unconditional Self-acceptance Questionnaire; BSS=Body Satisfaction Scale; DTS=Distress Tolerance Scale; NEO-FFI O domain= NEO-Five Factor Inventory, Openness to experience domain.

*Indicates significant correlation at p<.05.

Appendix F

Syntax for Linear Mixed Models

```
DATASET ACTIVATE DataSet1.
MIXED (mediating factor) BY Time
  /CRITERIA=CIN(95) MXITER(100) MXSTEP(10) SCORING(1)
SINGULAR(0.000000000001) HCONVERGE(0,
    ABSOLUTE) LCONVERGE(0, ABSOLUTE) PCONVERGE(0.000001,
ABSOLUTE)
  /FIXED=Time | SSTYPE(3)
  /METHOD=REML
  /REPEATED=Time | SUBJECT(id) COVTYPE(CS)
  /EMMEANS = TABLES(time)  COMPARE(time) ADJ(Bonf).
```

Appendix G

Syntax for longitudinal mediation

process y=(wellbeing variable)3/x=(exercise variable)/m=(mediating factor)2/cov=(mediating factor)1 (wellbeing variable)1 (wellbeing variable)2/cmatrix=1,1,0,1,1,1/model=4.

Appendix H

Longitudinal mediation table

Table H-1

Longitudinal mediation analyses for all variables using PROCESS (Hayes, 2022)

Predictor variable (X)	Output variable (Y)	Mediating variable (M)	N	Effect	Bootstrapping lower limit confidence interval (95%)	Bootstrapping upper limit confidence interval (95%)
Exercise frequency	BDI score	Distress tolerance	32	-.3164	-1.4410	.4217
		Self-esteem	31	-.1678	-1.1966	.5362
		Self-efficacy	30	-1.8490	-.5877	.5571
		Unconditional self-acceptance	29	-.0117	-1.2788	.5381
		Openness to experience	31	.2019	-.4543	1.0981
		Body satisfaction	31	-.3294	-2.9529	.2072
		Pain frequency	29	-.0642	-1.3239	.7137
		Pain intensity	29	.1303	-.8618	1.0665
		Tiredness	32	.1525	-.4417	.9906
		BMI	32	.0884	-.0657	.6211
	BAI score	Distress tolerance	31	.0001	-.4296	.5286
		Self-esteem	30	-.1197	-.5435	.4554
		Self-efficacy	30	-.0528	-.4638	.2941
		Unconditional self-acceptance	28	-.0048	-.4027	.3321
		Openness to experience	30	.3862	-.1114	1.3668
		Body satisfaction	30	-.1071	-.7504	.4128
		Pain frequency	28	-.0587	-.2693	.4735
		Pain intensity	28	-.0347	-.5773	.1528
		Tiredness	31	.0614	-.2441	.5689
		BMI	31	.0174	-.1081	.4337
	CORE-10	Distress tolerance	35	-.4229	-1.2441	.0214
		Self-esteem	35	-.1232	-.6147	.1937
		Self-efficacy	33	-.0848	-.5625	.2205
		Unconditional self-acceptance	33	-.0524	-.3636	.5312
		Openness to experience	34	.1636	-.1624	.6814
		Body satisfaction	34	-.1871	-.5658	.3043
		Pain frequency	33	-.0061	-.2842	.3055
		Pain intensity	31	-.0097	-.5756	.3903
		Tiredness	36	-.0049	-.3897	.2585
		BMI	36	-.0115	-.3320	.1728

Exercise Hours	BDI Score	Distress tolerance	32	-.1127	-.6785	.2800
		Self-esteem	31	-.2100	-1.3542	.3951
		Self-efficacy	30	-.0557	-.6829	.4763
		Unconditional self-acceptance	29	-.2390	-2.2191	.7051
		Openness to experience	31	-.0071	-.4500	.4694
		Body satisfaction	31	-.0213	-1.7376	1.2645
		Pain frequency	29	-.2571	-1.8908	.5305
		Pain intensity	29	-.0578	-1.1764	.6266
		Tiredness	32	.5349	-.3288	2.1355
		BMI	32	.1146	-.0655	.7477
	BAI Score	Distress tolerance	31	-.0094	-.2634	.1399
		Self-esteem	30	-.2043	-.8493	.2481
		Self-efficacy	30	-.0431	-.4093	.2852
		Unconditional self-acceptance	28	.1082	-.4001	.7996
		Openness to experience	30	.0688	-.2872	.5455
		Body satisfaction	30	.1008	-.4652	.6458
		Pain frequency	28	.1541	-.2028	.7778
		Pain intensity	28	.0134	-.4167	.2520
		Tiredness	31	.1580	-.2819	.9372
		BMI	31	.0154	-.1681	.4382
	CORE-10	Distress tolerance	35	-.2079	-.8370	.1499
		Self-esteem	35	-.1351	-.7338	.1406
		Self-efficacy	33	-.0418	-.4403	.2817
		Unconditional self-acceptance	33	-.2487	-1.0025	.1479
		Openness to experience	34	.0038	-.4132	.3082
		Body satisfaction	34	-.0225	-.5047	.3586
		Pain frequency	33	.0286	-.3124	.4109
		Pain intensity	31	-.0140	-.4723	.2885
		Tiredness	36	-.0039	-.3769	.4855
		BMI	36	-.0177	-.2883	.1370
Exercise Intensity	BDI Score	Distress tolerance	32	-.1169	-2.0293	1.1348
		Self-esteem	31	.2006	-.9264	1.7014
		Self-efficacy	30	.0657	-1.3482	1.1347
		Unconditional self-acceptance	29	-.6201	-3.9636	1.7976

	Openness to experience	31	.0419	-.8102	1.8594
	Body satisfaction	31	.6337	-.4895	6.3888
	Pain frequency	29	.3505	-.9651	3.0984
	Pain intensity	29	.8564	-1.0885	4.4163
	Tiredness	32	.1147	-.9910	1.1115
	BMI	32	.0759	-.6983	.4155
BAI scores	Distress tolerance	31	-.0354	-1.0280	.4401
	Self-esteem	30	.0011	-.6073	.4208
	Self-efficacy	30	.0688	-.7705	.9344
	Unconditional self-acceptance	28	.0803	-.4610	1.3789
	Openness to experience	30	.3149	-.4108	1.6344
	Body satisfaction	30	.2211	-.5294	1.8163
	Pain frequency	28	-.2995	-1.4288	.3544
	Pain intensity	28	-.9562	-2.5844	.0437
	Tiredness	31	-.0467	-.7578	.7504
	BMI	31	.0150	-.6465	.3311
CORE-10	Distress tolerance	35	-.1900	-2.0047	.8070
	Self-esteem	35	.0012	-.6699	.6372
	Self-efficacy	33	-.1072	-1.0731	.7020
	Unconditional self-acceptance	33	-.0433	-1.0622	.8344
	Openness to experience	34	-.0133	-.7021	.9783
	Body satisfaction	34	.0696	-.7246	.8970
	Pain frequency	33	-.2520	-1.4038	.3674
	Pain intensity	31	-.2947	-1.3492	.5799
	Tiredness	36	-.0314	-.7468	.6354
	BMI	36	-.0249	-.8063	.1743

Note. CORE-10=Clinical Outcomes in Routine Evaluation- 10 items; BDI=Back's Depression Inventory; BAI= Beck's Anxiety Inventory; RSES=Rosenberg Self-esteem Scale; NGSE= New General Self-Efficacy Scale; USAQ=Unconditional Self-acceptance Questionnaire; BSS=Body Satisfaction Scale; DTS=Distress Tolerance Scale; NEO-FFI O domain= NEO-Five Factor Inventory, Openness to experience domain.

Appendix I

Cross-sectional mediation table

Table I-1

Cross-sectional mediation analyses for all variables at Time 1 using PROCESS

Predictor variable (X)	Output variable (Y)	Mediating variable (M)	N	Effect	Bootstrapping lower limit confidence interval (95%)	Bootstrapping upper limit confidence interval (95%)
Exercise frequency	BDI score	Distress tolerance	65	-1.43	-3.51	-.247*
		Self-esteem	67	-2.22	-4.08	-.861*
		Self-efficacy	66	-1.20	-2.67	-.168*
		Unconditional self-acceptance	65	-1.81	-3.78	-.550*
		Openness to experience	65	-.397	-1.19	.0602
		Body satisfaction	65	-.698	-2.17	.590
		Pain frequency	66	-.0074	-.250	.255
		Pain intensity	63	-.0342	-.428	.214
		Tiredness	67	-.0621	-.870	.556
		BMI	67	-.116	-.796	.368
	BAI score	Distress tolerance	68	-1.23	-2.61	-.280*
		Self-esteem	70	-1.42	-2.79	-.438*
		Self-efficacy	69	-.817	-2.23	.0512
		Unconditional self-acceptance	68	-1.23	-2.65	-.338*
		Openness to experience	68	-.530	-1.32	-.0298*
		Body satisfaction	68	-.413	-1.71	.579
		Pain frequency	69	.0698	-.158	.536
		Pain intensity	67	.0805	-.294	.490
		Tiredness	69	-.0333	-.554	.349
		BMI	69	-.0772	-.734	.676
	CORE-10	Distress tolerance	67	-.597	-1.46	-.0630*
		Self-esteem	69	-.887	-1.75	-.260*
		Self-efficacy	68	-.737	-1.67	-.112*
		Unconditional self-acceptance	67	-.881	-1.72	-.293*
		Openness to experience	67	-.281	-.759	.0244
		Body satisfaction	66	-.376	-1.24	.323
		Pain frequency	68	.0082	-.141	.257
		Pain intensity	65	.0281	-.163	.262
		Tiredness	68	.0321	-.266	.328
		BMI	68	.156	-.182	.641
Exercise	BDI Score	Distress	65	-1.27	-3.11	.104*

Hours		tolerance				
		Self-esteem	67	-1.72	-3.52	-.536*
		Self-efficacy	66	-1.22	-2.82	-.127*
		Unconditional self-acceptance	65	-1.96	-4.09	-.605*
		Openness to experience	65	-.357	-1.12	.0961
		Body satisfaction	65	-.843	-2.63	.917
		Pain frequency	66	.0329	-.312	.513
		Pain intensity	63	-.0613	-.490	.168
		Tiredness	67	-.0393	-.547	.287
		BMI	67	-.154	-.729	.241
	BAI Score	Distress tolerance	68	-.919	-2.19	-.0651*
		Self-esteem	70	-.984	-2.26	-.185*
		Self-efficacy	69	-.823	-2.11	.124
		Unconditional self-acceptance	68	-1.28	-2.69	-.345*
		Openness to experience	68	-.512	-1.33	.0234*
		Body satisfaction	67	-.456	-1.94	.850
		Pain frequency	69	.161	-.178	.810
		Pain intensity	67	.128	-.206	.589
		Tiredness	69	.0087	-.282	.293
		BMI	69	-.0807	-.633	.522
	CORE-10	Distress tolerance	67	-.510	-1.33	-.0065*
		Self-esteem	69	-.715	-1.50	-.154*
		Self-efficacy	68	-.743	-1.60	-.130*
		Unconditional self-acceptance	67	-.971	-1.86	-.358*
		Openness to experience	67	-.302	-.855	.0147
		Body satisfaction	66	-.451	-1.44	.371
		Pain frequency	68	-.0659	-.158	.529
		Pain intensity	65	.0616	-.131	.374
		Tiredness	68	-.0009	-.208	.181
		BMI	68	-.0644	-.210	.400
Exercise Intensity	BDI Score	Distress tolerance	65	-1.61	-5.28	1.01
		Self-esteem	67	-1.82	-4.58	.617
		Self-efficacy	66	-1.83	-4.22	-.074*
		Unconditional self-acceptance	65	-1.14	-3.89	1.49
		Openness to experience	65	-.592	-2.07	.417
		Body satisfaction	65	-1.05	-3.26	.514
		Pain frequency	66	-.0140	-.553	.467
		Pain intensity	63	-.302	-1.84	.510

	Tiredness	67	-.209	-1.60	.784
	BMI	67	-.014	-.797	.790
BAI scores	Distress tolerance	68	-1.95	-4.61	.055
	Self-esteem	70	-1.22	-3.27	.498
	Self-efficacy	69	-1.14	-3.33	.104
	Unconditional self-acceptance	68	-.454	-2.38	1.47
	Openness to experience	68	-.796	-2.20	.266
	Body satisfaction	67	-.515	-2.22	.622
	Pain frequency	69	.0638	-.293	1.06
	Pain intensity	67	.607	-.491	1.87
	Tiredness	69	-.113	-1.01	.786
	BMI	69	-.0227	-.757	.586
CORE-10	Distress tolerance	67	-.927	-3.11	.404
	Self-esteem	69	-.973	-2.39	.322
	Self-efficacy	68	-1.46	-3.21	-.234*
	Unconditional self-acceptance	67	-.640	-2.19	.873
	Openness to experience	67	-.530	-1.57	.172
	Body satisfaction	66	-.798	-2.36	.267
	Pain frequency	68	-.003	-.295	.490
	Pain intensity	65	.175	-.516	.862
	Tiredness	68	-.0422	-.612	.474
	BMI	68	-.0089	-.389	.294

Note. CORE-10=Clinical Outcomes in Routine Evaluation- 10 items; BDI=Back's Depression Inventory; BAI= Beck's Anxiety Inventory; RSES=Rosenberg Self-esteem Scale; NGSE= New General Self-Efficacy Scale; USAQ=Unconditional Self-acceptance Questionnaire; BSS=Body Satisfaction Scale; DTS=Distress Tolerance Scale; NEO-FFI O domain= NEO-Five Factor Inventory, Openness to experience domain.

*Indicates significant result at the 95% bootstrapping confidence interval level