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Medical Encounters at Community-Based Physical Activity Events (parkrun*)* in the United Kingdom

Charles R Pedlar PhD[1,2], Kyriaki Myrissa[1], Megan Barry[1], Iman G Khwaja[1], Andrew J Simpkin[3], John Newell[3], Carl Scarrott[3], Gregory P Whyte[4], Courtney Kipps[2] and Aaron L Baggish[5]

Author Affiliations:

[1]Faculty of Sport, Allied Health and Performance Science, St Mary's University, Twickenham, UK
[2] Institute of Sport, Exercise and Health, Division of Surgery and Interventional Science, University College London (UCL), London, UK
[3]School of Mathematics, Statistics and Applied Mathematics, National University of Ireland Galway, Ireland
[4]Research Institute for Sport and Exercise Science, Liverpool John Moores University, Liverpool, UK
[5] Cardiovascular Performance Program, Massachusetts General Hospital, Harvard Medical School, Boston, USA

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Corresponding Author: Charles R. Pedlar
Faculty of Sport, Allied Health and Performance Science,
St Mary's University, Twickenham
Waldegrave Road,
Twickenham,
TW1 4SX
United Kingdom
Email: pedlarc@stmarys.ac.uk
Phone: +447725243739

Abstract:

Objective: To determine the incidence, clinical correlates and exposure risk of medical encounters during community-based physical activity events in the UK.

Methods: An analysis of medical data from weekly, community-based physical activity events (parkrun) at 702 UK locations over a 6-year period (29,476,294 participations between 2014 and 2019) was conducted in order to define the incidence and clinical correlates of serious life-threatening, non-life-threatening, and fatal medical encounters.

Results: 84 serious life-threatening encounters (overall incidence rate = 0.26/100,000 participations) occurred including 18 fatalities (0.056/100,000 participations). Statistical modelling revealed that the probabilities of serious life-threatening encounters were exceptionally low, however, male sex, increasing age, slower personal best parkrun time, and less prior running engagement/experience (average number of runs per year and number of years as a parkrun participant) were associated with increased probability of serious life-threatening encounters. These were largely accounted for by cardiac arrest (48/84, 57%) and acute coronary syndromes (20/84, 24%). Non-life-threatening medical encounters were mainly attributed to tripping or falling, with a reported incidence of 38.1/100,000 participations.

Conclusions: Serious life-threatening and fatal medical encounters associated with parkrun participation are extremely rare. In the context of a global public health crisis due to inactivity, this finding underscores the safety and corollary public health value of community running/walking events as a strategy to promote physical activity.

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What are the new findings?

- The present study advances our understanding of the medical risk of exercise. The study is unique in several ways: 1) the nature and location of the exercise involved, 2) the wide age range and near equal sex/gender distribution of the participants, and 3) the size of the cohort studied.
- The study demonstrates that the risk of serious life-threatening medical encounters at 5km and 2km community running/walking events is very rare and the risk of death is extremely rare.
- A higher probability of a serious life-threatening medical encounter exists in males vs females, with increasing age, slower parkrun finish time, with less parkrun engagement/experience.

How might it impact on clinical practice in the near future?

- Results from this study underscore the important role of on-site Automated External Defibrillators at mass-participation community-based 5km physical activity events such as parkrun but suggest that a medical infrastructure beyond basic first aid provision appears to be of limited value.

Introduction

The health benefits of routine physical activity (PA) including reductions in all-cause mortality,[1-3] cardiovascular disease,[4] and cancer,[5] are well established. Accordingly, physical activity guidelines recommending weekly target doses of PA have been promoted for disease prevention by numerous national and global organisations.[6-8] However, the majority of adults in developed countries worldwide fail to meet recommended PA targets.[9] Inactivity has emerged as a public health crisis with attendant clinical and financial implications, [10] and historically, strategies aimed at increasing PA have largely been ineffective and inadequate.

Strategies to improve adherence to PA recommendations including public policy,[11] purposeful design of the built environment,[12,13] and cognitive behavioural incentives, [14] have proven effective in some situations but have far from eliminated the problem. Mass endurance sporting events provide opportunities for PA, however, the financial cost, logistical challenges, and recommendations for on-site medical infrastructure associated with these events preclude most communities from supporting an adequate number of events to serve as an effective platform for routine PA. A network of free, weekly exercise events (parkrun) that began in the United Kingdom (UK), has emerged as a unique exception (http://www.parkrun.org.uk). Parkrun enables communities to hold weekly 5-kilometre run/walks over a measured course in public venues. In addition, 'junior' parkrun events of 2km distance are operated from some locations for individuals aged 4-14 years. In aggregate, parkrun has developed into the largest community-based exercise initiative worldwide.

Preliminary data emerging from the parkrun experience suggest that participants gain improvements in key determinants of health and longevity [15] and parkrun has been designated a social prescribing activity in the UK by the Royal College of General Practitioners for the promotion of health and wellbeing [16]. However, the well-established association between acute bouts of exercise and increased risk of adverse medical outcomes underscores the need to assess the risks,[4,17] in parallel with benefits, of the parkrun experience. Accordingly, we performed a comprehensive assessment of medical encounters recorded during a recent 6-year period in the UK with a primary goal of determining the incidence, clinical correlates and exposure risk (including the identification of higher risk sub-groups) of medical encounters occurring during parkrun participation. The term ‘encounters’ is deliberately used since it recognises that a proportion of medical problems occurring at parkrun events may not be formally recorded [18]. As an *a priori* secondary aim, we also sought to characterize less serious medical encounters defined broadly as not representing a threat to life.

Methods

Study design. We approached these synergistic aims by collaborating with the parkrun organization to extract and analyse data from their centralized medical encounter data repository as described below. While the first official parkrun was held in 2004, a standardized medical encounter reporting system was not implemented by the central sponsoring organisation until April 2013 and the use of this system became mandatory in 2014. As such, we confined our analyses to the entire population of participations and medical encounters during the 6-year time period spanning 2014 to 2019.

Medical encounter data capture. Every parkrun is coordinated by a volunteer run director, supported by a team of volunteer marshals. During the study period, run directors (or a substitute volunteer if the run director is not present) were required to describe any incident including medical encounters or to attest to an incident-free event on the day of event completion. This process was enabled by the use of a simple web-based incident reporting tool designed for use among run directors with no formal medical training (https://volunteer.parkrun.com/principles/incidents accessed April 2021). Compliance with this mandatory reporting system was maximized by the use of an automated system that withheld the posting of participant event results on the parkrun website until receipt of the incident data.

Serious life-threatening medical encounters. The central parkrun team reviewed all medical encounter data from all parkrun events held in the UK, assigning a numeric severity score ranging from '1' (least serious) to '5' (most serious) as defined in **Supplementary Table S1**. All encounters assigned a score 4 or 5 were followed up by direct correspondence with the corollary event director. The initial objective of this correspondence was to confirm the accuracy of the assigned encounter severity score. Following this confirmation, additional data (see supplementary material S2) were collected to further characterize each serious life-threatening encounter, defined in this analysis as events with a final adjudication score of 4 or 5.

Non-life-threatening medical encounters. Non-life-threatening medical encounters were characterized by performing a comprehensive independent review of the centralized parkrun data repository within the first 4 years of the study period (2014 through 2017). The primary goal of this review process was to confirm the incidence, aetiology, and disposition of all medical encounters characterized by a severity score of 1 through 3. This was necessary as the centralized parkrun data repository did not routinely assign these attributes for low severity encounters in a fashion analogous to its handling of serious life-threatening encounters. Two trained research assistants used all available data to assign each medical encounter an aetiology or mechanism of pathology (see supplementary material S3).

Statistical analysis. Incidence rates for the total number of serious life-threatening and fatal encounters were calculated as the simple proportion of encounters divided by the total number of parkrun participations within the 6-year period of study, with corresponding 95% confidence intervals where appropriate. The participations data included all finishers and the non-finishing encounters, but not all the starters since we did not have information on other non-finishers. This approach leads to a conservative over-estimation of risk, since the numerator is maximised and the denominator is minimised. For the purposes of this paper, junior participants are defined as those ≤14 years old in both the 2km and 5km events. All junior data were excluded from the statistical analysis since the risk factors are not comparable.

Comparisons of age (years), personal best parkrun time (minutes), and parkrun experience (completed parkruns), between those who survived serious medical incidents and those that died were made using the nonparametric Wilcoxon rank sum test. Poisson and logistic regression were used in the exploratory data analysis to model the changes in the aggregated yearly counts and rates of medical encounters respectively to provide simple unadjusted measures of risk. A chi-squared test was used to compare the proportions of deaths and serious events between males and females using a simulation based p-value due to the low counts.

A detailed multiple logistic regression encompassing data from all participants was used to quantify the impact of the risk factors of sex, age, personal best parkrun time (as a surrogate for running ability), average number of parkruns per year (as a surrogate for running consistency) and number of years as a parkrun participant (as a surrogate for running experience) on the risk of serious event occurrence. The binomial response data are the counts of each athlete's complete record of parkruns and any serious encounters during the exposure period of 2014-2019. Odds Ratios (OR) are reported for each factor except age, which was included as a smooth function (using thin plate splines) due to its nonlinear relationship with the outcome. The 95% confidence intervals for the odds ratio were calculated by exponentiation of the standard Wald confidence interval for estimated coefficient from the logistic regression. The odds ratio was approximately equal to the relative risk, since the encounters were rare events. The data were cleaned prior to modelling by removing all junior parkrun data (n=5,115,301) and parkrun times where no or unreliable data were available (n=1,940,322 participations were removed; see supplementary material S4). All analyses were performed using R (Version 4.0.3). A p-value of less than 0.05 was considered significant. The logistic modelling of this large dataset was made feasible using a highly memory efficient implementation of generalised additive models, incorporating efficient smoothing parameter estimation and generalised cross-validation to choosing the smoother complexity[19].

Results

Parkrun demographics. Weekly 5km parkrun events were held in 702 distinct locations within the UK during the 6-year study period (**Figure 1A)**. Junior parkrun events were held in 341 of these locations and were also typically held on a weekly basis. There were consistent increases in the number of male and female participants with a cumulative 6-years total of 2,090,129 5km participants (**Figure 1B, Table 1**) accounting for a total of 29,476,294 participations. There were 2,829,827 participations in junior 2km parkruns (**Figure 1C)** which consist 8.8% of the 32,306,118 total participations across 2km and 5km parkruns. The mean (standard deviation) number of 5km parkrun participations per participant each year was 7.9 (10.1) for males and 6.4 (8.6) for females. This trend was paralleled by similar growth among all global parkrun events (global 6-year total: 50,385,925 recorded parkrun participations from 3,755,478 participants). Excluding junior data, the UK-based participations were 57% male, but since females tended to do less runs per athlete on average, the proportion of unique male athletes was lower at 48%. The average age per participation was 41(12.5) years but, since the older runners tended to do more runs, the average age per unique athlete was lower at 36 (12.4) years. The median parkrun completion times among males and females were 25:20 (mins:secs; interquartile range: 22:34,28:46) and 31:00 (27:45,35:00) respectively (**Figure 1D**; **Table 1**).

Table 1: Descriptive information on UK 5km parkrun data (702 locations) and as stratified by participant sex during the 6-year time period (2014 - 2019).

	UK	Male	Female
Total participations	29,476,294 **25,250,495**	15,720,468 **14,306,085***	11,851,202 **10,944,410***
Total participants recording at least 1 parkrun	2,090,129 **1,808,324**	1,034,129 **874,112***	1,055,974 **934,212***
Mean (SD) age +	by run: 41.0 (12.5) by athlete: 36.0 (12.4)	by run: 41.9 (12.8) by athlete: 36.1 (12.9)	by run: 39.8 (12.0) by athlete: 35.8 (11.9)
Sex distribution (male:female)	by run = 57:43 by athlete = 48:52		
Finish time in mm:ss median (interquartile range)	27:47 (24:08 - 32:05)	25:20 (22:34 -28:46)	31:00 (27:45 -35:00)
Mean (SD) number of runs/year/participant	7.2 (9.4)	7.9 (10.1)	6.4 (8.6)
Mean (SD) number of years with at least 1 run recorded over 2014-19	1.95 (1.39)	2.08 (1.48)	1.84 (1.29)

Data in bold are the data included in the statistical analysis after data cleaning (reasons for removing data include unidentified finishers, all junior data etc.)

* sex not stated or "other" replaced by race category sex. One participant likely changed gender for which their majority gender was used.

+ age is determined by middle of age category they participated under, which is then averaged over all runs for the per athlete statistics.

The 5km parkrun events conducted early in the study sample period were dominated by faster club runners but gradual diversification occurred over time, characterized by increasing participation among recreational and older joggers and walkers, reflected in a gradual slowing of mean 5km completion times which is most notable in the extending upper tail of the finish time distributions (**Figure 1E**). In addition, 2,688,473 million volunteer instances accounted for the marshalling staff at events over the 6-year study period from 280,163 registered volunteers. The mean number of volunteer event participations per volunteer participant was 9.5(21.2).

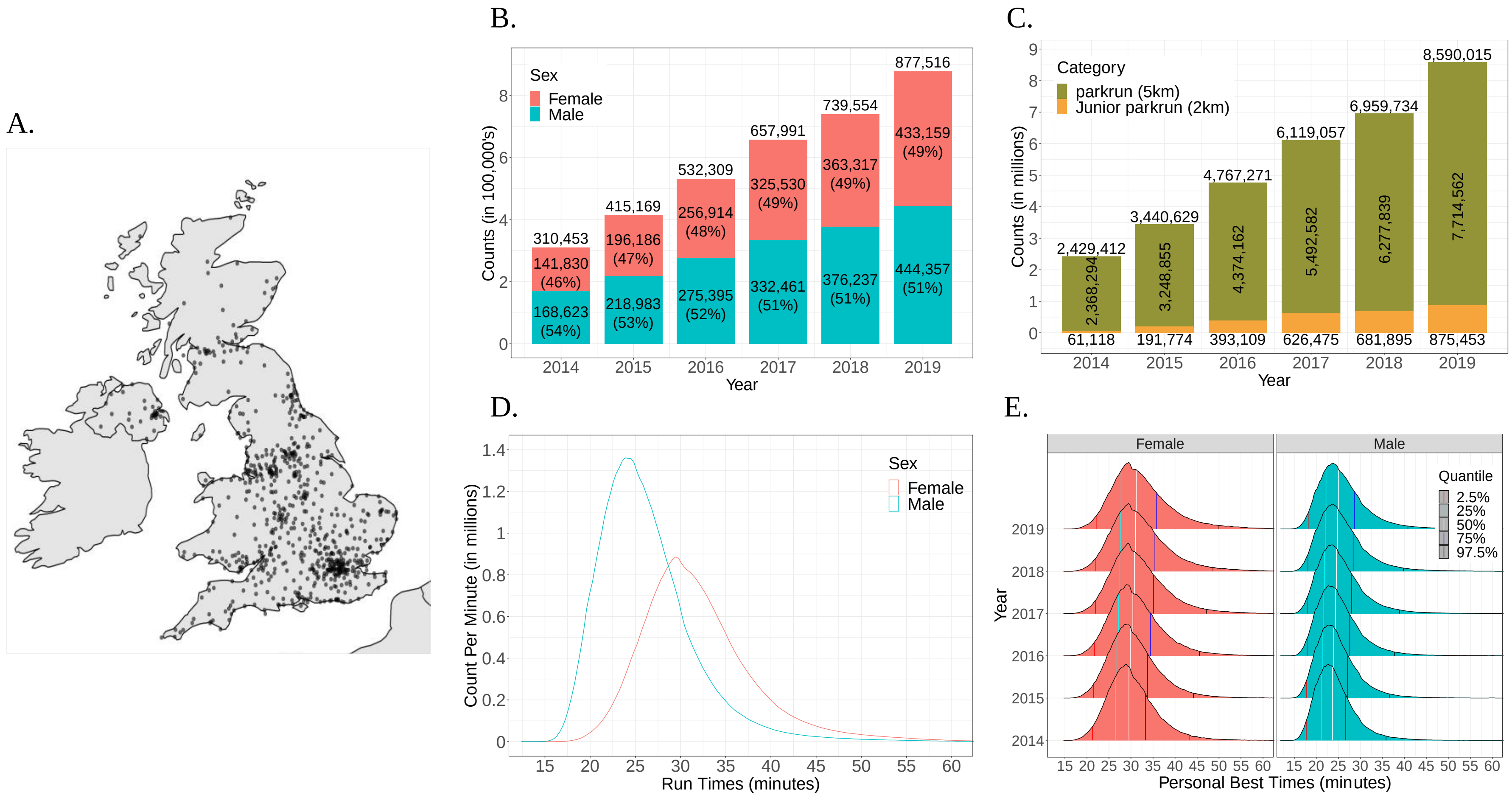

Figure 1: The parkrun story (6-year time period, 2014 – 2019; juniors and volunteers removed as appropriate) **A:** Map of the 702 United Kingdom parkrun events; **B:** Number of parkrun individual participants by year and sex; **C:** Number of parkrun participations by year; **D:** Distribution of finish times by sex; **E:** Finish time distributions by year and sex.

Serious life-threatening encounters. There were 84 serious life-threatening encounters, leading to an estimate of the probability per participation of all 2km and 5km parkrun events of 0.26/100,000 participations (95% confidence interval (CI): 0.20 to 0.32 per 100,000) during the 6-year study period. The aetiologic breakdown of all serious life-threatening encounters is shown in **Figure 2.** 57% (48/84) of these encounters were attributable to cardiac arrest among which 45/48 (93.8%) met criteria for defibrillation (electric shock therapy) from an automated external defibrillator. The survival rate among all cardiac arrest victims and among those known to have received defibrillation were 65% (31/48) and 69% (31/45), respectively. 24% (20/84) of serious encounters were attributed to acute coronary syndrome and 6% (5/84) of serious encounters were attributed to life-threatening arrythmia that was not attributed to myocardial ischemia. Cerebrovascular accident, inclusive of both haemorrhagic and ischemic stroke, accounted for 8/84 (10%) of cases. The remaining cases comprised: traumatic C-spine injury (n=1) and primary respiratory failure (n=2).

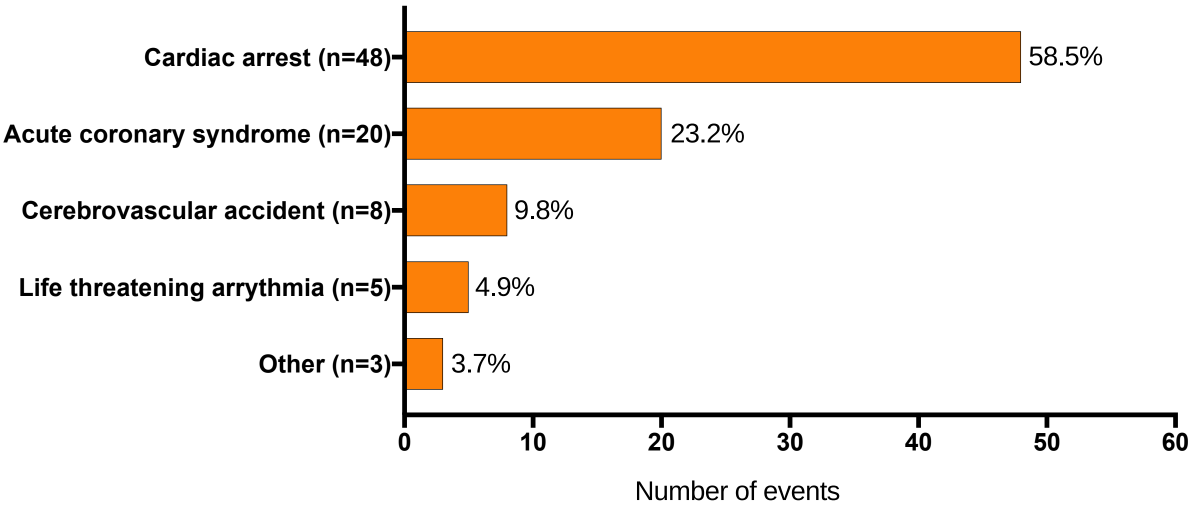

Figure 2: Aetiologic breakdown of all serious life-threatening medical encounters (n=84) over 6-years (2014-2019) including junior (2km) and 5km parkrun events.

Excluding cases among junior parkrun participants (n=2) the rate of serious life-threatening encounters was higher at 0.32 per 100,000 participations (95% CI: 0.25 to 0.40 per 100,000), confirming the resulting risk estimates are conservative. Among the serious life-threatening encounters, the majority occurred in men (67/82 = 82%; 95% CI: 71 to 89%; **Figure 3A**) and in participants ≥ 45 years of age (68/82 = 83%, 95% CI: 75 to 91%; **Figure 3B**). A total of 18/82 serious life-threatening encounters resulted in death (16 males, 2 females) yielding a rate of 0.071 deaths/100,000 participations (95% CI: 0.038 to 0.104 per 100,000). Thus, the mean fatality rate associated with serious life-threatening encounters was 22% (annual range 14% to 60%) and did not change significantly over time (**Figure 3C,** p=0.25).

The change in the annual absolute number of deaths over time was not significant (p=0.17) neither was the rate of fatalities per parkrun participation over time (p=0.83). The rate of serious life-threatening medical encounters per participation did increase over time (in **Figure 3D**, p=0.02) and there was a significant increase in the annual number of serious encounters (p < 0.001).

Parkrun personal best completion times were significantly slower in the fatality group compared to the survivors of serious encounters (p=0.007; **Figure 3E**). There were no significant differences in age between survivors of serious life-threatening encounters and fatal life-threatening encounters (p=0.70; **Figure 3B**). The participation distribution, as measured by the number of parkruns completed, was notably lower for those that had a fatal life-threatening encounter just reaching statistical significance (p=0.02; **Figure 3F**).

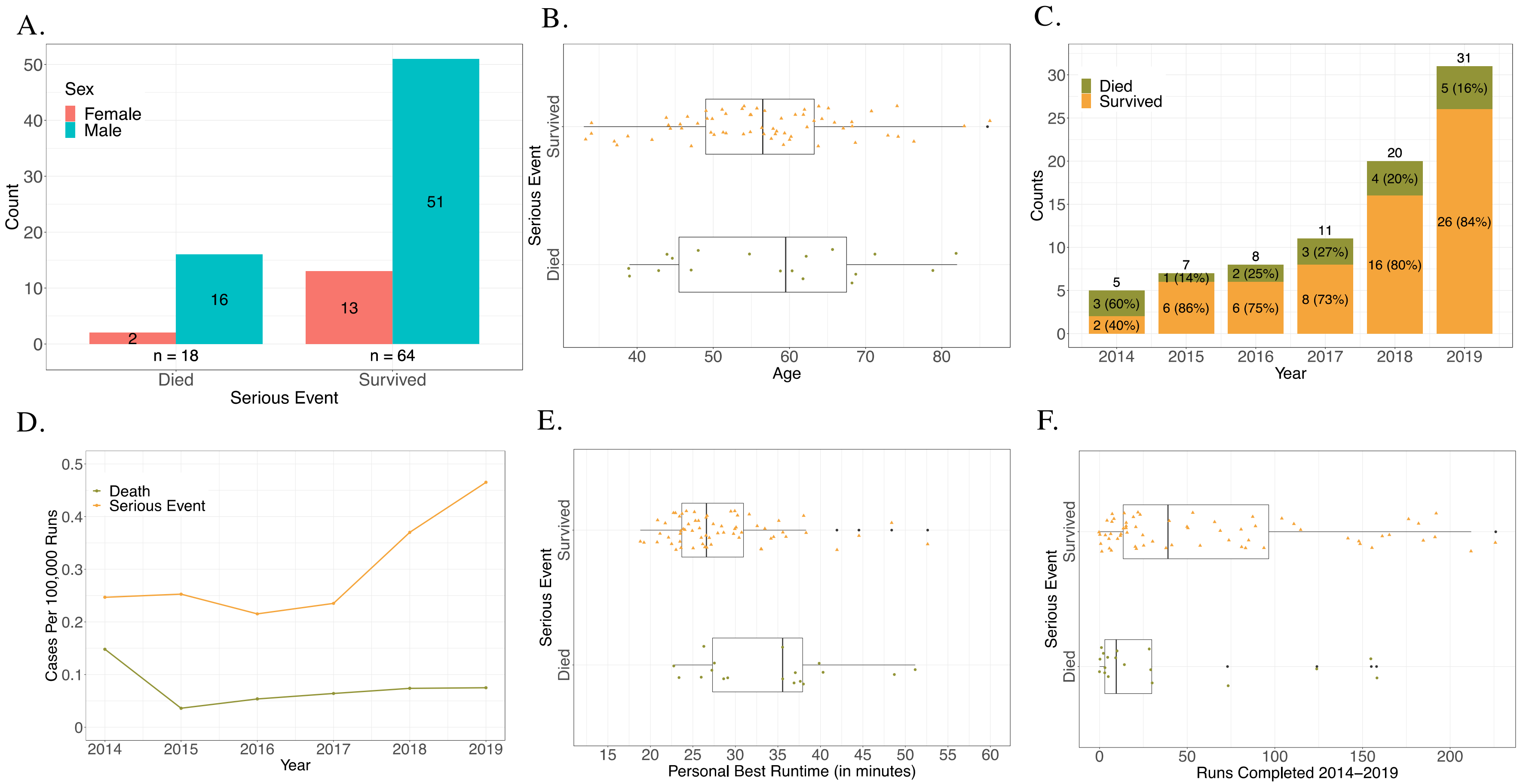

Figure 3: Serious life-threatening medical encounters and survival status at 5km parkrun events across the 2014-2019 time period A: by sex; B: by age; C: absolute count; D: /100,000 participations; E: by personal best parkrun time; F: by parkrun experience (number of parkruns completed per participant). Box plots represent median and interquartile range.

The results of the advanced logistic regression model to evaluate impacts of the risk factors (excludes junior parkrun serious incidents; n=2) are presented in **Figure 4** and **Table 2**.

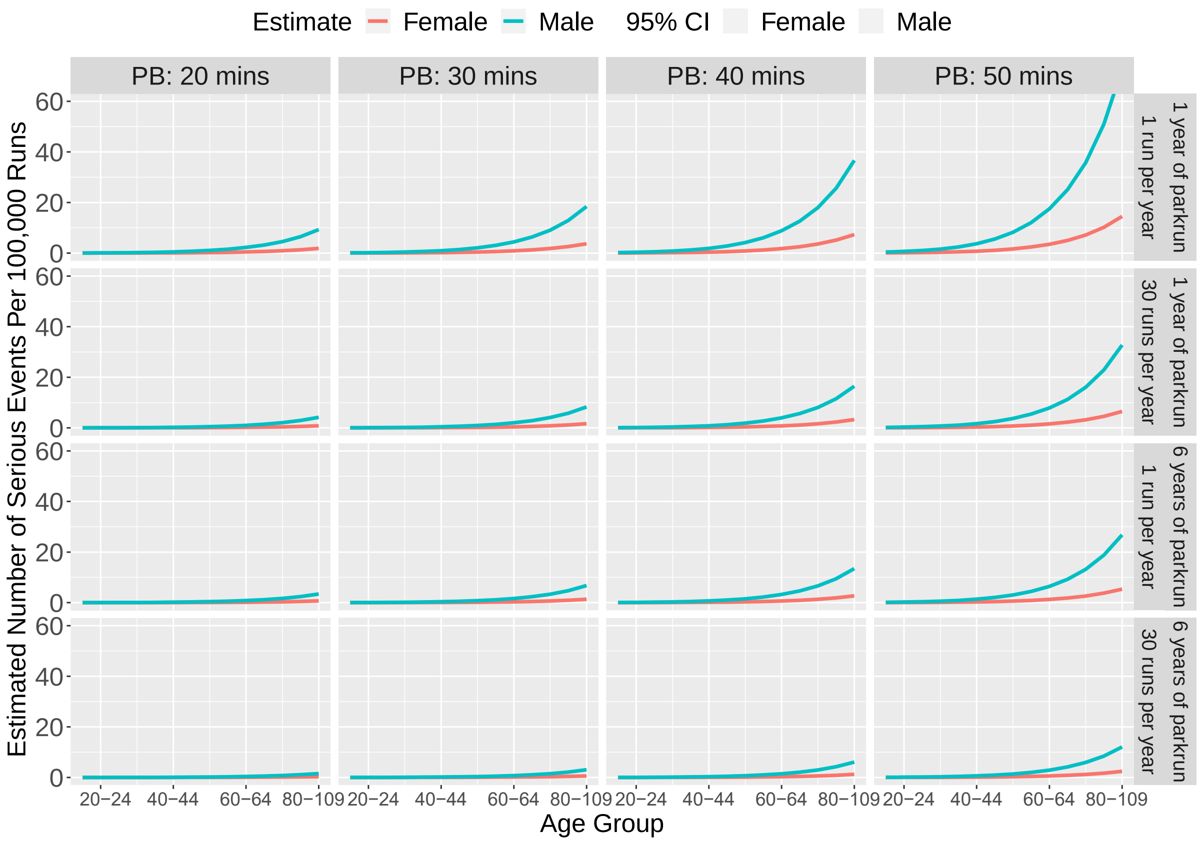

Figure 4: Example plots of the athlete specific estimated risk per participation at UK parkruns by personal best 5km run time (PB), age, sex and parkrun participation experience (number of runs per year and number of years of parkrun participation).

Participant age category, sex, personal best (as a surrogate for running ability and fitness level), average number of runs (as a surrogate for regular exercise) and number of years as a parkrun participant during 2014-2019 (as a surrogate for running experience) were identified as having a significant effect on the risk of a serious medical encounter. The risk was higher for males compared to females (OR 5.02; 95% CI: 2.73 to 9.20; p<0.0001) and for slower athletes (OR 1.07 per minute extra personal best; 95% CI: 1.03 to 1.11; p<0.0001) and decreased with increasing parkrun participation (OR 0.97; 95% CI: 0.95 to 0.99; p=0.02) and number of years participating (OR 0.82; 95% CI: 0.70 to 0.95; p=0.01). Insufficient evidence was found for non-linear effects of the personal best, average number of runs, or number of years as a parkrun participant on the risk. There was insufficient evidence of any interaction between these risk factors.

Table 2: Estimated coefficients and odds ratios for the risk of a serious life-threatening medical encounter at UK parkrun events.

Explanatory Variable*	Coefficient	Odds Ratio	95% CI for Odds Ratio	p-value
Intercept	-15.42			< 0.0001
Sex (male relative to female)	1.61	5.02	(2.73, 9.20)	< 0.0001
Personal best (minutes)	0.0687	1.07	(1.03, 1.11)	< 0.0001
Average number of *parkruns* per year	-0.0276	0.97	(0.95, 0.99)	0.020
Number of years participating	-0.200	0.82	(0.70, 0.95)	0.010

* Age ($p < 0.0001$). No odds ratio displayed since age was modelled using a smooth (thin plate spline) function. Response variable is the binomial pair of counts of number of completed runs and number of serious life-threatening medical encounters for each athlete (n = 1,808,324).

The magnitude of the reported odds ratios must be interpreted with care given the very low risk of serious events in general. A more informative summary is given by the plots of the (smooth) effect of age, sex, personal best, average number runs per year, and years participating in parkrun on the probability of a serious event (**Figure 4**) which translates the odds ratios into athlete specific estimated risk per participation. For example, the risk of experiencing a serious medical encounter, for a male runner aged 60-64 years, with a personal best of 40 minutes, who participated in an average of 1 parkrun event per year, in his first year of parkrun participation translates to 8.806 per 100,000 participations (95% CI: 5.483 to 14.144) which is higher than for the equivalent female runner at 1.756 per 100,000 participations (95% CI: 0.953 to 3.235). A personal best parkrun time of 40 minutes would place such a runner in the slowest 8% of this parkrun population. Notice that the ratio of the male:female probabilities is consistent with the OR of 5.02, since this risk ratio is approximately equal to the odds ratio due to the events being rare.

By contrast, the same runners with more experience (6 years of parkrun) and participation (30 participations on average per year) have a lower risk of 1.457 (95% CI: 0.699 to 3.038) for males and 0.290 (95% CI: 0.133 to 0.634) for females per 100,000 participations. Further, similarly experienced and high participation runners but in the lower age group of 20-24 years old have a much lower risk of 0.054 (95% CI: 0.014 to 0.209) for males and 0.011 (95% CI: 0.003 to 0.040) for females per 100,000 participations. So even though the male runners are at 5.02 times the risk compared to females, this risk is very low for younger adult runners.

Non-life-threatening medical encounters. Among 19,638,709 parkrun total participations that occurred during the first 4 years of study, we identified 7,492 non-life-threatening medical encounters which included 1,563 (20.1%) encounters occurring at junior parkrun events and 145 (1.9%) encounters impacting volunteers rather than participants. Among runners and walkers only, the rate of encounters was 1 per 2,552 parkrun participations or 0.392 encounters per 1,000 participations (95% CI: 0.381 to 0.398). The majority of all non-life-threatening encounters (94.2%) were minor (see **Table 3**), however, 698 encounters resulted in a hospital visit (1 per 28,136 parkrun participations or 0.036 per 100,000 participations; 95% CI: 0.033 to 0.038). 4,965 (66.3%) of the non-life-threatening encounters were associated with a trip or a fall and 305 (4.1%) encounters were associated with a collision.

Table 3: Non-serious medical encounters (n=7,492 during 19,638,709 *parkrun* participations over 4 years (2014-2018), including runners and volunteers:

Medical encounter category:	All encounters	Encounters leading to a hospital visit
Minor *blisters, nosebleeds, cuts and grazes, miscellaneous*	4,370	361
Musculoskeletal *dislocation, fracture, joint sprain, muscle cramp*	1,414	208
Collapse *Neurally mediated syncope, post-exertional syncope and seizure*	717	232
Head and Neck *headache, head or neck impact*	674	156
Gastrointestinal *stomach cramps, vomit, diarrhoea*	223	12
Respiratory *asthma, breathing problems*	215	20
Environmental and Animal *anaphylaxis, dog bites, insect stings, hyperthermia/hypothermia*	171	36

Note that medical encounters may appear multiple times in this table, e.g. a head impact leading to unconsciousness. 4965 encounters were associated with a trip or fall; 305 encounters were associated with a collision.

Discussion

Parkrun, a physical activity initiative that originated in the UK, now enables millions of individuals worldwide to participate in routine community-based exercise. The primary objective of this study was to determine the incidence, clinical correlates, and outcomes of all reported medical encounters attributable to parkrun. The *overall* rates of serious life-threatening and fatal medical encounters (1 per 384,597 parkrun participations and 1 per 1,794,784 parkrun participations, respectively) are substantially lower than those documented among other exercising cohorts including male recreational habitual joggers (1 fatality/396,000 hours of jogging), [20] competitive triathlon participants (1 fatality/39,151 male or female finishers), [21] and recreational marathon runners (1 fatality/259,000 male or female finishers). [22] Accordingly, the parkrun safety profile appears to be substantially better than those associated with other forms of organized sports and exercise. Further data for comparison were recently comprehensively reviewed and reported by Breslow et al. (2020) [17].

Routine moderate to vigorous physical activity reduces all-cause mortality, and physical activity recommendations have been published by numerous governing bodies. [6-8] However, inadequate physical activity is a major public health crisis with attendant clinical and economic implications. [10] Novel strategies that promote physical activity are a global health imperative, [23] however, the development and implementation of exercise adherence initiatives requires consideration of both the benefits and the risks. Accurate determination of the net benefit of physical activity interventions like parkrun necessitate data delineating both their benefit and harm. It is well established that acute bouts of vigorous physical activity transiently increase the risk of myocardial infarction, [24] and sudden cardiac death. [25,26] As summarized above, the incidence of fatal medical encounters during organized sports and athletics has been documented in numerous settings. Findings from the current study, the first large scale initiative designed to quantify the risks associated with a community-based weekly 5 kilometre running and walking programme, indicate that parkrun is associated with markedly lower encounter rates than previously reported in any prior cohorts.

Serious life-threatening medical encounters. Although extremely rare, several observations about serious life-threatening medical encounters during parkrun participation are noteworthy. First, male sex and increasing age were associated with increased risk of a serious medical encounter, and the majority of life-threatening encounters during parkrun participation were attributable to a cardiovascular etiology. These observations are in line with prior studies[22,27]. The number of, and rate of, serious encounters significantly increased over time and we speculate that this is due to the widening of the demographics of the participants, particularly the increasing proportion of older runners. Second, we observed a cardiac arrest survival rate of 65% in the context of near uniform utilization of automated external defibrillators (mandatory at all UK parkrun events). This survival rate approximates prior reports among other sporting cohorts and is substantially better than reported out-of-hospital cardiac arrest survival rates worldwide (approximately 10%)[28] underscoring the importance of defibrillator availability at community-based exercise events,. Third, less prior running experience, both in terms of the average number of parkrun participations per year (within the 6-year sample) and the number of years participating (within the 6-year sample) were associated with an increased risk of a serious medical encounter. Finally, we observed a low rate of serious life-threatening medical encounters attributed to heat illness. Compared to US data examining a popular summertime 10 kilometre run (1.6 heat illness encounters per 1000 finishers [29]) and Isreali data characterizing Tel Aviv-based races of 10 kilometre or greater distance (21 life-threatening heat illness cases among 137,580 runners [30]), we observed a markedly lower incidence (<0.01 per 1,000 parkrun participations) of serious life-threatening medical encounters related to heat. We speculate this discrepancy is attributable both to the comparatively short parkrun distance and the comparatively temperate UK climate.

Non-life-threatening medical encounters. This study also examined the incidence of non-life-threatening medical encounters finding an estimated incidence of 0.4 per 1,000 parkrun participations. This event rate compares favourably with data derived from prior studies of 10 km races (6.2 per 1,000 finishers)[29], half marathon races (2.2 per 100,000 registered participants)[27], and marathon races (18.9 per 1000 entrants)[31]. The majority of non-life-threatening medical encounters during parkrun were accounted for by soft tissue (*i.e.* cuts, scrapes, abrasions, etc.) and musculoskeletal injury (i.e. sprains, joint dislocations, and fractures). This etiologic profile is consistent with a prior report of medical encounters occurring during a half marathon distance event.[27] While the incidence of injury during parkrun compares favourably to longer distance running events, our data suggest a valuable role for basic first aid services at these community running events.

Study implications. There are direct public health and clinical implications of the findings generated in this study. Emerging data suggest positive impacts of parkrun participation on both mental and physical health. Stevinson et al (2014, 2018) reported a net increase in weekly physical activity of 39 minutes and reduced body mass coupled with increased happiness and reduced psychosocial stress after 12 months of parkrun participation. [32,33] Importantly, the beneficial effects of parkrun participation appear to be achievable by former non-runners and people with obesity and physical disability.

Preliminary data demonstrating the health benefits of parkrun participation coupled with the favourable safety profile documented in this study support the widespread use of parkrun as a safe and effective way to promote physical activity with its attendant health benefits. From a clinical perspective, findings from this study may inform the optimal provision of medical services at future parkrun and similar community-based events. At present, parkrun medical encounter recording and reporting requirements differ from recently published recommendations. [18] In addition, there is no requirement for medically trained personnel to be present for a parkrun event to go ahead, or for those reporting incidents in parkrun's incident database to be medically trained, which would be required to enable a greater degree of medical encounter reporting, closer to that described in a recent consensus statement [18]. While our data underscore the importance of access to defibrillators and basic first aid, the relative scarcity of serious medical encounters at parkrun suggests that investment in a more comprehensive medical infrastructure is unnecessary. Future potential mandates for comprehensive onsite medical services at parkrun [18], or a requirement for pre-participation screening, may translate into a marked decline in the number of communities capable of hosting parkrun, or deter individuals from participating. The important finding that a higher risk of a serious medical encounter exists in the older (notably over 60 years) age groups, and amongst slower, novice runners, warrants consideration of interventions to further reduce the rate of serious medical encounters at parkrun. One previous study demonstrated that intervening with targeted educational materials, and pre-participation clearance of higher risk runners from a medical practitioner, resulted in a reduction of all race-day medical encounters (by 29%) at a 21.1km and 56km running events in South Africa[34] and a 64% reduction in serious life-threatening medical encounters or death. A similar strategy may be applicable at parkrun. However, it should be noted that a far higher rate of serious life-threatening medical encounters or death was reported for these longer events (56 per 100,000 starters prior to the intervention, reducing to 21 after the intervention, compared to 0.32 per 100,000 in the present study). Regardless, the creation and implementation of specific strategies designed to reduce the risk of adverse events among parkrun participants represents a logical and important area of future work.

Limitations. While this study represents a unique large-scale analysis of a community-based exercise programme with capture of both medical encounters and total participation numbers, several potential limitations are noteworthy. First, we acknowledge that the parkrun database, a resource that requires medical encounter reporting by volunteer event organizers, may have failed to capture all relevant medical encounters. However, the impact of under reporting is anticipated to be minimal based on the mandatory reporting system implemented by parkrun, and the risk assessments and incident reporting typically required in public parks or recreational areas that host these events in the UK. Next, we did not have access to any pre-existing health conditions data collected at parkrun registration that would potentially have provided further insights into the risk of a serious medical encounter. Similarly, we did not have access to hospital records documenting the care of participants that experienced life-threatening events thereby introducing the possibility of aetiology misclassification. However, the parkrun system requires detailed follow-up of all life-threatening events thereby reducing the likelihood of inaccurate event causality classification. The risk estimates result from an observational study, so care must be taken if generalising to a wider population. Finally, data presented in this study characterize the medical risk of parkrun participation prior to the emergence of the COVID-19 pandemic. Continued acquisition and analyses of medical event data in the wake of this viral pandemic represents an important area of future work.

Conclusion. Participation in 5km community running and walking (parkrun) is associated with an exceptionally low incidence of serious life-threatening and fatal medical events. Accordingly, this rapidly growing mass-participation community-based exercise programme appears to be a safe and viable means of promoting physical activity on a large scale. The higher incidence among male, older, slower and less experienced parkrun participants warrants consideration for preventative strategies. Future work will be required to fully delineate the overall positive health impacts of parkrun in the context of a global physical inactivity health crisis.

Ethics: All aspects of this study were approved by the ethics committee of St Mary's University Twickenham, UK (Reference: SMEC_2018-19_059).

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Data sharing statement: Following publication, data analysed in the present study will be made available to other research groups subject to approval of a proposal and a signed data access agreement.

References

1. Mok A, Khaw K-T, Luben R, Wareham N, Brage S. Physical activity trajectories and mortality: population based cohort study. *BMJ (Clinical research ed)* 2019; **365**: l2323.
2. Pedersen BK, Saltin B. Exercise as medicine – evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scandinavian Journal of Medicine & Science in Sports* 2015; **25**(S3): 1-72.
3. Posadzki P, Pieper D, Bajpai R, et al. Exercise/physical activity and health outcomes: an overview of Cochrane systematic reviews. *BMC Public Health* 2020; **20**(1): 1724.
4. Thompson PD, Franklin BA, Balady GJ, et al. Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology. *Circulation* 2007; **115**(17): 2358-68.
5. Cormie P, Zopf EM, Zhang X, Schmitz KH. The Impact of Exercise on Cancer Mortality, Recurrence, and Treatment-Related Adverse Effects. *Epidemiol Rev* 2017; **39**(1): 71-92.
6. World Health Organisation. Global strategy on diet, physical activity and health. https://www.who.int/dietphysicalactivity/pa/en/ (accessed April 8 2020).
7. National Health Service (NHS). Exercise. 2019, October 8. https://www.nhs.uk/live-well/exercise/ (accessed April 8 2020).
8. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA* 2018; **320**(19): 2020-8.
9. Sparling PB, Howard BJ, Dunstan DW, Owen N. Recommendations for physical activity in older adults. *BMJ : British Medical Journal* 2015; **350**: h100.
10. Ding D, Lawson KD, Kolbe-Alexander TL, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet* 2016; **388**(10051): 1311-24.
11. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity. A systematic review. *Am J Prev Med* 2002; **22**(4 Suppl): 73-107.
12. Sallis JF, Cerin E, Conway TL, et al. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *Lancet* 2016; **387**(10034): 2207-17.
13. Patterson R, Webb E, Millett C, Laverty AA. Physical activity accrued as part of public transport use in England. *J Public Health (Oxf)* 2019; **41**(2): 222-30.
14. Ball K, Hunter RF, Maple JL, et al. Can an incentive-based intervention increase physical activity and reduce sitting among adults? the ACHIEVE (Active Choices IncEntiVE) feasibility study. *Int J Behav Nutr Phys Act* 2017; **14**(1): 35.
15. Stevinson C, Hickson M. Changes in physical activity, weight and wellbeing outcomes among attendees of a weekly mass participation event: a prospective 12-month study. *J Public Health (Oxf)* 2019; **41**(4): 807-14.
16. Fleming J. parkrun: increasing physical activity in primary care. *British Journal of General Practice* 2019; **69**(687): 483-4.
17. Breslow RG, Giberson-Chen CC, Roberts WO. Burden of Injury and Illness in the Road Race Medical Tent: A Narrative Review. *Clin J Sport Med* 2020.
18. Schwellnus M, Kipps C, Roberts WO, et al. Medical encounters (including injury and illness) at mass community-based endurance sports events: an international consensus statement on definitions and methods of data recording and reporting. *Br J Sports Med* 2019; **53**(17): 1048-55.
19. Wood SN, Goude Y, Shaw S. Generalized additive models for large data sets. *Journal of the Royal Statistical Society: Series C (Applied Statistics)* 2015; **64**(1): 139-55.

20. Thompson PD, Funk EJ, Carleton RA, Sturner WQ. Incidence of death during jogging in Rhode Island from 1975 through 1980. *Jama* 1982; **247**(18): 2535-8.
21. Harris KM, Creswell LL, Haas TS, et al. Death and Cardiac Arrest in U.S. Triathlon Participants, 1985 to 2016: A Case Series. *Ann Intern Med* 2017; **167**(8): 529-35.
22. Kim JH, Malhotra R, Chiampas G, et al. Cardiac arrest during long-distance running races. *The New England journal of medicine* 2012; **366**(2): 130-40.
23. King AC, Whitt-Glover MC, Marquez DX, et al. Physical Activity Promotion: Highlights from the 2018 Physical Activity Guidelines Advisory Committee Systematic Review. *Medicine and science in sports and exercise* 2019; **51**(6): 1340-53.
24. Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE. Triggering of acute myocardial infarction by heavy physical exertion. Protection against triggering by regular exertion. Determinants of Myocardial Infarction Onset Study Investigators. *The New England journal of medicine* 1993; **329**(23): 1677-83.
25. Siscovick DS, Weiss NS, Fletcher RH, Lasky T. The incidence of primary cardiac arrest during vigorous exercise. *The New England journal of medicine* 1984; **311**(14): 874-7.
26. Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE. Triggering of sudden death from cardiac causes by vigorous exertion. *The New England journal of medicine* 2000; **343**(19): 1355-61.
27. Tan CM, Tan IW, Kok WL, Lee MC, Lee VJ. Medical planning for mass-participation running events: a 3-year review of a half-marathon in Singapore. *BMC Public Health* 2014; **14**: 1109.
28. Yan S, Gan Y, Jiang N, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. *Critical Care* 2020; **24**(1): 61.
29. Breslow RG, Shrestha S, Feroe AG, Katz JN, Troyanos C, Collins JE. Medical Tent Utilization at 10-km Road Races: Injury, Illness, and Influencing Factors. *Medicine and science in sports and exercise* 2019; **51**(12): 2451-7.
30. Yankelson L, Sadeh B, Gershovitz L, et al. Life-threatening events during endurance sports: is heat stroke more prevalent than arrhythmic death? *J Am Coll Cardiol* 2014; **64**(5): 463-9.
31. Roberts WO. A 12-yr profile of medical injury and illness for the Twin Cities Marathon. *Medicine and science in sports and exercise* 2000; **32**(9): 1549-55.
32. Stevinson C, Hickson M. Changes in physical activity, weight and wellbeing outcomes among attendees of a weekly mass participation event: a prospective 12-month study. *J Public Health (Oxf)* 2018.
33. Stevinson C, Hickson M. Exploring the public health potential of a mass community participation event. *J Public Health (Oxf)* 2014; **36**(2): 268-74.
34. Schwellnus M, Swanevelder S, Derman W, Borjesson M, Schwabe K, Jordaan E. Prerace medical screening and education reduce medical encounters in distance road races: SAFER VIII study in 153 208 race starters. *British Journal of Sports Medicine* 2019; **53**(10): 634-9.

Supplementary material

Supplementary Table S1: Medical encounter categorisation at parkrun; levels of severity. CPR = cardiopulmonary resuscitation; AED = automated external defibrillator.

Severity classification	Descriptor	Examples
5	Significant threat to life	Collapse involving loss of consciousness/cessation of breathing/loss of pulse. CPR and/or AED required.
4	Possible threat to life; or significant risk of life-changing injury	Collapse involving seizure, possible loss of consciousness/serious head injury/multiple fractures/stroke
3	Individual requiring hospital treatment; or fit/seizure/extended loss of consciousness	Fractures/dislocations/severe sprains/cuts requiring stitches/epilepsy
2	Treatment required at the scene	Minor sprains/cuts requiring bandaging/fainting
1	Little or no treatment required at the scene	Minor cuts/grazes possibly requiring cleaning

S2. *Life-threatening medical encounters.* Following this confirmation of a serious life-threatening medical encounter by the central parkrun team, additional data were collected to further characterize each event including: 1) sex, age, and runner or volunteer status of the afflicted participant, 2) medical description of the event, 3) location where the incident occurred on the parkrun course, 4) requirement for on-site emergency medical services treatment, ambulance transport, and hospitalization, 5) use of an automated external defibrillator (AED), 6) survival or non-survival of the afflicted participant, and 7) number of previously completed parkruns and personal best parkrun time of the afflicted participant.

S3. *Non-life-threatening medical encounters.* The two trained research assistants used all available data to assign each medical encounter an aetiology or mechanism of pathology using the following designations: 1) cardiovascular, 2) disorder of thermoregulation, 3) pulmonary, 4) anaphylactic, 5) gastrointestinal, 6) neurologic, and 7) musculoskeletal which was further subdivided into cramping, sprain, fracture and dislocations, head and neck injury, skin abrasion, contusion, or blister. The cases deemed to be of ambiguous aetiology

(147/7840, 1.9%) were subsequently reviewed by an independent 4-person panel to establish a consensus aetiology, or to categorise as ‘unknown’.

S4. Statistical analysis

The data were cleaned prior to modelling by removing parkrun times where no or unreliable data are available on the athlete’s age, sex and previous run history (n=1,940,322). This further reduces the denominator in the calculation of the rate of serious encounters, so leads to an over-estimation of risk (more conservative). Multiple imputation was used for missing parkrun times (typically due to failed timing systems) based on each athlete’s previous or following parkrun time, where available. No substantive changes in the results presented were observed when the missing run times were simply dropped from the dataset, instead of being imputed.

The age categories of 80-84 to 105-109 were combined to 80-109 due to the small number of participants (851 equating to less than 0.05% of all participants). Junior parkrun participants (4-14 years olds in 2km or 5km parkrun events) were excluded from statistical analyses (n=5,115,301) since their risk factors are so different. Further, most junior runners undertake a shorter run of 2km so the runtime are not comparable to the 5km runs, and the junior’s performance varies substantially with age.

The risk exposure for each runner is accumulated by the number of parkruns completed during 2014-2019, assuming the risk is independent for each parkrun. An athlete’s main age was defined by the lower bound of the age group that the athlete participated most frequently during 2014-2019, since their date of birth was not available. The effect of age was modelled as a smooth function of main age category (using thin plate splines) while linear effects were assumed for the effect of personal best parkrun performance, average number of parkruns/year and number of years of parkrun participation during 2014-2019.

Cohen's kappa was calculated to assess the level of inter-observer agreement by the two trained research assistants categorising medical encounters using a (random) sample of all reported cases. The inter-observer agreement was determined to be strong (Cohen's $\kappa = .85$, $p<0.001$).