1   Research

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3   # The COVID-19 pandemic has increased health inequalities by

4   altering patterns of engagement with a mass participation event

5   after resumption post-lockdown

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13   Short title: Impacts of the pandemic on physical activity continue after lockdown

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Abstract

The global epidemic in physical inactivity has been exacerbated by lockdowns with concerning health inequalities accentuated as a result. Studies are needed of post-lockdown levels of activity to determine if there are lasting impacts beyond lockdown. This study uses parkrun in Scotland as a model system to address this urgent question. Generalised linear mixed models were used to identify patterns in the attendance, gender, age and performance of 500,000+ parkrun participations in Scotland for the year before the pandemic and the first year after lockdown. Total weekly attendance in Scotland had been increasing year-on-year but fell by 13% from 7,649 (95% CI 7,275 to 8.024) in the final-year pre-lockdown to 6,612 (95% CI 6,260 to 6,963) in the first-year post-lockdown. Attendance drops were disproportionately larger at events with larger attendances prior to lockdown. There was a disproportionate loss of female participants in more deprived areas. The gender gap in participation had been narrowing before lockdown but widened from 54.02% (95% CI 53.85 to 54.19%) in the final-year pre-lockdown to 56.29% male (95% CI 56.09 to 56.49%) in the first-year post-lockdown. The age of participants increased from 44.94 (95% CI 44.90 to 44.98) before lockdown to 46.58 (95% CI 46.53 to 46.64) after lockdown. The age gap between the genders widened after lockdown particularly at larger events and in more deprived areas. Performance was declining before lockdown but increased from 55.02% (95% CI 54.96 to 55.06%) to 55.93% (95% CI 55.88 to 55.97%) after lockdown. The pandemic has reduced attendance at parkrun in Scotland and the loss of participants has been non-random increasing health inequalities affecting women, the least fit and those in deprived areas. Some former participants are also now avoiding larger mass participation events. Investment and management strategies will be needed to address these worsening inequalities.

Keywords: parkrun, pandemic, social deprivation, simd, physical activity

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Introduction

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44   Variation in levels of physical activity have been found to be driving health inequalities

45   highlighting the importance of tracking levels of activity and identifying correlates of activity

46   among populations [1–3]. The COVID-19 pandemic had a major impact on levels of physical

47   activity [4–15]. Among the identified impacts of lockdown is an avoidance of larger events

48   found in runners in Greece [4]. A study tracking physical activity levels in the UK found it

49   declined 37% during lockdown, although the impacts varied with age, with older individuals

50   more likely to maintain their pre-lockdown levels of activity than younger adults [5]. The

51   impacts of the pandemic have also been found to vary with socio-economic background with

52   those in deprived areas finding it hardest to access places to exercise during lockdowns [6–

53   8]. By contrast, a study of levels of physical activity in Kenya found that people from higher

54   social classes were more likely to have reduced their activity during lockdown and this was

55   particularly the case for females [14]. A study of factors associated with physical activity

56   during lockdown in Australia noted the importance of connections to an exercise group for

57   older adults to maintain or even increase levels of activity [15]. The impacts of the pandemic

58   on levels of physical activity exacerbate the pre-existing problem with 1.4 billion adults

59   estimated to have been doing too little physical exercise prior to the pandemic [16]. This had

60   resulted in the promotion of wider participation in sport becoming a global priority [17]. The

61   negative impact of the pandemic on levels of physical fitness has only served to increase

62   this global priority. This leaves a key question. If lockdown impacted the demographics of

63   those engaging in physical exercise do those impacts extend into the post-lockdown era

64   [10]? Large-scale studies investigating changes in the patterns of exercising are urgently

65   needed to address this question [12].

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66   One very large dataset on activity levels is the parkrun results database. parkrun provide

67   free weekly 5km events at nearly 2,000 locations generating data for close to 100,000

68   events annually. There is huge potential for using parkrun as a model system for

69   investigating changes in the demographics of those engaging in physical activity and

70   identifying correlates of activity. Several studies have investigated the parkrun results

71   database [18–21] and some studies have identified correlates of participation on a very large

72   scale [22–28]. Few studies though have investigated changes in the demographics of

73   parkrun participants over time [22,29].

74   A survey of the behaviour of previous parkrun participants during lockdown found reduced

75   activity levels [29]. Increased inactivity during lockdown was particularly evident in younger

76   adults, people in deprived areas and the least active [29]. Consequently, the changing

77   patterns in activity among parkrun participants during lockdown are consistent with those

78   identified in other studies [4–8] revealing the potential value of using parkrun as a model

79   system. As more than 50,000 parkrun events have taken place in the UK alone since

80   lockdown ended a huge database has been generated on post-lockdown activity levels at a

81   mass participation event that not only has a key aim of encouraging the least active to

82   engage in physical activity but is also actively involved with social prescribing [30–32]. This

83   allows a unique opportunity to investigate what lasting impacts lockdowns have had on

84   levels and correlates of physical activity after they have been lifted and how lockdown might

85   have altered the demographic of parkrun participants. This is particularly important as

86   lockdowns are likely to have increased equalities in social prescription [33].

87   A previous study of all parkrun events in Scotland from 2004-2019 revealed various

88   changing correlates of participation with a narrowing gender ratio, reducing performance

89   scores and an increasing mean age of participants [22]. Another study of factors affecting

90   the likelihood of returning to parkrun for new participants in Scotland found that they are less

91   likely to return after attending larger events [28]. The pandemic could have increased risk

92   averse behaviour and exacerbated avoidance of larger parkrun events. The aim of this study

93   is to investigate how lockdown has impacted these changing demographics and correlates of

94   participation at parkrun in Scotland. Scotland has a range of different parkrun types from city

95   centre parks to remote island locations. Scottish parkrun locations also show considerable

96   variation in the level of deprivation of the surrounding areas in which they are located. This

97   makes Scottish parkrun events an ideal model system for investigating lasting impacts of

98   lockdown on the levels of physical activity by comparing characteristics of participants before

99   and after lockdown. Scottish parkrun events also vary considerably in their mean number of

100   attendees allowing an assessment of whether some former participants are not avoiding

101   larger parkrun events to reduce the risk of exposure to COVID-19.

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Methods

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104   This was an analytical study of aggregated publicly available secondary data. There was no

105   primary data collection and no active participants.

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Data sources

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108   The primary data source was the parkrun results for events that occurred in Scotland in the

109   year immediately prior to lockdown (16th March 2019 to 14th March 2020) and the year

110   immediately after the resumption (14th August 2021 to 13th August 2022). Data from 44

111   events were included. These were all the events that were in existence one year prior to the

112   start of the pandemic and which also returned after lockdown. The results for each event

113   were processed using an Excel macro which extracted gender, age category and age

114   graded performance score for all participants [34]. Age is provided as a 5-year cohort for

115   adults except for 18-19 year olds. Age was converted to a continuous variable by assigning

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116   participants the mid-point for their cohort group. Only adult participants were included in the

117   study. Gender is assigned by participants. Only participants selecting male or female were

118   included in the study as age graded performance scores are not provided by parkrun for

119   other gender options. The Scottish Index of Multiple Deprivation (simd) 2020 was

120   determined for the data zone within which each parkrun is located [35]. Scotland is

121   separated into 6,976 data zones which are ranked from the most deprived to the least

122   deprived, based upon income, employment, education, health, access to services, crime and

123   housing [35]. Event size was calculated from the mean attendance at each event for the year

124   prior to the pandemic.

125

Data analysis

127   The data were analysed using R x64 4.1.1 [36]. A generalised linear mixed model (GLMM)

128   of event attendance in Scotland in the year prior to lockdown and the first year after return

129   from lockdown was generated using the lme4 function [37]. Prior to modelling event

130   attendances were transformed to natural logarithms. This not only made the data fit a

131   Gaussian distribution but also allowed direct comparison between the rate of change in

132   attendance across events of different sizes. All continuous explanatory variables (date,

133   mean event size and simd ranking) were scaled to have a mean of zero and a standard

134   deviation of one. In addition, a binary variable denoting whether the event was pre- or post-

135   lockdown was included. Event location was included as a random effect. Minimum Akaike

136   Information Criterion was used to select the optimal model [37].

137   GLMMs were generated for gender, age and performance of participants for the participant

138   dataset. Event location was again used as random effect. A binomial error distribution was

139   used for the model of gender. The simd of the area within which event is located and the

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140   mean attendance for the year prior to lockdown were included as predictor variables after

141   scaling to have a mean of 0 and a standard deviation of 1.

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144   # Results

145   ## The impact of the COVID-19 lockdown on attendance at Scottish

146   ## parkrun events

147   Prior to lockdown attendances in Scotland had been increasing exponentially (Figure 1) but

148   a comparison of mean total attendance for the last year of parkrun in Scotland prior to the

149   pandemic (7,649, 95% CI 7,275 to 8.024) and the first-year post-lockdown (6,612, 95% CI

150   6,260 to 6,963) reveals a more than 13% decline. A model of the attendance at individual

151   events revealed a significant interaction between lockdown and event size revealing that

152   declines in attendance were disproportionately larger at larger events (β=--0.039; p<0.001).

153

154   Fig 1. Total attendance on each parkrun day in Scotland from day 0, 6th December 2008 until

155   March 18th 2023.

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157   ## The impact of COVID-19 lockdown on the gender ratio of participants at

158   ## Scottish parkrun events

159   A total of 554,696 participations at parkrun events in Scotland a year either side of lockdown

160   were included in the models consisting of 305,123 male participations and 249,573 female.

161   Prior to lockdown the gender gap in participation at Scottish parkrun events had been

162   narrowing [22]. A generalised linear model of gender ratio using a binomial error distribution

163   and including event location as a random effect revealed a highly significant increase (β

164   =0.088; p<0.001) in the gender ratio from 54.02% male (95% CI 53.85 to 54.19%) in the

165   year prior to lockdown to 56.29% male (95% CI 56.09 to 56.49%) in the year after lockdown.

166   An interaction term identified a significantly greater increase in gender ratio at larger events

167   after lockdown (β=0.080; p=0.007). Separating event size into small and large based upon

168   whether the scaled score for each event was positive (high) or negative (low) shows an

169   increase in the gender ratio from 52.87% male (95% CI 52.63 to 53.10) before lockdown to

170   54.96% male (95% CI 54.70 to 55.23) after lockdown at small events and an increase in the

171   gender ratio from 55.44% male (95% CI 55.18 to 55.70) before lockdown to 54.96% male

172   (95% CI 57.67 to 58.27) after lockdown at large events.

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The impact of COVID-19 lockdown on the age of participants at Scottish parkrun events

177   There had been a trend towards an increase in the age of participants prior to lockdown in

178   Scotland and a narrowing age gap between the genders [22]. A GLMM (Table 1) of the age

179   of participants identified an increase in age of participants from 44.94 (95% CI 44.90 to

180   44.98), in the year before lockdown to 46.58 (95% CI 46.53 to 46.64) in the year after

181   lockdown. A previous study reported an age gap between the sexes with male participants

182   being on average older than female participants [22]. The model found the age gap between

183   the genders has widened after lockdown (males: before lockdown 46.08 (95% CI 46.02 to

184   46.14), after lockdown 47.75 (95% CI 47.68 to 47.82); females: before lockdown 43.61 (95%

185   CI 46.54 to 46.67), after lockdown 45.08 (95% CI 45.01 to 45.16). Larger events had a

186   younger demographic, and this was more pronounced in female participants. More deprived

187   areas had an older demographic than less deprived areas prior to lockdown although this

188   association reversed after lockdown in female participants (Table 2). There was also a

189   disproportionate loss of female participants in more deprived areas and male participants in

190   less deprived areas after lockdown (χ^2=6.26; p=0.012, Table 2).

191

192   **Table 1.** A general linear mixed model of the age of participants at Scottish parkrun events

193   for the year before and the year after lockdown. Event location was included as a random

194   effect. All continuous explanatory variables were scaled. Event size was the mean

195   attendance at each event over the last year prior to lockdown.

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Parameter	Estimate	SE	P value
Intercept	43.58	0.279	<0.001
Gender (Male)	2.563	0.045	<0.001
Lockdown (Post)	1.442	0.050	<0.001
Event size	-1.126	0.288	<0.001
Simd	0.437	0.259	0.010
Gender (Male)*Event size	0.443	0.035	<0.001
Lockdown (Post)* Simd	-0.173	0.051	<0.001
Lockdown (Post)*Gender (Male)	0.199	0.068	0.003
Gender (Male)*Simd	-0.002	0.046	0.962
Lockdown (Post)*Gender (Male)*Simd	0.286	0.068	<0.001

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199   **Table 2.** The mean age and gender of participants at parkrun in Scotland in the year before

200   and after lockdown in low and high deprivation areas. Simd was separated into high and low

201   deprivation based upon whether the scaled score for each event was positive (low) or

202   negative (high).

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Lockdown	Simd	Gender	N	Mean	95% CI
Pre	high	Female	70 578	43.46	43.37 to 43.55
Post	high	Female	52 041	45.16	45.05 to 45.27
Pre	high	Male	84 190	45.90	45.82 to 45.98
Post	high	Male	66 929	47.54	47.44 to 47.64
Pre	low	Female	73 529	43.74	43.65 to 43.82
Post	low	Female	53 425	45.00	44.89 to 45.11
Pre	low	Male	85 104	46.26	46.17 to 46.34
Post	low	Male	68 900	47.95	47.85 to 48.04

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206   The Impact of COVID-19 lockdown on the Performance of Participants

207   at Scottish parkrun Events

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209   There has been a trend towards a reduction in the performance of participants prior to

210   lockdown in Scotland [22] as parkrun has become more inclusive to the less active. After

211   lockdown that trend reversed with a GLMM (Table 3) identifying a highly significant increase

212   in performance from 55.02% (95% CI 54.96-55.06%) pre-lockdown to 55.93% 95% CI 55.88

213   to 55.97%) after lockdown. The model identified that performance was positively correlated

214   with age, being male and event size. Significant interaction terms revealed a narrowing

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215   gender gap in performance with increasing age, event size and levels of deprivation,

216   together with a narrowing of the gender gap in performance after lockdown (males: before

217   lockdown 56.90%; 95% CI 56.85-56.95, after lockdown 57.49; 95% CI 57.43 to 57.54;

218   females: before lockdown 52.82; 95% CI 52.76 to 52.87, after lockdown 53.92; 95% CI 53.85

219   to 53.98). The model also revealed an increase in the performance gap between high and

220   low deprivation areas after lockdown (Table 4).

221

222   **Table 3.** A general linear mixed model of the age graded performance score of participants

223   at Scottish parkrun events for the year before and the year after lockdown. Event location

224   was included as a random effect. All continuous explanatory variables were scaled. Event

225   size was the mean attendance at each event over the last year prior to lockdown.

226

Parameter	Estimate	SE	P value
Intercept	53.21	0.319	<0.001
Age	2.914	0.027	<0.001
Gender (Male)	3.485	0.036	<0.001
Lockdown (Post)	0.798	0.041	<0.001
Event size	1.014	0.326	0.003
Simd	-0.188	0.302	0.536
Gender (Male)*Age	-1.163	0.037	<0.001
Gender (Male)*Event size	-0.484	0.028	<0.001
Lockdown (Post)*Gender (Male)	-0.404	0.054	<0.001
Lockdown (Post)*Age	0.255	0.041	<0.001
Gender (Male)*Simd	0.156	0.028	<0.001
Lockdown (Post)*Event size	0.149	0.031	<0.001

Lockdown (Post)*Simd	-0.117	0.028	<0.001
Simd*Event size	0.312	0.289	0.286
Lockdown (Post)*Gender (Male)*Age	-0.420	0.054	<0.001
Lockdown (Post)* Simd*Event size	0.127	0.026	<0.001

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228 **Table 4.** The mean age graded performance score of participants at parkrun events in

229 Scotland in the year before and after lockdown. Events were separated into low and high

230 simd based upon whether the scaled score for each event was positive (high) or negative

231 (low).

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Lockdown	Simd	Age Graded Performance Score	N	95% CI
Pre	low	54.70	154 768	54.64 to 54.75
Pre	high	55.34	158 633	55.29 to 55.39
Post	low	55.68	118 970	55.62 to 55.74
Post	high	56.16	122 325	56.10 to 56.22

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Discussion

236 The findings are consistent with previous studies that have identified that COVID-19

237 pandemic lockdowns reduced levels of physical activity particularly for the young, the less fit

238 and those in most deprived areas [4–9,29]. The current study has identified that these

239 patterns have continued into the post-lockdown period in a mass participation event in

240 Scotland. The study has also identified some new correlates of activity and new patterns of

241 association in existing correlates.

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242   Overall attendances are well down on where they would have been had they continued to

243   increase at pre-pandemic rates. The models identify several changes in correlates with

244   participation levels after lockdown which help identify the changing demographics of parkrun

245   attendees. A previous study identified that among parkrun participants from before the

246   pandemic that the activity levels had particularly declined in younger adults, the least active

247   and those in more deprived areas during lockdown [29].The current study reveals the

248   concerning finding that these impacts also extend into the post-lockdown period.

249   Furthermore, additional impacts were identified with a substantial shift in the gender ratio

250   with a higher rate of loss of female participants. These means that several existing health

251   inequalities have now only been exacerbated by lockdown but also that these impacts have

252   extended into the post-lockdown era.

253   A number of important correlates of levels of participation were identified that help shed light

254   on why some of these health inequalities have increased. The widening age gap between

255   the genders suggests that there has been a bias towards the loss of females amongst older

256   participants. The narrowing performance gap between the genders suggests that it is the

257   least fit female participants that have stopped attending. The widening gender age gap at

258   larger events suggests that there has also been a bias in the loss of older females from

259   larger events. This seems to be particularly the case in the least deprived parts of Scotland.

260   This could be related to older, less fit women avoiding more crowded parkruns to reduce

261   their risk of contracting COVID-19. Both age and fitness are associated with the increasing

262   risks of contracting COVID-19 [38,39] so it appears that older, less fit females could be more

263   risk averse and are avoiding busier events. This is consistent with a study in Kenya that

264   found that women in higher social classes were the most likely to reduce their levels of

265   physical activity during lockdown [14]. The increasing gender gap in age at events in the

266   least derived areas could be related to better awareness of the risks of contacting covid. The

267   finding that smaller events had the greatest increase in age also suggests that older

268   participants have altered their attendance patterns to avoid large crowds. This suggests that

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269   parkrun and other similar event organisers should continue to provide additional events in

270   areas where attendances at existing events are high.

271   The study revealed a bias in age of participants with a younger demographic at larger

272   parkruns and those in more deprived areas. The lack of places to exercise in more deprived

273   areas might have pushed younger adults out of the exercise habit during lockdown [6–8].

274   These findings suggest it is increasingly important for governments to put in place measures

275   to encourage younger adults to participate in more physical activity post-lockdown [5]. The

276   same can be applied to those from more deprived areas and the less fit. parkrun is an

277   extremely effective and relatively cheap mechanism of improving public health and well-

278   being so government interventions to help parkrun make up for the time lost to the pandemic

279   and reverse its impacts are now required. Studies have shown that the health benefits of

280   moderate and mild sport are particularly high and that there is likely to be great value gained

281   from organisations such as parkrun in stimulating the less active to engage in more activity,

282   so public funding to support and aid recovery after lockdown is key to mitigate the impacts of

283   the pandemic [40]. Furthermore, a study in China has shown that physical activity before the

284   pandemic significantly improved the outcome of those infected with COVID-19 showing a

285   community and population benefit to physical activity which makes the population more

286   resilient to future waves of COVID-19 and other potential pandemic events [38]. Studies

287   have also shown for older adults how important the social aspect of being part of a regular

288   exercise group, this is something that parkrun excels at providing [15]

289   Studies have also found that those in more vulnerable groups were the most likely to

290   reduce their physical activity levels and avoid green spaces during lockdown [39]. The

291   findings of the current study are entirely consistent with this as it is the lowest performing

292   parkrun participants from before lockdown who are the least likely to have returned, yet they

293   are those most likely to benefit from participation. There needs to be approaches developed

294   to encourage those who reduced their level of physical activity as a result of fear of catching

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295   COVID-19 back into engaging with more exercise. One key demographic affected by this

296   appears to be older women exacerbating another existing health inequality. More studies are

297   needed into the factors driving these demographic changes to better understand and put in

298   place measures to mitigate the impacts of lockdown of levels of physical activity.

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Conclusion

301   This large-scale study reveals that the impacts of the pandemic on levels of physical activity

302   have continued into the post-lockdown era. These impacts are increasing health inequalities

303   affecting women, younger adults, the least fit and are having different impacts based upon

304   the level of social deprivation within an area. The study also shows how valuable the parkrun

305   results database can be for uncovering the demographics of engagement with a mass

306   participation event.

307   With respect to parkrun the pandemic has had a number of negative impacts in Scotland. It

308   has reduced attendances, it has increased the gender ratio towards males, it has increased

309   the mean age of participants and their performance levels. This suggests that the pandemic

310   has undone some of the important work that parkrun had done to increase inclusivity. Prior

311   to the pandemic the gender ratio of participants was moving toward equality and the

312   performance levels dropping year on year as parkrun became more inclusive and

313   successfully removed barriers to women and the least fit taking part in exercise. The

314   pandemic has reversed these trends. As parkrun is a very cheap and effective mechanism of

315   increasing fitness and reducing burdens of healthcare systems government investment into

316   parkrun is needed to help them overcome the negative impacts of the pandemic and help

317   communities become more resilient to future pandemics [41].

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Ethics approval

320 The ethics approval was obtained from the ethics review board of the University of Stirling

321 (Reference No. EC 2023 14083 9598). There were no active participants in the study. This

322 was an analysis of aggregated publicly available secondary datasets.

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Availability of data and materials

326 The datasets used in the study are available in the University of Stirling DATAStorre.

327

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329

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332

Competing interests

334 The author has competing interests and no connection to parkrun Global but is a keen

335 parkrun participant and volunteer.

336

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339 accessed as a permitted act for independent non-commercial research purposes through fair

340   dealing legislation allowing access to publicly available databases. Only a tiny proportion of

341   the parkrun results database was accessed (data from just 44 of more than 2000 events).

342

References

344   1.   Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical
345   activity levels: surveillance progress, pitfalls, and prospects. The Lancet. 2012;380:
346   247–257. doi:10.1016/S0140-6736(12)60646-1

347   2.   Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical
348   activity: why are some people physically active and others not? The Lancet. 2012;380:
349   258–271. doi:10.1016/S0140-6736(12)60735-1

350   3.   Kohl HW, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, et al. The
351   pandemic of physical inactivity: global action for public health. The Lancet. 2012;380:
352   294–305. doi:10.1016/S0140-6736(12)60898-8

353   4.   Maditinos Z, Vassiliadis C, Tzavlopoulos Y, Vassiliadis SA. Sports events and the
354   COVID-19 pandemic: assessing runners' intentions for future participation in running
355   events – evidence from Greece. Tourism Recreation Research. 2021;46: 276–287.
356   doi:10.1080/02508281.2020.1847422

357   5.   McCarthy H, Potts HWW, Fisher A. Physical Activity Behavior Before, During, and After
358   COVID-19 Restrictions: Longitudinal Smartphone-Tracking Study of Adults in the
359   United Kingdom. J Med Internet Res. 2021;23: e23701. doi:10.2196/23701

360   6.   Wong AY-Y, Ling SK-K, Louie LH-T, Law GY-K, So RC-H, Lee DC-W, et al. Impact of
361   the COVID-19 pandemic on sports and exercise. Asia-Pacific Journal of Sports
362   Medicine, Arthroscopy, Rehabilitation and Technology. 2020;22: 39–44.
363   doi:10.1016/j.asmart.2020.07.006

364   7.   Lee S, Lee C, Xu M, Li W, Ory M. People living in disadvantaged areas faced greater
365   challenges in staying active and using recreational facilities during the COVID-19
366   pandemic. Health Place. 2022;75: 102805. doi:10.1016/j.healthplace.2022.102805

367   8.   Kyan A, Takakura M. Socio-economic inequalities in physical activity among Japanese
368   adults during the COVID-19 pandemic. Public Health. 2022;207: 7–13.
369   doi:10.1016/j.puhe.2022.03.006

370   9.   Park AH, Zhong S, Yang H, Jeong J, Lee C. Impact of COVID-19 on physical activity: A
371   rapid review. J Glob Health. 2022;12: 05003. doi:10.7189/jogh.12.05003

372   10.   Jago R, Salway R, House D, Walker R, Emm-Collison L, Sansum K, et al. Short and
373   medium-term effects of the COVID-19 lockdowns on child and parent accelerometer-
374   measured physical activity and sedentary time: a natural experiment. Int J Behav Nutr
375   Phys Act. 2023;20: 1–15. doi:10.1186/s12966-023-01441-1

11. Walker R, House D, Emm-Collison L, Salway R, Tibbitts B, Sansum K, et al. A multi-perspective qualitative exploration of the reasons for changes in the physical activity among 10–11-year-old children following the easing of the COVID-19 lockdown in the UK in 2021. Int J Behav Nutr Phys Act. 2022;19: 1–13. doi:10.1186/s12966-022-01356-3

12. Salway R, Foster C, de Vocht F, Tibbitts B, Emm-Collison L, House D, et al. Accelerometer-measured physical activity and sedentary time among children and their parents in the UK before and after COVID-19 lockdowns: a natural experiment. Int J Behav Nutr Phys Act. 2022;19: 1–14. doi:10.1186/s12966-022-01290-4

13. Watson KB, Whitfield GP, Huntzicker G, Omura JD, Ussery E, Chen TJ, et al. Cross-sectional study of changes in physical activity behavior during the COVID-19 pandemic among US adults. Int J Behav Nutr Phys Act. 2021;18: 1–10. doi:10.1186/s12966-021-01161-4

14. Magutah K, Mbuthia G. Physical activity engagement in Eldoret, Kenya, during COVID-19 pandemic. PLOS Global Public Health. 2022;2: e0000339. doi:10.1371/journal.pgph.0000339

15. Nosaka K, Fox-Harding C, Nosaka K. Impact of COVID-19 lockdown on physical activity behaviours of older adults who participated in a community-based exercise program prior to the lockdown. PLOS Global Public Health. 2022;2: e0001217. doi:10.1371/journal.pgph.0001217

16. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc Health. 2020;4: 23–35. doi:10.1016/S2352-4642(19)30323-2

17. World Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. 2018 [cited 5 Apr 2023]. Available: https://www.who.int/publications-detail-redirect/9789241514187

18. Cleland V, Nash M, Sharman MJ, Claflin S. Exploring the Health-Promoting Potential of the "parkrun" Phenomenon: What Factors are Associated With Higher Levels of Participation? Am J Health Promot. 2019;33: 13–23. doi:10.1177/0890117118770106

19. de Vries L, Kotze N, Morton Mckay T. Parks, participation and the Parkrun 'move-ment' in South Africa. South African Geographical Journal. 2022;104: 382–396. doi:10.1080/03736245.2022.2087727

20. Haake S, Heller B, Schneider P, Smith R, Green G. The influence of neighbourhood equity on parkrunners in a British city. Health Promotion International. 2022;37: daab138. doi:10.1093/heapro/daab138

21. Stevens M, Rees T, Polman R. Social identification, exercise participation, and positive exercise experiences: Evidence from parkrun. Journal of Sports Sciences. 2018;37: 1–8. doi:10.1080/02640414.2018.1489360

22. Gilburn AS. New Parkrunners Are Slower and the Attendance Gender Gap Narrowing Making Parkrun More Inclusive. Int J Environ Res Public Health. 2023;20: 3602. doi:10.3390/ijerph20043602
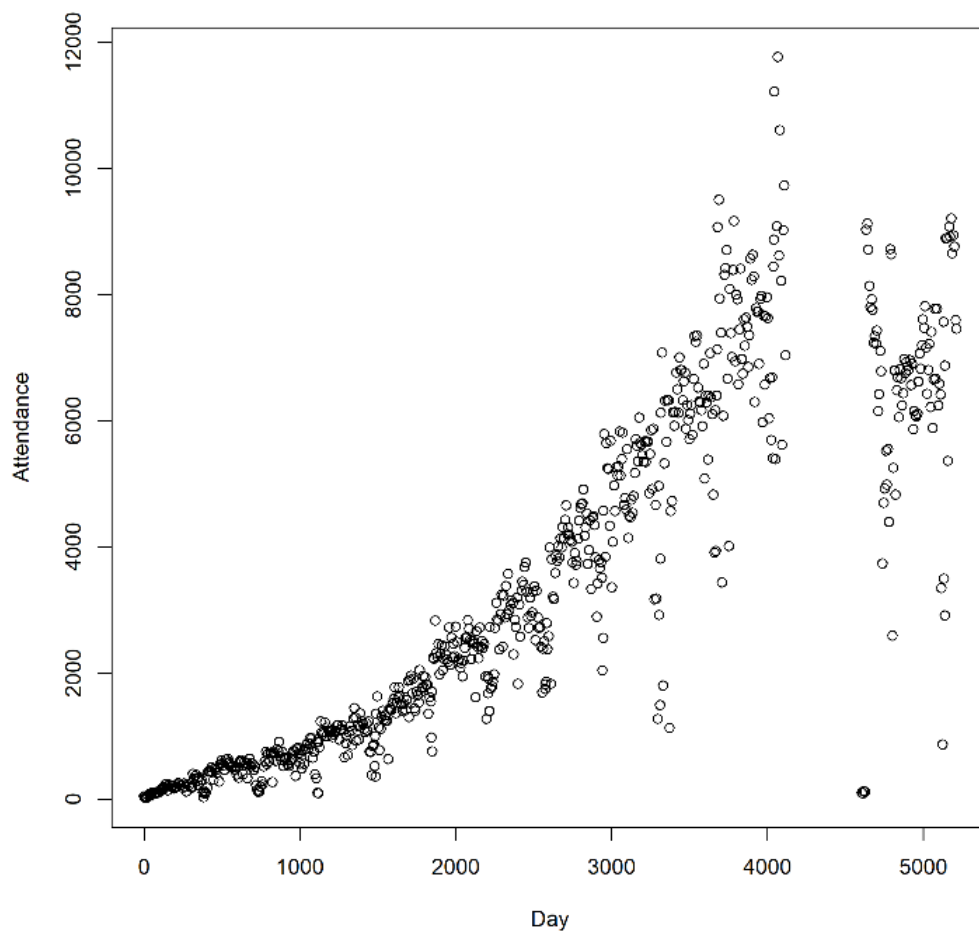
418 23. Reece LJ, Owen K, Graney M, Jackson C, Shields M, Turner G, et al. Barriers to
419   initiating and maintaining participation in parkrun. BMC Public Health. 2022;22: 83.
420   doi:10.1186/s12889-022-12546-w

421 24. Peterson BJ, Withers B, Hawke F, Spink M, Callister R, Chuter VH. Outcomes of
422   participation in parkrun, and factors influencing why and how often individuals
423   participate : a systematic review of quantitative studies. Journal of Sports Sciences.
424   2022; 1486–1499. doi:10.1080/02640414.2022.2086522

425 25. Quirk H, Bullas A, Haake S, Goyder E, Graney M, Wellington C, et al. Exploring the
426   benefits of participation in community-based running and walking events: a cross-
427   sectional survey of parkrun participants. BMC Public Health. 2021;21: 1978.
428   doi:10.1186/s12889-021-11986-0

429 26. Smith RA, Schneider PP, Cosulich R, Quirk H, Bullas AM, Haake SJ, et al.
430   Socioeconomic inequalities in distance to and participation in a community-based
431   running and walking activity: A longitudinal ecological study of parkrun 2010 to 2019.
432   Health & Place. 2021;71: 102626. doi:10.1016/j.healthplace.2021.102626

433 27. Stevinson C, Hickson M. Exploring the public health potential of a mass community
434   participation event. J Public Health (Oxf). 2014;36: 268–274.
435   doi:10.1093/pubmed/fdt082

436 28. Gilburn AS. Predictors of successful return to parkrun for first-time adult participants in
437   Scotland. PLOS Global Public Health. 2023;3: e0001786.
438   doi:10.1371/journal.pgph.0001786

439 29. Quirk H, Haake S, Goyder E, Bullas A, Graney M, Wellington C. Change in health,
440   wellbeing and physical activity levels during the COVID-19 pandemic: a longitudinal
441   cohort of parkrun participants in the United Kingdom. Health Promotion International.
442   2022; daac012. doi:10.1093/heapro/daac012

443 30. Fullagar S, Petris S, Sargent J, Allen S, Akhtar M, Ozakinci G. Action research with
444   parkrun UK volunteer organizers to develop inclusive strategies. Health Promot Int.
445   2020;35: 1199–1209. doi:10.1093/heapro/daz113

446 31. Fleming J, Bryce C, Parsons J, Wellington C, Dale J. Engagement with and delivery of
447   the "parkrun practice initiative" in general practice: a mixed methods study. Br J Gen
448   Pract. 2020;70: e573–e580. doi:10.3399/bjgp20X710453

449 32. Haake S, Quirk H, Bullas A. parkrun and the promotion of physical activity: insights for
450   primary care clinicians from an online survey. Br J Gen Pract. 2022;72: e634–e640.
451   doi:10.3399/BJGP.2022.0001

452 33. Fixsen A, Barrett S. Challenges and Approaches to Green Social Prescribing During
453   and in the Aftermath of COVID-19: A Qualitative Study. Frontiers in Psychology.
454   2022;13. Available: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.861107

455 34. parkrun statsgeek group | Version 4.6 of this macro that converts a parkrun results
456   page into a useful and function rich Excel table | Facebook. [cited 12 Apr 2023].
457   Available:
458   https://www.facebook.com/groups/parkrunstatsgeeks/permalink/3166888586881628

459   35.   SIMD (Scottish Index of Multiple Deprivation). In: Scottish Index of Multiple Deprivation
460   [Internet]. [cited 12 Apr 2023]. Available: http://simd.scot/

461   36.   R: The R Project for Statistical Computing. [cited 12 Apr 2023]. Available:
462   https://www.r-project.org/

463   37.   Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models Using
464   lme4. Journal of Statistical Software. 2015;67: 1–48. doi:10.18637/jss.v067.i01

465   38.   Lin R, Hu X, Chen S, Huang J. Sports Participation and Anti-Epidemic: Empirical
466   Evidence on the Influence of Regular Physical Activity on the COVID-19 Pandemic in
467   Mainland China. International Journal of Environmental Research and Public Health.
468   2022;19: 10689. doi:10.3390/ijerph191710689

469   39.   Rogers NT, Waterlow NR, Brindle H, Enria L, Eggo RM, Lees S, et al. Behavioral
470   Change Towards Reduced Intensity Physical Activity Is Disproportionately Prevalent
471   Among Adults With Serious Health Issues or Self-Perception of High Risk During the
472   UK COVID-19 Lockdown. Frontiers in Public Health. 2020;8. Available:
473   https://www.frontiersin.org/articles/10.3389/fpubh.2020.575091

474   40.   Wheatley D, Bickerton C. Valuing subjective well-being benefits from leisure activities:
475   informing post-Covid public funding of arts, culture and sport. Annals of Leisure
476   Research. 2022;0: 1–19. doi:10.1080/11745398.2022.2099436

477   41.   Pronk NP, Faghy MA. Causal systems mapping to promote healthy living for pandemic
478   preparedness: a call to action for global public health. Int J Behav Nutr Phys Act.
479   2022;19: 1–4. doi:10.1186/s12966-022-01255-7
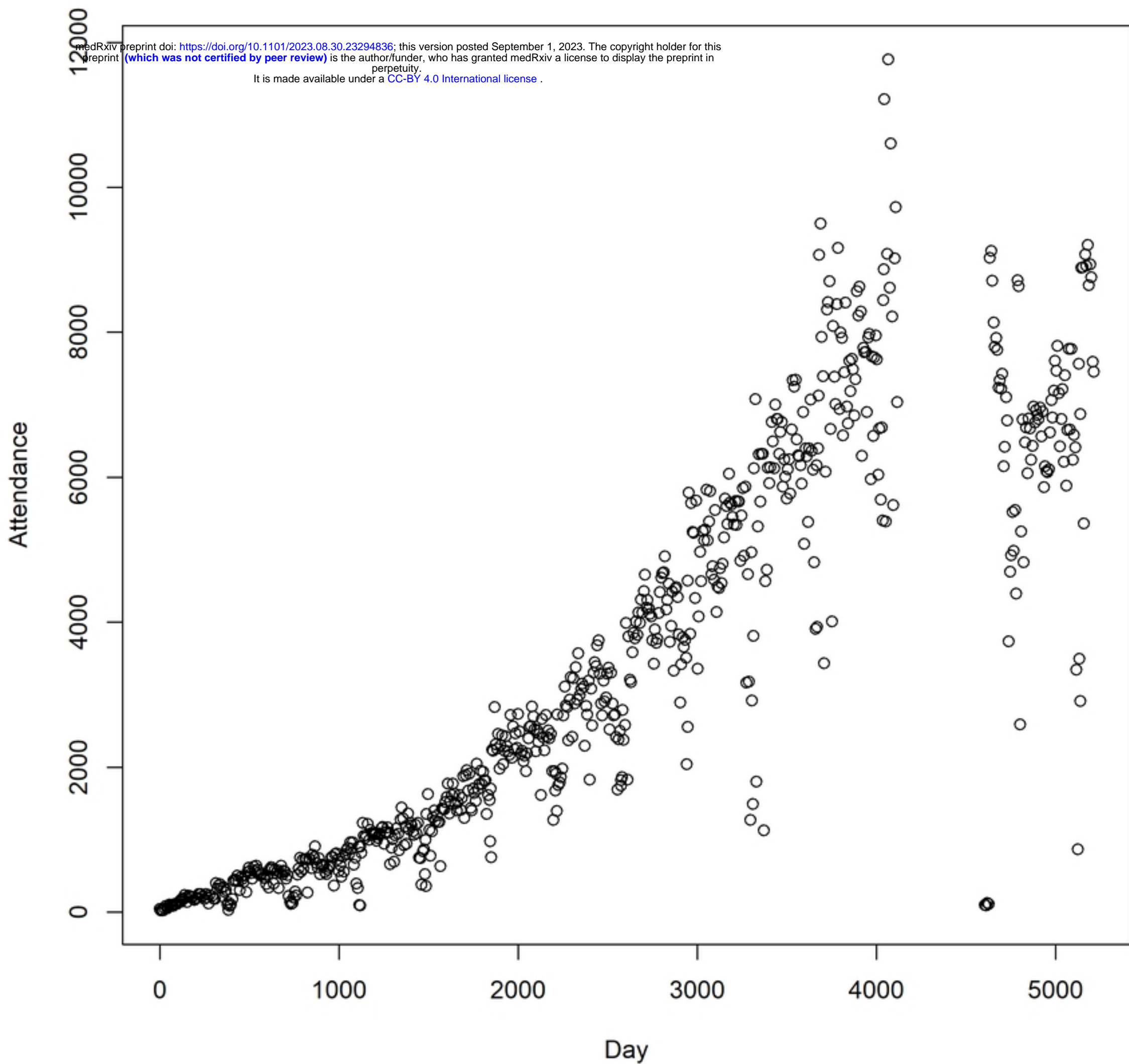
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482   **Tables and Figures**

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Fig 1. Total attendance on each parkrun day in Scotland from day 0, 6th December 2008 until

March 18th 2023.

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Figure