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ORIGINAL ARTICLE

Physical activity and sedentary behavior in amateur sports: master athletes are not free from prolonged sedentary time

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Abstract

Sedentary behavior (SED) and physical activity (PA) are distinct behavioral domains that must be considered before interpreting individual profiles, particularly for amateur athletes which are considered active. The aim was to describe the PA and SED of master amateur runners and footballers, the main individual and team sports. Sixteen male runners and 13 footballers (42 ± 6.9 and 43.9 ± 3.9 years) were monitored for 7 days using triaxial accelerometers (30 Hz). The median (interquartile range) of up to 10 min of moderate-to-vigorous PA (MVPA bouts) was similar among runners and footballers [33.3 (56.0) and 32.5 (47.8) min/day, respectively] and achieved the recommended activity level. Vigorous PA levels were achieved, but were higher for runners than footballers [9.8 (59.5) and 1.6 (3.9) min/day, respectively]. Week-day differences for runners and footballers were found for light [202.0 (139.1) and 261.3 (115.3) min/day, $P = 0.001$], moderate [47.7 (59.8) and 103.3 (82.7) min/day, $P < 0.001$] and vigorous PA [9.8 (58.9) and 1.7 (3.9) min/day, $P < 0.001$]. Athletes present alarming time in bouts of 30-min of sedentary activity on weekdays [202.8 (270.9) and 254.0 (224.3) min/day, $P = 0.07$]. On the weekends, differences were found in moderate [48.3 (54.9) and 60.8 (89.9) min/day, $P = 0.013$], MVPA bouts [48.2 (71.4) and 11.3 (44.8) min/day, $P < 0.001$), and vigorous PA [11.6 (62.4) and 1.3 (4.1) min/day, $P < 0.001$]. The results of the present study highlight the need to consider the excessive amounts of sedentary behavior in master athletes that cannot be masquerade by adequate PA profiles.

Keywords Physical activity · Sedentarism · Behavior · Accelerometry · Sports

Introduction

Recent research already described the enormous inequality in physical activity (PA) levels across the globe and discussed about its association to obesity [1], as well as cardiometabolic diseases [2, 3]. In the European context, southern Europe countries present the highest levels of physical inactivity when compared to the rest of Europe. Countries as Cyprus (53.7%), Portugal (50.6%) and Malta (48.7%) showed the highest proportion of inactive individuals, when compared to countries as Sweden (12.4%), the Netherlands (14.9%) and Finland (15.9%) [4].

Participation in sports for competitive or recreational purposes is one of the best ways for general population to maintain adequate levels of PA; in addition, it is attractive due to the social engagement it affords [5]. The available literature has recently identified in master athletes a model to understand the successful, and probably healthy, process of human aging [6, 7]. Running middle and long distances, and association football are the most popular lifelong physical activities practiced among adults globally [8]. This is a reflect of the continuous increase in the number of master athletes (i.e., > 40 years old) in endurance and ultra-endurance events over the past years [9, 10], as well as the amount of 500 million people practicing association football at recreational and amateur levels. Both practices are effective in improving the cardiometabolic profile of healthy, unhealthy, and untrained adults [11, 12]. The differences in the physical demands of both sports are well-known and basically derive

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from continuous versus intermittent aerobic stress experienced in running and association football, respectively. However, it seems that training in both sports is efficient in reducing body composition parameters when the training intensity is well matched [12]. This correspondence is still uncertain regarding the promotion of healthy levels of physical activity and reduction of sedentary behavior in the practitioners' or athletes' lifestyle.

The current guidelines of the World Health Organization recommend that adults should do at least 150 min of moderate-intensity aerobic PA throughout the week or, at least, 75 min of vigorous-intensity aerobic PA throughout the week or an equivalent combination of moderate and vigorous-intensity activity [3]. These recommendations are important to be considered since sedentary time and total moderate-to-vigorous (MVPA) activities are associated to health risk in adults [13, 14]. Besides the lack of PA, the sedentary behavior (SED), characterized by an energy expenditure less (or equal) than 1.5 metabolic equivalents [15] and associated to prolonged inactivity or body positions (sitting, lying and standing) during waking hours, has also been associated to cardiovascular disease mortality [16]. The context involving the definition of a unique solution to this issue is challenging.

Surprisingly, time spent in MVPA has been shown to be independent of sedentary time. Indeed, adults that meet the PA guidelines, as well as athletes, do not present less sedentary time when compared to sedentary adults at risk [17, 18]. The idea that sedentary and physically active times are two distinct behavioral domains indicates that both domains must be considered before determining and interpreting individual activity profiles. Particularly, because of the engagement in regular training and sports practice, there is little concern about the PA profile from recreational to amateur and high-level athletes, but the literature has been pointed out some evidences on the issue. Previous studies have shown that professional athletes can spend a large amount of time in sedentary activity [19, 20] or even fail to reach the recommended levels of PA [21]. In recreational level, habitual runners are also reported to present the same sedentary time when compared to sedentary people [22], despite the training regime. Although assessed by questionnaires, it has been shown that intensity and duration of sports practice are inversely associated to the amount of sedentary time master athletes accumulate [23]. However, the impact that different backgrounds inherent to specific sports practice has on the PA and SED profiles is still unknown and would be useful for optimizing compliance guidelines. Thus, the aim of the present study is to describe and compare the PA and SED activity profiles of older amateur runners and footballers. It was hypothesized that the differences imposed by specificities of each sport would reflect in different PA and SED profiles.

Materials and methods

Study design

A total of 16 male runners and 13 male footballers volunteered to participate in this study. Short, middle and long-distance master runners locally recruited formed the runners' group. The footballers group included local football association master players, which had a background of lifelong participation in football training. Criteria for inclusion were applied to ensure all runners compete at recreational level, with, at least, 2 years of competitive experience. Footballers also had to be engaged in a minimum of 3 h of football training per week. For all subjects, exclusion criteria included any history of musculoskeletal, neurological or orthopedic injuries in a period of a year before the time the study was performed, or symptoms of cardiovascular and hypertension disease. The study protocol was conformed to the recommendations of the Declaration of Helsinki and was approved and followed the guidelines stated by the local Institutional Research Ethics Committee (UID/DTP/04045). Participants fully informed about the protocol description and provided written informed consent before data collection. Age, anthropometric variables and characteristics of participants' training programs are described in Table 1.

The study design consisted of two laboratory visits. In the first visit, participants were given the Actigraph® GT9X Link + (Pensacola, FL, USA) to monitor PA and SED, as well as the instructions of how to use it. They should wear the monitor in their dominant wrist, for 7 days (including 5 weekdays and 2 weekend days), completing 9–12 h/day, and were allowed not to use it during sleep, personal care and activities under water. They were asked not to wear the accelerometer during competition, if there were any during the period of assessment. Participants were also asked to fill a daily report, where they would inform the approximate periods of monitor wearing and non-wearing. The second

Table 1 Description of the study participants and respective training program characteristics

	Runners ($n=16$)	Footballers ($n=13$)
Age (years)	42 ± 6.9	43.9 ± 3.9
Weight (kg)	75.6 ± 6	79.9 ± 6
Height (cm)	174.0 ± 6	171.6 ± 7
BMI	25.1 ± 2.37	27.2 ± 1.83
Training frequency (times/week)	4	3
Session duration (min)	60	60
Type of activity	Middle and long-distance running	Association football

visit was arranged 8–9 days after the first visit, to collect the monitors and the daily report. The participants also filled a customized questionnaire to characterize their training and competition intensities and frequency. Runners performed four training sessions while footballers trained three times during the week of assessments, distributed depending on each individual.

Measures

As a reliable way of analyzing PA and SED in free-living environment [24], the triaxial acceleration was recorded by the monitoring device at 30 Hz of sampling frequency. Raw acceleration data were processed in R using the R-package GGIR (http://cran.r-project.org/), which is designed for processing multiday raw accelerometer data [25, 26]. GGIR consists of processing an epoch-specific acceleration summary variable, called Euclidian Norm Minus One, which is calculated by subtracting the gravitational force from the vector magnitude of the three axes. Based on these data, the intensity-specific cut-points for sedentary, light, moderate, vigorous, and time in MVPA bouts were calculated as min/day, guided by Hildebrand and colleagues [27]. Time in MVPA bouts describe the total time in bouts of MVPA lasting up to 10 min. Individual days were excluded from the analysis if wear time was less than 10 h, following the procedures of vanHees et al. [28]. The average of valid hours obtained for the calculation of the energy expenditure variables was 9.5 h/day.

Statistics

The mean PA and SED profiles of runners and footballers were compared as function of the groups and week days, using Mann–Whitney test for non-parametric data ($P<0.05$), after testing the normality of the dataset with the Lilliefors test ($P<0.05$). Thresholds for effect size statistics interpretation will follow Cohen's guidelines for r, where <0.3, small; <0.5, medium; >0.5, large [29].

Results

The 7-day PA and SED profiles of runners and footballers are presented in Table 2. Footballers present significantly higher time of total light and moderate physical activity ($P<0.001$), with small and medium effect sizes, respectively. Runners, on the other hand, spend higher amount of time in vigorous physical activity when compared to the footballers ($P<0.001$, with medium effect size).

When weekdays (Fig. 1) and weekends (Fig. 2) profiles were analyzed separately, it was found that footballers on week days spend higher amount of time (min/day) in light [median (interquartile range) = 261.3 (115.3); mean rank = 94.7] and moderate PA [103.3 (82.7); 110.4] than runners [202.0 (139.1); 75.6 and 47.7 (59.8); 59.0]. Runners, on the other hand, showed higher amount of vigorous PA [9.8 (58.9); 100.4] than footballers [1.7 (3.9); 57.3]. The Mann–Whitney U value was found to be statistically significant for week days moderate ($U=1181$ ($Z=-6.9$), $P<0.001$) and vigorous PA ($U=1513$ ($Z=-5.8$), $P<0.001$), with medium effect sizes ($r=0.5$ for moderate and vigorous PA); and for week days light PA ($U=2292$ ($Z=-3,2$), $P=0.001$) with small effect size ($r=0.2$). Time spent in at least 30 min bouts of sedentary activity for footballers [254.0 (224.3); 89.1] presented a tendency to be higher than for runners [202.8 (270.9); 75.6], although not statistically significant [$U=2694$ ($Z=-1.8$), $P=0.07$, $r=-0.1$].

On the weekends, footballers and runners show a different PA and SED behavior. Runners show higher amount of vigorous activity [11.6 (62.4); 44.3] and time in MVPA bouts [48.2 (71.4); 41.9] than footballers [1.3 (4.8); 22.0 min and 11.3 (44.8); 24.8, respectively]. Footballers perform more moderate PA [60.8 (89.9); 40.34] on the weekends than

Table 2 Physical activity and sedentary behavior profile of master runners and footballers in typical 7-day period

	Runners		Footballers		Mann–Whitney		
	Median (IQR)	Mean rank	Median (IQR)	Mean rank	U (Z)	P	r
Time spent in at least 30 min bouts in sedentary activity (min/day)	218.6 (309.6)	109.80	256.8 (290.6)	121.48	5817 (−1.3)	0.18	−0.1
Total sedentary activity (min/day)	528.4 (202.3)	110.33	540.9 (195.2)	120.81	5884 (−1.2)	0.23	−0.1
Total of light activity (min/day)	177.6 (129.3)	102.50	239.9 (133.6)	130.56	4890 (−3.2)	0.001*	−0.2
Total of moderate activity (min/day)	47.7 (59.3)	86.80	89.5 (84.0)	150.12	2895 (−7.2)	<0.001*	−0.5
Total of vigorous activity (min/day)	9.8 (59.5)	144.17	1.6 (3.9)	78.68	2773 (−7.4)	<0.001*	−0.5
Time in MVPA bouts (min/day)	33.3 (56.0)	119.31	32.5 (47.8)	109.63	5929 (−1.1)	0.27	−0.1

PA physical activity; time in MVPA bouts = time in bouts up to 10 min of moderate-to-vigorous physical activity

*Significantly different between groups ($P<0.05$)

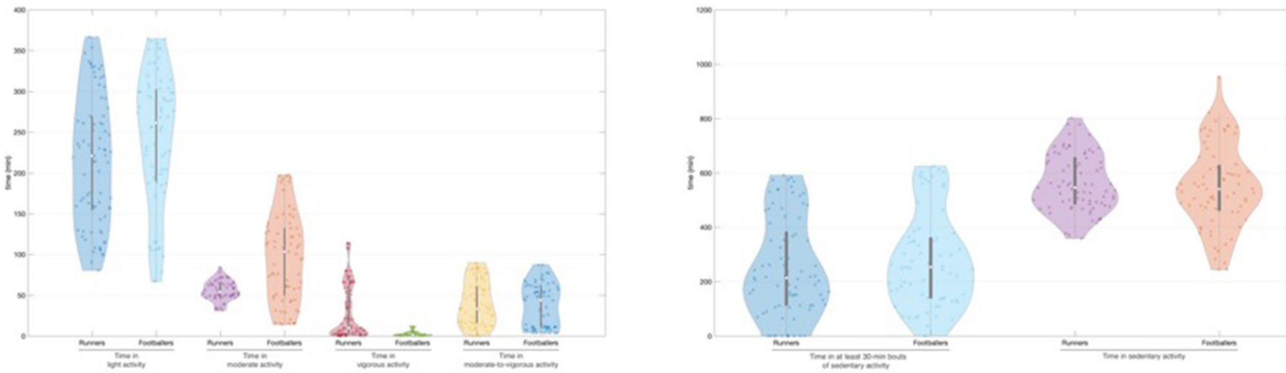

Fig. 1 Week days PA and SED profiles of master runners and footballers. *Significant difference between groups ($P<0.05$)

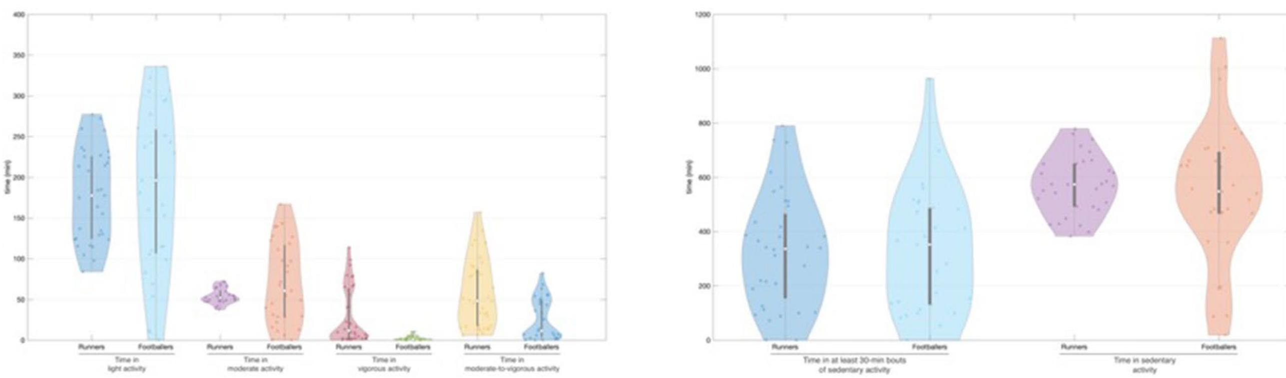

Fig. 2 Weekends PA and SED profiles of master runners and footballers. *Significant difference between groups ($P<0.05$)

runners [48.3 (54.9); 28.5]. Mann–Whitney U value was found to be statistically significant for weekends vigorous [$U=185.5$ ($Z=-4.7$), $P<0.001$] and MVPA [$U=273.5$ ($Z=-3.6$), $P<0.001$], with medium and large effect sizes ($r=0.4$ and 0.6, respectively); and moderate PA [$U=361.5$ ($Z=-2.5$), $P=0.013$] with medium effect size ($r=0.3$).

Sedentary behavior does not seem to be different between runners and footballers, even when the week periods are analyzed separately.

Discussion

The aim of the present study was to describe and compare the activity profile of master amateur runners and footballers, relating their PA and SED profiles. The main finding of the present study is that different sports influence on different distributions of PA levels in adults. Amateur runners tend to maintain higher amounts of vigorous PA, while footballers perform higher amounts of light and moderate PA. In terms of SED, no significant difference was found in the time both groups spent sedentary.

During the week, the distribution of time in MVPA bouts among different sports is not the same: on the week days, master runners and footballers present the similar time in MVPA bouts spent daily. On the weekends, runners present higher MVPA bouts than footballers. The WHO recommendations indicate that adults should accumulate 150 min of moderate or MVPA activities per week [3]. Yet, overall, both groups seem to accumulate the recommended levels of PA in a typical 7-day period, considering the results for moderate and time in MVPA bouts, which the latter represents a measure of sustained PA. As health can be considered the state in which the level of PA undertaken is sufficient to maintain the physiological function without the effects of sedentarism [7], MVPA participation has the effect of enhancing the cardiorespiratory fitness, which is a predictor of longevity [30]. Especially sustained time in MVPA of, at least, 10 min, has been related to decreased cardiometabolic risk [31]. WHO also established a recommendation alternative of 75 min of vigorous activity per week. Running and football training are effective ways of enhancing fitness parameters as body composition [12], maximal aerobic power and flexibility [32] in untrained adults, when training intensities match. Yet, in the present study, we found that runners present significantly higher daily vigorous activity time on the week and weekends, and overcome the WHO recommendations, which is not the case for footballers. It seems that, in master level, the high physical activity intensities of football practice may not reach what is recommended for maintaining or improving health status, which should be observed with caution, especially if sustained time in MVPA levels is not achieved.

Moreover, the approach on the PA and SED profiles has been changing in the last years. Sedentary behavior was recently argued to be independent of the physical activity levels [17, 33]. Runners' and footballers' SED were assessed in this study through the time spent in 30-min bouts in sedentary activity and total sedentary activity. There is a trend of higher prolonged sedentary time for footballers, as shown by the time spent in 30-min bouts of sedentary activity. Prolonged sedentary time is positively associated to overweight [34], arterial stiffness, and other cardiometabolic risk factors [35], although the underlying physiological mechanisms are not well defined. Both groups' total time in sedentary activity is also worrying. The literature have already reported that 9 h of daily exposure to sedentary behavior has been associated to all-cause mortality [36]. Thus, achieving considerate sustained time in MVPA levels and a fair amount of vigorous activity due to training and competitions does not avoid harmful SED in amateur athletes. It has been suggested that breaking sedentary time or even replacing sedentary time with MVPA [37, 38] can improve metabolic health markers [39], although it is not enough to eliminate health risk [40].

The present study shows evidence that monitoring sedentary time and behavior modes is the key to track whether health and performance measures are outlined to yield the best outcomes. A model has been proposed to describe the integration of aging, exercise and health in high-level master athletes as a successful way to explain the trajectory of human physiology aging process unaffected by the confounding effects of inactivity [7, 41, 42].

Running and association football are the most practiced sports worldwide [8]. Running is a popular alternative form of exercise by the independency on factors such as age, partners, income, and sportive structure. Association football is the most practiced of team sports, highly motivating for its social aspects [43], and also requires easy-access equipment for practice. Master athletes are encouraged to engage in the sport practice and caring about structuring and organizing specific training. We believe that these characteristics related to such level of competitions explain the variation in all the PA and SED levels among the different days of the week and differs from the results reported in the literature for habitual runners [22] and professional footballers during off-training time [19]. Therefore, performance issues have also to be considered in the discussion and demand criteria, thus it can be properly aligned to the health-related interpretation of the results. The balance between training and proper management of recovery is necessary to decrease injury risk and improve performance in athletes [19]: PA and SED profiles have to meet healthy levels but not compromise performance.

Even though the sample size of the present study seems small, the data obtained come from adults engaged in organized and amateur training and sports practice level, which is highlighting. Thus, the results support evidence to the benefits of sports practice and training by approaching these athletes to the model of successful aging discussed above. Although they are not professionals, we found that runners and footballers might stand above the set point, where they achieve more than sufficient physical activity levels to enhance physiological function, stimulated by the sport component of aiming to improve overall performance. This will lead to an approximation to the curve that represents the biological aging, towards the decline of performance as a natural process and without the effects of sedentarism. Nevertheless, adult master athletes also present risk factors as increased prolonged sedentary time, thus joining PA and SED is encouraged to allow a correct interpretation of their energy expenditure profiles. This is relevant in the public health level once, by enhancing the knowledge of the effects of regular and organized sports practice on adults' lifestyle, it may help guiding policies to prevent diseases and improve health.

Conclusion

The present study measured and compared the PA and SED of master runners and footballers. Both groups presented enough levels of sustained MVPA and vigorous activity regarding what is recommended by the World Health Organization, however, they also presented risky prolonged sedentary time. Thus, there is a need to bring attention to how to manage PA and SED of adults engaged in sports for middle-age people, thus health recommendations and performance demands are well balanced.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in the present study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study. This article does not contain any studies with animals performed by any of the authors.

References

1. Althoff T, Sosic R, Hicks JL, King AC, Delp SL, Leskovec J (2017) Large-scale physical activity data reveal worldwide activity inequality. Nature. https://doi.org/10.1038/nature23018
2. Brugnara L, Murillo S, Novials A, Rojo-Martinez G, Soriguer F, Goday A, Calle-Pascual A, Castano L, Gaztambide S, Valdes S, Franch J, Castell C, Vendrell J, Casamitjana R, Bosch-Comas A, Bordiu E, Carmena R, Catala M, Delgado E, Girbes J, Lopez-Alba A, Martinez-Larrad MT, Menendez E, Mora-Peces I, Pascual-Manich G, Serrano-Rios M, Gomis R, Ortega E (2016) Low physical activity and its association with diabetes and other cardiovascular risk factors: a nationwide, population-based study. PloS One 11(8):e0160959. https://doi.org/10.1371/journal.pone.0160959
3. World Health Organization (2011) Global status report on non-communicable diseases 2011. WHO, Geneva, Switzerland
4. Gerovasili V, Agaku IT, Vardavas CI, Filippidis FT (2015) Levels of physical activity among adults 18–64 years old in 28 European countries. Prev Med 81:87–91. https://doi.org/10.1016/j.ypmed.2015.08.005
5. Rios D, Cubedo M, Rios M (2013) Graphical study of reasons for engagement in physical activity in European Union. Springerplus 2:488. https://doi.org/10.1186/2193-1801-2-488
6. Tanaka H, Seals DR (2008) Endurance exercise performance in Masters athletes: age-associated changes and underlying physiological mechanisms. J Physiol 586(1):55–63. https://doi.org/10.1113/jphysiol.2007.141879
7. Lazarus NR, Harridge SDR (2017) Declining performance of master athletes: silhouettes of the trajectory of healthy human aging? J Physiol 595(9):2941–2948. https://doi.org/10.1113/JP272443
8. Hulteen RM, Smith JJ, Morgan PJ, Barnett LM, Hallal PC, Colyvas K, Lubans DR (2017) Global participation in sport and leisure-time physical activities: a systematic review and meta-analysis. Prev Med 95:14–25. https://doi.org/10.1016/j.ypmed.2016.11.027
9. Zaryski C, Smith DJ (2005) Training principles and issues for ultra-endurance athletes. Curr Sports Med Rep 4(3):165–170
10. Lepers R, Stapley PJ, Cattagni T (2016) Centenarian athletes: examples of ultimate human performance? Age Aging 45(5):732–736. https://doi.org/10.1093/aging/afw111
11. Milanovic Z, Pantelic S, Covic N, Sporis G, Krustrup P (2015) Is recreational soccer effective for improving VO_{2max} a systematic review and meta-analysis. Sports Med 45(9):1339–1353. https://doi.org/10.1007/s40279-015-0361-4
12. Milanovic Z, Pantelic S, Kostic R, Trajkovic N, Sporis G (2015) Soccer vs. running training effects in young adult men: which programme is more effective in improvement of body composition? Randomized controlled trial. Biol Sport 32(4):301–305. https://doi.org/10.5604/20831862.1163693
13. Matthews CE, George SM, Moore SC, Bowles HR, Blair A, Park Y, Troiano RP, Hollenbeck A, Schatzkin A (2012) Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 95(2):437–445. https://doi.org/10.3945/ajcn.111.019620
14. Inoue M, Yamamoto S, Kurahashi N, Iwasaki M, Sasazuki S, Tsugane S, Japan Public Health Center-Based Prospective Study G (2008) Daily total physical activity level and total cancer risk in men and women: results from a large-scale population-based cohort study in Japan. Am J Epidemiol 168(4):391–403. https://doi.org/10.1093/aje/kwn146
15. Sedentary Behavior Research N (2012) Letter to the Editor: standardized use of the terms "sedentary" and "sedentary behaviors". Appl Physiol Nutr Metab 37(3):540–542. https://doi.org/10.1139/h2012-024
16. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN (2010) Sedentary behaviors increase risk of cardiovascular disease mortality in men. Med Sci Sports Exerc 42(5):879–885. https://doi.org/10.1249/MSS.0b013e3181c3aa7e
17. Craft LL, Zderic TW, Gapstur SM, Vaniterson EH, Thomas DM, Siddique J, Hamilton MT (2012) Evidence that women meeting physical activity guidelines do not sit less: an observational inclinometry study. Int J Behav Nutr Phys Act 9:122. https://doi.org/10.1186/1479-5868-9-122
18. Judice PB, Silva AM, Magalhaes JP, Matias CN, Sardinha LB (2014) Sedentary behavior and adiposity in elite athletes. J Sports Sci 32(19):1760–1767. https://doi.org/10.1080/02640414.2014.926382
19. Weiler R, Aggio D, Hamer M, Taylor T, Kumar B (2015) Sedentary behavior among elite professional footballers: health and performance implications. BMJ Open Sport Exerc Med 1(1):e000023. https://doi.org/10.1136/bmjsem-2015-000023
20. Sperlich B, Becker M, Hotho A, Wallmann-Sperlich B, Sareban M, Winkert K, Steinacker JM, Treff G (2017) Sedentary behavior among national elite rowers during off-training—a pilot study. Front Physiol. https://doi.org/10.3389/fphys.2017.00655
21. Clemente FM, Nikolaidis PT, Martins FM, Mendes RS (2016) Physical activity patterns in university students: do they follow the public health guidelines? PloS One 11(3):e0152516. https://doi.org/10.1371/journal.pone.0152516
22. Rantalainen T, Pesola AJ, Quittner M, Ridgers ND, Belavy DL (2018) Are habitual runners physically inactive? J Sports Sci 36(16):1793–1800. https://doi.org/10.1080/02640414.2017.1420452
23. McCracken H, Dogra S (2018) Sedentary time in male and female masters and recreational athletes aged 55 and older. J Aging Phys Act 26(1):121–127. https://doi.org/10.1123/japa.2016-0324
24. Yang C-C, Hsu Y-L (2010) A review of accelerometry-based wearable motion detectors for physical activity monitoring. Sensors (Basel Switzerland) 10(8):7772–7788. https://doi.org/10.3390/s100807772
25. Sabia S, van Hees VT, Shipley MJ, Trenell MI, Hagger-Johnson G, Elbaz A, Kivimaki M, Singh-Manoux A (2014) Association between questionnaire- and accelerometer-assessed physical activity: the role of sociodemographic factors. Am J Epidemiol 179(6):781–790. https://doi.org/10.1093/aje/kwt330
26. van Hees VT, Gorzelniak L, Dean Leon EC, Eder M, Pias M, Taherian S, Ekelund U, Renstrom F, Franks PW, Horsch A, Brage S (2013) Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. PloS One 8(4):e61691. https://doi.org/10.1371/journal.pone.0061691
27. Hildebrand M, VT VANH, Hansen BH, Ekelund U (2014) Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. Med Sci Sports Exerc 46(9):1816–1824. https://doi.org/10.1249/MSS.0000000000000289
28. van Hees VT, Fang Z, Langford J, Assah F, Mohammad A, da Silva IC, Trenell MI, White T, Wareham NJ, Brage S (2014) Autocalibration of accelerometer data for free-living physical activity assessment using local gravity and temperature: an evaluation

on four continents. J Appl Physiol 117(7):738–744. https://doi.org/10.1152/japplphysiol.00421.2014
29. Coolican H (2009) Research methods and statistics in psychology, 5th edn. Hodder & Stoughton, London
30. Lee IM, Paffenbarger RS Jr (2000) Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. Am J Epidemiol 151(3):293–299
31. Glazer NL, Lyass A, Esliger DW, Blease SJ, Freedson PS, Massaro JM, Murabito JM, Vasan RS (2013) Sustained and shorter bouts of physical activity are related to cardiovascular health. Med Sci Sports Exerc 45(1):109–115. https://doi.org/10.1249/MSS.0b013e31826beae5
32. Milanovic Z, Pantelic S, Sporis G, Mohr M, Krustrup P (2015) Health-related physical fitness in healthy untrained men: effects on VO_{2max}, jump performance and flexibility of soccer and moderate-intensity continuous running. PloS One 10(8):e0135319. https://doi.org/10.1371/journal.pone.0135319
33. Swartz AM, Miller NE, Cho YI, Welch WA, Strath SJ (2017) A prospective examination of the impact of high levels of exercise training on sedentary behavior. Eur J Sport Sci 17(2):222–230. https://doi.org/10.1080/17461391.2016.1251496
34. Bowman SA (2006) Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Prev Chronic Dis 3(2):A38
35. Huynh QL, Blizzard CL, Sharman JE, Magnussen CG, Dwyer T, Venn AJ (2014) The cross-sectional association of sitting time with carotid artery stiffness in young adults. BMJ Open Sport Exerc Med 4(3):e004384. https://doi.org/10.1136/bmjopen-2013-004384
36. Thorp AA, Owen N, Neuhaus M, Dunstan DW (2011) Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies, 1996–2011. Am J Prev Med 41(2):207–215. https://doi.org/10.1016/j.amepre.2011.05.004
37. Owen N, Healy GN, Matthews CE, Dunstan DW (2010) Too much sitting: the population health science of sedentary behavior. Exerc Sport Sci Rev 38(3):105–113. https://doi.org/10.1097/JES.0b013e3181e373a2
38. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N (2008) Breaks in sedentary time: beneficial associations with metabolic risk. Diabetes Care 31(4):661–666. https://doi.org/10.2337/dc07-2046
39. Phillips CM, Dillon CB, Perry IJ (2017) Does replacing sedentary behavior with light or moderate to vigorous physical activity modulate inflammatory status in adults? Int J Behav Nutr Phys Act 14(1):138. https://doi.org/10.1186/s12966-017-0594-8
40. Ekelund U, Steene-Johannessen J, Brown WJ, Fagerland MW, Owen N, Powell KE, Bauman A, Lee IM, Lancet Physical Activity Series 2 Executive C, Lancet Sedentary Behavior Working G (2016) Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. Lancet 388(10051):1302–1310. https://doi.org/10.1016/S0140-6736(16)30370-1
41. Lazarus NR, Harridge SD (2007) Inherent aging in humans: the case for studying master athletes. Scand J Med Sci Sports 17(5):461–463. https://doi.org/10.1111/j.1600-0838.2007.00726.x
42. Hawkins SA, Wiswell RA, Marcell TJ (2003) Exercise and the master athlete—a model of successful aging? J Gerontol A Biol Sci Med Sci 58(11):1009–1011
43. Ottesen L, Jeppesen RS, Krustrup BR (2010) The development of social capital through football and running: studying an intervention program for inactive women. Scand J Med Sci Sports 20(Suppl 1):118–131. https://doi.org/10.1111/j.1600-0838.2010.01123.x