Sedentary Behavior and Physical Fitness

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Sedentary behavior has been considered an independent risk factor to health. The aim of this systematic review and meta-analysis was to examine associations between objectively measured sedentary time and physical fitness components in healthy adults. Methods: Four electronic databases (Web of Science, Scopus, Pubmed and Sport Discus) were searched (up to 20 September 2020) to retrieve studies on healthy adults which used observational, cohort and cross-sectional designs. Studies were included if sedentary time was measured objectively and examined associations with the health- or skill-related attributes of physical fitness (e.g., muscular strength, cardiorespiratory fitness, balance). After applying additional search criteria, 21 papers (11,101 participants) were selected from an initial pool of 5192 identified papers. Results: Significant negative associations were found between total sedentary time with cardiorespiratory fitness ($r = -0.164$, 95%CI: −0.240, −0.086, $p < 0.001$), muscular strength ($r = -0.147$, 95%CI: −0.266, −0.024, $p = 0.020$) and balance ($r = -0.133$, 95%CI: −0.255, −0.006, $p = 0.040$).

Keywords: sedentary time ; accelerometry ; physical capability ; performance ; cardiorespiratory fitness ; strength ; adults ; meta-analysis

1. Introduction

Physical fitness can be defined as a set of health- or skill-related attributes (e.g., cardiorespiratory fitness (CRF), muscular strength, balance, flexibility) that persons possess or achieve in order to carry out daily tasks [1]. Lower levels of physical fitness have been associated with a physical disability and loss of independence [2], increased falling risk and fractures [3] and increased risk of diseases with advancing age [4][5]. Furthermore, evidence shows that CRF and musculoskeletal fitness (mainly grip strength) are predictors of morbidity and all-cause mortality among middle-aged and older adults [6][7][8]. Flexibility, another health-related physical fitness component, is associated with better functional state, better ability to perform daily living activities [9] and better quality of life [10]. However, and unlike muscular strength and CRF, flexibility does not predict all-cause mortality [11]. Balance, as a skill-related component, has also been positively associated with functional capacity and can be predictive of physical independence in daily activities with age [12]. Thus, preservation of physical fitness has become a major public health concern, where the potential role of physical activity (PA) in maintaining functional independence and disease prevention has been recognized by many health organizations [4]. In turn, despite several studies supporting the positive association between PA and several health indicators (e.g., physical fitness), sedentary behavior (SB) is considered a new risk factor to health among adults, even after adjusting for PA levels [13][14][15]. SB, which is distinct from physical inactivity, is defined by any waking behavior characterized by an energy expenditure of ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture [16]. A recent study revealed that adults (aged between 20 and 75 years) of four different European countries presented an average sedentary time (ST) of 8.83 h per day [17].

Available data suggest that ST is detrimental to cardiometabolic health [18] and is associated with increased risk of all-cause mortality in adults [19][20]. Regarding adults' physical fitness, evidence shows that larger amounts of ST are associated with lower muscular strength [21][22][23][24], lower CRF [25][26][27][28] and lower balance [29]. However, other studies demonstrated that ST was not significantly associated with impaired muscular strength [30][31][32] and CRF [33][34][35] in adults. Even though some studies have focused on this topic, the associations between total ST and physical fitness components are still unclear. Moreover, it should be noted that a lot of studies employ subjective measures of ST, which are known to reduce data accuracy significantly, because of misreporting and recall bias [36]. Furthermore, cultural and linguistic issues in the interpretation of questions and/or concepts used could make comparability between countries and cultures difficult. Thus, it is advisable to use objective instruments to assess ST, in order to avoid subjective biases [36]. Regarding physical fitness components, Campbell et al. [37]conducted a recent systematic review and meta-analysis to analyze the associations between ST with body weight and composition in adults and concluded that there were no significant associations between SB and any measure of body weight or obesity, with the exception of waist circumference. Thus, body composition (as a component of physical fitness) was not included in our research strategy.

Since adults are typically physically inactive [38] and present high levels of SB (in Europe) , it is necessary to have a better understanding of the associations between ST and physical fitness. If such detrimental associations are verified, reducing SB can be important in preventing functional limitations and the loss of independence with age [39]. To the best of our knowledge, there is currently no systematic review and meta-analysis available that investigates the evidence regarding the associations between objectively measured ST and physical fitness (e.g., CRF, muscular strength, balance, speed, flexibility) in adults.

2. Discussion

The present systematic review and meta-analysis aimed to examine the magnitude of the effect size between objectively measured ST and physical fitness components in healthy adults. Thus, analyses were performed for each component of physical fitness (i.e., muscular strength, cardiorespiratory fitness, flexibility and balance). Overall, 5192 records were identified and 21 articles were ultimately included. The geographic distribution and the diversity of the countries involved in the analyzed studies demonstrated that there is a large-scale concern about the impact of SB on health and well-being. Moreover, the high quality of the studies included in the present meta-analysis revealed high scientific rigor by the researchers in this specific area. In spite of the findings from individual studies seeming ambiguous, when the data were analyzed using meta-analysis we can verify that ST shows a negative association with some physical fitness components, i.e., CRF, muscular strength and balance.

CRF is a well-established predictor of several adverse health outcomes [40], morbidity and all-cause mortality. Whereas factors such as age, body mass index and waist circumference show consistent evidence of an association with CRF, other factors show conflicting or insufficient evidence of such association, for example, the relationship between CRF and behavioral factors [40]. Our results suggest that total ST is negatively associated with CRF in adults and older adults. According to the results of individual studies, 8 of 13 studies included found a significant negative association, whereas 5 studies found no association. These discrepancies between studies may be attributable, at least in part, to the heterogeneity of the participants from the different study samples analyzed and the characteristics of device/ data reduction procedures [41]. Studies carried out by Gennuso et al. and Silva et al. had a reduced sample size when compared with all the other studies. Knaeps et al. had a heterogeneous sample with ages ranging from 29–82 years. Velde et al. and Prioreschi et al. had samples of young and healthy adults (ranging from 18–49 and 19–20 years old) and according to the authors' opinion, the effects of ST possibly only become apparent in an elderly population or when moderate to vigorous PA or fitness levels decrease below a certain threshold. Furthermore, Gennuso et al. was the only study included in our meta-analysis that used a posture-based activity monitor to assess sedentary behavior. This may also justify the differences. The mechanisms through which SB may affect CRF are not totally understood. This hypothetical effect could be explicated by vascular changes in response to SB [42]. According to Thijssen et al. [42], the pathways through which these changes arise appear to be different from pathways that are involved in vascular changes in response to PA. However, we believe it is imperative to produce further research to determine the mechanisms/molecular basis by which SB affects CRF.

Upper and lower body muscular strength is also a predictor of cardiovascular mortality and all-cause mortality in adults and old people . Adults with lower levels of muscular strength experience more difficulties when performing their daily life activities and, as a result of that, levels of PA decrease leading to greater muscle mass loss [43]. This decreasing process may justify why adults may be more susceptible to injurious falls or adverse events. Results from our meta-analysis suggest that ST is negatively associated with upper and lower body strength in adults. This negative association was found in the majority of the individual studies included. The mechanisms through which SB may affect muscular strength remain uncertain. Some authors have proposed that continual underloading due to SB may affect negatively the muscle-tendon proprieties, since muscle-tendon disuse causes changes such as muscle atrophy [44]. Furthermore, long periods of SB result in low energy expenditure and may contribute to weight gain and obesity [45]. Evidence suggests that concurrent increases in visceral and intermuscular fat can stimulate the release of pro-inflammatory cytokines and decrease anti-inflammatory markers from adipose tissue, which can have a catabolic effect on muscle by impairing muscle protein synthesis [46]. This will affect muscle mass and strength [47][48].

Regarding balance, Breton et al. show that balance is associated with functional capacity and can be predictive of physical independence in daily activities with age. The risk factors for postural instability can be explained by inactivity and aging [49]. Studies show that old women have more pronounced changes in their postural stability; however, a significant decline in the ability to maintain balance in challenging environments (e.g., eyes closed) has also been observed in women over 50 years old [50]. The results of our meta-analysis seem to confirm the evidence found in the literature since they suggest a negative association between ST and balance in adults.

Flexibility declines with age [51] and is associated with better functional state and ability to perform daily activities and better quality of life . However, unlike muscular strength and CRF, flexibility does not predict fall [52] and all-cause mortality . Our meta-analysis does not provide evidence of a negative association between ST and flexibility. Moreover, the majority of studies involved in this meta-analysis did not find a significant negative association between ST and upper and lower limb flexibility, so the role of ST in flexibility is unclear.

Few previous reviews are comparable to this work. Mañas et al. [53] performed a systematic review and concluded that the association between objectively measured SB and physical performance in old people is strong, with just one study included not showing a significant association. Wirth et al. [54] also conducted a systematic review to investigate the associations between SB (objectively measured and self-reported) and various biomarkers in older adults. The authors found five studies evaluating the associations between SB and performance and concluded that SB was associated in an unfavorable way with performance biomarkers [54]. Wullems et al. also conducted a systematic review and verified that the literature reports negative associations in SB in the elderly, such as less favorable cardiometabolic health, physical functioning, musculoskeletal health and body composition; however, the authors considered the evidence so far to be inconclusive. Overall, the results of these three reviews suggest a negative association between the ST and physical fitness components, however these reviews included only studies carried out in the elderly and with subjective measures of SB.

The results of this meta-analysis have major public health implications since the decline of analyzed physical fitness components (i.e., CRF, muscular strength and balance) are associated with physical disability and loss of independence , falling risk and fractures and an increased risk of morbidity and all-cause mortality in adults. Thus, the results of this meta-analysis should be taken into consideration. In general, authors from the included studies recommended developing strategies to reduce ST and to increase PA levels among these age groups. In addition, supplementary analyses carried out in some studies suggested a frequent interruption of ST and replacement of even small amounts of ST with LPA (light physical activity) or MVPA (moderate to vigorous physical activity), in order to contribute to improvements in physical fitness. Biddle et al. affirms that “the best posture is the next posture” and reinforces the importance of regularly breaking up ST and replacing this with postural shifts and movement to improve health [55].

The random effects model was used to run the meta-analysis because of the assumption of heterogeneity between studies (e.g., use of different instruments and data reduction to evaluate ST; different physical fitness tests) and between their participants (e.g., age of participants, social background). The results of the present meta-analysis should be interpreted with caution because of heterogeneity in the assessment of physical fitness tests and the devices used to measure ST. Moreover, our results were derived from cross-sectional studies and thus should be interpreted accordingly. Poor physical fitness levels may be a determinant as well as a consequence of SB and they may influence the context of SB. In this sense, quality evidence from studies using longitudinal and/or intervention designs are needed to examine reverse-causal relationships between SB and physical fitness in adults. Furthermore, necessary studies are those that determine the molecular basis by which SB is associated with reduced CRF, muscle strength and balance [56][57]. Since our meta-analysis does not take into account the mediation of levels of PA, we suggest that future reviews should analyze the association between SB and physical fitness, with the mediation of PA levels.

Strengths and Limitations

The eligibility criteria ensured that only papers that utilized objective measures to quantify cross-sectional associations between ST and physical fitness components were included. To the best of our knowledge, this systematic review and meta-analysis is the first quantitative synthesis of associations between total ST and physical fitness. Despite the high methodological quality of the included studies, this work has several limitations. First, our research strategy was limited to studies published in the English language since 2010, which may have resulted in a linguistic or cultural bias, however, our extensive research in four databases incorporated several studies conducted in different countries. Second, as there were few studies for some outcomes, meta-analysis could not be conducted to test all components of physical fitness, such as agility, coordination, speed, power and reaction time. Third, another limitation is related to the heterogeneity of samples included in the studies, which may limit the interpretation of our results. We included seven studies in adults aged between 18 to 64 years old and nine studies including participants aged ≥65 years. Other studies included participants aged between 50 to 67 years old , 50 to 80 years old , 60 to 78 years old , 29 to 82 years old and 60 to 69 years old . Since these studies did not perform correlation analyses by age group, it is difficult to carry out extra comparative analyses between adults and elderly. However, the meta-analysis performed by Powell et al. also included studies where the age range of participants was large (18–87 years). Fourth, objective measures also have their own challenges, as there is no consensus regarding the processing and collection of accelerometer data (e.g., definitions of non-wear time and number of valid days), which can limit the interpretation of our results [58]. There needs to be evidence to reach a consensus on SB data reduction protocols. Fifth, the statistical procedures used also have their own limitations.

For example, to assess the heterogeneity we used Cochran's Q test (based on a chi-square distribution) which is known to be poor at detecting true heterogeneity, especially when the number of studies is small. However, to address this limitation, we also performed I^2 and T^2 tests to analyze the heterogeneity of the studies, which, unlike Q, does not depend upon the number of studies considered. Furthermore, the funnel plot and Egger's intercept test to evaluate the risk of publication bias were not used in the flexibility and balance analysis, because the capacity of this test to detect bias is limited in meta-analysis with small number of studies (<10 studies).

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