Journal of Science and Medicine in Sport 19 (2016) 605–610

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

The association between the activity profile and cardiovascular risk

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ARTICLE INFO

Article history:
Received 23 January 2015
Received in revised form 31 July 2015
Accepted 7 August 2015
Available online 15 August 2015

Keywords:
Motor activity
Physical activity
Sedentary lifestyle
Sitting
Cardiovascular diseases
Accelerometer

ABSTRACT

Objectives: This study sought to better understand the interrelationships between physical activity and sedentary behaviour and the relationship to risk of cardiovascular disease (CVDR) in adults aged 30–75 years.
Design: Cross-sectional.
Methods: Data from two-year waves (2003–2004 and 2005–2006) of the National Health and Nutritional Examination survey were analysed in 2014. Accelerometer-derived time and proportion of time spent sedentary and on moderate-to-vigorous physical activity (MVPA) were calculated to generate four activity profiles based on cut-points to define low and high levels for the respective behaviours. Using health outcome data, CVDR was calculated for each person. Weighted multiple linear regression models were used to evaluate the predicted effects of sedentary and physical activity behaviours on the CVDR score, adjusting for participants' sex, age group, race, annual household income, and accelerometer wear time.
Results: The lowest CVDR was observed among Busy Exercisers (high MVPA and low sedentary; 8.5%), whereas Couch Potatoes (low MVPA and high sedentary) had the highest (18.6%). Compared with the reference group (Busy Exercisers), the activity profile associated with the highest CVDR was Couch Potatoes (adjusted mean difference 3.6, SE 0.38, $p < 0.0001$). A smoothed three-dimensional response surface "risk landscape" was developed to better visualise the conjoint associations of MVPA and sedentary behaviour on CVDR for each activity profile. The association between MVPA was greater than that of sedentary behaviour; however, for people with low MVPA, shifts in sedentary behaviour may have the greatest impact on CVDR.
Conclusions: Activity profiles that consider the interrelationships between physical activity and sedentary behaviour differ in terms of CVDR. Future interventions may need to be tailored to specific profiles and be dynamic enough to reflect change in the profile over time.

1. Introduction

Sixty years ago Morris and colleagues highlighted the association between physical inactivity and cardiovascular (CVD) mortality.[1] In their Lancet publication, it was shown that London Transport Authority conductors on English double decker buses were more active and were at lowered risk of cardiac events than their bus driving peers. In this paper Morris et al. used the term "physical inactivity" to describe the more sedentary type of work performed by bus drivers, which was characterised by prolonged periods of sitting. Six decades later there has been a proliferation of research focussed on the detrimental health benefits of sitting or sedentary behaviour. While the concepts of physical inactivity (doing little or no physical activity) and sedentariness are similar, current research defines sedentary behaviour as any waking activity characterized by energy expenditure $\leq$1.5 metabolic equivalents *and* a sitting or reclining posture. In general this means that any time a person is sitting or lying down, they are engaging in sedentary behaviour. Common sedentary behaviours include TV viewing, video game playing, computer use (collectively termed "screen time"), driving automobiles, and reading.[2]

The health benefits of regular physical activity participation are considerable. A systematic review and meta-analysis of 33 studies (n = 883,372) found that regular physical activity was associated with a 35% reduced risk of CVD mortality, and a 33% reduced risk of all-cause mortality compared to those who did not perform

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http://dx.doi.org/10.1016/j.jsams.2015.08.001
1440-2440/

regular physical activity.[3] Despite this, worldwide the prevalence of physical inactivity has been estimated at 17.4% (95%CI 15.1–19.7) and is the fourth leading risk factor for global mortality.[4]

Daily time spent being sedentary is associated with increased risk of disease and mortality in adults, independent of physical activity.[5–7] Several studies have demonstrated a 46–48% increased risk of all-cause mortality,[5,6,8] 80% increased risk of CVD mortality[5] and 125% increased risk of cardiovascular events (fatal and non-fatal)[6] for individuals spending more than 4 h per day engaged in sedentary screen activities (e.g., television watching) compared with those who spent less than 2 h per day in screen activities. Another study among healthy adults who met current guidelines for physical activity, found detrimental dose-response relationships between television watching and waist circumference, blood pressure and blood glucose, known as the "active couch potato phenomenon".[9]

While physical activity and sedentary behaviour have been independently associated with varying degrees of health risk[8,10] it is important to consider the interrelationships between behaviours. To illustrate, a meta-analysis demonstrated that while higher amounts of sedentary time were associated with increased risk of all-cause mortality, moderate-to-vigorous intensity physical activity (MVPA) appeared to attenuate the association.[8] Similar findings were observed in a recent systematic review and meta-analysis, which sought to quantify the association between sedentary time and hospitalisation and health outcomes. Significant hazard ratio (HR) associations were found for all-cause mortality, CVD incidence and mortality, cancer incidence and mortality, and type 2 diabetes incidence;[12] however the hazard ratios for sedentary time and outcomes were generally larger at lower levels of physical activity than at higher levels.

Further, a recent study created cardiometabolic profiles and showed that adults with lower levels of sedentary behaviour and higher levels of MVPA demonstrated the healthiest cardiometabolic profiles, compared to those with high levels of sedentary behaviour and low MVPA, who were older and had an elevated risk.[13] Collectively, these findings highlight the need to consider physical activity and sedentary behaviour together to better understand health outcomes. We propose the concept of an 'activity profile' to better understand the interrelationships between physical activity and sedentary behaviour. Within a given day (24 h), individuals may allocate time to many different activities, and allocation of time to one activity will necessarily displace time from another. Rather than viewing physical activity and sedentary time separately, the activity profile considers the proportion of daily waking time spent in sedentary behaviour and physical activity.

The purpose of this research is to characterise typical activity profiles and to determine the association with their risk of CVD.

2. Methods

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[14] guidelines for reporting and analysis were followed for this research. A cross sectional analysis was conducted using data obtained from two two-year waves of the "continuous" National Health and Nutritional Examination survey (NHANES), which uses a complex multistage probability design to obtain a representative sample of the United States (U.S) civilian non-institutionalised population. Full details of the survey are available at http://www.cdc.gov/nchs/nhanes.htm. In brief, NHANES participants perform an at-home interview, followed by a standardised clinical examination at a mobile examination centre, approximately two weeks later, and lasting 3–4 h. The National Centre for Health Statistics Ethics Review Board approved the protocols and all participants provided informed consent.

For this study, demographic, health and accelerometer data were extracted from both the 2003–2004 (N = 10,122) and 2005–2006 (N = 10,348) surveys. Per-minute accelerometer data of all men and women aged 30–75 years who participated in one of the respective surveys were downloaded, and merged with their health outcomes for the purpose of analysis. To reduce bias associated with self-report, objectively assessed movement data were obtained using the Actigraph 7164 accelerometer (Actigraph www.theactigraph.com), which participants were asked to wear on their right hip during waking hours (except water activities) for seven consecutive days. Data were summarised in 1-min epochs. Full details of the NHANES accelerometer protocol are available at http://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/Physical_Activity_Monitor_Manual.pdf.

Data processing was conducted on the per-minute accelerometer records as follows. First, non-wear time defined as 60 min or more of consecutive zeroes in activity counts was removed for each recorded day. Records were also removed if reliability of data were flagged in the original dataset (this included extreme activity count values). The total number of valid minutes retained for each recorded day was assessed and only valid days with at least 10 h of valid minutes were included. At least one day of valid accelerometer data was required for analysis. For each valid day, time spent (in min) on sedentary, light, and MVPA was calculated according to published intensity thresholds.[15] The cut-points were: sedentary (counts per minute < 100); light (100 ≤ cpm < 2020); and MVPA (cpm ≥ 2020). The proportion of daily wear time spent sedentary and for each level of physical activity was also calculated. The median time and proportion of wear time spent on the respective behaviours were calculated over all valid days, as the typical values for each participant. The sample medians were estimated using the two typical values from all participants, and used as the cut-points to define low and high levels for both MVPA and sedentary behaviours. Values below the median were classified as low and values at and above the median were classified as high. The cut-points for median time spent in sedentary and MVPA were 509 and 9 min, respectively. The cut-points for median proportion of time on sedentary (SED) and MVPA were 60% and 2%, respectively. Four activity profiles were created using these cut-points as follows:

(1) Busy Exercisers (High MVPA Low SED; the reference)
(2) Techno-Actives (High MVPA, High SED)
(3) Potterers (Low MVPA, Low SED)
(4) Couch Potatoes (Low MVPA, High SED)

Both approaches were considered to define the four activity profiles in order to compare their association with participant's risk of CVD. Light physical activity was not considered when calculating activity profiles for two reasons. First, MVPA is recommended in many national guidelines for enhancing cardiorespiratory fitness.[16] Second, the inclusion of light intensity physical activity would result in issues of multi-collinearity since sedentary behaviour, light physical activity and MVPA would make up the entire accelerometer record.

Participants' CVDR was estimated using the recent version of the Framingham equation,[17] which incorporates age, sex, smoking status and health data (systolic blood pressure, total cholesterol and HDL cholesterol). The Framingham Risk Score is a sex-specific algorithm used to estimate the 10-year risk of developing coronary heart disease.[18] This risk prediction equation was developed to assist clinicians in estimating a person's absolute risk for developing coronary heart disease. Because the score gives an indication of the risk of developing CVD, it can signal who would most likely benefit from prevention. Recommended age levels for initiating CVDR assessment are 35 years in people with known risk factors for CVD, and 45 years for people who are asymptomatic.[19] To capture both