Preventive Medicine 57 (2013) 201–205

Contents lists available at SciVerse ScienceDirect

Preventive Medicine

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

Objectively measured physical activity, cardiorespiratory fitness and cardiometabolic risk factors in the Health Survey for England

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ARTICLE INFO

Available online 31 May 2013

Keywords:
Exercise
Physical fitness
Accelerometry
Step test

ABSTRACT

Objectives. The study aims to test the hypothesis that physical activity (PA) and cardiorespiratory fitness (CRF) are associated with cardiometabolic risk factors; and to test the hypothesis that CRF modifies (changes the direction and/or strength of) the associations between PA and cardiometabolic risk factors.

Methods. PA and CRF were objectively measured in the 2008 Health Survey for England and the present study included 536 adults who completed at least 4 min of the eight-minute sub-maximal step test and wore an accelerometer for at least 10 h on at least four days. Linear regression models were fitted to examine the relationship between PA and cardiometabolic risk factors and between CRF and cardiometabolic risk factors. A test of interaction was performed to examine whether CRF modifies the associations between PA and cardiometabolic risk factors.

Results. PA and CRF were associated with HDL cholesterol, the ratio of total to HDL cholesterol, glycated haemoglobin and BMI after adjustment for potential confounders. There was little evidence that CRF changed the direction or strength of associations between PA and cardiometabolic risk factors.

Conclusions. PA and CRF are associated with cardiometabolic risk factors. A larger sample is required to determine if CRF modifies associations between PA and cardiometabolic risk factors.

Introduction

Physical activity and cardiorespiratory fitness are associated with reductions in the risks of type 2 diabetes (Gill and Cooper, 2008; Sieverdes et al., 2010) and cardiovascular disease (CVD) (Shiroma and Lee, 2010; Williams, 2001). Physical activity improves cardiorespiratory fitness in most adults (Skinner et al., 2000) and vigorous-intensity activity produces greater improvements in cardiorespiratory fitness than the same volume of moderate-intensity activity (Kraus et al., 2002; O'Donovan et al., 2005). Nonetheless, it has been suggested that the pursuit of cardiorespiratory fitness is unnecessary or unrealistic (Després and Lamarche, 1994; Lee et al., 2001; Pate et al., 1995). It is also suggested that the observed association between cardiorespiratory fitness and health is greater than that between physical activity and health because fitness has been measured with greater accuracy (Shiroma and Lee, 2010). Objective measures of physical activity are now more readily available (Warren et al., 2010), but there have been few reports on the associations between objectively measured physical activity, objectively measured cardiorespiratory fitness, and cardiometabolic risk factors (Franks et al., 2004; Schmidt et al., 2008). Physical activity (Chaudhury and Esliger, 2010) and cardiorespiratory fitness (Aresu et al., 2010) were objectively measured in the 2008 Health Survey for England and the purpose of the present study was to investigate the relationship between physical activity and cardiorespiratory fitness (predictors) and cardiometabolic risk factors (outcomes). Some authors have used linear regression to investigate the independent effects of activity and fitness on cardiometabolic risk factors (Ekblom-Bak et al., 2010; Franks et al., 2004; Lakka and Salonen, 1993; Sassen et al., 2009; Schmidt et al., 2008); however, activity and fitness are not independent predictors: physical activity improves (Skinner et al., 2000) and can explain much of the variance (Lakoski et al., 2011) in cardiorespiratory fitness. Franks et al. (2004) investigated the interaction of objectively measured physical activity and objectively measured cardiorespiratory fitness on the metabolic syndrome in white men and women in the UK, but participants were not drawn from a nationally representative sample. Ekblom-Bak et al. (2010) investigated the interaction of physical activity and cardiorespiratory fitness on the clustering of CVD risk factors in a representative sample of men and women in Sweden, but physical activity was not

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http://dx.doi.org/10.1016/j.ypmed.2013.05.022

objectively measured. Participants in the present study were drawn from a survey that was designed to be representative of the national population, and physical activity and cardiorespiratory fitness were objectively measured. We tested the hypothesis that both physical activity and cardiorespiratory fitness are associated with cardiometabolic risk factors. We also tested the hypothesis that cardiorespiratory fitness modifies (changes the direction and/or strength of) the associations between physical activity and cardiometabolic risk factors.

Methods

Health Survey for England

The sample design (Craig et al., 2010a) and data weighting (Craig et al., 2010b) of the 2008 Health Survey for England are described in detail elsewhere. The core sample was designed to be representative of the population living in private households in England and comprised 16,056 addresses selected at random in 1176 postcode sectors. Fifteen thousand, one hundred and two (15,102) adults from 9191 households took part in the study; 88% of participants were interviewed, 63% saw a nurse and 44% gave a non-fasting blood sample. Blood samples were not taken from pregnant women, those who were HIV positive or had hepatitis B or C, those with clotting or bleeding disorders, those who had ever had a fit (including an epileptic fit, a convulsion, or a convulsion associated with a high fever), those on anticoagulant drugs, or those who were not willing or not able to give consent in writing. The Oxford A Research Ethics Committee approved the 2008 Health Survey for England and all participants gave written informed consent (reference number 07/H0604/102).

Assessment of physical activity and cardiorespiratory fitness

The objective assessment of physical activity (Chaudhury and Esliger, 2010) and cardiorespiratory fitness (Aresu et al., 2010) in the 2008 Health Survey for England is described in detail elsewhere. Two thousand, seven hundred (2700) addresses in 180 postcode sectors were selected for the physical activity and cardiorespiratory fitness sub-sample. Four thousand, five hundred and seven (4507) adults were invited to take part in the sub-sample, 80% agreed to wear an accelerometer and 48% wore the device for at least 10 h per day on at least four days (Chaudhury and Esliger, 2010). A uni-axial accelerometer was worn at the waist (GT1M, ActiGraph, Florida, USA) and accelerometer counts were processed using specialist software (KineSoft version 3.0.98, KineSoft, New Brunswick, Canada). Non-wear time was defined as ≥60 consecutive minutes of zero counts per minute and prevailing cut-offs were used to calculate time in each intensity band: 200 counts per minute was regarded as the threshold for light-intensity activity (around 1.5–3 METs), 2020 counts per minute was regarded as the threshold for moderate-intensity activity (around 3–6 METs) and 5999 counts per minute was regarded as the threshold for vigorous-intensity activity (≥6 METs, where 1 MET is equivalent to the energy expended at rest) (Troiano et al., 2008). The present study only included moderate- to vigorous-intensity physical activity (MVPA) and physical activity counts were expressed in minutes.

Fitness tests were administered to individuals aged 16 to 74 years in households in the sub-sample that nurses visited. Three thousand, six hundred and forty five (3645) adults were selected for the test, but 3% refused to participate and 41% of men and 45% of women were excluded because they reported dizzy spells (25%), took beta blockers or had high blood pressure (24.5%), had musculoskeletal problems (18.5%), had CVD (12%), felt unsafe (9.5%), were pregnant (4%), or had other reasons (6.5%) (Aresu et al., 2010). Nurses supervised eligible volunteers during a sub-maximal step test on a 215 mm high step, which was designed to predict maximal oxygen uptake (VO_2 max) (Aresu et al., 2010; Brage et al., 2005, 2007). Six hundred and thirty one (631) men and 486 women completed the eight-minute test and 1812 of 1969 (92%) adults completed at least 4 min, thereby providing sufficient data to predict VO_2 max. Around 50% of participants stopped early because the heart rate exceeded 85% of predicted maximum. The present study included 536 adults who completed at least 4 min of the fitness test and wore an accelerometer for at least 10 h on at least four days.

Demographic and clinical variables

Trained interviewers measured height and weight and asked about smoking habit, alcohol intake and the occupation of the head of household, which provided an indication of socioeconomic status. Trained and qualified nurses asked about medication use (indicative of health status), obtained a venous blood sample and measured blood pressure three times after 5 min of seated rest using an automated device (Omron HEM-907, Omron Healthcare, Kyoto, Japan). Blood samples were posted to the Biochemistry Department at the Royal Victoria Infirmary in Newcastle for the measurement of glycated haemoglobin (HbA1C) (G7 analyser, Tosoh, Tokyo, Japan), total cholesterol and high-density lipoprotein cholesterol (HDL-C) (640 analyser, Olympus Corporation, Tokyo, Japan). The coefficient of variation for the assays was less than 4%.

Data analysis

We used data from the 2008 Health Survey for England. Linear regression models were fitted to examine the associations between physical activity (predictor, quantified as the sum of moderate- and vigorous-intensity physical activity in minutes per day) and cardiometabolic risk factors (outcomes). For each outcome two models were fitted. Model 1 was adjusted for age and sex and model 2 was adjusted for age, sex, smoking habit (never/previous/current), socioeconomic status (managerial and professional occupation/intermediate occupation/routine and manual occupation/other), alcohol intake (at least once per month/monthly/rarely or never) and CVD medication use (beta blockers, ACE inhibitors, diuretics, calcium blockers, lipid lowering agents). The two models were repeated using cardiorespiratory fitness (quantified using VO_2 max) instead of physical activity as the main predictor. To examine whether the association between MVPA and cardiometabolic risk factors was modified by level of fitness an interaction term between MVPA and VO_2 max was added to the fully adjusted models after categorising VO_2 max into three categories using tertiles as cutpoints. The Wald test was used to quantify evidence for an interaction. MVPA in minutes per day was divided by 10 so that the regression coefficients estimated the mean change in the cardiometabolic risk factors corresponding to a 10-minute increase in MVPA, consistent with current public health recommendations. All analyses were undertaken in Stata software (Version 12.0, StataCorp, Texas).

Results

Table 1 presents participants' characteristics. Participants in the present study who had valid data for both MVPA and VO_2 max had a mean (±SD) age of 46 ± 14 years compared to participants in the core sample who had a mean age of 49 ± 19 years. Forty eight per cent of adults in the present study and 45% of adults in the core sample were male. Sixteen per cent of participants in the present study and 20% of participants in the core sample were smokers. Forty two per cent of participants in the present study and 32% of participants in the core sample were employed in managerial and professional occupations or intermediate occupations. Sixty six per cent of participants in the present study and 58% of participants in the core sample reported drinking alcohol at least once per week in the last 12 months. Eight per cent of participants in the present study and 28% of participants in the core sample reported using medication for CVD. Blood-borne variables were similar in the two samples; for example, the ratio of total cholesterol to HDL-C (TC:HDL-C) was 3.83 ± 1.02 in the present study and 3.87 ± 1.15 in the core sample. HDL-C was 1.53 ± 0.37 in the present study and 1.50 ± 0.37 in the core sample. Systolic blood pressure was 124 ± 13 mm Hg in the present study and 128 ± 18 mm Hg in the core sample. Body mass index (BMI) was 26.7 ± 4.4 $kg \cdot m^{-2}$ in the present study and 27.2 ± 5.2 $kg \cdot m^{-2}$ in the core sample.

The range of recorded MVPA was zero to 130 min per day and predicted VO_2 max ranged from 16.5 to 53 $ml \cdot kg^{-1} \cdot min^{-1}$ (Table 1). The correlation between MVPA and VO_2 max was 0.29 ($p < 0.001$). Table 2 shows the regression coefficients between physical activity and the cardiometabolic risk factors. MVPA was associated with HDL-C, TC:HDL-C, HbA1C and BMI in the partially adjusted and fully adjusted models. Table 3 shows the regression coefficients between cardiorespiratory fitness and the cardiometabolic risk factors. Predicted VO_2 max was associated with HDL-C, TC:HDL-C, HbA1C and BMI in the partially adjusted and fully adjusted models. Predicted VO_2 max was also associated with systolic blood pressure in the fully adjusted model. Tests of