Association Between Cardiorespiratory Fitness and Accelerometer-Derived Physical Activity and Sedentary Time in the General Population

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Abstract

Objective: To determine the association between cardiorespiratory fitness and sedentary behavior, independent of exercise activity.

Patients and Methods: We included 2223 participants (aged 12-49 years; 1053 females [47%]) without known heart disease who had both cardiovascular fitness testing and at least 1 day of accelerometer data from the National Health and Nutrition Examination Survey 2003-2004. From accelerometer data, we quantified bouts of exercise as mean minutes per day for each participant. Sedentary time was defined as less than 100 counts per minute in mean minutes per day. Cardiorespiratory fitness was derived from a submaximal exercise treadmill test. Multivariable-adjusted linear regression analyses were performed with fitness as the dependent variable. Models were stratified by sex, adjusted for age, body mass index, and wear time, and included sedentary and exercise time.

Results: An additional hour of daily exercise activity time was associated with a 0.88 (0.37-1.39; $P<.001$) metabolic equivalent of task (MET) higher fitness for men and a 1.37 (0.43-2.31; $P=.004$) MET higher fitness for women. An additional hour of sedentary time was associated with a −0.12 (−0.02 to −0.22; $P=.03$) and a −0.24 (−0.10 to −0.38; $P<.001$) MET difference in fitness for men and women, respectively.

Conclusion: After adjustment for exercise activity, sedentary behavior appears to have an inverse association with fitness. These findings suggest that the risk related to sedentary behavior might be mediated, in part, through lower fitness levels.

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Cardiorespiratory fitness (CRF) is known to be one of the strongest predictors of cardiovascular health and longevity.[1] Determinants of fitness are both nonmodifiable (age, sex, genetics) and modifiable (body mass index [calculated as the weight in kilograms divided by the height in meters squared] and physical activity).[2] Numerous prospective cohort studies have solidified the relationship between physical activity, CRF, and reduced risk of cardiovascular disease, coronary heart disease, and all-cause mortality.[3] Therefore, current guidelines recommend at least 150 min/wk of moderate-intensity physical activity or 75 min/wk of vigorous-intensity aerobic physical activity, performed in bouts lasting at least 8 to 10 minutes.[4] Despite the well-established benefits of exercise and the release of these guidelines in 2008, most adults do not meet these physical activity recommendations.[5]

Recent epidemiologic evidence suggests that long-term health consequences related to a lack of moderate-to-vigorous physical activity (too little exercise) are distinct from those of habitual sedentary behavior[3,6-10] (sitting too much). However, less is known about the role of sedentary behavior in this context. *Sedentary behavior* is defined as behaviors that involve low levels of energy expenditure[7] (1.0-1.5 metabolic equivalent of tasks [METs], including sitting, watching TV, reading, and driving). In addition to the risks associated with low physical activity, the burden of sedentary behavior appears to be a separate risk factor that is independent of physical activity levels, with multiple observational studies showing increased risk for total

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all-cause and cardiovascular mortality for individuals with increased sedentary time.[8-10] For example, in a recent report from the Women's Health Initiative, women who reported more than 10 h/d of sitting had an 18% increased risk of cardiovascular disease than did women who sat less than 5 h/d, regardless of physical activity levels.[10] These data suggest that sedentary behavior is more than merely the lack of purposeful exercise.

The mechanism through which sedentary behavior may contribute to increased risk remains uncertain. Sedentary behavior has been associated with obesity, the metabolic syndrome, reduced lipoprotein lipase levels, insulin resistance, and microvascular dysfunction.[8,11-17] However, to our knowledge, the association between sedentary behavior and CRF has not been studied. Because of the prognostic importance of CRF on health and mortality,[1,3] this knowledge could provide an insight into the mechanisms through which sedentary behavior influences cardiovascular disease risk. In addition, this would have potential implications for novel strategies designed to increase CRF. Therefore, we sought to characterize the associations between sedentary behavior and CRF using data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004.

PATIENTS AND METHODS

Cohort Description

The NHANES is an ongoing series of surveys that have been conducted by the National Center for Health Statistics since the early 1960s to assess the health and nutritional status of the US civilian, noninstitutionalized population. Fifteen geographic locations are selected annually and sampled to represent the general population with a complex, multistage probability design. The 3 main components of the study include an interview in the participants' home, a medical examination completed at a mobile examination center, and several medical and laboratory tests. The interview includes demographic, socioeconomic, dietary, and health-related questions. Comorbidities are assessed by self-report. The NHANES 2003-2004 included a CRF test component for participants aged 12 to 49 years. All participants were also eligible for physical activity monitoring using an accelerometer device. The National Center for Health Statistics Ethics Review Board approved the protocols, and informed consent was obtained from all subjects.

From NHANES participants in 2003-2004, 4902 individuals aged 12 to 49 years were examined at the mobile examination center. Of these, 1439 participants met prespecified exclusion criteria for fitness testing because of 1 or more of the following reasons: physical limitations that would prevent them from using the treadmill (n=328); history of cardiovascular disease or active conditions or symptoms (n=336); asthma or other lung and breathing conditions or symptoms (n=291); pregnancy of more than 12 weeks (n=203); use of β-blockers, antiarrhythmic agents, calcium channel blockers, nitrates, or digitalis (n=97); refused fitness testing (n=67); or other reasons (n=117). Among individuals who were eligible to participate in the fitness test, 415 did not have their fitness level estimated. For 387 of these, the test was terminated prematurely because of predefined early stopping criteria (symptoms and/or safety concerns). There were missing data to estimate maximum oxygen consumption ($\dot{V}O_2max$) in 12 participants. In 16 additional participants, technical problems or technician errors were the cause for inability to estimate fitness. After excluding an additional 825 participants lacking 1 valid day of physical activity monitoring (a valid day is defined as ≥10 hours of accelerometer wear time), we were left with 2223 participants with both CRF testing and sufficient accelerometer data.

Accelerometry

Participants were asked to wear a single-axis ActiGraph model 7164 accelerometer (ActiGraph, LLC) on their right hip during all waking hours for 7 consecutive days (except when exposed to water—bathing, showering, swimming, etc). Details of the accelerometer protocol are available.[18] The data collected by the physical activity monitor reflect the intensity of activity as counts in a set period of time (1-minute intervals) and were analyzed using SAS syntax provided by the National Cancer Institute.[19] Wear time was determined by subtracting non—wear time from 24 hours. Non—wear time was defined by an interval of at least 60 consecutive minutes of zero activity counts, with allowance of up to 2 minutes of counts between 0 and 100. Intensity-threshold criteria for

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