ORIGINAL ARTICLE

Sedentary Time, Cardiorespiratory Fitness, and Cardiovascular Risk Factor Clustering in Older Adults–the Generation 100 Study

Silvana B. Sandbakk, MSc; Javaid Nauman, PhD; Nina Zisko, MSc; Øyvind Sandbakk, PhD; Nils Petter Aspvik, MSc; Dorthe Stensvold, PhD; and Ulrik Wisløff, PhD

Abstract

Objective: To determine whether meeting physical activity (PA) recommendations and/or having high age-specific cardiorespiratory fitness (CRF) attenuate the adverse effect of prolonged sedentary time on cardiovascular risk factor (CV-RF) clustering in older adults.

Patients and Methods: We conducted a cross-sectional study of Norwegian women (495) and men (379) aged 70 to 77 years from August 22, 2012, through June 30, 2013. Sedentary time and PA were assessed by accelerometers and CRF by directly measured peak oxygen uptake (VO_{2peak}). Logistic regression was used to estimate adjusted odds ratios (ORs) and CIs for the association between sedentary time and prevalence of CV-RF clustering ($\geq$3 of the following: hypertension, high blood glucose level, high waist circumference, low high-density lipoprotein cholesterol level, or high triglyceride level) and for the modifying effect of PA and CRF.

Results: Overall, 163 of the 495 women (32.9%) and 140 of the 379 men (36.9%) had CV-RF clustering. Each additional hour of sedentary time was associated with 22% (OR, 1.22; 95% CI, 1.02-1.45) and 27% (OR, 1.27; 95% CI, 1.04-1.55) higher likelihood of having CV-RF clustering in women and men, respectively, whereas a 1−metabolic equivalent decrement in VO_{2peak} corresponded to 57% (OR, 1.57; 95% CI, 1.34-1.84) and 67% (OR, 1.67; 95% CI, 1.44-1.95) higher likelihood of CV-RF clustering in women and men, respectively. High CRF (VO_{2peak} >27.5 mL/kg per minute in women and >34.4 mL/kg per minute in men) attenuated the adverse effects of high sedentary time on CV-RF clustering, even among individuals not meeting recommendations for PA.

Conclusion: High age-specific CRF fully attenuates the adverse effect of prolonged sedentary time on CV-RF clustering, independent of meeting the PA consensus recommendation in older adults.

 ■ Mayo Clin Proc. 2016;91(11):1525-1534

Prolonged time spent sedentary is regarded as one of the key modifiable factors contributing to cardiovascular disease (CVD).[1-7] This risk may apply particularly to older adults (≥70 years old), who are the most sedentary age group.[8] Because most studies have reported the association between sedentary time (ST) and risk of CVD to be independent of physical activity (PA),[1-7] ST and insufficient PA may represent separate and distinct risk factors for CVD. Even among individuals who meet the PA recommendations, the risk of CVD associated with high ST persists.[2,9]

Independent of PA, cardiorespiratory fitness (CRF) appears to be the single strongest predictor of cardiovascular morbidity and mortality.[10-15] High levels of CRF are associated with reduced levels of traditional cardiovascular risk factors (CV-RFs) used to identify individuals at high risk for CVD,[16] including hypertension, central obesity, type 2 diabetes, and dyslipidemia, both in the general adult population[17-24] and in older adults.[25,26]

Recent studies indicate that the detrimental association between ST and CV-RFs is attenuated when CRF is taken into account in the general adult population.[27,28] However,

From the K.G. Jebsen Center for Exercise in Medicine, Department of Circulation and Medical Imaging, Faculty of Medicine (S.B.S., J.N., N.Z., D.S., U.W.), Centre for Elite Sports Research, Department of Neuroscience (Ø.S.), and Institute for Science in Sport (N.P.A.), Norwegian University of Science and Technology, Trondheim, Norway; and School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Australia (U.W.).

in these studies, relatively few older adults were represented (mean age, 47±14 and 46±9 years), CRF was measured indirectly or estimated, and neither PA nor ST were measured objectively. Because decline in CRF is one of the hallmarks of aging[29,30] and some of the CV-RFs may be age facilitated,[31] the possible preventive effect of high CRF on risk of CVD associated with prolonged ST requires a reappraisal among older adults.

Therefore, the primary aim of this study was to determine whether meeting PA recommendations and/or having high age-specific CRF attenuates the adverse effect of prolonged ST on CV-RF clustering in older adults.

PATIENTS AND METHODS

Study Participants

This study is part of the Generation 100 study, a randomized controlled clinical trial with the main objective of investigating the effect of exercise training on morbidity and mortality in the older adult population. A detailed description of the Generation 100 study has been published previously.[32] The current study was approved by the Regional Committee for Medical Research Ethics (REK Midt: 2013/1609) and complies with the Norwegian laws and the principles of the Declaration of Helsinki. All participants signed informed consent documents before participation.

All inhabitants of Trondheim municipality, Norway, born between January 1, 1936, and December 31, 1942 (n=6966), were invited to participate in the Generation 100 study. On invitation, all individuals, independent of willingness and ability to complete baseline examinations, were asked to return a health-related questionnaire and consent form. A comparison of demographic information of participants (n=1567) and nonparticipants (n=1361) has been published previously in the Generation 100 protocol.[32] A total of 1567 participants (790 women) accepted the invitation, met the inclusion criteria for Generation 100, and fulfilled baseline testing. For the current study, participants with known CVD (n=302), missing or incomplete accelerometer data describing ST and PA (n=249), missing peak oxygen uptake (VO_{2peak}) (n=12), and/or incomplete data on CV-RF clustering (n=130) were excluded. Overall, a total of 874 (495 women) participants were included in the current study (Figure).

Clinical Measurements and Questionnaire-based Information

Clinical testing was carried out between August 22, 2012, and June 30, 2013. Measurements of body mass, body height, waist circumference, blood pressure, and blood samples were conducted by trained personnel and followed standardized routines described in detail previously.[32] The participants were asked to arrive in a fasting state and to refrain from exercise training, caffeine, nicotine, and alcohol 12 hours before the clinical examination, and participants fasting for less than 8 hours were excluded from the analysis. Participants were asked to continue their regular medication routines. Previously described questionnaires[32] provided information about the use of prescription medication (for hypertension, diabetes, and dyslipidemia), health status, prevalence of CVD (including myocardial infarction, angina pectoris, heart failure, atrial fibrillation, other heart diseases, and stroke), smoking, and alcohol consumption.

Cardiovascular risk factor clustering was defined as the presence of at least 3 of the following 5 risk factors: elevated waist circumference (≥80 cm in women and ≥94 cm in men); elevated triglyceride level (≥1.7 mmol/L) or drug treatment for dyslipidemia; reduced high-density lipoprotein cholesterol level (<1.3 mmol/L in women and <1.0 mmol/L in men) or drug treatment for dyslipidemia; elevated blood pressure (systolic ≥130 mm Hg and/or diastolic ≥85 mm Hg) or drug treatment for hypertension; and elevated fasting glucose level (≥100 mg/dL; to convert to mmol/L, multiply by 0.0555) or drug treatment for diabetes. The combination of these factors defines the metabolic syndrome.[33]

Directly Measured CRF

Gas exchange measurements were used to determine VO_{2peak} by treadmill walking or running with increases in workload every 1 to 2 minutes until voluntary exhaustion. The test protocol and equipment were identical to those used in previously published studies from our group.[32,34]

Mayo Clin Proc. ■ November 2016;91(11):1525-1534 ■ http://dx.doi.org/10.1016/j.mayocp.2016.07.020
www.mayoclinicproceedings.org

Objectively Measured ST and PA

To estimate ST and PA, participants wore an ActiGraph GT3X+ accelerometer (ActiGraph, LLC), which was removed only during water exposure, for 7 consecutive days. The ActiLife software version 6.11.5 (ActiGraph, LLC) was used to analyze the data. Epochs were set with 10-second intervals, and data between 6:00 AM and midnight were included in the analysis. The data were converted into activity counts to reflect the intensity of bodily movement.[35] Non–wear time was excluded from the analysis. Non–wear time was defined as time periods with more than 60 consecutive minutes of zero counts, with allowance of 2 minutes of counts greater than zero.[36] Data were included in the analysis if a participant had at least 4 days of 10 h/d or more validly recorded.[36]

Sedentary time was estimated as all registered accelerometer data (minutes) below 100 counts/min (CPM) based on the uniaxial CPM.[37] The amount of moderate to vigorous PA was estimated by summing the time spent in sustained bouts of at least 10 minutes with 1952 CPM or more, with allowance of a maximum of 2 interruptions of 2 minutes in total.[37] Sedentary time and time spent in moderate to vigorous PA were adjusted for wear time by multiplying the recorded time by 1080 minutes (ie, a complete day of 18 hours excluding night time) and dividing it by the total wear time in minutes. Sedentary time was further converted to hours per day.

Classification of meeting or not meeting PA recommendations was based on the current American College of Sports Medicine/American Heart Association guidelines for older adults.[38] Hence, an accumulated time of 21.43 min/d or more (ie, $\geq$150 min/wk) spent in moderate- to vigorous-intensity PA (in bouts of at least 10 minutes) was considered to meet the current PA recommendations.

Statistical Analyses

Descriptive data are presented as mean $\pm$ SD for continuous variables and number (percentage) for categorical variables. Sedentary time was divided into sex-specific tertiles. Cardiorespiratory fitness was classified into 3 sex-specific categories, as previously suggested[10,39]: low CRF was defined as the 20% least fit participants, moderate CRF as the middle 40%, and high CRF as the most fit 40%.

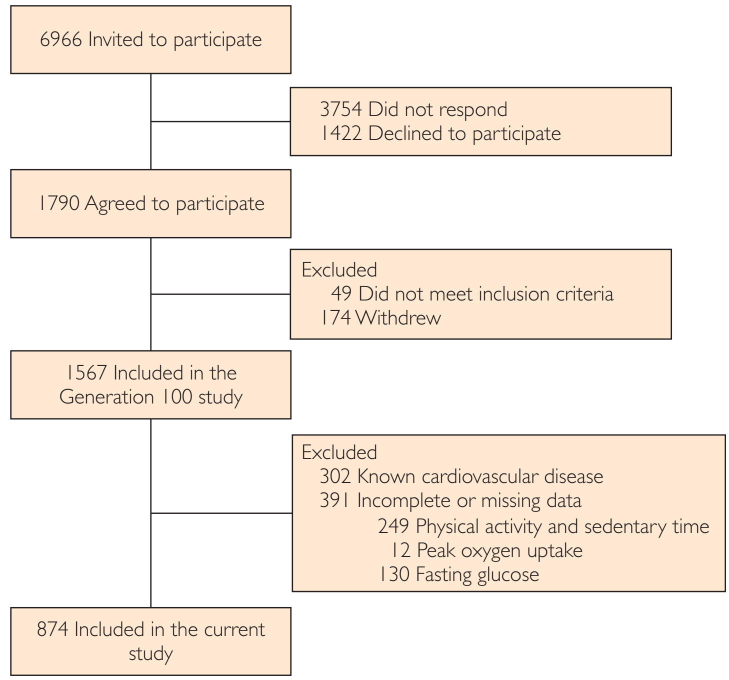

FIGURE. Patient flowchart.

Logistic regression analyses were used to estimate the associations between CRF, ST, and CV-RF clustering. Our basic models were adjusted for age, smoking status, and alcohol consumption (model 1), followed by additional adjustments for meeting or not meeting PA recommendations (model 2) and for ST or CRF (model 3). The results using these models are presented as odds ratios (ORs), and the precision of estimates was assessed by 95% CIs. In separate logistic regression analyses, the combined associations of ST, PA, and CRF with the likelihood of CV-RF clustering were assessed. Participants with high CRF, who met the current recommendations for PA and had low ST, were used as the reference group. All statistical tests were 2-sided, and $P<.05$ was considered statistically significant. The statistical analyses were conducted using Stata statistical software, version 13.1 (StataCorp).

RESULTS

The characteristics of the 874 participants are presented in Table 1. The mean age was

TABLE 1. Characteristics of the 874 Study Participants Aged 70 to 77 Years[a,b,c]

Characteristic	Women (N = 495)	Men (N = 379)
Age (y)	72.5±2.1	72.4±2.1
Cardiovascular risk factor clustering[d]	163 (32.9)	140 (36.9)
Waist circumference (cm)	89.2±10.7	96.9±9.6
Elevated waist circumference	395 (79.8)	224 (59.1)
Triglycerides (mmol/L)	1.10±0.53	1.16±0.56
Elevated triglycerides or drug treatment	82 (16.6)	76 (20.1)
HDL cholesterol (mmol/L)	1.92±0.49	1.57±0.41
Reduced HDL cholesterol	64 (12.9)	35 (9.2)
Blood pressure (mm Hg)		
Systolic	134±19	133±16
Diastolic	74±9	77±9
Elevated blood pressure or drug treatment	322 (65.1)	254 (67.0)
Fasting glucose (mg/dL)	5.55±0.60	5.85±0.77
Elevated fasting glucose or drug treatment	146 (46.8)	159 (63.1)
Currently smoking	33 (6.8)	32 (8.7)
Alcohol use (U/wk)	2.5±2.8	4.7±4.6
Sedentary time (h/d)	13.5±1.2	14.0±1.1
Sedentary time (% of waking hours)	75.0	77.8
Moderate to vigorous physical activity (min/d)	18.9±19.5	20.2±21.8
Meeting physical activity recommendations	175 (35.4)	134 (35.4)
VO_{2peak} (mL/kg/min)	26.7±5.1	32.8±6.5

[a]HDL = high-density lipoprotein; VO_{2peak} = peak oxygen uptake.

[b]Data are presented as mean ± SD or No. (percentage) of patients unless indicated otherwise.

[c]SI conversion factors: To convert glucose value to mmol/L, multiply by 0.0555.

[d]Cardiovascular risk factor clustering was defined as the presence of at least 3 of the following 5 risk factors: elevated waist circumference (≥80 cm in women and ≥94 cm in men); elevated triglyceride level (≥1.7 mmol/L) or drug treatment for dyslipidemia; reduced HDL cholesterol (<1.3 mmol/L in women and <1.0 mmol/L in men) or drug treatment for dyslipidemia; elevated blood pressure (systolic ≥130 mm Hg and/or diastolic ≥85 mm Hg) or drug treatment for hypertension; and elevated fasting glucose level (≥100 mg/dL) or drug treatment for diabetes.

72.5±2.1 years, with 56.6% of the sample (495) being women and 10.1% of all participants (88) defined as obese (body mass index [calculated as weight in kilograms divided by height in meters squared] ≥30 kg/m^2).

Accelerometer wear time (excluding night time from midnight to 6 AM) was on average 16.1±1.1 h/d. Following adjustments for wear time, the participants spent (76.1% 13.7±1.2 h/d of 18 h waking time) in sedentary behavior and 19.5±20.4 min/d performing moderate to vigorous PA. In total, 309 of the 874 participants (35.4%) met the current American College of Sports Medicine/American Heart Association recommendations for PA for older adults. The VO_{2peak} was 26.7±5.1 mL/kg per minute in women and 32.8±6.5 mL/kg per minute in men. Overall, 163 of the 495 women (32.9%) and 140 of the 379 men (36.9%) had CV-RF clustering.

The predominant CV-RF in the 495 women was elevated waist circumference with a prevalence of 79.8% (395), followed by elevated blood pressure and/or drug treatment for hypertension exhibiting a prevalence of 65.1% (322). In men, 67.0% (254 of 379) had elevated blood pressure and/or received drug treatment for hypertension, followed by elevated fasting glucose level and/or drug treatment for diabetes in 63.1% (159 of 252) and elevated waist circumference in 59.1% (224 of 379). In total, 131 women (26.5%) and 107 men (28.2%) were receiving drug treatment for hypertension, 15 women (3.0%) and 27 men (7.1%) were medically treated for diabetes, and 26 women (5.3%) and 22 men (5.8%) were medically treated for dyslipidemia.

CRF and CV-RF Clustering

Individuals characterized as having high CRF (ie, the most fit 40%) had a VO_{2peak} of more than 27.5 mL/kg per minute in women and more than 34.4 mL/kg per minute in men, the moderately fit participants (ie, the middle 40%) had a VO_{2peak} of 22.5 to 27.5 mL/kg per minute in women and 27.2 to 34.4 mL/kg per minute in men, and those with low CRF (ie, the least fit 20%) had a VO_{2peak} of less than 22.5 mL/kg per minute in women and less than 27.2 mL/kg per minute in men.

Every 1−metabolic equivalent (ie, 3.5 mL/kg per minute) lower CRF corresponded to 57% higher likelihood in women (OR, 1.57; 95% CI, 1.34-1.84) and 67% higher likelihood in men (OR, 1.67; 95% CI, 1.44-1.95) of having CV-RF clustering, following basic adjustments. Low CRF was associated with a 3.6-fold higher likelihood in women (OR, 3.55; 95% CI, 2.08-6.06) and 7.7-fold higher likelihood in men (OR, 7.68; 95% CI, 4.03-14.61) for having CV-RF clustering compared with individuals with high CRF, following basic adjustments (Table 2, model 1). This association was independent of meeting or not meeting PA recommendations (model 2: OR, 3.56 [95% CI, 2.02-6.28] in women and OR, 7.19 [95% CI, 3.76-13.76] in men) and ST (model 3: OR, 3.44 [95% CI, 1.94-6.10] in women and OR, 6.62 [95% CI, 3.37-13.02] in men).

TABLE 2. Adjusted Odds Ratios for the Prevalence of Cardiovascular Risk Factor Clustering According to Objectively Measured Peak Oxygen Uptake and Sedentary Time in 495 Women and 379 Men Aged 70 to 77 Years[a]

	CV-RF clustering[b] (No. of patients)		Odds ratio (95% CI)		
Variable	No	Yes	Model 1[c]	Model 2[d]	Model 3[e]
VO_{2peak}					
Women					
>27.5 mL/kg/min	154	44	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
22.5-27.5 mL/kg/min	128	70	1.91 (1.22-3.00)	1.92 (1.20-3.06)	1.87 (1.17-2.99)
<22.5 mL/kg/min	50	49	3.55 (2.08-6.06)	3.56 (2.02-6.28)	3.44 (1.94-6.10)
Per MET decrease	332	163	1.57 (1.34-1.84)	1.60 (1.35-1.90)	1.59 (1.34-1.88)
Men					
>34.4 mL/kg/min	123	28	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
27.2-34.4 mL/kg/min	87	65	3.37 (1.98-5.74)	3.15 (1.84-5.39)	3.16 (1.85-5.42)
<27.2 mL/kg/min	29	47	7.68 (4.03-14.61)	7.19 (3.76-13.76)	6.62 (3.37-13.02)
Per MET decrease	239	140	1.67 (1.44-1.95)	1.65 (1.41-1.92)	1.63 (1.39-1.91)
Sedentary time					
Women					
<13.2 h/d	121	44	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
13.2-14.1 h/d	110	55	1.36 (0.84-2.20)	1.33 (0.82-2.15)	1.26 (0.77-2.08)
>14.1 h/d	101	64	1.72 (1.07-2.75)	1.64 (1.02-2.64)	1.38 (0.84-2.26)
Per hour increase	332	163	1.22 (1.02-1.45)	1.20 (1.00-1.42)	1.09 (0.91-1.31)
Men					
<13.6 h/d	88	39	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
13.6-14.6 h/d	82	44	1.23 (0.72-2.10)	1.30 (0.75-2.24)	1.23 (0.69-2.18)
>14.6 h/d	69	57	1.91 (1.14-3.23)	1.93 (1.14-3.27)	1.27 (0.71-2.25)
Per hour increase	239	140	1.27 (1.04-1.55)	1.27 (1.04-1.55)	1.07 (0.87-1.32)

[a]CV-RF = cardiovascular risk factor; HDL = high-density lipoprotein; MET = metabolic equivalent; VO_{2peak} = peak oxygen uptake.
[b]CV-RF clustering was defined as the presence of at least 3 of the following 5 risk factors: elevated waist circumference (≥80 cm in women and ≥94 cm in men); elevated triglyceride level (≥1.7 mmol/L) or drug treatment for dyslipidemia; reduced HDL cholesterol (<1.3 mmol/L in women and <1.0 mmol/L in men) or drug treatment for dyslipidemia; elevated blood pressure (systolic ≥130 mm Hg and/or diastolic ≥85 mm Hg) or drug treatment for hypertension; and elevated fasting glucose level (≥100 mg/dL; to convert to mmol/L, multiply by 0.0555) or drug treatment for diabetes.
[c]Adjusted for age, smoking status, and alcohol consumption.
[d]Adjusted for age, smoking status, alcohol consumption, and physical activity recommendations.
[e]For VO_{2peak}, adjusted for age, smoking status, alcohol consumption, physical activity recommendation, and sedentary time; for sedentary time, adjusted for age, smoking status, alcohol consumption, physical activity recommendations, and VO_{2peak}.

ST and CV-RF Clustering

Women and men categorized as having high ST (ie, the highest tertile) spent on average 14.6 h/d (range, 14.1-16.3 h/d) and 15.1 h/d (range, 14.6-16.9 h/d), respectively, in sedentary behavior. Corresponding values for those categorized as having moderate ST were 13.6 h/d (range, 13.2-14.1 h/d) for women and 14.1 h/d (range, 13.6-14.6 h/d) for men, whereas women and men with low ST (ie, the lowest tertile) spent 12.3 h/d (range, 8.7-13.2 h/d) and 12.7 h/d (range, 8.7-13.6 h/d), respectively, in sedentary behavior.

Each hour of ST was associated with 22% and 27% higher likelihood of having CV-RF clustering in women (OR, 1.22; 95% CI, 1.02-1.45) and men (OR, 1.27; 95% CI, 1.04-1.55), respectively, following basic adjustments. Individuals with high ST had a higher likelihood of having CV-RF clustering compared with individuals who had low ST. Women with high ST had 72% higher likelihood (OR, 1.72; 95% CI, 1.07-2.75) of having CV-RF clustering compared with the reference group. In men, there was a corresponding 91% higher likelihood (OR, 1.91; 95% CI, 1.14-3.23) of having CV-RF clustering associated with high ST (Table 2, model 1). This association was independent of meeting or not meeting PA recommendations (model 2: OR,

TABLE 3. Adjusted Odds Ratios for the Prevalence of Cardiovascular Risk Factor Clustering According to Combinations of Objectively Measured Sedentary Time and Cardiorespiratory Fitness in 495 Women and 379 Men Aged 70 to 77 Years[a]

	High CRF[b]			Moderate CRF[b]			Low CRF[b]		
	CV-RF clustering[c] (No. of patients)		Odds ratio[d]	CV-RF clustering[c] (No. of patients)		Odds ratio[d]	CV-RF clustering[c] (No. of patients)		Odds ratio[d]
Sedentary time	No	Yes	(95% CI)	No	Yes	(95% CI)	No	Yes	(95% CI)
Women									
<13.2 h/d	65	15	1.00 (Reference)	43	16	1.66 (0.73-3.76)	13	13	4.34 (1.62-11.59)
13.2-14.1 h/d	51	16	1.30 (0.59-2.90)	45	23	2.24 (1.03-4.86)	14	16	5.56 (2.14-14.44)
>14.1 h/d	38	13	1.55 (0.66-3.64)	40	31	3.37 (1.57-7.22)	23	20	3.89 (1.61-9.37)
Men									
<13.6 h/d	48	10	1.00 (Reference)	38	21	2.49 (1.03-6.00)	2	8	17.71 (3.19-98.21)
13.6-14.6 h/d	44	10	1.18 (0.45-3.15)	30	24	3.98 (1.63-9.94)	8	10	7.00 (2.10-23.37)
>14.6 h/d	31	8	1.22 (0.43-3.47)	19	20	5.03 (1.96-12.94)	19	29	7.41 (2.97-18.47)

[a]CRF = cardiorespiratory fitness; CV-RF = cardiovascular risk factor; HDL = high-density lipoprotein.
[b]CRF values were peak oxygen uptake <22.5 mL/kg/min for low, 22.5-27.5 mL/kg/min for moderate, and >27.5 mL/kg/min for high fitness levels in women and <27.2 mL/kg/min for low, 27.2-34.4 mL/kg/min for moderate, and >34.4 mL/kg/min for high fitness levels in men.
[c]CV-RF clustering was defined as the presence of at least 3 of the following 5 risk factors: elevated waist circumference (≥80 cm in women and ≥94 cm in men); elevated triglyceride level (≥1.7 mmol/L) or drug treatment for dyslipidemia; reduced HDL cholesterol (<1.3 mmol/L in women and <1.0 mmol/L in men) or drug treatment for dyslipidemia; elevated blood pressure (systolic ≥130 mm Hg and/or diastolic ≥85 mm Hg) or drug treatment for hypertension; and elevated fasting glucose level (≥100 mg/dL; to convert to mmol/L, multiply by 0.0555) or drug treatment for diabetes.
[d]Adjusted for age, smoking status, alcohol consumption, and physical activity recommendations.

1.64 [95% CI, 1.02-2.64] in women and OR, 1.93 [95% CI, 1.14-3.27] in men). Additional adjustment for CRF attenuated the detrimental effects of high ST on the likelihood of having CV-RF clustering, demonstrated by an OR of 1.38 (95% CI, 0.84-2.26) in women and 1.27 (95% CI, 0.71-2.25) in men for having CV-RF clustering associated with high ST compared with the reference group (model 3).

Modifying Effects of CRF

Table 3 presents the multiadjusted ORs for CV-RF clustering according to levels of ST and CRF. Among individuals with high CRF, ORs associated with high ST were not significant, independent of PA. Compared with the reference group with high CRF and low ST, women with high ST and high CRF had an adjusted OR of 1.55 (95% CI, 0.66-3.64). The corresponding OR for men was 1.22 (95% CI, 0.43-3.47).

Combined Modifying Effects of Meeting PA Recommendations and CRF

Fit women and men did not have a higher likelihood of CV-RF clustering associated with prolonged ST and/or not meeting PA recommendations compared with the reference group of high CRF, low ST, and meeting the PA recommendations (Table 4). Specifically, individuals with high ST but high CRF had an OR of 1.28 (95% CI, 0.49-3.30) when meeting PA recommendations and an OR of 1.70 (95% CI, 0.70-4.17) when not meeting PA recommendations compared with the reference group. Conversely, individuals with low CRF who met the PA recommendations had more than a 7-fold higher likelihood of having CV-RF clustering for moderate ST (OR, 7.14; 95% CI, 1.92-26.51) and high ST (OR, 7.13; 95% CI, 2.11-24.03).

DISCUSSION

The main finding of the current study is that high CRF attenuates the adverse effect of prolonged ST on the prevalence of CV-RF clustering among women and men 70 to 77 years old. This attenuation applies even to participants who do not meet the current recommendations for moderate to vigorous PA.

CRF and CV-RF Clustering

The strong and independent inverse association between high CRF and the prevalence of CV-RF clustering found in the current study extends previous research data in the general population[17-19] and in older adults.[25,26] In a previous study,[25] older adults aged 57 to 79 years had a

TABLE 4. Adjusted Odds Ratios for the Prevalence of Cardiovascular Risk Factor Clustering According to Objectively Measured Sedentary Time, Cardiorespiratory Fitness, and Physical Activity Recommendations in 495 Women and 379 Men Aged 70 to 77 Years[a]

	High CRF[b]			Moderate CRF[b]			Low CRF[b]		
	CV-RF clustering[c] (No. of patients		Odds ratio[d]	CV-RF clustering[c] (No. of patients)		Odds ratio[d]	CV-RF clustering[c] (No. of patients)		Odds ratio[d]
Variable	No	Yes	(95% CI)	No	Yes	(95% CI)	No	Yes	(95% CI)
Meeting physical activity recommendations									
Sedentary time[e]									
Low	63	13	1.00 (Reference)	23	9	1.86 (0.70-4.96)	3	3	NA[f]
Moderate	48	12	1.19 (0.50-2.85)	22	14	3.11 (1.26-7.69)	5	7	7.14 (1.92-26.51)
High	35	9	1.28 (0.49-3.30)	18	10	2.69 (1.00-7.20)	6	9	7.13 (2.11-24.03)
Not meeting physical activity recommendations									
Sedentary time[e]									
Low	50	12	1.13 (0.47-2.72)	58	28	2.34 (1.10-4.98)	12	18	7.39 (2.87-19.04)
Moderate	47	14	1.43 (0.61-3.34)	53	33	3.07 (1.46-6.46)	17	19	6.06 (2.46-14.96)
High	34	12	1.70 (0.70-4.17)	41	41	5.00 (2.38-10.50)	36	40	5.39 (2.53-11.48)

[a]CRF = cardiorespiratory fitness; CV-RF = cardiovascular risk factor; HDL = high-density lipoprotein; NA = not applicable.

[b]CRF values were <22.5 mL/kg/min for low, 22.5-27.5 mL/kg/min for moderate, and >27.5 mL/kg/min for high fitness levels in women and <27.2 mL/kg/min for low, 27.2-34.4 mL/kg/min for moderate, and >34.4 mL/kg/min for high fitness levels in men.

[c]Cardiovascular risk factor clustering was defined as the presence of at least 3 of the following 5 risk factors: elevated waist circumference (≥80 cm in women and ≥94 cm in men); elevated triglyceride level (≥1.7 mmol/L) or drug treatment for dyslipidemia; reduced HDL cholesterol (<1.3 mmol/L in women and <1.0 mmol/L in men) or drug treatment for dyslipidemia; elevated blood pressure (systolic ≥130 mm Hg and/or diastolic ≥85 mm Hg) or drug treatment for hypertension; and elevated fasting glucose level (≥100 mg/dL; to convert to mmol/L, multiply by 0.0555) or drug treatment for diabetes.

[d]Adjusted for age, sex, smoking status, and alcohol consumption.

[e]Tertiles of sedentary time with sex-specific cut points: low, <13.2 h/d in women and <13.6 h/d in men; moderate, 13.2-14.1 h/d in women and 13.6-14.6 h/d in men; and high, >14.1 h/d in women and >14.6 h/d in men.

[f]Not applicable due to low number of participants.

10-fold higher likelihood of metabolic syndrome associated with low CRF. This rate is higher than the 3.6-fold and 7.7-fold higher likelihood of having CV-RF clustering in women and men, respectively, observed in our study. However, in this study, we examined a more age-homogeneous group and also adjusted for ST and PA. This difference might explain the somewhat lower effect of CRF on the likelihood of CV-RF clustering observed in our study. Furthermore, every 1−metabolic equivalent (ie, 3.5 mL/kg per minute) decrement in VO_{2peak} corresponded to 57% and 67% higher likelihood of having CV-RF clustering in women and men, respectively. Hence, a moderate and realistically attainable increase in CRF could decrease the risk of CVD dramatically.

ST and CV-RF Clustering

The positive association between ST and the prevalence of CV-RF clustering found in this study is consistent with the findings of other studies in the general adult population[2-4,6] and in the elderly.[1,5] However, most previous studies have used self-reported measurements of sedentary behavior, which may be subject to a misclassification bias and tend to grossly underestimate ST.[7] In the current study, objectively measured daily ST accounted for as much as 75.0% and 77.8% of waking hours in women and men, respectively, and we identified detrimental associations between ST and CV-RF clustering in the largest examined sample of older women and men to date. Given the increasing number of older adults and the fact that older adults are the most sedentary age group, identifying modifying factors to counteract the adverse health outcomes of prolonged ST is therefore of high clinical importance.

The underlying mechanisms related to the deleterious effects of ST on cardiometabolic health are not completely understood.[14,40,41] In addition to sharing some common mechanisms of not being sufficiently physically active,[22] prolonged ST, which results in insufficient skeletal muscle contractions, could promote visceral or ectopic fat accumulation,[42] suppress lipoprotein lipase activity,[43] and affect the expression in numerous genes involved in glycemic control.[44] Nonetheless, future research elucidating underlying mechanisms associated with sedentary behavior is clearly warranted.

Modifying Effects of CRF

Our study found that high CRF attenuated the adverse association between high ST and the likelihood of having CV-RF clustering among older adults. The same finding has been reported previously in the general adult population (aged 47±14 and 46±9 years).[27,28] Together, these studies highlight the protective role of high CRF for the risk of CVD, and in our study, specifically among older women and men. This protective role was exemplified in our study by the 3.4-fold and 6.6-fold increased likelihood of having CV-RF clustering in women and men, respectively, with low CRF compared with those with high CRF. This association was independent of ST and whether participants were meeting PA recommendations.

Because of the cross-sectional design of our study, a causal relationship between increased CRF and decreased cardiovascular risk could not be documented. However, our data indicate that relatively small changes in CRF could have major effects on the prevalence of CV-RF clustering, at least in older adults with initially low CRF.

One of the main factors related to CRF is the level of PA, and most previous studies have reported that higher levels of PA per se are associated with lower risk of CVD in both women and men.[6,7,9,45] However, although the present and previous findings[5,27] reveal that meeting the PA recommendations cannot ameliorate the negative associations between ST and CV-RFs in older adults, we found that having high CRF can. This finding supports those of previous studies reporting that CRF is a more powerful predictor of all-cause mortality[10] and further highlights the potential protective role of high CRF for cardiovascular health in older adults.

Cardiorespiratory fitness is an integral reflection of overall cardiovascular health and function,[12] influenced by a genetic component[46] and habitual PA.[38] Our results indicate that the recommendations for PA should focus on activities that increase CRF, and future research should have a particular focus on behavioral strategies to increase CRF, the underlying mechanisms of CRF, and their subsequent effects on CVD risk reduction.

Strengths and Limitations

The use of gas exchange measurements and a test protocol performed until exhaustion to assess CRF, as well as objective measurements of ST and PA and detailed information on CV-RFs are the main strengths of this study. Although the use of accelerometers provides objective estimates of sedentary behavior, outcomes might differ based on methodology. The uniaxial 100 CPM cutoff used in the current and numerous other studies is an estimation of sedentary behavior because the ActiGraph GT3X+ accelerometer lacks postural assessment. Furthermore, the 1952-CPM cutoff used to assess moderate to vigorous PA is derived from healthy younger populations who are generally more fit and might therefore underestimate PA for populations of older adults. Furthermore, determinations of causality could not be made because of the cross-sectional study design.

A limitation of our study may be selection bias because the included participants reported better health and higher education than nonparticipants.[32] In addition, compared to US populations,[47] our participants appear to be more fit and active. However, the values for CRF in our study correspond well with those reported for individuals aged 70 years or older who did not have CVD by identical measurement methods in an independent Norwegian population (HUNT3 [Nord-Trøndelag Health Study 2006-2008]).[30]

Our study population was diverse and included both healthy individuals and those with comorbidities. Although our findings need to be confirmed in other populations of older adults, the benefits of high CRF for cardiovascular health are well documented.[12] Furthermore, a previous study including 12,274 men and 14,209 women aged 20 years or older reached conclusions similar to ours.[27] Thus, we consider it likely that the main findings of this study also apply to other populations with different activity and fitness profiles.

CONCLUSION

Our study results reveal that high age-specific CRF attenuates the adverse effect of prolonged ST on CV-RF clustering among older adults, independent of PA that meets the consensus recommendation. Our findings contribute to the mounting evidence of the benefits of high CRF for cardiovascular health and encourage implementation of strategies specifically aimed to improve CRF in older adults in future public health programs.

ACKNOWLEDGMENTS

The cardiopulmonary tests were performed at the core facility NeXt Move, Norwegian University of Science and Technology. We thank the Clinical Research Facility at St. Olavs Hospital for excellent assistance during the testing periods and all personnel for the contribution to the collection of data. We are also indebted to the participants of the Generation 100 study.

The funding organizations had no role in the design and execution of the study, in the collection, analyses, and interpretation of the data, or in the preparation, review, or approval of the submitted manuscript.

Abbreviations and Acronyms: **CPM** = counts per minute; **CRF** = cardiorespiratory fitness; **CVD** = cardiovascular disease; **CV-RF** = cardiovascular risk factor; **OR** = odds ratio; **PA** = physical activity; **ST** = sedentary time; **VO_{2peak}** = peak oxygen uptake

Grant Support: This study was funded by grants from the K. G. Jebsen Foundation, the Research Council of Norway, and the Liaison Committee between the Central Norway Regional Health Authority and the Norwegian University of Science and Technology.

Correspondence: Address to Ulrik Wisløff, PhD, K.G. Jebsen Center for Exercise in Medicine, Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Post Box 8905, Medisinsk Teknisk Forskningssenter, 7491 Trondheim, Norway (ulrik.wisloff@ntnu.no).

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