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Sedentary time is associated with the metabolic syndrome in older adults with mobility limitations — The LIFE Study

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Abstract

Background—Epidemiological and objective studies report an association between sedentary time and lower risk of the metabolic syndrome (MetS) and its risk factors in young and middle-age adults. To date, there is a lack of objective data on the association between sedentary time and MetS among older adults.

Methods—The association between objectively measured sedentary time (accelerometry) with MetS and MetS components was examined in a large sample of older adults with mobility limitations ($N = 1198$; mean age = 78.7 ± 5.3 years) enrolled in the Lifestyle Interventions and Independence for Elders (LIFE) study. Participants were divided into tertiles according to percentage of daily sedentary time, and the relation between sedentary time with MetS and MetS components was examined after adjusting for age, sex, ethnicity, and BMI.

Results—Participants in the highest sedentary time tertile had significantly higher odds of MetS (OR = 1.54) (95% CI 1.13 to 2.11) in comparison with participants in the lowest tertile ($p = 0.03$).

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Participants in the highest sedentary time tertile had larger waist circumference ($p = 0.0001$) and lower HDL-C ($p = 0.0003$) than participants in the lowest sedentary time tertile.

Conclusions—Sedentary time was strongly related to higher odds of MetS. These results, based on objectively measured sedentary time, suggest that sedentary time may represent an important risk factor for the development of MetS in older adults with high likelihood for disability.

Keywords

Aging; Accelerometry; Glucose; Disability; Waist circumference

1. Introduction

The metabolic syndrome (MetS) is a combination of interrelated risk factors of metabolic origin that has become more prevalent in an aging population. Over half (53%) of adults aged 60 years or older in the United States currently have MetS, whereas less than 20% of adults below the age of 40 have MetS (Ervin, 2009). This is of concern as MetS has been found to directly promote the development of cardiovascular disease (CVD) and type 2 diabetes mellitus (DM2) (Grundy et al., 2005). As older adults represent the fastest growing segment of the population (Shetty, 2012), improvement of clinical management and preventive strategies directed at MetS (Matthews et al., 2012) in this high risk population is crucial.

With increasing age, a larger percentage of adults live a sedentary lifestyle, as defined by not meeting minimum level of activity recommended in current guidelines. For example, the prevalence of sedentary time is ~39% in adults between 30 and 44 years, ~46% in adults between 45 and 59 years, and 60% in adults age 60 years and older (Troiano et al., 2008). Moreover, only a small percentage of older adults 60 years and older, 20% and 12% of older men and women respectively (Hallal et al., 2012), are meeting current physical activity guidelines (Kraschnewski et al., 2014; Brach et al., 2004).

Traditionally, it has been thought that individuals are protected from cardio-metabolic disease conditions if they meet recommended levels of physical activity, regardless of their activity levels throughout the remainder of the day (Churilla and Fitzhugh, 2009; Holme et al., 2007; Rennie et al., 2003). Recent studies have indicated, however, that meeting the nationally recommended levels of PA does not prevent cardio-metabolic disease if individuals engage in high levels of sedentary time throughout the day. For example, Matthews et al. found that meeting the recommended amounts of PA failed to mitigate cardio-metabolic health risks among American adults aged 50–71 years who reported television viewing for more than 7 h per day. Specifically, these individuals were found to have a 50% greater risk of all-cause mortality and a two-fold greater risk of cardiovascular disease compared to those who spent <1 h/day on television viewing after adjusting for moderate to vigorous PA (MVPA) (Matthews et al., 2012).

To our knowledge, only one study has examined the association of sedentary time with MetS, using objective measures (i.e., accelerometry) in middle age adults. In this cross-sectional study, which included 521 healthy middle-age Japanese participants, activity levels

were measured for 7 days, and the association between activity levels with MetS was evaluated (Kim et al., 2013). The key finding of this study was that sedentary time was independently associated with higher risk for MetS in middle-age adults (30–64 years), regardless of whether or not they engaged in recommended levels of physical activity (Kim et al., 2013).

The relative contribution that sedentary time, measured objectively, has in relation to the probability of MetS and associated MetS components in an older adult population is not currently known. Based on findings from epidemiological studies and recent clinical trials in middle-aged adults (Matthews et al., 2012; Kim et al., 2013), we hypothesized that more time spent being sedentary would be associated with a higher prevalence of MetS and MetS components in older adults with mobility limitations.

2. Methods

2.1. Participants

All participants volunteered to participate in a long-term lifestyle intervention study (minimum 24 months up to 42 months), the Lifestyle Interventions and Independence for Elders (LIFE) study, which tested whether a long-term structured physical activity program is more effective than a health education program (also referred to as a successful aging program) in lowering the likelihood for major disability. A total of 1635 sedentary men and women aged 70 to 89 years were recruited across eight clinical sites (Marsh et al., 2013). Participants were eligible to participate if they had physical limitations, defined as a score on the Short Physical Performance Battery (SPPB) (Guralnik et al., 1995) of 9 or below, but were able to walk 400 m. Detailed descriptions of participant characteristics, as well as inclusion and exclusion criteria, have previously been provided (Fielding et al., 2011). A key exclusion factor for the LIFE Study was self-reported activity, defined as spending less than 20 min/week in the past month getting regular physical activity and reporting less than 125 min/week of moderate PA (<125 min/week). The analytical sample for the present study included LIFE participants with validated baseline accelerometry and laboratory data.

2.2. Sedentary and physical activity monitoring

The Actigraph tri-axial accelerometer (Model GT3X; Actigraph Inc., Pensacola, FL) was used to objectively measure sedentary and physical activity time. Participants were asked to wear an accelerometer for 7 days immediately following their baseline clinic visit. During the 7-day monitoring period, participants were asked to put the monitor on each morning (after dressing) and remove the monitor just prior to going to bed at night. Sedentary time was recorded only during awake time, as participants did not wear accelerometers while sleeping. The monitor was removed for bathing, showering, or any other activity that might result in exposure to water. Activity was recorded using 1-second epochs, which were added up 60 s epochs (Choi et al., 2012). Non-wear time was defined as a 60-minute window of zero counts in all three axes, allowing for up to 2 min of non-zero counts (cts) <100 in the vertical axis. A cut point of <100 cts/min was used to designate sedentary time. The vast majority of studies have used a cut-point of <100 counts per min to designate sedentary time with additional checks during data cleaning to identify periods of no-wear time (Gorman et

al., 2014). For the data to be included in this study, participants had to wear the accelerometer during at least 3 consecutive days for 10 h per day in free-living conditions.

2.3. MetS classification

MetS was defined in accordance with the harmonized criteria recommended in the 2009 Joint Interim Statement from multiple scientific associations (Alberti et al., 2009), as the presence of 3 or more components, including (1) abdominal obesity (men: waist circumference ≥ 102 cm or women: waist circumference ≥ 88 cm); (2) hypertension (systolic blood pressure (SBP) ≥ 130 mm Hg and/or diastolic blood pressure (DBP) ≥ 85 mm Hg) or use of antihypertensive medication and a history of physician-diagnosed hypertension; (3) decreased HDL-C cholesterol level (men: HDL-C <40 mg/dL and women: <50 mg/dL) or use of HDL-C-raising medication; (4) elevated triglycerides levels (triglycerides ≥ 150 mg/dL) or use of triglyceride-lowering medication and (5) elevated plasma fasting blood glucose level (glucose ≥ 100 mg/dL) or use of glucose-controlling medication.

2.4. Baseline blood analysis

Blood samples for assessment of a lipid panel and fasting plasma glucose were collected in the early morning, after a 12-hour fast at the baseline assessment visit. Blood (57.5–69.5 ml) was collected via venipuncture into plain, serum-separation, EDTA-treated, heparin-treated, vacutainers by a trained phlebotomist. Baseline samples were sent to a central diagnostic testing laboratory for a lipid panel (triglycerides, total cholesterol, HDL-cholesterol, LDL-cholesterol (calculated) and fasting glucose levels. The baseline data were used to determine MetS and its components in the basis of the standardized criteria, stated above.

2.5. Statistical analyses

Demographic and clinical characteristics were summarized across sedentary time tertiles using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Means were compared across tertiles using one-way analysis of variance, and categorical proportions (including MetS and MetS components) across tertiles were compared using Wald chi-square tests from unadjusted logistic regression models. The odds of classification to MetS or MetS components by standardized sedentary time measures were estimated using logistic regression models adjusted for age, sex, and race/ethnicity. Next, models were repeated with additional adjustment for body mass index (BMI; kg/m^2). All analyses were performed using SAS v 9.3 (SAS Institute, Cary, NC). Statistical tests were performed assuming a Type I error rate of 0.05, and pairwise comparisons across tertiles were deemed significant at a Bonferroni-adjusted $p = 0.0167$ level.

3. Results

3.1. Baseline characteristics of participants

From the total of 1635 participants, 359 participants were excluded due to missing or insufficient accelerometry data and a further 78 participants lacked sufficient information for determining MetS status. The participants excluded from these analyses only differed from the study sample with respect to the Modified Mini-Mental State (3MS) scores (0–100

scale). Specifically, excluded participants had significantly lower 3MS scores (<80) than participants in our study sample (91.5 ± 5.5) (Pahor et al., 2014), which may have affected their ability to adhere to the accelerometry protocol. This led to a sample size of 1198 participants in the present study. The mean (\pm SD) age of included participants was 78.7 ± 5.3 years, 33.8% were men, and 23.0% were racial/ethnic minorities (nonwhite). Average BMI of the participants was 30.2 ± 6.0 kg/m². Participants were divided into tertiles of sedentary time based on mean percent daily sedentary time measured over valid wear days as follows: 74.2% lowest tertile, >74.2% but $\leq 81.1\%$ middle tertile, and $>81.1\%$ highest tertile. Table 1 displays characteristics of participants based on sedentary time levels.

3.2. Increased likelihood of MetS and MetS components according to tertiles of sedentary time

Older age in male participants was associated with increased sedentary time ($p < 0.0001$) (Table 1). Participants in the highest sedentary time tertile had a higher prevalence of MetS, approaching significance, ($p = 0.06$) compared to participants in the lowest tertile (Table 2) but did not differ from participants in the middle tertile.

Table 2 shows the prevalence of MetS and its components (plasma glucose levels, abdominal obesity, HDL-C, TG levels and higher blood pressure) among participants with MetS according to tertiles of sedentary time. The fasting glucose component (fasting glucose ≥ 100 mg/dL) of MetS was significantly higher among participants in the highest sedentary time tertile in comparison with participants the lowest sedentary time tertile ($p = 0.003$) but did not differ from participants in the middle tertile. No significant differences were found across tertiles for the following MetS components: abdominal obesity, HDL-C, triglycerides, and blood pressure.

Table 3 shows significantly higher overall odds of MetS ($p = 0.002$) and higher likelihood for abnormal plasma glucose levels ($p = 0.007$) among participants with higher amounts of sedentary time. Specifically, for each standard deviation increase in sedentary time, overall odds of MetS and plasma glucose were 22% and 19% higher, respectively. This logistic regression model was adjusted for sex, age, ethnicity, and BMI according to tertiles of sedentary time.

4. Discussion

The present investigation examined whether the amount of time spent in sedentary behavior in older adults with mobility limitations was related to MetS and its components. The major finding of our investigation was that higher amounts of sedentary time were associated with higher odds of MetS. In addition, we found that higher levels of sedentary time were related to higher prevalence of specific components of MetS, including plasma glucose levels and low HDL-C levels. We also found extremely high levels of sedentary time in this population based on objective accelerometry measurement. Specifically, participants spent approximately 11 h per day in sedentary activities. The time spent in sedentary pursuits ranged between 9 and 12 h per day for participants in the least sedentary versus most sedentary tertiles. Moreover, levels of sedentary time increased with age, and we also observed higher prevalence of MetS with increasing age.

In line with previous findings in teenagers and middle-age adults, (Kim et al., 2013; Hsu et al., 2011) we found that sedentary time was positively associated with occurrence of MetS among older adults with mobility limitations participating in the LIFE Study. Specifically, the present study found that participants with the highest odds of MetS spent approximately three more hours per day engaged in sedentary time than participants with the lowest odds (12 h versus 9 h of awake time). Our findings suggest that higher amounts of sedentary time may increase the probability of MetS, even among sedentary older adults. Thus, our findings add to the literature by demonstrating a strong positive association between sedentary time and likelihood of MetS in an older adult population with mobility limitations.

Our study extends the previous literature (Kim et al., 2013; Duvivier et al., 2013) by showing that there is also a strong positive association between sedentary time and plasma glucose levels in older adults with MetS, suggesting that high levels of sedentary time may independently impair regulation of glycemia across all adult populations. Compared to participants with lower levels of sedentary time, participants with higher levels of sedentary time were also observed to have lower levels of HDL-C and increased waist circumference, (Table 1) which have both been found to increase cardiometabolic dysfunction probability in older adults (Tehrani et al., 2013; Chase et al., 2014; Stamatakis et al., 2012). Our results are in accordance with an epidemiological study conducted by Kim et al, which measured activity levels objectively and reported that prevalence of dyslipidemia in a Japanese population was higher in a more sedentary group compared to a less sedentary group (>5.4 h/day versus <3.5 h/day of sedentary time) (Kim et al., 2013).

We report a higher percentage of sedentary time [~11 h of awake time] in this sample of older adults with mobility limitations than what has been reported in middle-age adults [~63% (~9 h/day) of awake time] (Craft et al., 2012). The participants in the current study were specifically recruited because they were not achieving current national recommendations for physical activity. An important strength of this study is the use of objective measurements to obtain estimates of sedentary time in a large study sample of older adults. Other objective studies investigating the impact of sedentary time on the association with MetS were based on self-report (Matthews et al., 2012; Gardiner et al., 2011) or used smaller study samples in younger and middle-aged adults (Kim et al., 2013; Craft et al., 2012). Our sample also consisted of older adults with a high prevalence of MetS components, allowing for a more comprehensive evaluation of the connection between sedentary time and likelihood of MetS (Kim et al., 2013).

The present findings are limited by the cross-sectional nature of our analyses. Another limitation is that sedentary time was measured during relatively brief time periods (i.e., 3–7 days). This may have led to an under- or overestimation of actual sedentary time of the participants and associations between sedentary time and physical activity in their daily life. However, given that MetS, sedentary behavior, and functional limitations are quite prevalent in older adults, our results are likely generalizable to most older adults. Finally, a sizable percentage (~22%) of participants were excluded due to lack of accelerometry data, and ~5% lacked sufficient information for determining MetS status.

5. Conclusion

In conclusion, the results from the present investigation indicate that older adults with mobility limitations spend a large proportion of their time engaged in sedentary behavior, and that time spent being sedentary was strongly related to higher likelihood of MetS. Our findings suggest that sedentary time represents an important risk factor for the development of MetS in older adults with mobility limitations, and thus deserves further investigation. Prospective studies are needed, however, to further investigate the effects that sedentary time has on likelihood of MetS in this population, as well as whether reducing sedentary time in older adults may lower probability of MetS.

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Table 1

Characteristics of the LIFE Study participants according to percentage of sedentary time.

	<u>Lowest tertile (n = 399)</u>	<u>Middle tertile (n = 400)</u>	<u>Highest tertile (n = 399)</u>	<u>p-Value across tertiles</u>
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	
Age (years)	77.47 ± 5.0^{b, c}	78.86 ± 5.5^{a, c}	79.92 ± 5.1	0.0001
Gender (men)	90 (22.6)^{b, c}	124 (31.0)^{a, c}	191 (47.9)	0.0001
Race (white)	291 (72.9)	312 (78.0)	319 (80.0)	0.66
BMI (kg/m ²)	29.90 ± 5.7	30.65 ± 6.0	30.26 ± 6.4	0.21
Waist circumference (cm)	99.56 ± 14.5^{b, c}	102.54 ± 15.4^{a, c}	104.41 ± 16.5	0.0001
Plasma glucose (mg/dL)	102.28 ± 21.3	103.73 ± 24.5	105.28 ± 24.7	0.20
HDL cholesterol (mg/dL)	63.81 ± 18.2^{b, c}	61.16 ± 16.4^{a, c}	58.67 ± 18.7	0.0003
Triglycerides (mg/dL)	118.9 ± 54.2	120.65 ± 50.9	126.27 ± 65.3	0.17

Percentage of sedentary time levels: 74.2% lowest tertile, >74.2% but 81.1% middle tertile, >81.1% highest tertile. % — percentage of the total number of participants. Superscripts mean significant difference between (a) the lowest tertile, (b) the middle tertile, and (c) the highest tertile.

Table 2

MetS and MetS components based on percentage of sedentary time tertiles among participants.

	<u>Lowest tertile (n = 399)</u>	<u>Middle tertile (n = 400)</u>	<u>Highest tertile (n = 399)</u>	<u>p-Value across tertiles</u>
	n (%)	n (%)	n (%)	
Metabolic syndrome	180 (45.1)	200 (50.0)	213 (53.4) ^a	0.06
MetS plasma glucose	176 (44.3)^c	198 (49.5)	224 (56.2)	0.003
MetS HDL cholesterol	82 (20.7)	76 (19.1)	100 (25.3)	0.09
MetS triglycerides	116 (29.2)	111 (28.0)	124 (31.5)	0.56
MetS abdominal obesity	287 (72.5)	299 (75.1)	289 (73.0)	0.61
MetS blood pressure	315 (79.0)	318 (79.5)	317 (79.5)	0.98

Categorical measures are reported as number (n) and percentage (%) of participants with MetS and MetS components according to sedentary time tertiles. Sedentary time levels: highest tertile: 74.2% lowest tertile, >74.2 but 81.1% middle tertile, >81.1% highest tertile. Superscripts mean significant difference between (a) the lowest tertile, (b) the middle tertile, and (c) the highest tertiles.

Table 3

Odds ratios of meeting MetS and MetS components per standard deviation change in percentage spent in sedentary time.

	Sedentary time With BMI adjustment		Sedentary time Without BMI adjustment	
	OR	95% CI	p-Value	p-Value
Overall MetS	1.22	(1.07, 1.39)	0.002	0.0002
Plasma glucose	1.19	(1.05, 1.34)	0.007	0.002
HDL-C cholesterol	1.15	(0.99, 1.34)	0.07	0.04
Triglycerides	1.10	(0.96, 1.26)	0.19	0.09
Waist circumference	1.06	(0.87, 1.30)	0.57	0.09
Blood pressure	1.06	(0.91, 1.22)	0.47	0.27

All models adjusted for age, sex, and race/eth. Additional adjustment for BMI was added where indicated. Odds ratio per standard deviation change in sedentary behavior measure. 1SD for % sedentary activity is 8.18%. CI — confidence interval.