Standing, Obesity, and Metabolic Syndrome: Findings From the Cooper Center Longitudinal Study

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Abstract

Objective: To examine the cross-sectional relationships between standing time, obesity, and metabolic syndrome alongside and independent of leisure-time physical activity (LTPA).

Participants and Methods: The primary study sample consisted of 7075 adult patients (aged 20-79 years) from Cooper Clinic (Dallas, Texas). In this cross-sectional study we assessed the associations between reported standing time and directly measured obesity (body mass index ≥30), elevated waist circumference (men: ≥102 cm; women: ≥88 cm), body fat percentage (men: ≥25%; women ≥30%), and metabolic syndrome (yes/no). In addition, the joint associations of standing and LTPA on each outcome were examined. Multivariable logistic regression adjusting for confounders was used for statistical analyses.

Results: Standing a quarter of the time or more was significantly associated with reduced odds of an elevated body fat percentage in men ($P<.001$) and a reduced likelihood of obesity ($P<.009$) and abdominal obesity ($P=.04$) in women. In addition, joint association analyses indicated that compared with the reference group (ie, not meeting the physical activity guidelines/standing almost none of the time), men and women who met the physical activity guidelines had lower odds of all obesity outcomes and metabolic syndrome with incremental additions of standing time (ie, a dose-response relationship).

Conclusion: Standing a quarter of the time per day or more is associated with reduced odds of obesity. The inverse relationship of standing to obesity and metabolic syndrome is more robust when combined with health-promoting LTPA. Prospective studies are warranted to confirm these findings and establish a causal relationship.

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During the past several decades, there has been a major reduction in daily energy expenditure in developed and developing countries as a result of physical activity being "engineered" out of our lives through increased use of motorized transportation and a sedentary lifestyle at home and at work.[1] Recent analyses of US national time use data in women, for example, found a 25% increase in screen-based media use replacing light- to moderate-intensity household work.[2,3] Similarly, a study by Ng and Popkin[4] observed a decrease in total physical activity in the United States from 235 metabolic equivalent (MET) hours per week in 1965 to 160 MET hours per week in 2009 stemming from reduced occupational, domestic, and transportation-related physical activity; they projected additional decreases in activity through 2030. This decline in overall physical activity levels coupled with increased sedentary time (7.7 hours daily in the United States) and an abundance of available food has resulted in the high prevalence of obesity today.[5,6] Indeed, in 2011-2012, almost 35% of US adults were obese, which is a major independent risk factor for numerous chronic diseases (eg, type 2 diabetes, coronary heart disease, and some cancers) and premature death.[7]

Recent studies have specifically explored the effects of sedentary behavior (activities in a sitting or reclining posture requiring expending 1.0-1.5 times the resting metabolic rate) on obesity and other health outcomes, independent of physical activity.[8-11] Prolonged sedentary time has been linked to obesity and other chronic diseases and to mortality from all causes and from cardiovascular disease.[10] Thus, recent tools and interventions have specifically focused on assessing

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TABLE 1. Characteristics of the 7075 Study Participants by Standing Time Stratified by Sex: The Cooper Center Longitudinal Study 2010-2014

	Men (n=4923) Standing time[a]					Women (n=2152) Standing time[a]				
Characteristic	Almost none of the time (n=1360)	1/4 of the time (n=2923)	1/2 of the time (n=442)	≥3/4 of the time (n=198)	*P* value	Almost none of the time (n=398)	1/4 of the time (n=1002)	1/2 of the time (n=390)	≥3/4 of the time (n=362)	*P* value
Age (y), mean ± SD	49.2±9.3	51.0±9.7	51.1±10.3	50.4±12.0	.12	46.5±9.9	49.2±10.2	49.0±11.3	49.4±11.1	<.001
Physical activity guidelines (No. [%])[b]										
Not meeting	399 (29.3)	902 (30.9)	146 (33.0)	68 (34.3)		158 (39.7)	361 (36.0)	127 (32.6)	105 (29.0)	
Meeting	961 (70.7)	2021 (69.1)	296 (67.0)	130 (65.7)	.07	240 (60.3)	641 (64.0)	263 (67.4)	257 (71.0)	.001
Current smoker (No. (%])										
No	1241 (91.3)	2595 (88.8)	384 (86.9)	167 (84.3)		387 (97.2)	967 (96.5)	375 (96.2)	346 (95.6)	
Yes	119 (8.8)	328 (11.2)	58 (13.1)	31 (15.7)	<.001	11 (2.8)	35 (3.5)	15 (3.9)	16 (4.4)	.21
Obese (No. [%])[c]	342 (25.2)	651 (22.3)	113 (25.6)	42 (21.2)	.22	66 (16.6)	114 (11.4)	21 (5.4)	28 (7.7)	<.001
Elevated waist circumference (No. [%])[c]	299 (22.0)	597 (20.4)	98 (22.2)	38 (19.2)	.43	85 (21.4)	157 (15.7)	50 (12.8)	38 (10.5)	<.001
Elevated body fat percentage (No. [%])[c]	241 (34.0)	387 (26.0)	48 (22.5)	23 (25.8)	<.001	64 (31.1)	126 (25.5)	46 (22.0)	41 (22.2)	.02
Metabolic syndrome (No. [%])[d]	293 (21.5)	648 (22.2)	95 (21.5)	38 (19.2)	.89	40 (10.1)	74 (7.4)	27 (6.9)	20 (5.5)	.02

[a]Standing was based on responses to the following survey question: "For those activities that you do most days of the week (such as work, school, and housework), how much time do you spend standing? Almost all of the time; approximately three-quarters of the time; approximately half of the time; approximately one-quarter of the time; almost none of the time." For analysis, the categories "almost all of the time" and "about three-quarters of the time" were combined.

[b]Physical activity was based on responses to a survey gauging the frequency, duration, and intensity of leisure-time physical activities; resultant metabolic equivalent (MET) minutes per week were divided into the following 2 categories based on the US Department of Health and Human Services Physical Activity Guidelines: (1) not meeting the guidelines (<500 METs) and (2) meeting/exceeding the guidelines (≥500 METs).

[c]Obese was defined as a body mass index of at least 30; elevated waist circumference, at least 102 cm for men and at least 88 cm for women; and elevated body fat percentage (n=2502 for men; n=1094 for women), at least 25% for men and at least 30% for women.

[d]Metabolic syndrome was defined as meeting at least 3 of the following criteria: (1) an elevated waist circumference (≥102 cm for men or ≥88 cm for women), (2) an elevated level of triglycerides (≥150 mg/dL [to convert to mmol/L, multiply by 0.0113]), (3) a personal history of hypertension or measured blood pressure of at least 130 mm Hg systolic or at least 85 mm Hg diastolic, (4) a personal history of diabetes or a fasting glucose level of at least 100 mg/dL (to convert to mmol/L, multiply by 0.0555), and (5) an abnormal high-density lipoprotein cholesterol level less than 40 mg/dL (to convert to mmol/L, multiply by 0.0259) for men or less than 50 mg/dL (to convert to mmol/L, multiply by 0.0259) or women.

TABLE 2. Associations Between Standing Time and Obesity and Metabolic Syndrome: Logistic Regression[a,b]

Characteristic	Participants (No. ([%])	Standing time (OR [95%CI])[c]				Linear trend *P* value
		Almost none of the time (reference group)	1/4 of the time	1/2 of the time	≥ 3/4 of the time	
Men						
Obese[d]	1148 (23.3)	1.0	0.82 (0.70-0.96)	0.99 (0.76-1.27)	0.69 (0.47-1.01)	.43
Elevated waist circumference[d]	1032 (21.0)	1.0	0.84 (0.72-1.00)	0.93 (0.71-1.22)	0.71 (0.48-1.05)	.49
Elevated body fat percentage[d]	699 (27.9)	1.0	0.62 (0.50-0.76)	0.51 (0.36-0.74)	0.61 (0.36-1.03)	<.001
Metabolic syndrome[e]	1074 (21.8)	1.0	0.98 (0.83-1.15)	0.92 (0.70-1.19)	0.78 (0.53-1.15)	.78
Women						
Obese[d]	229 (10.6)	1.0	0.68 (0.48-0.96)	0.30 (0.18-0.52)	0.47 (0.29-0.77)	.009
Elevated waist circumference[d]	330 (15.3)	1.0	0.65 (0.48-0.89)	0.53 (0.35-0.79)	0.43 (0.28-0.66)	.04
Elevated body fat percentage[d]	277 (25.3)	1.0	0.74 (0.51-1.07)	0.63 (0.40-0.99)	0.64 (0.40-1.03)	.14
Metabolic syndrome[d]	161 (7.5)	1.0	0.62 (0.41-0.95)	0.59 (0.35-0.99)	0.47 (0.27-0.84)	.09

[a]OR = odds ratio.
[b]Multivariable models adjusted for age, current smoking status, and meeting vs not meeting the physical activity guidelines based on reported leisure-time activity. For the obesity measures (body mass index, waist circumference, and body fat percentage), models were further adjusted for personal history of diabetes and hypertension.
[c]Standing was based on responses to the following survey question: "For those activities that you do most days of the week (such as work, school, and housework), how much time do you spend standing? Almost all of the time; approximately three-quarters of the time; approximately half of the time; approximately one-quarter of the time; almost none of the time." For analysis, the categories "almost all of the time" and "approximately three-quarters of the time" were combined.
[d]Obese was defined as a body mass index of at least 30; elevated waist circumference, at least 102 cm for men and at least 88 cm for women; and elevated body fat (n=2502 for men; n=1094 for women), at least 25% for men and at least 30% for women.
[e]Metabolic syndrome was defined as meeting at least 3 of the following criteria: (1) elevated waist circumference (≥102 cm for men or ≥88 cm for women), (2) an elevated level of triglycerides (≥150 mg/dL [to convert to mmol/L, multiply by 0.0113]), (3) a personal history of hypertension or measured blood pressure of at least 130 mm Hg systolic or at least 85 mm Hg diastolic, (4) a personal history of diabetes or a fasting glucose level of at least 100 mg/dL (to convert to mmol/L, multiply by 0.0555), and (5) an abnormal high-density lipoprotein cholesterol level less than 40 mg/dL (to convert to mmol/L, multiply by 0.0259) for men or less than 50 mg/dL (to convert to mmol/L, multiply by 0.0259) or women.

and reducing sedentary time by encouraging increased standing and moving activities,[12] such as through the use of sit-stand desks in schools and workplaces.[13] Although evidence pertaining to the health benefits of breaking up sitting time by replacing it with light- to moderate-intensity physical activity is accumulating,[14] few studies have specifically explored whether standing is related to obesity and cardiometabolic risk. Hence, in the present study, we sought to bridge this gap in the literature by assessing the cross-sectional relationships between standing and obesity and metabolic syndrome (MetS) in adult men and women.

METHODS

Participants and Design

Study participants consisted of adults (aged 20-79 years) attending Cooper Clinic (Dallas, Texas) for a preventive medicine visit who enrolled in the Cooper Center Longitudinal Study (CCLS) and provided written informed consent. The CCLS is reviewed and approved annually by The Cooper Institute Institutional Review Board. The CCLS, previously described,[15] is an ongoing prospective investigation established in 1970 that aims primarily to explore the effects of physical activity and fitness on morbidity and mortality risk.[8] For the present study, we examined the cross-sectional relationships between reported standing (independent variable) and objectively measured obesity outcomes—body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared), waist circumference, and body fat percentage—while also considering the protective effects of leisure-time physical activity (LTPA). An additional clinical outcome was MetS, a clustering of cardiometabolic risk factors related to increased risk of cardiovascular morbidity.[16]

For the present investigation, we included patients enrolled in the CCLS starting in 2010, because questions pertaining to standing patterns were not included in the medical history before that year. A total of 7718 CCLS participants (aged 20-79 years) who presented to Cooper Clinic from June 16, 2010, through April 2, 2015, who had complete information on the primary exposures and outcomes (BMI, waist circumference, and MetS) and who did not have a personal history of myocardial infarction,

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stroke, or cancer were considered for inclusion. Of these, 643 participants were excluded due to abnormal electrocardiographic findings, inability to complete maximal exercise testing, or being underweight (BMI <18.5), all potentially indicative of an underlying medical condition. This resulted in a primary analytic sample of 7075 participants who were primarily white (88.9%) and college educated (85.6%). However, the analytic sample for body fat percentage was smaller (n=3596) due to the necessity of skinfold measurements.

Primary Measures

Standing. Participants' standing patterns were ascertained from responses to survey questions derived from the Canada Fitness Survey Questionnaire,[17] which asked participants about their typical standing behavior performed on most days of the week.[18] Specifically, participants were asked, "For those activities that you do most days of the week (such as work, school, and housework), how much time do you spend standing? Almost all of the time; approximately three-quarters of the time; approximately half of the time; approximately one-quarter of the time; almost none of the time."[17,18] Because the number of participants selecting 'almost all of the time' was relatively small compared with the other categories, the responses "three-quarters of the time" and "almost all of the time" were combined (ie, three quarters of the time or more).

Leisure-Time Physical Activity. Physical activity was determined based on responses to survey questions pertaining to LTPA. Specifically, participants were asked to indicate the frequency and duration they engaged in the following activities: walking, running, using a treadmill, swimming, stationary cycling, cycling, using an elliptical, aerobics (dance), racket sports, vigorous sports, or other leisure activities.[19] The METs for each activity type were derived from the Compendium of Physical Activities[20] and then were multiplied by the frequency and duration of the activity.[21] These MET values ($MET \cdot min \cdot wk^{-1}$) were then dichotomized into categories that reflect meeting ($\geq$500 $MET \cdot min \cdot wk^{-1}$) or not meeting (<500 $MET \cdot min \cdot wk^{-1}$) the guidelines for moderate- or vigorous-intensity aerobic physical activity.[21,22]

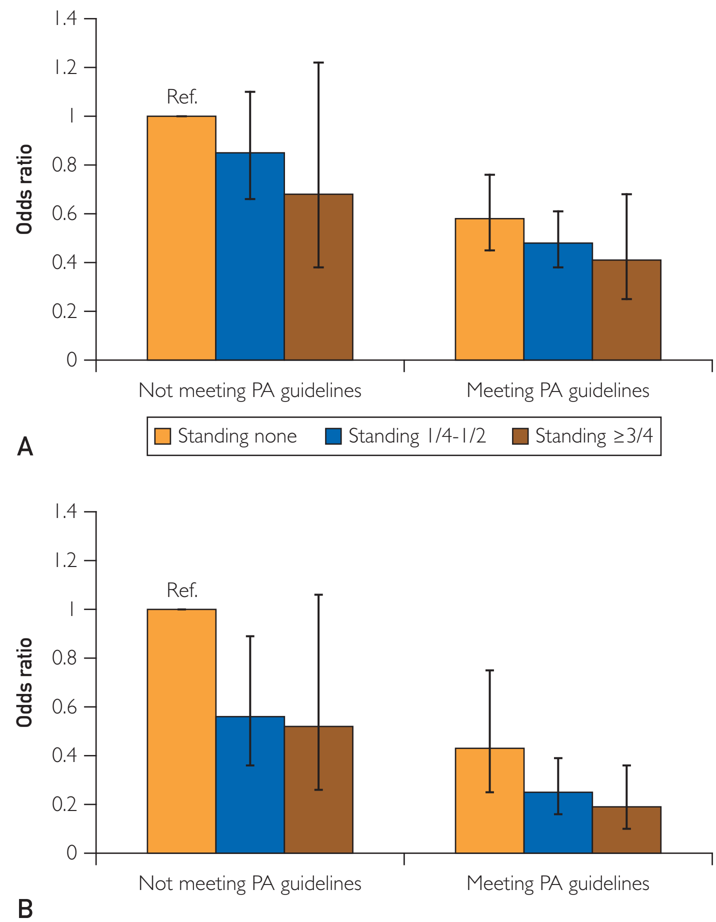

FIGURE 1. Joint associations of standing and leisure-time physical activity with obesity in men (A) and women (B). Joint association multivariable models were adjusted for age, current smoking status, and personal history of diabetes and hypertension. Standing was based on responses to the following survey question: "For those activities that you do most days of the week (such as work, school, and housework), how much time do you spend standing?" For joint analyses, categories consisted of almost none of the time, approximately one-quarter to half of the time, and at least three-quarters of the time. Physical activity was based on responses to a survey gauging the frequency, duration, and intensity of leisure-time physical activities; resultant metabolic equivalent (MET) minutes per week were divided into the following 2 categories based on the US Department of Health and Human Services Physical Activity Guidelines: (1) not meeting the guidelines (<500 $MET \cdot min \cdot wk^{-1}$) and (2) meeting/exceeding the guidelines ($\geq$500 $MET \cdot min \cdot wk^{-1}$). Obesity was defined as a body mass index of at least 30. Error bars represent 95% CIs; crossing an odds ratio of 1 is indicative of a nonsignificant association (P<.05). PA = physical activity; Ref. = reference category (not meeting the physical activity guidelines and standing almost none of the time).

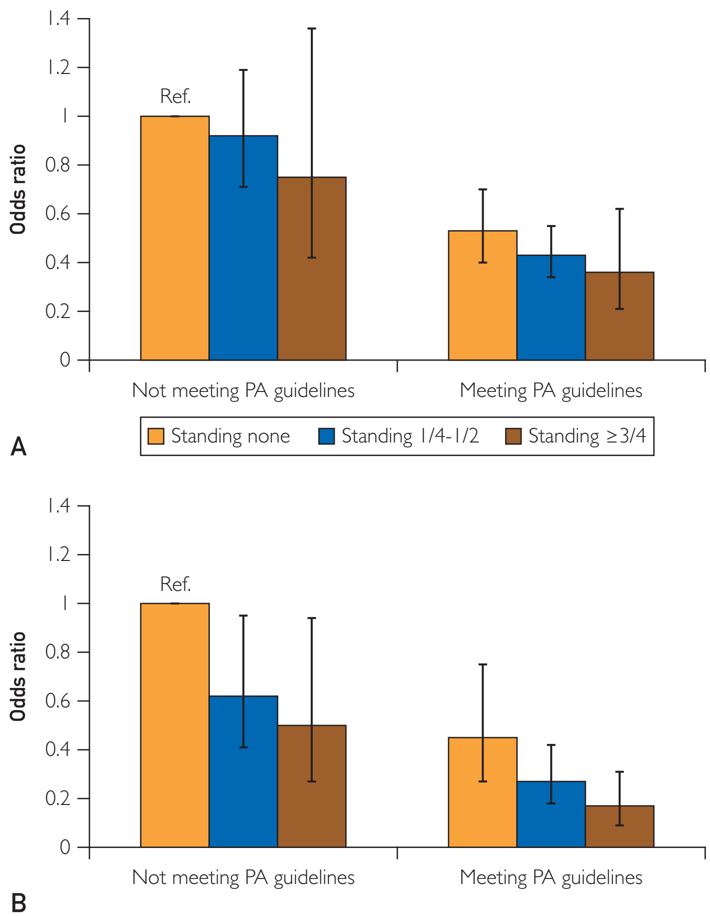

FIGURE 2. Joint associations of standing and leisure time physical activity with elevated waist circumference in men (A) and women (B). For descriptions of joint associations, standing, and physical activity, see the legend to Figure 1. Elevated waist circumference was defined as at least 102 cm for men and at least 88 cm for women. Error bars represent 95% CIs; crossing an odds ratio of 1 is indicative of a nonsignificant association (P<.05). PA = physical activity; Ref. = reference category (not meeting the physical activity guidelines and standing almost none of the time).

Obesity Measures and MetS. The outcome measures consisted of 3 adiposity measures and MetS. These measures were assessed by trained staff during a clinic visit at Cooper Clinic, as previously described.[8,23] Specifically, the adiposity measures examined were BMI of 30 or greater, elevated waist circumference (≥102 cm for men or ≥88 cm for women), and elevated body fat percentage (≥25% for men or ≥30% for women).[16,24,25] In addition, MetS was defined as meeting at least 3 of the following criteria: (1) an elevated waist circumference (≥102 cm for men or ≥88 cm for women), (2) an elevated level of triglycerides (≥150 mg/dL [to convert to mmol/L, multiply by 0.0113]), (3) a personal history of hypertension or measured blood pressure of at least 130 mm Hg systolic or at least 85 mm Hg diastolic, (4) a personal history of diabetes or a fasting glucose level of 100 mg/dL or greater (to convert to mmol/L, multiply by 0.0555), and (5) an abnormal high-density lipoprotein cholesterol level (<40 mg/dL for men or <50 mg/dL for women [to convert to mmol/L, multiply by 0.0259]).[8,16,23,26]

Statistical Analyses

Descriptive and analytic statistics were used to depict participants' characteristics by categories of standing time stratified by sex because the standing × sex interaction in relation to the outcomes was statistically significant (P<.05 for all models). In addition, we constructed multivariable logistic regression models to determine the relation between standing and each outcome stratified by sex while adjusting for age, current smoking (yes/no), and LTPA (meeting vs not meeting the Physical Activity Guidelines for Americans). For the obesity outcomes (BMI, waist circumference, and body fat percentage), the models were further adjusted for personal history of diabetes and hypertension because these could confound the relationships between standing and obesity outcomes. Moreover, the joint associations of standing and LTPA with each outcome measure were examined using logistic regression while adjusting for confounders. SAS software, version 9.4 (SAS Institute Inc) was used to perform the statistical analyses, and statistical significance was set at P<.05 and 2-sided.

RESULTS

Participants were primarily men (69.6%) and had a mean ± SD age of 50.0±10.1 years. In addition, 19.5% of participants were obese (ie, BMI ≥30), 19.3% had an elevated waist circumference, and 27.1% had an elevated body fat percentage. Also, 19.7% of participants reported standing half of the time or more, and only 32.0% did not meet the physical activity guidelines. The bivariate associations between standing and outcome measures and covariates stratified by sex are presented in Table 1. Briefly, more standing was significantly (linear trend P<.001) and inversely associated with 1 outcome measure—elevated body fat percentage—in men. In comparison, in women, more standing was significantly and inversely related to all obesity measures and MetS (linear trend $P<.05$ for all).

The multivariable relationships between standing and the outcome measures are shown in Table 2. Analyses revealed that in men, increased standing was significantly associated with a lower likelihood of elevated body fat percentage (linear trend $P<.001$); however, relationships with the other outcomes were primarily nonsignificant. In comparison, in women, when examining the linear trend between standing and outcomes, more standing was significantly and inversely related to obesity (as defined by BMI: linear trend $P=.009$) and an elevated waist circumference (linear trend $P=.04$). In women, when examining standing categorically in relation to the outcomes, standing a quarter, half, or at least three-quarters of the time was associated with reduced odds of obesity and an elevated waist circumference as well as MetS compared with the reference group (ie, standing almost none of the time). For example, standing half and at least three-quarters of the time was related to 41% and 53% reduced odds of MetS, respectively (half: OR=0.59 [95% CI, 0.35-0.99]; at least three-quarters: OR=0.47 [95% CI, 0.27-0.84]).

In addition, we examined the joint associations of standing (almost none of the time, a quarter to half of the time, and three-quarters of the time or more) and LTPA (meeting the guidelines vs not meeting the guidelines) in relation to the obesity measures and MetS in men and women (Figures 1-4). Multivariable analysis results reveal that compared with the reference group (ie, not meeting the physical activity guidelines/standing almost none of time), men and women who met the physical activity guidelines had lower odds of obesity and MetS with incremental additions of standing time. Specifically, a dose-response relationship was observed between more standing time and lower odds of obesity and MetS in those meeting the physical activity guidelines. For example, men who met the physical activity guidelines and mostly did not stand during the day had a 47% reduced likelihood of abdominal obesity (elevated waist circumference), whereas those standing one-quarter to half of the time had a 57% reduced odds, and those standing at least three-quarters of the time had a 64% reduced odds (OR=0.53 [95% CI, 0.40-0.70], OR=0.43 [95% CI, 0.34-0.55], OR=0.36 [95% CI, 0.21-0.62], respectively).

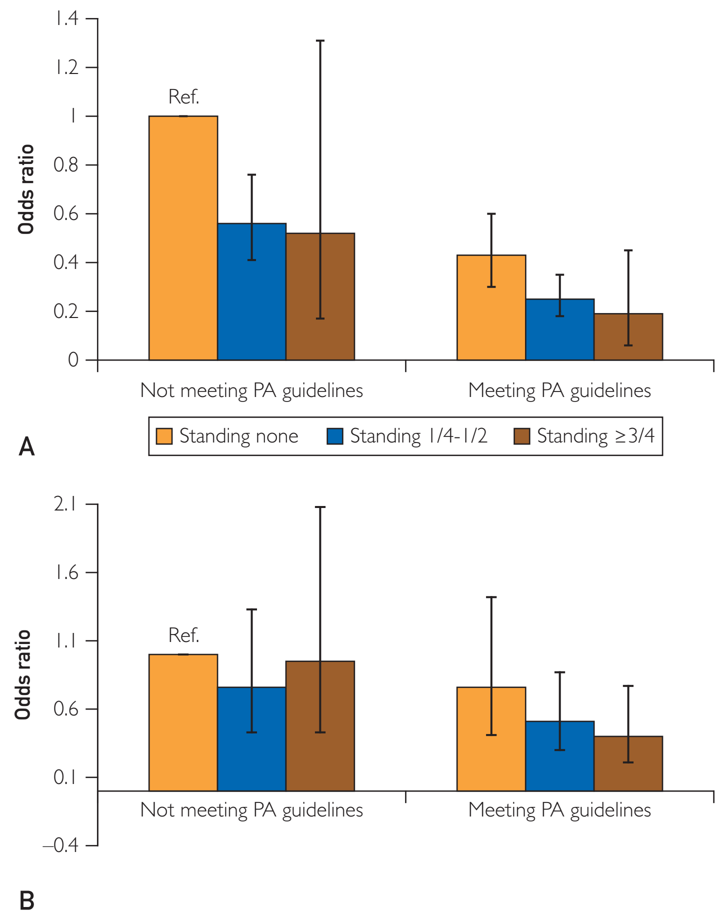

FIGURE 3. Joint associations of standing and leisure-time physical activity with elevated body fat percentage in men (A) and women (B). For descriptions of joint associations, standing, and physical activity, see the legend to Figure 1. Elevated body fat (n=2502 for men; n=1094 for women) was defined as at least 25% for men and at least 30% for women. Error bars represent 95% CIs; crossing an odds ratio of 1 is indicative of a nonsignificant association ($P<.05$). PA = physical activity; Ref. = reference category (not meeting the physical activity guidelines and standing almost none of the time).

DISCUSSION

Scant research has examined the relationship between standing and cardiometabolic risk; therefore, the present study aimed to determine whether standing is related to an increased likelihood of obesity and MetS while also considering the protective effects of meeting the physical activity guidelines. Findings indicate that increased standing (ie, beyond a quarter

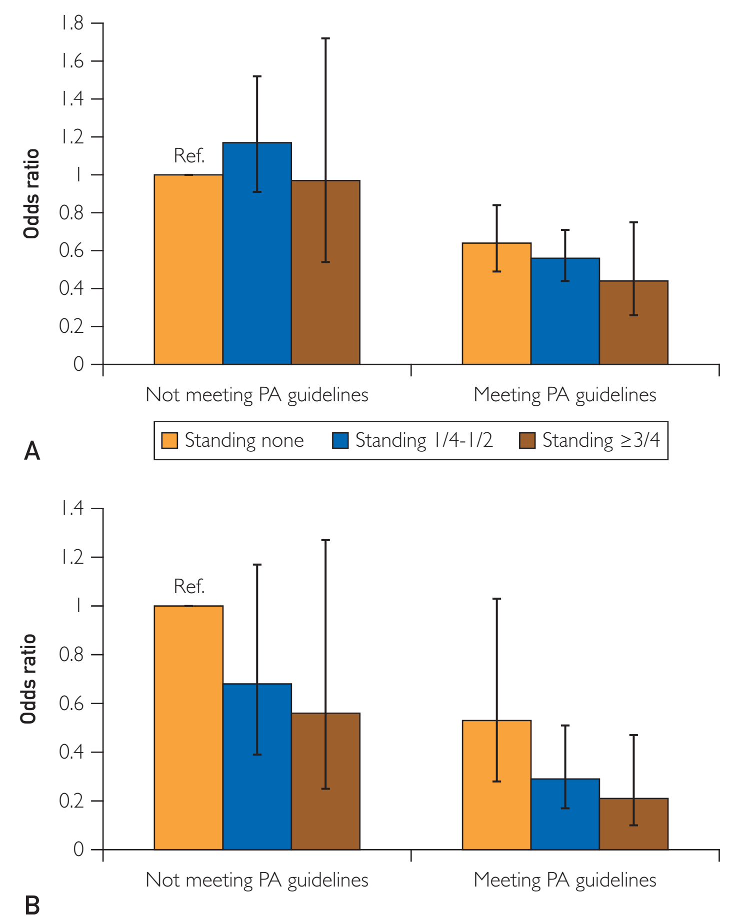

FIGURE 4. Joint associations of standing and leisure-time physical activity with metabolic syndrome in men (A) and women (B). For descriptions of joint associations, standing, and physical activity, see the legend to Figure 1. Metabolic syndrome was defined as meeting at least 3 of the following criteria: (1) an elevated waist circumference (≥102 cm for men or ≥88 cm for women), (2) an elevated level of triglycerides (≥150 mg/dL [to convert to mmol/L, multiply by 0.0113]), (3) a personal history of hypertension or measured blood pressure of at least 130 mm Hg systolic or at least 85 mm Hg diastolic, (4) a personal history of diabetes or a fasting glucose level of at least 100 mg/dL (to convert to mmol/L, multiply by 0.0555), and (5) an abnormal high-density lipoprotein cholesterol level less than 40 mg/dL (to convert to mmol/L, multiply by 0.0259) for men or less than 50 mg/dL (to convert to mmol/L, multiply by 0.0259) or women. Error bars represent 95% CIs; crossing an odds ratio of 1 is indicative of a nonsignificant association ($P<.05$). PA = physical activity; Ref. = reference category (not meeting the physical activity guidelines and standing almost none of the time).

of the time) is related to reduced odds of obesity based on a variety of adiposity measures. Importantly, a dose-response relationship between standing, obesity, and MetS was observed in men and women meeting the physical activity guidelines. That is, more standing seems to provide incremental benefits against cardiometabolic risk in individuals who are sufficiently physically active. However, caution should be taken when interpreting these findings given that these data are cross sectional and temporality cannot be established. Thus, these data prohibit the ability to conclude whether more standing reduces the risk of obesity and MetS or whether being obese or having MetS leads to less standing. Therefore, although the present findings contribute importantly to the dearth of evidence on the topic, prospective studies are clearly warranted to assess whether a cause-effect relationship exists between standing and cardiometabolic risk.

Hence, although cross-sectional and longitudinal studies have found a dose-response relationship between higher physical activity levels and lower cardiometabolic risk,[22] no studies, to our knowledge, have examined the effects of both LTPA and standing on obesity and MetS. The present findings demonstrate a dose-response relationship between more standing and a reduced likelihood of obesity and MetS when combined with health-promoting LTPA. For example, in women meeting the physical activity guidelines, those who mostly did not stand had a 57% reduced likelihood of obesity, whereas those who stood a quarter to half of the time reduced their odds by 75%, and those who stood three-quarters of the time or more reduced their odds even further to 81%. This finding is most likely due to the fact that most physical activities are initiated with the standing posture, thereby promoting increased total energy expenditure throughout the day.[27] Thus, although standing quietly without much movement requires an energy expenditure similar to sitting quietly (both 1.3 METs), standing and moving necessitates higher energy expenditure (1.8 METs).[20] There is evidence to suggest that moving activities resulting in light-intensity activities (eg, walking around the office) are linked to decreased insulin resistance and other health benefits.[14,28-30] Thus, the present results are likely due to standing and moving activities, which increase total energy expenditure throughout the day compared with standing still.[27] This supposition, however, cannot be substantiated without more precise measurement of the exposure because we assessed standing with a survey question that examined overall standing, which did not differentiate between simply standing

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and standing while engaging in movement (eg, ambulation).

To date, there is insufficient evidence specifically focusing on the public health and medical implications of increasing daily standing time as a potential tool for health promotion. In a recent study, Katzmarzyk[18] prospectively assessed the effects of standing at baseline on mortality in a sample of more than 16,000 Canadians. He observed significant incremental reductions in all-cause and cardiovascular disease mortality (33% and 25%, respectively) for standing almost all of the day.[18] Although 47.1% of the adult men and women in Katzmarzyk's study stood half of the time or more,[18] only 19.7% of the present study sample stood at least half of the time. This is likely due to the fact that standing was assessed 34 years ago in the study by Katzmarzyk, whereas standing was determined more recently (2010-2015) in the present study, possibly a result of the secular changes in occupation and household-related activity noted previously. In addition, a pilot program that examined the efficacy of using standing desks on caloric expenditure in schoolchildren found that students using the sit-stand desks had a 17% increased caloric expenditure compared with the control group not using this equipment.[31] Furthermore, a pilot work site intervention examining the effects of sit-stand workstations observed a slight increase in high-density lipoprotein cholesterol levels in the intervention group; however, no effect on anthropometrics or other biomarkers was found.[32] Neuhaus et al,[13] in a systematic review, concluded that although "activity-permissive workstations" are feasible and do not adversely impact work productively, their effects on adiposity and other health outcomes are inconclusive. Thus, the present findings pertaining to potential protective health effects of increased standing contribute to the literature on the topic. Nevertheless, studies have also found adverse effects to increased standing, such as psychological and muscle fatigue as well as increased risk of varicose veins.[33,34] However, intermittent standing has actually been found to lessen fatigue and musculoskeletal discomfort.[29]

The present study has several strengths and limitations. Its strengths include the timeliness of the research question: sit-stand desks are becoming pervasive without sufficient evidence on the health benefits of increasing standing during the day. In addition, the study used 3 adiposity measures based on objective measurements (rather than self-report) and MetS. However, the standing and LTPA measures were based on self-report, which might result in either overreporting or underreporting of these behaviors. An additional limitation (as previously mentioned) is the cross-sectional study design, which prohibits determining temporality; thus, further prospective studies are needed. Also of note is that dietary intake, an important contributor to obesity risk, was not adjusted for in the multivariable analysis due to insufficient data in this sample. Finally, the study sample was homogenous in terms of demographic characteristics (eg, mostly white and college educated); thus, future studies in more diverse samples are needed to generalize these findings.

CONCLUSION

The results of the present study indicate that standing more than a quarter of the time is related to reduced odds of elevated adiposity. Furthermore, findings from the joint association analyses underscore the potential protective health benefits from meeting the physical activity guidelines and increasing standing time. Thus, clinicians and public health practitioners should consider encouraging patients to achieve the physical activity guidelines and increase standing time for chronic disease prevention. However, study findings should be substantiated by future well-designed randomized controlled trials to conclusively determine a causal relationship between standing time and cardiometabolic risk.

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Abbreviations and Acronyms: **BMI** = body mass index; **CCLS** = Cooper Center Longitudinal Study; **LTPA** = leisure-time physical activity; **MET** = metabolic equivalent; **MetS** = metabolic syndrome; **PA** = physical activity; **Ref.** = reference category

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