Objective Measured Sedentary Time and Cardiometabolic Biomarkers in US Hispanic/Latino Adults

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL)

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Background—Sedentary behavior is recognized as a distinct construct from lack of moderate-vigorous physical activity and is associated with deleterious health outcomes. Previous studies have primarily relied on self-reported data, whereas data on the relationship between objectively measured sedentary time and cardiometabolic biomarkers are sparse, especially among US Hispanics/Latinos.

Methods and Results—We examined associations of objectively measured sedentary time (via Actical accelerometers for 7 days) and multiple cardiometabolic biomarkers among 12,083 participants, aged 18 to 74 years, from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL). Hispanics/Latinos of diverse backgrounds (Central American, Cuban, Dominican, Mexican, Puerto Rican, and South American) were recruited from 4 US cities between 2008 and 2011. Sedentary time (<100 counts/min) was standardized to 16 hours/d of wear time. The mean sedentary time was 11.9 hours/d (74% of accelerometer wear time). After adjustment for moderate-vigorous physical activity and confounding variables, prolonged sedentary time was associated with decreased high-density lipoprotein cholesterol ($P=0.04$), and increased triglycerides, 2-hour glucose, fasting insulin, and homeostatic model assessment of insulin resistance (all $P<0.0001$). These associations were generally consistent across age, sex, Hispanic/Latino backgrounds, and physical activity levels. Even among individuals meeting physical activity guidelines, sedentary time was detrimentally associated with several cardiometabolic biomarkers (diastolic blood pressure, high-density lipoprotein cholesterol, fasting and 2-hour glucose, fasting insulin and homeostatic model assessment of insulin resistance; all $P<0.05$).

Conclusions—Our large population-based, objectively derived data showed deleterious associations between sedentary time and cardiometabolic biomarkers, independent of physical activity, in US Hispanics/Latinos. Our findings emphasize the importance of reducing sedentary behavior for the prevention of cardiometabolic diseases, even in those who meet physical activity recommendations. (Circulation. 2015;132:1560–1569. DOI: 10.1161/CIRCULATIONAHA.115.016938.)

Key Words: cardiovascular diseases ■ epidemiology ■ Hispanic Americans ■ risk factors ■ sedentary lifestyle

Sedentary behavior, characterized as sitting or reclining with the energy expenditure between 1.0 and 1.5 metabolic equivalents, is recognized as a distinct construct that is qualitatively different from lack of physical activity.1 Recently, a systematic review and meta-analysis demonstrated that prolonged sedentary time is significantly associated with an increased risk of type 2 diabetes mellitus, cardiovascular disease, cancer, and mortality, independent of physical activity.2 Several studies have investigated the relationships between sedentary behavior and cardiometabolic biomarkers.3–5 However, these previous studies are largely based on self-reported sedentary time and physical activity data.

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behavior rather than objective measurements may underesti-
mate the magnitude of the relationships between sedentari-
ness and cardiometabolic risk factors. Nevertheless, most
existing studies of objectively measured sedentary behavior
and cardiometabolic risk are limited by small sample size and
are largely restricted to non-Hispanic white populations. Data
from the largest analysis to date of objectively measured
sedentary time and cardiometabolic biomarkers (US National
Health and Nutrition Examination Survey [NHANES]: full
sample, n=4757; fasting subsample, n=2118), representing
mostly non-Hispanic whites (74%), indicated some significant
racial/ethnic differences, and associations of sedentary time
with some cardiometabolic biomarkers remains unclear in
Mexican Americans and non-Hispanic blacks. Thus, studies
on sedentary behavior and cardiometabolic risk factors need
to expand beyond predominantly white populations.

Cardiovascular disease is the major cause of death among
US Hispanics/Latinos who are also disproportionately affected
by obesity and related cardiometabolic conditions. However,
the relationship between objectively measured sedentary time
and cardiometabolic risk in this population has only been
examined in Mexican Americans, and the results remain
unclear, possibly because of the relatively small sample size.
Moreover, whether associations between sedentary time and
cardiometabolic biomarkers are different among Hispanic/
Latino background groups has not been investigated. In the
current study, therefore, we aimed to examine associations
between objectively measured sedentary time and multiple
cardiometabolic biomarkers in participants from the Hispanic
Community Health Study/Study of Latinos (HCHS/SOL), a
large population sample of Hispanic/Latino adults of diverse
backgrounds in the United States.

Methods

Study Population
The HCHS/SOL is a prospective population-based study of 16,415
Hispanic/Latino adults aged 18 to 74 years at recruitment living in 4
US metropolitan areas (Bronx, NY; Chicago, IL; Miami, FL; and San
Diego, CA). Participants were recruited by using a 2-stage probability
sample design, as described previously. A comprehensive battery
of interviews relating to personal and family characteristics, health
status and behaviors, and a clinical assessment with blood draw
were conducted at in-person clinic baseline visit during 2008 to 2011.
A total of up to 12,083 participants with complete data on cardiomet-
abolic biomarkers were included in the current analysis after exclusion
of 3,665 (22%) who were not adherent to the accelerometer protocol.
Also excluded from all analyses were 119 (1%) with accelerometer
wear time in excess of 23 hours per day; those without a fasting blood
sample (n=188) or complete medication data (n=251); and those with
body mass index (BMI) of <18.5 (n=109). The study was approved
by the institutional review boards at all participating institutions, and
all participants gave written informed consent.

Assessment of Physical Activity and Sedentary
Behavior
At the HCHS/SOL baseline examination, participants were instructed
to wear an Actical version B-1 (model 198-0200-03; Respironics Co.
Inc., Bend, OR) accelerometer for 7 days, positioned above the iliac
crest, with removal only for swimming, showering, and sleeping.
Previous studies have shown the Actical to have acceptable techni-
cal reliability for counts and steps. The Actical was programmed
to capture accelerations in counts in 1-minute epochs based on the
convention used in previous studies. Nonwear time was deter-
mined using the Choi algorithm; defined as at least 90 consecutive
minutes of zero counts, with allowance of 1 or 2 minutes of nonzero
counts if no counts were detected in a 30-minute window upstream
and downstream of the 90-minute period. An adherent day was defined
as at least 10 hours of wear time, and at least 3 adherent days were
required for inclusion in this analysis. In the current analysis, 89%
of participants had at least 1 adherent weekend day. Accelerometer
counts were used to classify sedentary behavior (<100 counts/min)
and moderate to vigorous physical activity (MVPA) (≥1535 counts/
min). Detailed information on accelerometer performance and adher-
ence has been described elsewhere.

Assessment of Cardiometabolic Biomarkers
Participants were asked to fast and refrain from smoking in the morn-
ing before the HCHS/SOL clinic visit. Following a 5-minute rest
period, 3 seated blood pressure measurements were obtained with an
automatic sphygmomanometer; the second and third readings were
averaged. Measurements of total cholesterol, high-density lipoprotein
(HDL) cholesterol, low-density lipoprotein cholesterol, triglycerides,
fasting and 2-hour glucose have been described previously. Fasting
insulin was measured by using 2 commercial immunoas-
says (ELISA, Merckodia AB, Uppsala, Sweden; and sandwich immu-
noassay on a Roche Elecsys 2010 Analyzer, Roche Diagnostics,
Indianapolis, IN); early measures conducted with the Merckodia assay
were calibrated, and values were equivalent to the Roche method.
Homeostatic model assessment of insulin resistance (HOMA-IR) was
computed by using the following equation: fasting glucose × fasting
insulin/405.21. High-sensitivity C-reactive protein (CRP) was mea-
sured by using an immunoturbidimetric method (Roche Diagnostics).

Assessment of Covariates
Height, waist circumference, and hip circumference were measured to
the nearest centimeter and weight to the nearest 0.1 kg. Body mass
index (BMI) was calculated as weight in kilograms divided by height
in meters squared. Waist-to-hip ratio was calculated as waist cir-
mference divided by hip circumference. Interviewer-administered
questionnaires were used to collect information on age, sex, annual
household income, educational attainment, Hispanic/Latino back-
ground, employment status, health insurance status, cigarette use
history, alcohol consumption, self-reported health, and number of
doctor visits in the past 12 months. Participants were instructed to
bring all prescription and nonprescription medications taken in the
past 4 weeks; their preparations, concentrations, and units were coded
for analysis. The alternative healthy eating index-2010 was calcu-
lated based on two 24-hour dietary recalls using the National Cancer
Institute methodology.

Statistical Analysis
All results were estimated by using sampling weights to account for
nonresponse and oversampling of specific population subgroups.
Weights were trimmed and calibrated to 2010 US Census charac-
teristics by age, sex, and Hispanic/Latino background in each field
center’s target population, in accordance with procedures com-
monly used in large population-based studies. Despite favorable
accelerometer compliance in comparison with previous studies, we
additional adjusted for missing or incomplete accelerometer
data (n=3665, 22%) using inverse probability weighting. In brief,
an inverse probability weighting weight was created from a logistic
regression model predicting Actical compliance based on age, sex,
income level, marital status, education, employment status, language
preference, immigrant generation, self-reported physical activity
from the World Health Organization Global Physical Activity
Questionnaire, BMI, aggregate self-reported physical health score,
field center by Hispanic/Latino background cross-classification,
sampling stratum, and sampling weight. Because some participants
(n=917, 5.6%) also had sporadic missing data for ≥1 covariates in
the inverse probability weighting model, the missing covariates
were first imputed by multiple imputation. Finally, the weight used in the
analyses of accelerometer-measured sedentary time in relation to cardiometabolic markers was the product of the inverse probability weighting (to weight the results for the compliant subset back to the whole CHHS/SOL sample) and the CHHS/SOL sampling weight (to further weight the results back to the Hispanic/Latino population in the target areas). Unweighted analyses and data management were performed by using SAS software version 9.3 (SAS Institute, Cary, NC). Weighted analyses were conducted with survey regression procedures, which properly accounted for the 2-stage stratified sampling and clustering of participants within sampling units, using SUDAAN release 11.0.1 (RTI International, Research Triangle Park, NC).

Because of a high correlation between sedentary time and wear time ($r=0.83$), we standardized sedentary time to 16 hours of wear time per day (the approximate average of both daily wear time and waking time in our study) using the residual from regressing sedentary time on wear time.\textsuperscript{13,31} First, we regressed measured sedentary time against accelerometer wear time, field center, and the interaction between wear time and field center using weighted linear regression, and calculated residuals to represent the observed minus predicted sedentary time. We then summed each participant's residue sedentary time value with the field center–specific mean predicted sedentary time given a mean wear time of 16 hours/d.

Age-adjusted descriptive characteristics across sedentary time quartiles were computed for continuous variables as predicted marginals of the mean from survey linear regression, and for categorical variables as predicted marginals of the prevalence from survey logistic regression.\textsuperscript{32} A series of survey linear regression models were constructed with cardiometabolic markers as the dependent variables and quartiles of sedentary time as the independent variables. Quartiles of sedentary time were modeled to better portray the nature of the relationship with outcomes and avoid assuming a linear association. Triglycerides, fasting insulin, HOMA-IR, and CRP variables were natural log-transformed before analysis. We adjusted for several sociodemographic, behavioral, and health-related potential confounders, including medications specific to each marker (anti-hypertensive medications for blood pressure; lipid-lowering drugs for blood lipids; and antidiabetic medications for glycemic traits). Subsequent models further adjusted for time spent in minutes/d of MVPA, BMI, and waist-to-hip ratio. MVPA was dichotomized for stratified analyses according to the 2008 Physical Activity Guidelines for Americans,\textsuperscript{34} which recommend at least 150 minutes/wk moderate-intensity activity, 75 minutes/wk vigorous-intensity activity, or $\geq$150 minutes/wk for a combination of the 2 (multiplying vigorous by 2 and summing). Additional stratified models were created across Hispanic/Latino background groups, age groups, sex, BMI categories, and field centers.

Results

Participant Characteristics

After standardizing to a 16-hour waking day, the estimated mean time spent in sedentary behavior was 11.9 hours/d, accounting for 74% of accelerometer wear time. Participant characteristics according quartiles of sedentary time are shown in Table 1. Individuals in quartiles characterized by greater sedentary time were less likely to meet the US physical activity guidelines than their lower sedentary time quartile counterparts, and were more likely to be residing in the Bronx, of Dominican or Puerto Rican background, and not currently employed. After adjusting for age, more sedentary time was also associated with poorer diet and self-reported health, and more healthcare and medication use.

Sedentary Time and Cardiometabolic Biomarkers

As shown in Table 2, more time spent sedentary was associated with decreased HDL cholesterol and increased diastolic blood pressure, triglycerides, 2-hour glucose, fasting insulin, HOMA-IR, and CRP after multivariable adjustment (all $P$ for trend $<0.0001$). After further adjustment for MVPA, the associations were attenuated, although still significant for HDL cholesterol ($P=0.04$), triglycerides ($P<0.0001$), 2-hour glucose ($P<0.0001$), fasting insulin ($P<0.0001$), and HOMA-IR ($P<0.0001$). After further adjustment for BMI and waist-to-hip ratio, the relationships remained significant with respect to triglycerides, 2-hour glucose, fasting insulin, and HOMA-IR (all $P$ for trend $<0.0001$). After excluding participants with antihypertensive medications, lipid-lowering drugs, or antidiabetic medications, and excluding those reporting a previous diagnosis of coronary heart disease and stroke,\textsuperscript{25} sensitivity analyses showed similar results with respect to all cardiometabolic biomarkers. In addition, sensitivity analyses among participants who contributed at least 1 adherent weekend day to the calculation of average daily sedentary time also yielded similar results (data not shown).

Stratification by Physical Activity

The deleterious associations between sedentary time and cardiometabolic biomarkers were similar among those meeting or not 2008 US physical activity guidelines (Figure 1). Of note, even among those meeting the 2008 physical activity guidelines, sedentary time was significantly associated with increased fasting glucose ($P$ for trend=$0.02$), 2-hour glucose ($P$ for trend=$0.003$), HOMA-IR ($P$ for trend $<0.001$) and fasting insulin (data not shown, very similar to HOMA-IR; $P$ for trend=$0.001$), and decreased HDL cholesterol ($P$ for trend=$0.014$). In analyses further adjusted for MVPA differences within strata, neither the magnitude nor the significance of the effect of sedentary behavior was meaningfully altered (data not shown).

Stratifications by Hispanic/Latino Background and Other Variables

Sedentary time varied by Hispanic/Latino background groups, ranging from 11.5 hours/d among individuals of Mexican background, to 12.5 hours/d among those of Dominican background. Associations between sedentary time and cardiometabolic biomarkers were, in general, consistent across Hispanic/Latino background groups. However, there was possible heterogeneity in the association between sedentary time and 2-hour glucose ($P$ for interaction $=0.001$), driven mainly by a lack of association in those of Dominican background.

Stratification analyses where sedentary time was treated as a continuous variable indicate generally consistent associations with cardiometabolic biomarkers across subgroups defined by sex, age, BMI, and field center (Table I in the...
### Table 1. Age-Adjusted Characteristics of Hispanic/Latino Individuals by Quartiles of Sedentary Time, HCHS/SOL 2008 to 2011

<table>
<thead>
<tr>
<th>Quartile of Sedentary Time</th>
<th>Quartile 1 (n=3020)</th>
<th>Quartile 2 (n=3021)</th>
<th>Quartile 3 (n=3021)</th>
<th>Quartile 4 (n=3021)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary hours/d, median (range)*</td>
<td>9.9 (0.8–10.9)</td>
<td>11.6 (10.9–12.1)</td>
<td>12.6 (12.1–13.1)</td>
<td>13.7 (13.1–16.0)</td>
<td>n/a</td>
</tr>
<tr>
<td>MVPA minutes/d, mean (95% CI)*</td>
<td>43 (40–46)</td>
<td>24 (23–26)</td>
<td>18 (17–20)</td>
<td>13 (12–14)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2008 US physical activity guidelines, n (%)*</td>
<td>1088 (33)</td>
<td>1722 (54)</td>
<td>2089 (65)</td>
<td>2528 (79)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Demographic characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean (95% CI)</td>
<td>39 (38–40)</td>
<td>40 (39–41)</td>
<td>41 (40–42)</td>
<td>45 (44–46)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sex, % (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Females</td>
<td>42 (39–45)</td>
<td>54 (51–57)</td>
<td>59 (57–62)</td>
<td>54 (51–57)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Males</td>
<td>58 (55–61)</td>
<td>46 (43–49)</td>
<td>41 (38–43)</td>
<td>46 (43–49)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Annual household income, % (95% CI)</td>
<td>41 (38–45)</td>
<td>40 (37–43)</td>
<td>41 (38–44)</td>
<td>45 (42–49)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>&lt;$20,000 or less</td>
<td>42 (39–45)</td>
<td>37 (35–40)</td>
<td>35 (32–38)</td>
<td>34 (30–37)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>$20,001–$50,000</td>
<td>10 (8–12)</td>
<td>14 (11–16)</td>
<td>14 (12–17)</td>
<td>10 (8–13)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>&gt;$50,000</td>
<td>7 (5–8)</td>
<td>9 (8–11)</td>
<td>11 (9–12)</td>
<td>11 (9–13)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Education level, % (95% CI)</td>
<td>20 (17–24)</td>
<td>22 (19–25)</td>
<td>28 (24–32)</td>
<td>46 (42–51)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>&lt;9th grade</td>
<td>21 (19–24)</td>
<td>17 (15–19)</td>
<td>15 (14–17)</td>
<td>17 (15–19)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Some high school</td>
<td>14 (13–17)</td>
<td>15 (13–17)</td>
<td>14 (12–17)</td>
<td>16 (14–19)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>High school graduate/equivalent</td>
<td>30 (28–32)</td>
<td>26 (23–28)</td>
<td>27 (25–30)</td>
<td>28 (25–32)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>More than high school</td>
<td>34 (31–37)</td>
<td>43 (40–45)</td>
<td>43 (40–46)</td>
<td>39 (36–43)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Field center, % (95% CI)</td>
<td>20 (17–24)</td>
<td>22 (19–25)</td>
<td>28 (24–32)</td>
<td>46 (42–51)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Bronx</td>
<td>21 (18–24)</td>
<td>16 (13–18)</td>
<td>13 (11–16)</td>
<td>13 (11–15)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chicago</td>
<td>29 (24–34)</td>
<td>32 (28–38)</td>
<td>33 (28–38)</td>
<td>27 (22–32)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Miami</td>
<td>30 (26–35)</td>
<td>30 (27–34)</td>
<td>26 (22–31)</td>
<td>14 (12–18)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>South American</td>
<td>6 (4–8)</td>
<td>7 (5–8)</td>
<td>10 (8–12)</td>
<td>19 (15–23)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dominican</td>
<td>8 (6–9)</td>
<td>7 (6–9)</td>
<td>7 (6–9)</td>
<td>8 (7–10)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Central American</td>
<td>18 (15–22)</td>
<td>22 (18–26)</td>
<td>23 (19–28)</td>
<td>19 (16–23)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cuban</td>
<td>49 (45–54)</td>
<td>41 (37–45)</td>
<td>34 (30–38)</td>
<td>24 (21–27)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mexican</td>
<td>12 (9–14)</td>
<td>14 (12–17)</td>
<td>17 (14–20)</td>
<td>21 (18–23)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Puerto Rican</td>
<td>4 (3–5)</td>
<td>6 (4–7)</td>
<td>6 (5–7)</td>
<td>5 (4–6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>South American</td>
<td>3 (2–5)</td>
<td>4 (3–5)</td>
<td>3 (2–5)</td>
<td>5 (3–7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Other/more than one</td>
<td>3 (2–4)</td>
<td>5 (4–6)</td>
<td>8 (7–10)</td>
<td>16 (15–19)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Employment status, % (95% CI)</td>
<td>25 (23–28)</td>
<td>40 (37–43)</td>
<td>48 (45–51)</td>
<td>51 (48–54)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Retired and not currently employed</td>
<td>21 (19–23)</td>
<td>20 (18–22)</td>
<td>16 (14–18)</td>
<td>11 (9–13)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Not retired and not currently employed</td>
<td>51 (48–54)</td>
<td>35 (33–38)</td>
<td>28 (25–30)</td>
<td>22 (19–24)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Health insurance, % (95% CI)</td>
<td>44 (41–47)</td>
<td>48 (45–51)</td>
<td>53 (49–56)</td>
<td>57 (54–61)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Waist-to-hip ratio (WHR), mean (95% CI)</td>
<td>0.92 (0.92–0.93)</td>
<td>0.92 (0.91–0.92)</td>
<td>0.91 (0.91–0.91)</td>
<td>0.92 (0.92–0.92)</td>
<td>0.1427</td>
</tr>
<tr>
<td>Body mass index (BMI) category, % (95% CI)</td>
<td>23 (21–26)</td>
<td>22 (19–24)</td>
<td>25 (22–28)</td>
<td>20 (18–23)</td>
<td>0.0009</td>
</tr>
<tr>
<td>&lt; 25</td>
<td>40 (37–43)</td>
<td>39 (37–42)</td>
<td>37 (34–40)</td>
<td>34 (31–38)</td>
<td>0.0009</td>
</tr>
<tr>
<td>25–30</td>
<td>37 (34–39)</td>
<td>39 (37–42)</td>
<td>38 (35–41)</td>
<td>45 (42–49)</td>
<td>0.0009</td>
</tr>
</tbody>
</table>

(Continued)
online-only Data Supplement). Significant interactions were only observed for diastolic blood pressure ($P$ for interaction with age, 0.013), 2-hour glucose ($P$ for interaction with field center, 0.016), and CRP ($P$ for interaction with BMI, 0.003). Results were qualitatively similar in stratification analyses using quartiles of sedentary time (data not shown).

## Discussion

Our findings are, in general, consistent with previous studies with objectively measured data showing that sedentary time was strongly associated with triglycerides and indices of insulin resistance, but not related to blood pressure or cholesterol levels. We also confirmed a strong association between sedentary behavior and 2-hour plasma glucose, which was not observed in the NHANES probably owing to a relatively small subsample of participants with oral glucose tolerance test data. Interestingly, the associations with insulin resistance and 2-hour plasma glucose are consistent with a recent meta-analysis showing the largest and most persistent effect of sedentary behavior on health outcomes is risk of type 2 diabetes mellitus. This is in line with potential mechanisms to explain the association. Specifically, decreased skeletal muscle contractions from prolonged sedentary time may reduce the uptake of plasma triglycerides and free fatty acid into skeletal muscle through suppression of lipoprotein lipase activity, and also reduce plasma glucose uptake through blunted translocation of GLUT4 glucose transporters. Finally, we did not observe an association between sedentary behavior and CRP levels; previous studies on this association have been largely inconsistent.

Two unique contributions of our study in comparison with most previous work are the use of accelerometer-measured sedentary time and the diverse Hispanic/Latino backgrounds of our sample. Self-reported sedentary time has previously been reported to be associated with obesity, glucose tolerance, diabetes mellitus, and hypertension in Hispanics/Latinos. However, the relationships between objectively measured sedentary time and cardiometabolic risk factors in US Hispanics have been examined only among Mexican Americans from the NHANES, where a relatively small sample size may have obscured associations. The associations have not previously been investigated in other Hispanic/Latino groups. Sedentary time varied by Hispanic/Latino background groups and accounted for a larger percentage of accelerometer wear time (74%) in the present study than in previous work in the NHANES that described the sedentariness of white, black, and Mexican American adults. In general, even though sedentary time and levels of some cardiometabolic biomarkers (eg, triglycerides) differed among Hispanic/Latino background groups, our data show consistent detrimental associations between sedentary time and cardiometabolic biomarkers across these groups. We also showed little evidence of effect modification by other characteristics such as age or BMI, with a few nominally statistically significant tests for interaction likely reflecting chance findings.

Another important contribution of this study comes from analyses stratified by physical activity. Stratification rather than adjustment is helpful to minimize residual confounding because physical activity is strongly related to sedentary behavior and cardiometabolic risk factors. Our results indicate
that the associations between sedentary behavior and several cardiometabolic risk factors persist even among those with high levels of MVPA. Owing to the limited sample size in previous studies with objectively measured sedentary time, analyses stratified by physical activity level have not previously been performed. Our findings are consistent with at least 1 previous study that showed self-reported television viewing time positively associated with metabolic risk factors in healthy Australian adults who met physical activity guidelines. Several studies have also suggested that sedentary behavior is associated with health outcomes at both low and high levels of physical activity, although more research is needed because the number of available studies remains limited. Taken together, our findings emphasize the public health priority of reducing sedentary behavior for the prevention of cardiometabolic diseases, even among those who meet physical activity guidelines.

To the best of our knowledge, this is the largest study to date with sedentary behavior and physical activity measured by using accelerometers. This is also the first study investigating relationships between sedentary behavior and cardiometabolic risk factors in a large representative population sample of US Hispanics/Latinos of diverse national backgrounds across a wide age range. Additional strengths of the study are the adjustment for noncompliance with device wear protocols, thorough reporting of accelerometer data handling/methodological decisions, multiple measures of cardiometabolic risk factors including 2-hour glucose levels from a large oral glucose tolerance test data set, and careful adjustment for potential confounding factors.

Objective measurement is more accurate and may reduce biases of self-report, but some limitations of accelerometer-derived measures need to be acknowledged. Our measures

### Table 2. Adjusted Means of Cardiometabolic Biomarkers by Quartiles Of Sedentary Time

<table>
<thead>
<tr>
<th></th>
<th>Systolic blood pressure, mmHg</th>
<th>Diastolic blood pressure, mmHg</th>
<th>LDL-cholesterol, mg/dL</th>
<th>HDL-cholesterol, mg/dL</th>
<th>Triglycerides, mg/dL</th>
<th>Fasting glucose, mg/dL</th>
<th>2-h glucose, mg/dL</th>
<th>HOMA-IR*</th>
<th>CRP, mg/L*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartile 1</td>
<td>120 (119–121)</td>
<td>71 (71–72)</td>
<td>120 (117–122)</td>
<td>50 (49–50)</td>
<td>105 (102–108)</td>
<td>101 (99–103)</td>
<td>112 (110–114)</td>
<td>2.23</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td>(n=11 607)</td>
<td>(n=11 601)</td>
<td>(n=11 364)</td>
<td>(n=11 586)</td>
<td>(n=11 588)</td>
<td>(n=11 566)</td>
<td>(n=9517)</td>
<td>(n=11 536)</td>
<td>(n=11 584)</td>
</tr>
<tr>
<td>P-trend</td>
<td>0.8500</td>
<td>&lt;0.0001</td>
<td>0.1500</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.1300</td>
<td>&lt;0.0001</td>
<td>0.0600</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Quartile 2</td>
<td>120 (119–121)</td>
<td>72 (72–73)</td>
<td>120 (118–121)</td>
<td>49 (48–49)</td>
<td>111 (108–115)</td>
<td>102 (100–103)</td>
<td>118 (116–119)</td>
<td>2.52</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>(n=11 601)</td>
<td>(n=11 601)</td>
<td>(n=11 364)</td>
<td>(n=11 586)</td>
<td>(n=11 588)</td>
<td>(n=11 566)</td>
<td>(n=9517)</td>
<td>(n=11 536)</td>
<td>(n=11 584)</td>
</tr>
<tr>
<td>P-trend</td>
<td>0.5900</td>
<td>0.0600</td>
<td>0.5000</td>
<td>0.0400</td>
<td>&lt;0.0001</td>
<td>0.3400</td>
<td>&lt;0.0001</td>
<td>0.0600</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>120 (119–120)</td>
<td>72 (71–72)</td>
<td>120 (118–122)</td>
<td>49 (48–49)</td>
<td>110 (107–113)</td>
<td>101 (100–103)</td>
<td>117 (115–119)</td>
<td>2.48</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>(n=11 600)</td>
<td>(n=11 600)</td>
<td>(n=11 363)</td>
<td>(n=11 585)</td>
<td>(n=11 587)</td>
<td>(n=11 565)</td>
<td>(n=9516)</td>
<td>(n=11 535)</td>
<td>(n=11 583)</td>
</tr>
<tr>
<td>P-trend</td>
<td>0.4900</td>
<td>0.1400</td>
<td>0.5200</td>
<td>0.0700</td>
<td>&lt;0.0001</td>
<td>0.3300</td>
<td>&lt;0.0001</td>
<td>0.0700</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Quartile 4</td>
<td>120 (120–121)</td>
<td>73 (72–74)</td>
<td>122 (120–123)</td>
<td>47 (47–48)</td>
<td>122 (117–127)</td>
<td>103 (101–104)</td>
<td>122 (120–124)</td>
<td>2.87</td>
<td>2.18</td>
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<tr>
<td></td>
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<td>(n=11 364)</td>
<td>(n=11 586)</td>
<td>(n=11 588)</td>
<td>(n=11 566)</td>
<td>(n=9517)</td>
<td>(n=11 536)</td>
<td>(n=11 584)</td>
</tr>
<tr>
<td>P-trend</td>
<td>0.4900</td>
<td>0.1400</td>
<td>0.5200</td>
<td>0.0700</td>
<td>&lt;0.0001</td>
<td>0.3300</td>
<td>&lt;0.0001</td>
<td>0.0700</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are means (95% confidence intervals), adjusted for: Model 1, adjusted for age, sex, household income, education, employment status, Hispanic/Latino background, field center, smoking, alcohol consumption, health insurance status, healthcare use, self-reported health, diet quality, and medications specific to each marker; Model 2, additionally adjusted for minutes per day in MVPA; and Model 3, additionally adjusted for BMI and waist-hip ratio. BMI indicates body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment of insulin resistance; LDL, low-density lipoprotein; MVPA, moderate to vigorous physical activity; and WHR, waist-to-hip ratio.

*Geometric means are presented for triglycerides, fasting insulin, HOMA-IR, and CRP.
of sedentary time and MVPA were inferred from measures of spatial displacement (or lack thereof) in multiple dimensions derived from accelerometers. Therefore, some standing still time may be measured as sitting time because different postures cannot be differentiated by the accelerometer, and variability in accelerometer placement or body habitus may also affect measurements. Because accelerometer-derived sedentary time is highly correlated with wear time, we used a previously reported residual approach to standardize sedentary time to a wear time of 16 hours/d. However, the results might be biased if sedentary time while wearing the device were substantively different from that while the device was not worn. In addition, our accelerometer protocol specified a 1-minute epoch length and it is unknown whether use of a shorter epoch length may affect our results. Despite these potential biases, because vagaries in accelerometer measurement were most likely nonselective with respect to cardiometabolic markers, they would generally be expected to attenuate rather than exaggerate observed associations.

Other limitations of the study include the self-reported nature of several potential behavioral confounders including diet, alcohol drinking and smoking. The study is also limited in its cross-sectional nature and, hence, a lack of data on the incidence of cardiovascular disease or its risk factors.
However, our analysis focuses on subclinical markers of cardiometabolic risk, which should reduce the impact of reverse causation. In addition, we adjusted for a comprehensive measure of self-reported physical health, and performed sensitivity analyses, excluding those with prevalent related chronic diseases (coronary heart disease, stroke, and diabetes mellitus), to account for the fact that those with prevalent disease may be more sedentary because of their health conditions. Despite the consistency in our observed associations and the rigorous control for alternative explanations, further prospective and intervention studies are needed to clarify the causal nature of deleterious associations between sedentary behavior and health outcomes.

In summary, our findings based on objectively measured data provide strong evidence for the link between sedentary behavior and cardiometabolic risk, regardless of physical activity, in US Hispanic/Latino adults. These associations, in general, were consistent across Hispanic/Latino background groups. Furthermore, the significant deleterious associations between sedentary time and cardiometabolic risk are observed even in individuals meeting physical activity guidelines. Our data support the recommendation for both increasing exercise levels and reducing sedentary behavior for the prevention of cardiometabolic diseases.

Acknowledgments
We thank the staff and participants of HCHS/SOL for their important contributions. A complete list of staff and investigators has been provided by Sorlie and colleagues\(^1\) and is also available on the study web site http://www.cscc.unc.edu/hchs/.

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**Figure 2.** Cardiometabolic markers and quartiles of sedentary time by Hispanic/Latino background. Values are means (95% confidence intervals), adjusted for moderate-vigorous physical activity, age, sex, household income, education, employment status, medications specific to each marker, Hispanic/Latino background, field center, smoking, alcohol consumption, health insurance status, healthcare use, self-reported health, diet quality, BMI, and waist-hip ratio. Geometric means are presented for triglycerides and HOMA-IR. BMI indicates body mass index; HDL, high-density lipoprotein; and HOMA-IR, homeostatic model assessment of insulin resistance.
of Deafness and Other Communications Disorders, the National Institute of Dental and Craniofacial Research, the National Institute of Diabetes and Digestive and Kidney Diseases, the National Institute of Neurological Disorders and Stroke, and the NIH Office of Dietary Supplements.

Disclosures

None.

References


of cardiovascular disease, even among those who meet physical activity recommendations. Taken together, our findings emphasize the public health priority of reducing sedentary behaviors for the prevention of cardiometabolic diseases, even among those meeting US government physical activity guidelines.

**CLINICAL PERSPECTIVE**

Sedentary behaviors consist of those performed while sitting or reclining and are characterized by energy expenditure between 1 and 1.5 times an individual’s basal metabolic rate. Several published observational studies have shown a relationship between time spent in sedentary behaviors and adverse health outcomes, independent of physical activity levels. However, the bulk of previous large studies have been limited by reliance on self-reported measures for the levels of physical activity and sedentary behaviors. Previous studies have also been largely restricted to non-Hispanic whites with little representation of US Hispanics, the fastest growing population nationally with a disproportionate burden of cardiometabolic conditions. In the Hispanic Community Health Study/Study of Latinos (HCHS/SOL), we therefore objectively assessed time spent in sedentary behaviors among >12,000 Hispanic/Latino adults. We then related sedentary time to several subclinical markers of cardiometabolic risk while adjusting for moderate-to-vigorous physical activity and several potential confounders. Our analysis suggests that sedentary behaviors are most strongly linked to triglycerides and measures of insulin resistance, including 2-hour postchallenge plasma glucose and fasting insulin. We also observed generally consistent associations between sedentary time and cardiometabolic risk factors across Hispanic/Latino background groups. Furthermore, even among those meeting US government physical activity recommendations, we observed a deleterious association between increased sedentary time and cardiometabolic health. Taken together, our findings emphasize the public health priority of reducing sedentary behaviors for the prevention of cardiometabolic diseases, even among those who meet physical activity guidelines.