**Substituting sedentary time with physical activity domains: an isotemporal substitution analysis in Chile**

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**Word Counts**

Abstract: 299

Manuscript: 3578

Tables: 4

Appendix Table: 1

**Author Disclosures**

No potential conflicts of interest was reported by Kabir P. Sadarangani

No potential conflicts of interest was reported by Verónica Cabanas-Sánchez

No potential conflicts of interest was reported by Astrid Von Oetinger

No potential conflicts of interest was reported by Carlos Cristi-Montero

No potential conflicts of interest was reported by Carlos Celis-Morales

No potential conflicts of interest was reported by Nicolás Aguilar-Farías

No potential conflicts of interest was reported by Sara Higueras-Fresnillo

No potential conflicts of interest was reported by Miguel A. De la Cámara

No potential conflicts of interest was reported by Borja Suarez-Villadat

No potential conflicts of interest was reported by David Martínez-Gómez

**Funding Statement**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Kabir P. Sadarangani has no financial disclosures

Verónica Cabanas-Sánchez has no financial disclosures

Astrid Von Oetinger has no financial disclosures

Carlos Cristi-Montero has no financial disclosures

Carlos Celis-Morales has no financial disclosures

Nicolás Aguilar-Farías has no financial disclosures

Sara Higueras-Fresnillo has no financial disclosures

Miguel A. De la Cámara has no financial disclosures

Borja Suarez-Villadat has no financial disclosures

David Martínez-Gómez has no financial disclosures

**Abstract**

*Introduction*

Sedentary behavior (SB), physical inactivity and obesity are main risk factors for non-communicable diseases. However, it is unknow whether reallocating SB time with physical activity (PA) domains related to travel, occupational and leisure activities is associated with lower levels of adiposity. The aim of this study, therefore, was to examine independent associations and theoretical reallocations of SB and physical activity (PA) domains with obesity indicators in a nationally representative sample from Chile.

*Methods*

Randomly selected participants were enrolled in the 2009–2010 Chilean National Health Survey. Cross-sectional self-reported SB and PA domains were collected using the Global PA Questionnaire. Isotemporal substitution modeling was applied to examine the potential effects of reallocating 10 min/day of SB with occupational or travel or LTPA in relation to Body Mass Index (BMI) and Waist Circumference (WC).

*Results*

3552 participants aged between 15-65 years [mean (standard deviation); age=40.2 (14.07) years, BMI=27.7 (5.38) kg/m2, WC=91.2 (24.09) cm] reported an overall sitting time of 196.3 min/day and spent 15.4 min/day in LTPA. LTPA was negatively associated to both BMI and WC independently of SB. Substituting 10 min/day of SB with an equal amount of travel PA resulted in lower BMI (B=-0.033 95% CI: -0.055; -0.011) and WC (B=-0.089 95% CI: -0.172; -0.007) independent of sociodemographic variables and sleep time. Notably, the strongest association with obesity indicators was observed when SB time was reallocated for LTPA (BMI B=-0.080 95% CI: -0.122; -0.037 and WC: (B=-0.373 95% CI: -0.500; -0.245).

*Conclusion*

Replacing SB not only with LTPA but also travel PA appears to be favorably associated with lower levels of obesity indicators. Walking and cycling as part of our travel PA may be a more feasible way of increasing PA levels than moderate or vigorous intensities PA in the overall population, at lower costs and environmentally friendly.

## 1.1 Introduction

Worldwide in 2016, 39% (1.9 billion) of adults were overweight and 13% (650 million) were obese (World Health Organization, 2018a). Overall, Latin America and the Caribbean leads with the highest prevalence within regions with 58% (360 million) of their adults living with overweight and 23% (140 million) with obesity (Food and Agriculture Organization of the United Nations and Pan American Health Organization, 2017). Moreover, according to the Organization and Economic Co-operation and Development, Chile in 2016 had the highest rates of excessive weight (74.2%) in population aged 15 and over (Organization and Economic Co-operation and Development, 2018), and this burden is projected to cost on average US$1 billion per year (United Nations. Economic Commission for Latin America and the Caribbean. World Food Programme, 2017).

Intervention strategies preventing and treating obesity includes modification of dietary and lifestyle habits such as reducing; portions, energy-dense food, and time spent watching television, among others (Grundy et al., 1999). However, regular physical activity (PA) arises as the cornerstone favouring energy expenditure, curving the obesity pandemic (Jakicic and Otto, 2005). Time-use components such as sleep, sedentary behavior (SB), light intensity physical activity (LIPA) and moderate-to-vigorous PA (MVPA) distributes across a 24-hour day. Although, previous studies have reported associations of these components with CVD risk factors in isolation (Buman et al., 2014; Healy et al., 2008; Larsen et al., 2014; Rosique-Esteban et al., 2017; Stamatakis et al., 2009; Whitaker et al., 2018; Wijndaele et al., 2010), time is restricted and finite for all individuals, and participation in one activity necessary displaces in some measure, one or more co-dependent activities. One of the statistical methods that enables to estimate the association of substituting time spent in one activity with another, while holding total time constant, is the Isotemporal Substitution Modeling (ISM) analysis (Mekary et al., 2009). This ISM paradigm has recently been used by researchers exploring associations between reallocating activity components and health outcomes such as, mortality, cardiometabolic biomarkers, and obesity indicators, among others (Buman et al., 2014; Colley et al., 2018; Fishman et al., 2016; Gupta et al., 2016; Hamer et al., 2014; Rosique-Esteban et al., 2017; Van Der Berg et al., 2017; Whitaker et al., 2018). Although there is existing evidence that suggest that displacing SB by MVPA is associated with lower adiposity levels, none of the previous studies has investigated the potential health-related association of reallocating time in different PA domains (occupational, travel and leisure-time) with overall and abdominal obesity indicators. Moreover, most of these information has been derived using accelerometers (Grgic et al., 2018), and, accelerometers do not allow us to estimate PA levels related to different domains such as work, leisure and travel-related PA. Taken this into account, the aims of this study were (i) to examine the independent association of daily activities components (SB, occupational PA, travel PA and leisure-time PA [LTPA]) with overall and abdominal obesity indicators (body mass index [BMI] and waist circumference [WC], respectively)  and (ii) to examine how reallocating time between these daily activities components is associated with these obesity indicators, in the Chilean population.

## 1.2 Material and Methods

### *1.2.1 Study Sample*

This cross-sectional study included 3552 participants recruited from the Chilean National Health Survey (CNHS) 2009 – 2010 (Ministerio de Salud, 2009). The CNHS cohort comprised 5412 participant's ≥15 years old, from both urban and rural areas and utilized stratified multistage probability sampling (Ministerio de Salud, 2009). Furthermore, the CNHS is conducted every 6 years and obtains biological, lifestyle, dietary and health data (Ministerio de Salud, 2009). Data was collected, in accordance with standardized protocols, by trained interviewers and nurses in a two-part face-to-face interview (Ministerio de Salud, 2009). Interviews were carried out in the homes of participants, with the interviewers obtaining information on participant physical and mental health, household income and socio-economic status (Ministerio de Salud, 2009). Following on from this, the second part of the interview involved the administration of CNHS validated questionnaires and collection of anthropometric measurements, such as BMI and WC (Ministerio de Salud, 2009).

Only participants who were aged 15–65 years, with BMI and WC measurements were considered for this study (n=3960). Participants were excluded if they reported >960 minutes/day (16 hours/day) in SB (n=44), >960 minutes/day of either occupational PA, travel PA, LTPA (n=55), and total activity time (n=125), defined as the sum of each component (SB + occupational PA + travel PA + LTPA). Additionally, participants were also excluded if data for the outcomes, exposure and covariates used in this study (n=184) were missing, leading to a total sample of 3552 subjects.

The CNHS 2009-2010 was funded by the Chilean Ministry of Health and led by the Department of Public Health from the Pontificia Universidad Católica de Chile (PUC). The study protocol was approved by the Ethics Research Committee of the faculty of medicine at the PUC and carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinky). All participants provided written informed consent prior to participation.

*1.2.2 Socio-demographic*

Participants were classified according to: gender; age (15–29; 30–44; 45–65 years); region of residence (north: I–IV and XV, central: V–VIII and XIII, and south: IX–XII and XIV); and educational level (low: <8 schooling years, intermediate: 8–12 schooling years, and high >12 schooling years).

*1.2.3 Physical Activity*

The Global Physical Activity Questionnaire (GPAQ) is a useful tool by which levels of PA and SB are measured (Bull et al., 2009). It was developed by the World Health Organization, with version 2 being utilized in the 2009-2010 CNHS (World Health Organization, 2009). The GPAQ has been identified as a valid and reliable instrument, which has been utilized to assess other population's levels of PA and SB (Bull et al., 2009).

Total occupational PA, travel PA and LTPA can be ascertained from the GPAQ (World Health Organization, 2009). Travel PA refers to commuting between destinations by either walking or cycling (non-motorized), while LTPA represents participants doing sports, fitness and recreational activities. Occupational PA instead, indicates participations in household chores, carrying or lifting heavy loads, harvesting food/crops, etc.… To account for the energy expenditure related to different PA domains, the total amount of PA and MVPA was reported as Metabolic Equivalents (METS), which is the ratio of a person´s working metabolic rate relative to the resting metabolic rate (1 kcal/kg/hour) (Jetté et al., 1990; World Health Organization, 2009). Both, leisure-time and occupational domains are considered as MVPA intensity domains (>4METs), while travel PA is contemplated as a moderate intensity activity (4–8 METs) only. Noteworthy, all domains emphasize in a continuous 10-minutes minimum bout of time for the activity to be performed, in order to meet the current PA guidelines (World Health Organization, 2010). On the other hand, SB was calculated by using the following question: "How much time do you usually spend sitting or reclining on a typical day?" Examples were provided, such as sitting at a desk, sitting with friends, reading, watching television were valid, excepting time spent sleeping.

Total minutes per day (min/day) were derived from SB, while MVPA and moderate min/day calculated from leisure-time, occupational and travel PA domains separately, respectively.

### *1.2.4 Obesity Indicators*

Weight and height were measured in light clothing and without shoes, according to a standardized method (Ministerio de Salud, 2009). Weight and height were measured to the nearest 0.1kg and 0.1cm, respectively. BMI was calculated as weight (kg) divided by the height in squared meters ($m^2$).

Waist circumference was registered with a unextendible tape to the nearest 0.1cm, and measured in the mid axillary line at the midpoint between the lower margin of the last detectable rib and the top of the iliac crest, after normal exhalation (Ministerio de Salud, 2009).

### *1.2.5 Other Potential Confounding Variables*

Sleep time (min/day) was derived multiplying by 60 the following question: "*how many hours of sleep do you usually take during weekdays*?" Also, self-reported health (poor/fair/good/very good/excellent), diabetes (fasting plasma glucose $\geq$126mg/dl or self-reported physician-diagnosed) and hypertension (systolic blood pressure $\geq$140mmHg and/or diastolic blood pressure $\geq$90 mmHg, plus normotensive participants with pharmacological treatment) were registered (Ministerio de Salud, 2009).

### *1.2.6 Statistical Analysis*

All analyses were weighted for CNHS 2009 - 2010 design using the command ‘svy’ in STATA v.13 (StataCorp LP). Continues variables were summarized as mean and standard deviations (SD), and as frequencies (percentages) for categorical variables.

Bivariate correlations were used to determine the relationship among PA domains and SB. Three different multiple linear regression models (single activity, partitioned and isotemporal substitution) were used to assess the magnitude of the associations between 10 minutes time units SB, occupational PA, travel PA and LTPA, and the two obesity indicators (BMI and WC). All models were first adjusted for sex, age groups, educational level and region of residence (model A), then additionally controlled for sleep time (model B), and finally, adjustments for diabetes, hypertension and self-reported health (model C) were also accounted. Confounders were retained via backwards elimination as significantly associated with the outcomes at p-values $<$0.2.

First, a single activity model was fitted to assess each component separately (SB, occupational, travel and LTPA) with BMI and WC, without taking into account the other activity types. Moreover, to precisely assess the independent effect of an activity (SB or each PA domain), further adjustments for total PA (occupational PA + travel PA + LTPA) and SB were accounted, respectively (model D and E).

Second, partition models were fitted to estimate the "unique associations" of each component (SB, occupational PA, travel PA and LTPA) with BMI and WC, independent of confounders and other activity types. Thus, represents the effect of adding rather than substituting and activity type by entering simultaneously each component without adjusting for total activity time.
Third, an ISM analysis, examined the theoretical effect of replacing a preset amount of time in one activity component with the same amount in another activity (e.g., reallocating 10 min/day of SB to 10 min/day of travel PA), while holding total activity time (SB + occupational PA + travel PA + LTPA) constant. Including total activity time variable in the model permits for direct associations to be made among independent variables and obesity indicators (Buman et al., 2014). Thus, an ISM analysis that examines the effect of replacing SB (behavior of interest) with other PA domains includes: occupational PA, travel PA, LTPA, covariates plus total activity time entered simultaneously into the model. By dropping SB, the remaining coefficients (occupational PA, travel PA, LTPA) represent the consequence of substituting 10 min/day of that PA domain instead of SB while holding other activity types constant.
As all interactions (by age, sex, and region of residence) were not statistically significant, pooled analysis with unstandardized regression coefficients are presented. Statistical significance level was 2-sided and set at $P < .05$.

**1.3 Results**

The analysis included 3552 participants, mean age 40.2 (SD=14.07), mean BMI 27.7 (SD=5.38) and mean WC 91.2 (SD=24.09). Moreover, 60.2% were women and most of the population had 8-12 years of education (60.6%), lived in the central region (41.5%), and reported good overall health (42.9%). On average, participants spent 196.3 min/day in SB and participation in occupational PA (133.3 min/day) was highest among other domains (travel PA= 48.6 min/day and LTPA= 15.4 min/day). Sample characteristics are presented in Table 1.

Table A.1 summarizes bivariate correlations between daily minutes spent in SB and the different PA domains (all $r<0.3$).

The results of the single activity and partition models for BMI and WC is represented in table 2. In the single models, every 10 minutes bout of SB was associated with a significant increase for BMI (B =0.016; 95% CI: 0.005 ; 0.027) and WC (B=0.044; 95% CI: 0.005 ; 0.083) after adjusting for sociodemographic and sleep time. Conversely, LTPA and travel PA were associated with a significant decrease for same obesity indicators. Moreover, LTPA showed an independent association with BMI and WC after adjusting for SB (model D).

In the partition models, where the time in each of the activities was held constant, LTPA domain remained favorably associated with BMI (B = -0.063; 95% CI: -0.104 ; -0.022) and WC (B = -0.342; 95% CI: -0.469 ; -0.215). However, SB was only negatively associated with BMI (B = 0.016; 95% CI: 0.005 ; 0.028) after controlling for sociodemographic characteristics. Findings slightly attenuated but remained significant in the fully adjusted model (model C).

The isotemporal substitution models suggest that replacing a 10-min/day bout in travel PA or LTPA for 10 min/day increase in SB is significantly associated with greater BMI (Table 3), while holding total time constant. Similar results were obtained when travel PA was replaced with occupational PA (B = 0.026; 95% CI: 0.003 ; 0.048). Also, the estimates of WC increased significantly when any PA domain was replaced with SB bouts (Table 4). Moreover, replacing 10 min/day of LTPA with 10 min/day increase in occupational PA was adversely associated with WC (B = 0.323; 95% CI: 0.198 ; 0.448).

Lastly, for both isotemporal substitution models, reallocating 10 min/day bout of SB, occupational PA or travel PA with 10 min/day in LTPA was associated with favorable effects in all obesity indicators.

## 1.4 Discussion

This cross-sectional study examined the associations of activity components with obesity indicators in a national representative sample participating in the 2009-2010 CNHS. One of the main findings in this paper is that 10 min/day spent in LTPA was independently associated with lower levels of BMI and WC, however the magnitude of the association was higher for WC than BMI. Whereas 10 min/day time spent in SB was independently associated with higher BMI but not WC. Secondly, the Isotemporal substitution analyses revealed slightly stronger beneficial effects for BMI ($\beta$ -0.06, $p<0.001$) and WC ($\beta$ -0.04, $p=0.015$), when we theoretically replaced 10 min/day of SB with equal amounts of LTPA. Furthermore, it was also shown that replacing SB with travel PA was associated with lower levels of obesity indicators however the magnitude of the effect was smaller than those observed for LTPA (BMI= $\beta$ -0.05, $p=0.003$ and WC= $\beta$ -0.04, $p=0.031$).

The present findings seem to be consistent with other research which found that LTPA is independently and favorably associated with lower obesity indicators (Du et al., 2013; Jakes et al., 2003; Martínez-González et al., 1999; Stamatakis et al., 2009). In addition, a recent study conducted in Spain (PREDIMED PLUS-Trial) found that adults engaging 1 hour/day in moderate-to-vigorous LTPA was independently associated with 5% and 3% lower prevalence of overall obesity (RR=0.95; 95% CI: 0.93 ; 0.97) and abdominal obesity (RR=0.97; 95% CI: 0.96 ; 0.98), respectively (Rosique-Esteban et al., 2017). However, this study conducted in Spain, had older participants (65±4.9 years), higher proportion of males (51.9%), higher sitting time (294±138 min/day) and LTPA (66.8 min/day) than our sample (Rosique-Esteban et al., 2017).

In accordance with the present results, previous studies have demonstrated that SB is independently associated with BMI (Jakes et al., 2003; Su et al., 2017). Moreover, a major study conducted in 15 European member states (n=15239) found that for each 1 hour/week increase in time spent sitting was independently associated with higher BMI in males and females, equivalent to 0.026 grams and 0.065 grams, respectively (Martínez-González et al., 1999). Despite our findings, some studies have found independent associations with WC (Healy et al., 2008; Whitaker et al., 2018; Wijndaele et al., 2010), while others for both obesity indicators (Du et al., 2013; Stamatakis et al., 2009). These discrepancies could be attributed to the unexplained mechanisms responsible for determining the location of fat distribution. In addition to this, a study conducted in United States, showed no association between sitting time and intra-thoracic, subcutaneous, visceral, and intermuscular fat measured by computed tomography (Larsen et al., 2014). However, 1 hour/day increase of daily sitting was associated with 3.94$cm^2$ greater pericardial fat (Larsen et al., 2014), highlighting its association with cardiovascular morbidity and mortality (Mahabadi et al., 2008; Rosito et al., 2008).

Compelling evidence from epidemiological studies suggests that reallocating time from SB to MVPA has significant beneficial associations with obesity indicators (Colley et al., 2018; Dahl-Petersen et al., 2017; Grgic et al., 2018; Gupta et al., 2016; Hamer et al., 2014; Mekary et al., 2009). Also, a recent meta-analysis which included 10 studies using objective-assessment found that replacing 30 minutes of sedentary time with MVPA was associated with reductions in BMI ($\beta$= -1.07; 95% CI: -1.80 ; -0.35) and WC ($\beta$= -2.95; 95% CI: -3.88 ; -2.03) (del Pozo-Cruz et al., 2018). Differences in magnitudes for BMI and WC between studies could be due to the methods assessing PA; as questionnaires tend to overestimate the amount of PA needed to reduce obesity indicators, and underestimated the benefits of PA. However, previous studies have not dealt with theoretical substitutions among different PA domains and most of the evidence been based to reallocations of SB with LTPA (Mekary et al., 2009; Rosique-Esteban et al., 2017). An example of this is the cross-sectional study conducted in 5776 Spanish adults were substituting 1 hour/day of LTPA for same amount of TV-viewing time, resulted in 8% (RR=0.92; 95% CI: 0.90 – 0.94) and 3% (RR=0.97; 95% CI: 0.96 – 0.98) lower prevalence of overall and abdominal obesity, respectively (Rosique-Esteban et al., 2017). In the present study, the results for obesity indicators of replacing 10 min/day of SB with LTPA are less than the observed in Rosique-Esteban and colleagues study (Rosique-Esteban et al., 2017), probably due to greater benefits in energy expenditure with MVPA in older individuals with higher BMI and WC (Colley et al., 2018). Moreover, another possible explanation could be that screen time has a more negative association with obesity indicators than other SB such as reading, doing paperwork, car travel and phone utilization (Whitaker et al., 2018).

Nonetheless, realistic reallocations of SB to LTPA might be limited, including common impediments such as insufficient time, costs, lack of confidence, encouragement (Withall et al., 2011). Hence, travel PA would act as a keystone in the substitution model, providing an alternative opportunity to overcoming traditional barriers associated to lack of PA (Furie and Desai, 2012). Moreover, this type of PA practiced at lower-intensities seems easier to incorporate into a daily routine, and previous studies have shown negative associations with CVD risk factors and mortality (Hamer and Chida, 2008; Saunders et al., 2013), inclusively in Chilean population (Sadarangani et al., 2018).

Consistent with our results, international public health approaches such as the global action plan on PA and strategies like “Move more, Sit less”, have advocated for ideal reallocation of time for health, decreasing time in less active behaviors and engaging into more MVPA (Salmon, 2016; World Health Organization, 2018b). Moreover, the present findings suggest that cross-sectoral collaboration and integrated decision making between Health, Transport and Environment should be decisive for achieving sustainable transport patterns. Promotion of safe cycling and walking offers reductions in traffic congestion, noise, carbon dioxide and pollutants emissions (Dombois et al., 2006). Moreover, it would increase population PA levels, energy efficiency and quality of urban life (Dombois et al., 2006). However, for this to happen environmental and transportation infrastructure are needed, such as green spaces, park and playgrounds, street connectivity offering multi-modal transportation, pedestrians sidewalks and bicycle lanes separated from traffic, etc... taking advantage from the recent road harmony modification law and speed limit reduction (50 km/hour) in urban areas (de Nazelle et al., 2011; Dombois et al., 2006; Telecomunicaciones, 2018).

### *1.4.1 Strengths and Limitations*

Strengths of this study includes a large random representative sample (urban, rural and regional) with low refusal rates (12%) (Ministerio de Salud, 2009). Trained nurses and standard operating procedures used for anthropometric measures. However, a number of important limitations need to be considered. First, the cross-sectional design of our study does not allow to assume causality and reverse causality cannot be excluded. However, sensitive analysis was performed excluding those who reported a history of stroke, deep vein thrombosis or myocardial infarction (n=3398) and results remained significant when substituting 10 min/day of SB with travel PA and LTPA. Second, despite examining a potential effect of a large set of confounders, residual confounding factors remains as a possibility, such as not controlling for diet could influence obesity indicators. Third, self-reported measure of PA and SB is not always reliable and can incur bias.

Moreover, the GPAQ instrument only include PA bouts of at least 10-minute duration, so by not accounting for bouts of MVPA below 10-min our analyses could underestimating the associations observed. Due to this, objective devices (accelerometers and Global Positioning System) complemented with a PA diary should be used to deliver reliable information plus differentiate between SB and PA types, standing and LIPA. Nevertheless, the GPAQ has shown good criterion validity against 343 accelerometers in this population (Aguilar-Farías, Nicolás; Leppe, 2014). Forth, our isotemporal analysis did not consider LIPA (not measured in this survey) thus, it is unclear how these activities relate with obesity indicators.

**1.5 Conclusion**

In conclusion, this study is the first to our knowledge to examine the associations of replacing time spent in SB with time spent in different PA domains and obesity indicators. Our findings demonstrate that replacing SB not only with LTPA but also with travel PA was associated with lower levels of BMI and WC. These findings may hold important public health relevance as engaging in travel PA would be beneficial even for those less able to tolerate higher-intensity activities, and at lower cost. Further work including interventional studies are needed to better understand the relationship between PA domains and obesity indicators, in order to assess for causal relationships and clarify possible mechanisms involved.

**Acknowledgements**

*Authors Contributions Statement*

KS and VCS did the statistical analysis; KS prepared the first draft and VCS, AV, CCM, CCM, NAF, SHF, MDC, BSV and DMG re-wrote parts of the manuscript; all authors review critically several drafts of the manuscript and approved the final version before submission.

*Author Disclosures*

Conflict of interest: None declared.

*Funding Sources*

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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**Table 1** Socio-demographic, anthropometric, clinical and physical activity characteristics of the study population, Chilean National Health Survey 2009-2010 (n=3552)

| Variable | | All n=3552 |
|---|---|---|
| | | **Mean (SD)** |
| Age (years) | | 40.2 (14.07) |
| Body Mass Index (kg/m$^2$) | | 27.7 (5.38) |
| Waist Circumference (cm) | | 91.2 (24.09) |
| Sleep (min/day) | | 439.7 (95.97) |
| Sedentary Behavior (min/day) | | 196.3 (158.49) |
| Travel Physical Activity (min/day) | | 48.6 (83.70) |
| Occupational Physical Activity (min/day) | | 133.3 (176.55) |
| Leisure Time Physical Activity (min/day) | | 15.4 (42.55) |
| | | **n (%)** |
| Sex | Male | 1415 (39.8) |
| | Female | 2137 (60.2) |
| Region of Residence | North (I – IV and XV) | 1065 (30.0) |
| | Central (V- VIII and XIII) | 1475 (41.5) |
| | South (IX – XII and XIV) | 1012 (28.5) |
| Educational Level | Low (< 8 years of education) | 613 (17.3) |
| | Middle (8 – 12 years of education) | 2154 (60.6) |
| | High (>12 years of education) | 785 (22.1) |
| Self-Rated Health | Excellent | 174 (4.9) |
| | Very Good | 310 (8.7) |
| | Good | 1523 (42.9) |
| | Fair | 1323 (37.3) |
| | Poor | 222 (6.2) |
| Diabetes[a] | No | 3259 (91.7) |
| | Yes | 293 (8.3) |
| Hypertension[b] | No | 2785 (78.4) |
| | Yes | 767 (21.6) |

[a] Diabetes: Fasting plasma glucose ≥126 mg/dl or self-reported physician-diagnosed
[b] Hypertension: systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, plus normotensive participants with pharmacological treatment

**Table 2** Associations of each 10 min/day of sedentary behavior and physical activity domains with body mass index and waist circumference, Chilean National Health Survey 2009-2010 (n=3552)

**Analysis Method: Single Activity Models**

**Body Mass Index (kg/m²)**

| | Sedentary Behavior **β (95% CI)** | Occupational PA[a] **β (95% CI)** | Travel PA[a] **β (95% CI)** | Leisure-Time PA[a] **β (95% CI)** |
|---|---|---|---|---|
| Model A | **0.015 (0.004 ; 0.026)*** | 0.006 (-0.004 ; 0.016) | **-0.023 (-0.043 ; -0.003)***** | **-0.069 (-0.110 ; -0.029)*** |
| Model B | **0.016 (0.005 ; 0.027)*** | 0.006 (-0.004 ; 0.015) | **-0.023 (-0.043; -0.002)***** | **-0.069 (-0.110 ; -0.028)*** |
| Model C | **0.013 (0.002 ; 0.024)***** | 0.005 (-0.004 ; 0.015) | -0.015 (-0.035 ; 0.005) | **-0.063 (-0.103 ; -0.024)*** |
| Model D | **-** | 0.009 (-0.001 ; 0.019) | -0.012 (-0.032 ; 0.008) | **-0.062 (-0.102 ; -0.022)*** |
| Model E | **0.014 (0.003 ; 0.025)***** | - | - | - |

**Waist Circumference (cm)**

| | Sedentary Behavior **β (95% CI)** | Occupational PA[a] **β (95% CI)** | Travel PA[a] **β (95% CI)** | Leisure-Time PA[a] **β (95% CI)** |
|---|---|---|---|---|
| Model A | **0.042 (0.002 ; 0.081)***** | -0.017 (-0.053 ; 0.019) | **-0.108 (-0.191 ; -0.025)**** | **-0.362 (-0.490 ; -0.234)*** |
| Model B | **0.044 (0.005 ; 0.083)***** | -0.021 (-0.058 ; 0.015) | **-0.104 (-0.185 ; -0.023)**** | **-0.361 (-0.489 ; -0.233)*** |
| Model C | **0.047 (0.007 ; 0.087)***** | -0.029 (-0.063 ; 0.006) | **-0.091 (-0.170 ; -0.012)***** | **-0.327 (-0.453 ; -0.201)*** |
| Model D | - | -0.020 (-0.057 ; 0.017) | -0.080 (-0.161 ; 0.001) | **-0.320 (-0.444 ; -0.196)*** |
| Model E | 0.034 (-0.008 ; 0.075) | - | - | - |

**Analysis Method: Partition Models**

**Body Mass Index (kg/m²)**

| | Sedentary Behavior **β (95% CI)** | Occupational PA[a] **β (95% CI)** | Travel PA[a] **β (95% CI)** | Leisure-Time PA[a] **β (95% CI)** |
|---|---|---|---|---|
| | | | | |
| Model A | **0.016 (0.005 ; 0.028)*** | 0.009 (-0.012 ; 0.019) | -0.017 (-0.037 ; 0.004) | **-0.063 (-0.104 ; -0.022)*** |
| Model B | **0.016 (0.005 ; 0.027)*** | 0.009 (-0.002 ; 0.019) | -0.017 (-0.037 ; 0.004) | **-0.063 (-0.104 ; -0.022)*** |
| Model C | **0.014 (0.003 ; 0.025)*** | 0.008 (-0.002 ; 0.018) | -0.010 (-0.030 ; 0.010) | **-0.059 (-0.099 ; -0.019)*** |

**Waist Circumference (cm)**

| | Sedentary Behavior **β (95% CI)** | Occupational PA[a] **β (95% CI)** | Travel PA[a] **β (95% CI)** | Leisure-Time PA[a] **β (95% CI)** |
|---|---|---|---|---|
| Model A | 0.031 (-0.010 ; 0.072) | -0.018 (-0.055 ; 0.020) | -0.062 (-0.145 ; 0.020) | **-0.342 (-0.469 ; -0.215)*** |

| | | | | |
|---|---|---|---|---|
| Model B | 0.033 (-0.008 ; 0.074) | -0.021 (-0.060 ; 0.017) | -0.057 (-0.137 ; 0.024) | **-0.344 (-0.471 ; -0.218)*** |
| Model C | 0.034 (-0.007 ; 0.076) | -0.027 (-0.064 ; 0.009) | -0.047 (-0.125 ; 0.032) | **-0.315 (-0.438 ; -0.191)*** |

Data presented as unstandardized regression coefficients (β)

[a] PA: Physical Activity

Model A: Adjusted for age, sex, educational level (low, middle, high) and region of residence (north, center, south)

Model B: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south) and sleep time.

Model C: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south), sleep time, self-reported health, diabetes and hypertension.

Model D: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south), sleep time, self-reported health, diabetes, hypertension and Sedentary Behavior.

Model E: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south), sleep time, self-reported health, diabetes, hypertension and Total Physical Activity (Occupational, Travel and Leisure-Time).

Boldface indicates statistical significance: *p<0.001 **p<0.01 ***p<0.05

**Table 3** Isotemporal substitution models examining the relation between 10 min/day changes in time spent in sedentary behavior, occupation, travel and leisure-time physical activity and body mass index, Chilean National Health Survey 2009-2010 (n=3552).

| **Analysis Method** | Sedentary Behavior **β (95% CI)** | Occupational PA[a] **β (95% CI)** | Travel PA[a] **β (95% CI)** | Leisure-Time PA[a] **β (95% CI)** |
|---|---|---|---|---|
| **Isotemporal** | | | | |
| Substitution of Activity to Replace Sedentary Behaviour | Dropped | | | |
| Model A | | -0.007 (-0.021 ; 0.006) | **-0.033 (-0.055 ; -0.011)**** | **-0.080 (-0.122 ; -0.037)*** |
| Model B | | -0.008 (-0.021; 0.006) | **-0.033 (-0.055 ; -0.011)**** | **-0.080 (-0.122 ; -0.037)*** |
| Model C | | -0.006 (-0.019 ; 0.007) | **-0.024 (-0.045 ; -0.002)***** | **-0.073 (-0.114 ; -0.032)*** |
| Substitution of Activity to Replace Occupational PA[a] | | Dropped | | |
| Model A | 0.007 (-0.006 ; 0.021) | | **-0.026 (-0.048 ; -0.003)***** | **-0.072 (-0.114 ; -0.031)*** |
| Model B | 0.008 (-0.006 ; 0.021) | | **-0.025 (-0.048 ; -0.003)***** | **-0.072 (-0.113 ; -0.030)*** |
| Model C | 0.006 (-0.007 ; 0.019) | | -0.018 (-0.040 ; 0.005) | **-0.067 (-0.107 ; -0.026)*** |
| Substitution of Activity to Replace Travel PA[a] | | | Dropped | |
| Model A | **0.033 (0.011 ; 0.055)**** | **0.026 (0.003 ; 0.048)***** | | **-0.046 (-0.093 ; 0.000)** |
| Model B | **0.033 (0.011 ; 0.055)**** | **0.025 (0.003 ; 0.048)***** | | **-0.047 (-0.094 ; 0.000)** |
| Model C | **0.024 (0.002 ; 0.045)***** | 0.018 (-0.005 ; 0.040) | | **-0.049 (-0.095 ; -0.003)***** |
| Substitution of Activity to Replace Leisure-Time PA[a] | | | | Dropped |
| Model A | **0.080 (0.037 ; 0.122)*** | **0.072 (0.031 ; 0.114)*** | **0.046 (-0.000 ; 0.093)** | |
| Model B | **0.080 (0.037 ; 0.122)*** | **0.072 (0.030 ; 0.113)*** | **0.047 (-0.001 ; 0.094)** | |
| Model C | **0.073 (0.032 ; 0.114)*** | **0.067 (0.026 ; 0.107)*** | **0.049 (0.003 ; 0.095)***** | |
| | | | | |

Data presented as unstandardized regression coefficients (β)
[a] PA: Physical Activity
Model A: Adjusted for age, sex, educational level (low, middle, high) and region of residence (north, center, south)
Model B: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south) and sleep time.

Model C: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south), sleep time, self-reported health, diabetes and hypertension.

Boldface indicates statistical significance: *p<0.001 **p<0.01 ***p<0.05

**Table 4** Isotemporal substitution models examining the relation between 10 min/day changes in time spent in sedentary behavior, occupation, travel and leisure-time physical activity and waist circumference, Chilean National Health Survey 2009-2010 (n=3552).

| **Analysis Method** | Sedentary Behavior<br>**β (95% CI)** | Occupational PA[a]<br>**β (95% CI)** | Travel PA[a]<br>**β (95% CI)** | Leisure-Time PA[a]<br>**β (95% CI)** |
|---|---|---|---|---|
| **Isotemporal** | | | | |
| Substitution of Activity to Replace Sedentary Behaviour | Dropped | | | |
| Model A | | **-0.048 (-0.094 ; -0.003)*** ** | **-0.093 (-0.177 ; -0.010)*** ** | **-0.373 (-0.500 ; -0.245)*** |
| Model B | | **-0.054 (-0.100; -0.008)*** ** | **-0.089 (-0.172 ; -0.007)*** ** | **-0.377 (-0.505 ; -0.249)*** |
| Model C | | **-0.062 (-0.107 ; -0.016)** ** | **-0.081 (-0.161 ; -0.001)*** ** | **-0.349 (-0.476 ; -0.222)*** |
| Substitution of Activity to Replace Occupational PA[a] | | Dropped | | |
| Model A | **0.048 (0.003 ; 0.094)*** ** | | -0.045 (-0.136 ; 0.047) | **-0.324 (-0.449 ; -0.200)*** |
| Model B | **0.054 (0.008 ; 0.100)*** ** | | -0.035 (-0.125 ; 0.054) | **-0.323 (-0.448 ; -0.198)*** |
| Model C | **0.062 (0.016 ; 0.107)** ** | | -0.019 (-0.106 ; 0.067) | **-0.288 (-0.411 ; -0.164)*** |
| Substitution of Activity to Replace Travel PA[a] | | | Dropped | |
| Model A | **0.093 (0.010 ; 0.176)*** ** | 0.045 (-0.047 ; 0.136) | | **-0.280 (-0.434 ; -0.125)*** |
| Model B | **0.089 (0.007 ; 0.172)*** ** | 0.035 (-0.054 ; 0.125) | | **-0.288 (-0.442 ; -0.134)*** |
| Model C | **0.081 (0.001 ; 0.161)*** ** | 0.019 (-0.067 ; 0.106) | | **-0.268 (-0.419 ; -0.117)*** |
| Substitution of Activity to Replace Leisure-Time PA[a] | | | | Dropped |
| Model A | **0.373 (0.245 ; 0.500)*** | **0.324 (0.200 ; 0.449)*** | **0.280 (0.125 ; 0.434)*** | |
| Model B | **0.377 (0.249 ; 0.505)*** | **0.323 (0.198 ; 0.448)*** | **0.288 (0.134 ; 0.442)*** | |
| Model C | **0.349 (0.222 ; 0.476)*** | **0.288 (0.164 ; 0.411)** | **0.268 (0.117 ; 0.419)*** | |
| | | | | |

Data presented as unstandardized regression coefficients (β)

[a] PA: Physical Activity

Model A: Adjusted for age, sex, educational level (low, middle, high) and region of residence (north, center, south)

Model B: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south) and sleep time.

Model C: Adjusted for age, sex, educational level (low, middle, high), region of residence (north, center, south), sleep time, self-reported health, diabetes and hypertension.

Boldface indicates statistical significance: *$p<0.001$ **$p<0.01$ ***$p<0.05$

Appendix Table 1

Pearson correlations coefficients between daily activities components, Chilean National Health Survey 2009-2010 (n=3552).

| | Sedentary Behavior | Travel PA[a] | Occupational PA[a] | Leisure-Time PA[a] |
|---|---|---|---|---|
| Sedentary Behaviour | 1.0 | | | |
| Travel PA[a] | -0.141* | 1.0 | | |
| Occupational PA[a] | -0.245* | 0.131* | 1.0 | |
| Leisure-Time PA[a] | 0.046** | 0.124* | -0.007 | 1.0 |

[a] PA: Physical Activity

Boldface indicates statistical significance: *p<0.001 **p<0.01