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# Obesity as a moderator of the relationship between neighborhood environment and objective measures of physical activity in Chilean adults



Damián Chandia-Poblete<sup>a</sup>, Nicolas Aguilar-Farias<sup>b,c</sup>, Pamela Serón<sup>d</sup>, Sergio Muñoz<sup>a,c</sup>, Teresa Balboa-Castillo<sup>a,c,\*</sup>

<sup>a</sup> Department of Public Health, Universidad de La Frontera, Temuco, Chile

<sup>b</sup> Department of Physical Education, Sports and Recreation, Universidad de La Frontera, Temuco, Chile

<sup>c</sup> EPICYN Research Center, School of Medicine, Universidad de La Frontera, Temuco, Chile

<sup>d</sup> Department of Internal Medicine, Universidad de La Frontera, Temuco, Chile

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### ABSTRACT

**Introduction:** The aim of this study was to analyze the association between neighborhood environment and the objective measures of physical activity (PA) according to nutritional status in the adult population.

**Methods:** A cross-sectional study design was employed. The information was collected from 161 representative subjects of the CESCAS study population from Temuco- Chile. The perception of the neighborhood environment was determined using the IPAQ Environmental- Module. PA was measured objectively by a triaxial accelerometer for 7 consecutive days. Weight and height were measured. The relationship between the residential environment and the PA levels was summarized through linear regression models stratified by nutritional status.

**Results:** The perceived residential environmental attributes that support active transport were positively associated with total moderate-vigorous PA (MVPA) ( $\beta$  397 min/week, CI 80–714,  $p = 0.019$ ) in people with normal nutritional status, but not in overweight and obese individuals. In addition, living near to a public transport stop was associated with higher levels of moderate PA only in normal-weight subjects ( $\beta$  383 min/week, CI 72–694,  $p = 0.021$ ). Also living in a neighborhood with traffic safety was associated with higher levels of light PA in normal-weight subjects ( $\beta$  518 min/week, CI 208–829,  $p = 0.004$ ).

**Conclusions:** There was no significant association between perceived neighborhood environment and PA in people with obesity.

### RESUMEN

**Introducción:** El objetivo de este estudio fue analizar la asociación entre la percepción del entorno de residencia y medidas objetivas de actividad física (AF) de acuerdo al estado nutricional en población adulta.

**Métodos:** Estudio de corte transversal realizado en 161 participantes representativos del estudio CESCAS de Temuco-Chile. La percepción del entorno de residencia fue determinada usando el Modulo Ambiental del IPAQ. La actividad física fue medida objetivamente por un acelerómetro

\* Corresponding author. Department of Public Health, School of Medicine, Universidad de La Frontera, General Carrera 228, 4781135, Temuco, Chile.

E-mail address: [teresa.balboa@ufrontera.cl](mailto:teresa.balboa@ufrontera.cl) (T. Balboa-Castillo).

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triaxial por siete días consecutivos. El peso y la talla fueron medidos de forma estandarizada. La relación entre el entorno de residencia y los niveles de AF fue analizada mediante modelos de regresión lineal estratificados por estado nutricional.

**Resultados:** La percepción de los atributos del entorno de residencia que promueven el transporte activo, fue positivamente asociado con el total de AF moderada y vigorosa ( $\beta$  397 min/week, CI 80–714,  $p = 0.019$ ) en personas con estado nutricional normal, pero no en personas con sobrepeso u obesidad. Además, vivir cerca de una parada de transporte público fue asociado con altos niveles de AF moderada sólo en personas con estado nutricional normal ( $\beta$  383 min/week, CI 72–694,  $p = 0.021$ ). Finalmente, vivir en un barrio con seguridad en el tránsito, fue asociado con altos niveles de AF ligera en sujetos normo-peso ( $\beta$  518 min/week, CI 208–829,  $p = 0.004$ ).

**Conclusión:** No hubo asociación significativa entre el entorno de residencia y AF en personas con obesidad.

## R E S U M O

**Introdução:** Este estudo tem como objetivo analisar a associação entre o ambiente residencial e as medidas objetivas de atividade física (AF) de acordo com o estado nutricional na população adulta.

**Métodos:** Estudo transversal realizado em 161 participantes do estudo CESCAS em Temuco, Chile. A percepção do ambiente residencial foi determinada usando o IPAQ Environmental Module. A atividade física foi medida objetivamente por um acelerômetro triaxial por sete dias consecutivos. Peso e altura foram medidos de forma padronizada. A relação entre o ambiente de residência e os níveis de AF foi analisada utilizando modelos de regressão linear estratificados por estado nutricional.

**Resultados:** Os atributos percebidos do ambiente residencial que suportam o transporte ativo foram positivamente associados com AF moderada-vigorosa total ( $\beta$  397 min/semana, IC 80–714,  $p = 0,019$ ) em pessoas com estado nutricional normal, mas não em indivíduos com sobrepeso e obesidade. Também, morar próximo a uma parada do transporte público estava associado a níveis mais altos de AF moderada somente em indivíduos com peso normal ( $\beta$  383 min/semana, IC 72–694,  $p = 0,021$ ). Adicionalmente, morar em um ambiente residencial com segurança no trânsito foi associado com níveis mais elevados do AF ligeira em indivíduos com peso normal ( $\beta$  518 min/semana, CI 208–829,  $p = 0,004$ ).

**Conclusões:** Não houve associação significativa entre ambiente residencial e AF em pessoas com obesidade.

## 1. Introduction

Physical inactivity and obesity have been recognized as a major contributor to the global burden of diseases (Wang et al., 2011; Ding et al., 2016). It is well established that increasing physical activity (PA) is essential to preventing obesity and reducing the risk for many diseases (Giannuzzi et al., 2003; Warburton et al., 2006), like cardiovascular diseases (Wannamethee and Shaper, 2001), some cancers (Lemane et al., 2013) and mental disorders (Takács, 2014). However, globally most adults do not engage in enough PA (Hallal et al., 2012), and obesity prevalence has risen dramatically in recent decades (Ng et al., 2014; NCD Risk Factor Collaboration (NCD-RisC), 2016). Nowadays, it is recognized that no single factor alone accounts for increased physical activity, but rather components of socio-ecological models that include the individual, the social environment (culture and interpersonal interactions), policy and the physical environment have been identified as determinants of increased participation in all types of PA among the population.

In recent years, intervention efforts have focused on the built environment because the evidence has shown a strong association with PA (Handy et al., 2002; Sallis et al., 2009). Most environmental features have links to PA levels, but in Latin American cities, such connections are less consistent than in developed countries (Ding et al., 2013). In most of these developed cities, transportation behavior and a supportive urban environment show the most promising results to increase physical activity among population (Gomez et al., 2010; Becerra et al., 2013; Hino et al., 2014). Evidence has shown that neighborhood environmental features, mainly attributes related to the “transportation system” such as roads, pedestrian pathways, cycle paths, access to public transport, and traffic levels are consistently associated with physical activity in the community (Ding et al., 2013; Christiansen et al., 2016; McCormack, 2017; Wang et al., 2019). Environment features can influence active forms of transport, such as walking and cycling, and provide opportunities to incorporate physical activity into daily living and reduce obesity. Some previous studies have found associations between active transport and reduced obesity risk (Lindström, 2008; Millett et al., 2013; Flint et al., 2014). Also, higher walkability neighborhoods are associated with a lower prevalence of obesity (Creatore et al., 2016). The presence of pedestrian pathways has been found to be positively associated with PA levels, and specifically to contribute to walking time (Inoue et al., 2009). Poorly maintained pedestrian pathways are related to overweight in adult males (Oyeyemi et al., 2012). Moreover, evidence shows that heavier traffic could make walking difficult or unpleasant and thus reduce the time spent in walking (Wallmann et al., 2012). To date, it is not clear if a built environment affects physical activity levels in the same way in people with and without obesity. Only one

study has suggested that body mass index (BMI) status would be a potential moderator between the perceived environment and PA; however, they used self-reported measures of height, weight and PA levels, and these results may underestimate the true effect of BMI on the relationship(Liao et al., 2011).

The purpose of this study was to describe the associations between perceptions of the neighborhood environment and their associations with objective physical activity according to nutritional status in an adult population.

## 2. Methods

### 2.1. Study design and data collection

Participants were selected from the CESCAS study (South American Centre of Excellence in Cardiovascular Health), which is an observational prospective cohort study with a multistage probability sample of 8000 adults aged 35–74 years from four mid-sized cities (Bariloche and Marcos Paz-Argentina, Temuco-Chile and Canelones-Uruguay) representing the Southern Cone of Latin America. A detailed description of the study population and design has been presented elsewhere(Rubinstein et al., 2011).

The information was collected from 161 representative subjects of the CESCAS study population from Temuco- Chile. Data collection was conducted between May 2015 and January 2016 by personal interview and physical examination performed by trained personnel.

### 2.2. Demographic variables

Sociodemographic data were obtained from a questionnaire specifically designed for this study. Information was gathered regarding sex (male/female), age (years), marital status coded as married and unmarried, which includes single, separated, divorced or widowed, and educational level classified into completed primary, secondary and university studies.

### 2.3. Anthropometric measures

Participants were measured without shoes and wearing light clothes using digital scales (Omron HN-289, Illinois, U.S.A.) and a portable stadiometer (SECA 217, GmbH & Co, KG, Germany). Height and weight were measured twice for each individual to the nearest 1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated using weight in kilograms divided by height in meters squared to place participants in nutritional categories (underweight BMI < 18.5 kg/m<sup>2</sup>, normal BMI ≥ 18.5 kg/m<sup>2</sup> & < 25 kg/m<sup>2</sup>, overweight BMI ≥ 25 kg/m<sup>2</sup> & < 30 kg/m<sup>2</sup> and obese ≥ 30 kg/m<sup>2</sup>) according to the World Health Organization (WHO) classification references.

### 2.4. Objectively measured physical activity

Participants wore an Actigraph GT3X + accelerometer (Actigraph, Pensacola, FL, USA) for 7 consecutive days placed on the waist over the right hip with an elastic belt. They were instructed to remove the device only for sleeping and water-based activities. Data were downloaded and analysed at the individual level using the Actilife 6 Software. An automated algorithm was used to identify wearing and non-wearing periods (i.e., 90 min of consecutive inactivity)(Choi et al., 2011; Peeters et al., 2013). A day was considered valid if the participant wore the device for at least 10 h. Accelerometer data were included in the analyses if participants had valid information at least three weekdays and one weekend day(Sasaki et al., 2018). Each minute (i.e., 60-s) of accelerometer data was classified as sedentary, light, moderate or vigorous intensity PA based on Freedson and Sasaki's cut-off points for the vector magnitude(Sasaki et al., 2011).

### 2.5. Perceived environmental attributes

The perceived environmental attributes related to PA were assessed with the Spanish version of the International Physical Activity Questionnaire Environment Module (IPAQ-E). The reliability of the IPAQ-E has been assessed previously, showing moderate to almost perfect repeatability(Alexander, 2006; Oyeyemi et al., 2008; Santos et al., 2009). This module comprises three categories of items, with seven core items, four recommended items and six optional items(Craig et al., 2003). These 17 items are related to neighborhood and environmental characteristics where the participant could walk for 10–15 min from their residence.

In the present study, the neighborhood environmental characteristics related to transport systems were included: (1) *Access to public transport*: 'It is within a 10–15 min walk to a transit stop from my home'; (2) *Presence of pedestrian pathways*: 'There are sidewalks on most of the streets in my neighborhood'; (3) *Traffic safety*: 'There is so much traffic on the streets that it is difficult or unpleasant to walk in my neighborhood' These three questions were rated on a four-point Likert scale: strongly disagree; somewhat disagree; somewhat agree and strongly agree. The perceived environmental attributes were assessed in two different ways: (a) The result for each question was recoded separately as a "barrier or no support for PA" if the answer was strongly disagree or somewhat disagree (barrier score = 0), or a "facilitator or support for PA" if the answer was somewhat agree or strongly agree (facilitator score = 1). (b) The binary classifications from the three questions about perceived environmental attributes were added to create an *Environmental Attributes Score (EAS)*. A score equal to or less than 1 was classified as "Less support for PA", whereas a score equal to or greater than 2 was classified as "Support for PA".

## 2.6. Statistical analysis

Multiple linear regression models were used to examine the relationship between the perceived environmental attributes and PA. For the analysis, the dependent variable was PA, representing the number of (continuous) minutes spent in a week at different PA intensities. The perceived environmental attributes were treated as binary variables (independent) as previously explained.

To examine the influence of nutritional status on the study association, the analyses were stratified according to BMI (normal vs. overweight/obese). All models were adjusted by sex (binary), age (continuous), educational level (categorical) and time spent sedentary during the week (continuous). All analyses were conducted with Stata 13 (StataCorp, USA), and the significance level was set at  $P < 0.05$ .

## 3. Results

Sociodemographic characteristics and environmental attributes by nutritional status are shown in Table 1. Overall, 52% were male; the average age of the sample was 53 years (SD 7.6 years), 83% had at least 8 years of education, while 11% had normal weight, 46% overweight and 43% were obese. No significant differences were observed in the perceived environmental attributes according to nutritional status. More than 80% of the subjects reported having public transit stops near their home, 89% reported having pedestrian pathways present in the neighborhood, and 54% reported perception of safety from traffic while walking.

The associations between objectively assessed PA and EAS are shown in Table 2. The environmental attributes that support active transport were positively associated with moderate PA ( $\beta$  383 min/week, 95% confidence interval [CI] 72–694,  $p = 0.021$ ) and total moderate-vigorous PA (MVPA) ( $\beta$  397 min/week, CI 80–714,  $p = 0.019$ ) in people with normal nutritional status but not in overweight and obese individuals. Also, the attributes that support active transport were positively associated with light PA in normal weight subjects; however, this was of borderline statistical significance ( $\beta$  358 min/week, CI -8-724,  $p = 0.055$ ).

In addition, when neighborhood environmental attributes were measured individually by the characteristics related to a transport system, the results showed significant associations with PA only in normal weight subjects (Table 3). Living near a public transport stop was associated with higher levels of moderate PA in normal-weight subjects than the reference category ( $\beta$  383 min/week 95% CI 72–694,  $p < 0.05$ ). Also, living in a neighborhood with traffic safety was associated with higher levels of light PA in normal-weight subjects ( $\beta$  518 min/week 95% CI 208–829,  $p < 0.01$ ). In overweight and obese individuals, there was no significant association between neighborhood environmental characteristics and PA. The presence of pedestrian pathways was not associated with

**Table 1**  
Sociodemographic characteristics and environmental attributes by nutritional status.

	Total		BMI			
			Normal weight		Overweight/obese	
N	161		17		144	
SOCIODEMOGRAPHIC CHARACTERISTICS	N	(%)	n	(%)	n	(%)
<b>Sex</b>						
Female	83	(52)	8	(47)	75	(52)
Male	78	(48)	9	(53)	69	(48)
<b>Age</b>						
< 46	37	(23)	2	(12)	35	(24)
46-59	79	(49)	11	(65)	68	(47)
$\geq 59$	45	(27)	4	(24)	41	(29)
<b>Marital Status</b>						
Married	118	(73)	12	(71)	106	(74)
Unmarried	43	(27)	5	(29)	38	(26)
<b>Educational Level</b>						
Primary	28	(17)	5	(29)	23	(16)
Secondary	79	(49)	6	(35)	73	(51)
University	54	(34)	6	(35)	48	(33)
<b>ENVIRONMENTAL ATTRIBUTES</b>						
<b>Access to public transport</b>						
Poor	28	(17)	5	(29)	23	(16)
Good	133	(83)	12	(71)	121	(84)
<b>Presence of Pedestrian pathways</b>						
No	17	(11)	1	(6)	16	(11)
Yes	144	(89)	16	(94)	128	(89)
<b>Traffic safety</b>						
Not safe	73	(45)	8	(47)	65	(45)
Safe	88	(55)	9	(53)	79	(55)

Percentages of sociodemographic characteristics and environmental attributes were calculated in columns to expose nutritional status differences. BMI = body mass index; IPAQ = International Physical Activity Questionnaire.

**Table 2**

Standardized regression coefficients and 95% confidence intervals from multivariate linear regression model predicting objective physical activity by environmental attributes and nutritional status for each physical activity level.

OBJECTIVE PHYSICAL ACTIVITY LEVEL (MIN/WEEK)								
Environmental Attributes Score	Light Physical Activity		Moderate Physical Activity		Vigorous Physical Activity		Total MVPA	
	Normal Weight	Overweight /Obese	Normal Weight	Overweight /Obese	Normal Weight	Overweight /Obese	Normal Weight	Overweight /Obese
<b>Less support PA</b>	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
<b>Support PA</b>	358.1 <sup>δ</sup> (- 8.8 - 724.9)	- 47.5 (- 214.8-119.7)	383.4* (72.3-694.6)	- 27.5 (- 126.3-71.2)	6.2 (- 120.3-132.7)	9.1 (- 16.3-34.5)	397.5* (80.1-714.8)	- 21.4 (- 136.6-93.7)

\*p < 0.05;  $\delta$  = 0.055; Models adjusted for sex, age, educational level and time spent sedentary.

PA levels in the sample.

#### 4. Discussion

The results of this study show an association between perceived transport-related environmental attributes, and objective measures of PA in normal weight adults. Though most variables of perceived environmental attributes were associated with objective PA levels, there was a significant positive relationship with moderate and total moderate-vigorous PA in people with normal nutritional status but not in overweight and obese individuals.

This finding expands knowledge in this field because it shows that nutritional status may be a potential moderator between perceived neighborhood environment and PA. That environmental attributes are associated with objective physical activity, and this association differs according to nutritional status.

Similar to our results, in a previous study, access to public transport, showed different environmental correlates of PA between normal-weight and overweight men (Liao et al., 2011). However, the authors used self-reported measures of nutritional status and PA, so the results could be affected by social desirability bias (Adams et al., 2005), because it has been found that people underreport their weight and overreport PA.

In our sample, normal weight people with good access to public transport practiced more than 6 h/week of PA compared to those with poor access. Previous studies had shown that adults who perceived good connectivity of streets were more likely to walk (Bergman et al., 2009; Herazo-Beltrán and Domínguez-Anaya, 2010; Liao et al., 2011, 2015; Wallmann et al., 2012). In addition, evidence shows that walking to and from public transportation can help meet the recommended greater or equal 30 min of PA daily, and approximately 30% of transit users achieved the PA recommendation simply by walking to/from transit (Besser and Dannenberg, 2005). Additionally, although we assessed only the accessibility but not the use of public transportation, our results go in the same direction as others studies conducted in Latin American cities, which found that public transport users were more likely to walk to transportation for  $\geq 150$  min per week (Lemoine et al., 2016) (Parra et al., 2010).

Regarding the presence of pedestrian pathways, we found no association with PA levels. Our findings can be explained because we not assessed the perception in relation to comfort and safety of pedestrian pathways, and pavement adverse conditions can reduce levels of walking in the community. Also, in our study, residing in a neighborhood with traffic safety was associated with more time performing light PA among subjects of normal weight. Other studies replicated this finding in a general population, but with no differentiation in nutritional status (Jongeneel-Grimen et al., 2013).

Multiple mechanisms may explain the relationship between perceived transport-related environmental attributes and PA and the differences between nutritional status. First, well-connected transportation networks have been linked to increased walking and the effects of PA are associated with reducing the incidence of obesity and many cardiovascular risk factors. Given that our results demonstrate a cross-sectional association, we could not ascertain the time sequence among PA levels and nutritional status. Second, our results probably reflect the association between neighborhood environment and transportation walking more than other types of PA. There is evidence that normal-weight adults engage in significantly more MVPA than overweight or obese subjects. Moreover, evidence shows that walking contributes to nearly half of all moderate activity among obese subjects (Spees et al., 2012).

Finally, there are different barriers to PA in obese adults. By itself, feeling too fat to exercise is a common barrier among overweight and obese people (Ball et al., 2000). Also, there is evidence that weight perceptions may affect PA, and for those overweight adults who perceive themselves as being in the acceptable weight range, there are fewer perceived benefits to engaging in regular PA (Atlantis et al., 2008).

Our study has several strengths and limitations. The main study limitation was the cross-sectional design, because explicit information about temporal precedence was not provided, as exposure to neighborhood and PA are assessed simultaneously. Another limitation is the low sample size of the study, which can only detect effects that happen to be large. However, in our study, the association between neighborhood environmental and PA was statistically significant only in normal weight subjects, which is the smallest stratum of the sample and the results indicate the strength of the relationship in this subgroup. One important strength is that we used objective measures of PA and BMI, as well as a validated instrument to measure perceived environmental attributes. Also,

**Table 3**  
Physical activity (PA) minutes associated with environmental attributes, stratified by nutritional status, for each physical activity level.

Environmental Attributes	OBJECTIVE PHYSICAL ACTIVITY LEVEL (MIN/WEEK)											
	LIGHT PA			MODERATE PA			VIGOROUS PA			TOTAL MVPA		
	Normal Weight	Overweight /Obese	Ref.	Normal Weight	Overweight /Obese	Ref.	Normal Weight	Overweight /Obese	Ref.	Normal Weight	Overweight /Obese	Ref.
<b>Access to transport</b>												
Poor	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Good	358 <sup>§</sup> (-8.7 - 724.9)	-70.1 (-240.7-100.4)		383.4* (72.2-694.6)	-13.2 (-114.1-87.7)		6.1 (-120.3-132.6)	9.8 (-16-35.8)		397.5* (80.1-714.7)	-5.7 (-123.4-111.9)	
<b>Pedestrian pathways</b>												
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	-512.3 (-1149.3-124.6)	12.9 (-187.5-213.3)		-75.8 (-751.3-599.6)	-92.7 (-210-24.5)		18.5 (-189.2-226.2)	-20.8 (-51.1-9.3)		-53.0 (-747.9-641.9)	-116.1 (-252.6-20.4)	
<b>Traffic safety</b>												
Not safe	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Safe	518.9** (208.4-829.4)	-36.4 (-165.4-92.6)		104.9 (-332.8-542.7)	-3.2 (-79.5-73)		14.1 (-121.8-150.1)	11.5 (-8-31)		121.9 (-325.8-569.7)	8.1 (-80.8-96.9)	

Models were adjusted for sex, age, educational level and time spent sedentary. \*P < 0.05; \*\*p < 0.01; <sup>§</sup> = 0.055.

our analyses were adjusted simultaneously for the major confounding factors.

Finally, our findings suggest that a good public transport system and integrating public transport with non-motorized transport (bicycles, pedestrian pathways) is a promising strategy for enhancing public health efforts to reduce physical inactivity, achieve the PA recommendation and to prevent obesity in the population (Duncan et al., 2005; Chaix et al., 2014). In addition, the multifactorial obesity problem requires interventions and approaches involving changes in individual, social, environmental, and economic elements to promote health and reduce the obesity epidemic.

In conclusions, our study adds to a growing evidence on the relationship between neighborhood environment and PA. Additionally our results suggest that obesity could be a relevant moderator in this association.

### Ethics approval and consent to participate

All participants provided written informed consent. The study was approved by the ethical committees of Universidad de La Frontera, Temuco, Chile.

### Availability of data and material

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

### Competing interests

None.

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### Authors' contributions

All authors approved the manuscript and this submission. TBC and DC had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: TBC, NAF and DC. Acquisition of data: DC and TBC. Statistical analysis: TBC, DC and SM. Interpretation of data: TBC, DC and NAF. Drafting of the manuscript: TBC and DC. Critical revision of the manuscript for important intellectual content: DC, TBC, NAF, SM and PS.

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