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Nutritional and metabolic benefits associated with active and public transport: Results from the Chilean National Health Survey, ENS 2016–2017

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ABSTRACT

Background: Physical inactivity is one of the main risk factors for death worldwide. There is a paucity of studies about the association between transport and objective health measures using nationally representative samples worldwide, especially from Latin American countries. The aim of this research is to explore the relationship between active transportation and objective health measures in Chile.
Methods: We analysed the Chilean National Health Survey (ENS) 2016–2017, based on a nationally representative sample of non-institutionalised adults aged ≥15 years (n = 6,113). ENS included anthropometric measures (weight, height, waist circumference), a specific question about the main mode of transportation and several metabolic markers.
Results: 41%, 38% and 21% of participants used public transport, motor vehicles and active (cycling and walking) transport respectively. Higher levels of active transport were observed in males, younger groups, less educated and rural populations. Both active and public transport were associated with multiple nutritional and metabolic benefits such as lower BMI, lower waist circumference, less obesity, higher vitamin D, lower cholesterol and lower hepatic inflammation. Associations persisted after adjusting for other healthy lifestyles. Stronger benefits were observed in males than in females.
Conclusions: Promoting active transportation in urban planning policies may help Chile tackle the growing burden of chronic diseases.

RESUMEN

Antecedentes: La inactividad física es uno de los principales factores de riesgo de muerte en todo el mundo. Hay una escasez de estudios sobre la asociación entre el transporte y las medidas objetivas de salud utilizando muestras representativas a nivel nacional en todo el mundo,

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especialmente de países latinoamericanos. El objetivo de esta investigación es explorar la relación entre el transporte activo y las medidas de salud objetivas en Chile.
Métodos: Analizamos la Encuesta Nacional de Salud de Chile (ENS) 2016–2017, basada en una muestra representativa a nivel nacional de adultos no institucionalizados con edades ≥15 años (n = 6.113). ENS incluyó medidas antropométricas (peso, altura, circunferencia de la cintura), una pregunta específica sobre el modo principal de transporte y varios marcadores metabólicos.
Resultados: 41%, 38% y 21% de los participantes usaron transporte público, vehículos de motor y transporte activo (ciclismo y caminata) respectivamente. Se observaron niveles más altos de transporte activo en hombres, grupos más jóvenes, poblaciones menos educadas y rurales. Tanto el transporte activo como el público se asociaron con múltiples beneficios nutricionales y metabólicos, como un IMC más bajo, una circunferencia de cintura más baja, menos obesidad, más vitamina D, menos colesterol y una menor inflamación hepática. Las asociaciones persistieron después de ajustar por otros estilos de vida saludables. Se observaron beneficios más fuertes en hombres que en mujeres.
Conclusiones: Promover el transporte activo en las políticas de planificación urbana puede ayudar a Chile a enfrentar la creciente carga de enfermedades crónicas.

A B S T R A T O

Antecedentes: A inatividade física é um dos principais fatores de risco para a mortalidade no mundo. Há uma escassez de estudos sobre a associação entre transporte e medidas objetivas de saúde, utilizando amostras nacionalmente representativas em todo o mundo, principalmente de países da América Latina. O objetivo desta pesquisa é explorar a relação entre transporte ativo e medidas objetivas de saúde no Chile.
Métodos: Analisamos a Pesquisa Nacional de Saúde do Chile (ENS) 2016–2017, com base em uma amostra nacionalmente representativa de adultos não institucionalizados com idade ≥15 anos (n = 6.113). A ENS incluiu medidas antropométricas (peso, altura, circunferência da cintura), uma pergunta específica sobre o principal meio de transporte e vários marcadores metabólicos.
Resultados: 41%, 38% e 21% dos participantes usaram transporte público, veículos motorizados e transporte ativo (ciclismo e caminhada), respectivamente. Níveis mais altos de transporte ativo foram observados em homens, grupos mais jovens, populações menos instruídas e rurais. Tanto o transporte ativo quanto o público foram associados a múltiplos benefícios nutricionais e metabólicos, como menor IMC, menor circunferência da cintura, menos obesidade, maior vitamina D, menor colesterol e menor inflamação hepática. As associações persistiram após o ajuste para outros estilos de vida saudáveis. Benefícios mais fortes foram observados nos homens do que nas mulheres.
Conclusões: A promoção do transporte ativo nas políticas de planejamento urbano pode ajudar o Chile a enfrentar o crescente fardo das doenças crônicas.

1. Introduction

According to the World Health Organization, physical inactivity is one of the main risk factors for death worldwide, responsible for 13.4 million DALYs worldwide and causing a higher burden among low-income and middle-income countries (75% of attributable DALYs) (Ding et al., 2016). Motor vehicle traffic is associated with premature mortality and morbidity through traffic injuries, physical inactivity and traffic-related environmental exposures including increases in air pollution, noise and temperature levels, as well as reductions in green space (Khreis et al., 2016). Active modes of transport (e.g. cycling, walking) are those ways of travelling involving physical activity during the whole trip or as a part of it. Evidence indicates that shifting from a non-active to active transport increases physical activity, reduces obesity, noise and air pollution, traffic injuries and social isolation (Brown et al., 2017; de Nazelle et al., 2011; Maizlish et al., 2017; Martin et al., 2015; Sugiyama et al., 2013).

Additionally, studies have shown that health benefits of cycling outweigh risks of injuries and mortality (Andersen et al., 2018; de Hartog et al., 2010; Mueller et al., 2015). Public transport is also associated with increased physical activity (Besser and Dannenberg, 2005; Voss et al., 2016) since most transit trips involve walking to/from transportation stops or between transport modes (van Soest et al., 2019). Probably because of this, public transport use is related to other health benefits such as reduced obesity, hypertension, diabetes, and mental disorders when compared with travel by private motor vehicles modes (Tajalli and Hajbabaie, 2017). Celis-Morales et al. (2017) examined a sample of 263,000 participants from the prospective UK Biobank study and found that commuting by bicycle was associated with a lower risk of cardiovascular disease, cancer, and all-cause mortality, while walking was associated with a lower risk of cardiovascular disease only. The authors argue that active commuting should be encouraged to reduce the risk of death and the burden of important chronic conditions. Prior research using objective measures of health outcomes, such as BMI, waist circumference (Tajalli and Hajbabaie, 2017), lipid profile (Xu et al., 2013) and mortality (Celis-Morales et al., 2017) are valuable since they helped to show some health benefits related to transport modes and overcome the limitations of self-reported data. Research using metabolic biomarkers has not been extensively explored, and it would provide more strength to the evidence of the health impacts related to transport modes. For instance, vitamin D levels are higher among those with more "outdoors" activities and active commuting (Donneyong et al., 2016; Solis-Urra et al., 2019). Since vitamin D synthesis is mainly based on sunlight, both active and public transport modes can be expected to increase vitamin D levels. Physical activity has been associated with lower levels of hepatic inflammation markers (Keating et al., 2012). It could be suggested that those using more active modes of transport could have a better hepatic profile. To our knowledge, there is no prior research evaluating the association between public transport and active transport, analysed separately, with Vitamin D or hepatic inflammation markers.

The evidence showing the relationship between transport modes and health outcomes in Latin American is scarce and mixed, focusing mainly on active commuting. Ramírez-Vélez et al. (2017) found that Colombian children and adolescents who regularly commuted to school by bicycle showed a lower incidence of metabolic syndrome and better physical fitness than their non-cyclist counterparts. Another study that analysed Colombian university students showed that those who walked to campus were less likely to have high blood pressure, obesity and low HDL cholesterol (García-Hermoso et al., 2018). Counterintuitively, in Brazil, Treff et al. (2017) showed a protective effect of leisure-time physical activity against hypertension amongst adult women, but not for physical activity during transportation. To our knowledge, only two studies have explored this topic in Chile. Both of them used data from the ENS 2010, and both found associations of travel-related physical activity and cardiometabolic markers such as triglycerides, waist circumference, BMI as well as health outcomes such as metabolic syndrome and diabetes (Sadarangani et al., 2018; Steell et al., 2018). However, as in the aforementioned Latin American studies, the associations of public transport and health have not been individually examined yet, therefore, we do not know if public transport by itself may also contribute to an improved cardiometabolic profile in Latin America.

Chile is a very centralised country, with approximately 40% of its population living in its capital city, Santiago (INE, 2018). The country is motorising quite fast; in 2002 there were 144 cars per 1,000 inhabitants (Roque and Masoumi, 2016), while now this has risen to around 270 (INE, 2017). The modal share has also changed quite drastically in the last decades. In the case of Santiago, the modal share of private car use increased 12% in 1977 to 46% in 2012 (SECTRA and Universidad Alberto Hurtado, 2014), despite massive investments in an impressive Metro network and public transport subsidies. Some Chilean cities have seen a remarkable increment in bicycle use. In the case of Santiago, according to the citywide origin-destination survey, cycling's contribution to urban mobility doubled between 2001 and 2012, reaching 4% of daily trips (SECTRA and Universidad Alberto Hurtado, 2014). Since then, most observers agree that bicycle use has kept growing in Santiago, fed by active cycling advocacy groups (Sagaris, 2015); a broader and better bike path network; and the appearance of docked and dockless public bikes in the most affluent area of the city.

In Chile, transport investments are carefully evaluated before implementing them (OECD, 2017). This involves a quite rigorous process, in which future flows and levels of service are predicted, to decide whether a given project should move ahead. Based on this prediction, several direct impacts as time savings or operational costs are estimated. Although methodologies to include indirect health-related impacts, such as pollution, crashes and injuries, have been developed, they are still waiting to be incorporated (Ministerio de Desarrollo Social de Chile, 2019): the impact of transport mode choice on individual health has been largely ignored. Planners are aware that someone shifting from car to cycle for the commuting trip would receive important health benefits at the individual level. However, the current cost-benefit methodology to evaluate the convenience of infrastructure projects neglects individual health impacts. Thus, if the time taken by the bike trip takes longer than by car, the methodology might treat the modal shift as a cost, which appears as a contradiction given the personal option of the traveller and the positive health impacts. Thus, identifying an association between mode choice and health condition is relevant to incorporate a key attribute that differentiates between different transport modes, especially between active modes as walking and bicycling, and passive transport modes as the automobile.

There is a paucity of studies about the association between transport and objective measures of health as anthropometric and metabolic markers using nationally representative samples worldwide, especially among Latin American countries. Given that, the recent ENS 2016–2017 added a new, specific question about the main type of transport and added new metabolic markers (e.g. serum vitamin D). It, therefore, provides an opportunity to further explore the relationship between active transportation and objective measures of health in Chile. The primary aim of this study was to assess the association between demographic and socioeconomic factors with transport mode. The secondary aim was to explore the association between anthropometric and metabolic markers with transport mode.

2. Methods

2.1. Data source and sample

ENS 2016–2017 was a household survey with a stratified multistage probability sample of 6,233 non-institutionalised participants aged ≥15 years from urban and rural Chile including the 15 Chilean geographical regions. The data collection was done between August 2016 and March 2017. Sample size was calculated with 20% relative error for the estimation of national prevalence over 3%. One participant per household was randomly selected using a computational Kish algorithm. Response rate was 67%; refusal rate was 9.8%, with no replacements. The study protocol and ethical consent forms were approved by the ethics committee of the Pontificia Universidad Católica de Chile (PUC) and the Ministry of Health. A team of lay interviewers and certified nurses were trained and supervised to apply the survey using electronic devices for data capture. In the first home visit, a lay interviewer applied health questionnaires, including a question on the main type of transport used at least once a week. A trained nurse applied questionnaires, measured anthropometry (waist circumference, weight and height) and performed multiple biological sampling in a second-day visit to 89% of the sample. Excluding the missing values on mode of transport (n = 110), the analysed sample consisted of 6,113 participants.

2.2. Variables analysed

Mode of transport: self-reported main mode of transport measured with the following question: “out of the following alternatives, what is the transportation mode you most frequently use, at least once a week?“. Three categories of transport were created based on the original response categories 1. Motor vehicle (vehicle driver or light vehicle passenger); 2. Active modes (cycling or walking) and 3. Public transport.

Anthropometry: nurse measurement of waist circumference (WC) in cm, body mass index (BMI) in kg/m^2 and obesity (BMI≥30 kg/m^2).

Laboratory analyses: all blood samples were run at a central laboratory (UC Christus). Serum vitamin D: Serum 25-Hydroxy Vitamin D2 and D3 (ng/mL) were measured among females 15–49 years and males and females of 65 or older, using liquid chromatography-tandem mass spectrometry (LC-MS/MS) (Q TRAP 4500/AB SCIEX). We used the sum of D2 and D3. Serum total cholesterol (mg/dL) was measured using an enzymatic, colorimetric method (CHOD-PAP). Cholesterol samples with 9 h or more of fasting were included in the analyses. Gamma-glutamyltransferase (GGT) (U/L) was measured using an enzymatic, colorimetric method. Alanine transaminase (ALT) (U/L) was measured with UV test according to the IFCC method without pyridoxal-5-phosphate activation. Total cholesterol, GGT and ALT were measured among a random subsample of 62% of the total sample, using the Cobas 8000-c702/Roche. Details of the laboratory methods and variation coefficients are described elsewhere (Ministerio de Salud de Chile, 2018).

Healthy lifestyles: Current smoker was defined as occasional or daily smoker. Water intake was measured with the following question: “How many glasses of water do you drink daily?” and it was dichotomized into <6 or ≥6 glasses/day. Reduced-fat dairy consumption was defined according to the question: “What kind of dairy do you preferably consume?“. Three categories were constructed: 1. dairy-free diet, 2. skimmed/low-fat and 3. Whole milk. Fruit and vegetable consumption, according to the number of days per week and the number of portions per day in a typical week, was dichotomized into <5 or ≥5 portion/day. Alcohol use disorders were assessed with the AUDIT score. Frequency of physical activity during leisure time was measured with the following question: “In the last month, did you practice sports or physical activities outside of your work schedule, for 30 min or more each time?” with four options as answers: 1. ≥3 times/week, 2. Once or twice/week, 3. <4 times/month and 4. No sports in the last month.

2.3. Statistical analyses

We described the sample of 6,113 participants with valid data in mode of transport, according to gender, age (mean and categories: 15–24, 25–44, 45–64, ≥65 years) educational level (i.e. low:<8y, medium:8-12y, high:>12y of formal education) and urban/rural residence.

For the first aim we analysed mode of transport as the outcome and age, gender, educational level and urban/rural residence as the exposure variables. First, the distribution of modes of transport was described according to the exposure variables. Secondly, separate multinomial logit regression models were performed to determine the associations between the transport mode and age, gender, educational level and urban/rural residence. Models were adjusted for age and gender. Age was included in the models as a continuous variable; the other independent variables were entered as categorical. From these models, we estimated Relative Risk Ratios (RRR) with accompanying 95% confidence intervals (95% CI) for active and public transport, using motor vehicle as the reference category.

For the second aim we analysed WC, BMI and obesity as the outcomes and mode of transport as the exposure variable. First, we described mean WC, mean BMI and obesity prevalence with 95% CI according to mode of transport and gender. Secondly, associations between WC and BMI with mode of transport were calculated by linear regression, and associations between obesity and mode of transport using logistic regression. Three regression models were performed for each outcome (WC, BMI and obesity) and stratified by gender: model 1, non-adjusted; model 2, adjusted by age; model 3, adjusted by age and healthy lifestyles: current smoker, water intake ≥6 glasses/day, reduced-fat dairy consumption, fruit and vegetable consumption ≥5 portion/day, AUDIT score and frequency of physical activity during leisure time. Age and AUDIT score were included in the models as continuous variables; the other independent variables were entered as categorical. Thirdly, gender-specific serum vitamin D, total cholesterol, ALT and GGT levels were also evaluated against transport mode using the three models described above. Vitamin D analyses were stratified in two age groups (15-49y and ≥65y) and self-reported sunlight exposure (*little* or *a lot* in the last week) was also included in the model (3).

Analyses were based on complete-cases. We used the appropriate weights in all analyses; these account for differences in selection probability and minimise bias from non-response. P-values <0.05 were classed as significant (two-tailed). All analyses were conducted in Stata V14.0 (StataCorp LP, College Station, Texas) adjusting for the complex survey design.

3. Results

3.1. Descriptive statistics of the sample

The total ENS 2016–2017 sample included 6,233 participants aged ≥15 years, of whom 6,113 had valid information on transport modes and demographic variables, and 5,385 and 5,382 had valid measures of BMI and WC respectively. Demographic characteristics of the sample with valid data on transport mode are presented in Table 1.

3.2. Mode of transport associated with socio-demographic variables

As seen in Fig. 1, motor vehicle was the most frequently reported transport mode (41%); followed by public transport (38%) and active modes (21%). The use of public transport was higher among females (44% females; 31% males) while the prevalence of motor vehicle use was lower for females (36% females; 47% males). Active travellers were: 15%, walkers (17% females; 13% males) and 6% cyclists (3% females, 9% males). Chile, a long narrow country, has 15 geographical regions. The main type of transport varied by geographical region, with highly populated regions (located centrally in the country) having higher rates of public transport use, as shown in Fig. 2.

The age-adjusted multinomial regression (Fig. 3) showed that females were more likely than males to use public transport, with a Relative Risk Ratio (RRR) of 1.90 (95% CI 1.55, 2.32, reference: motor vehicle). Active and public transport decreased with age (RRR = 0.56 (0.38–0.82) and RRR = 0.35 (0.25–0.49), respectively, age ≥65 vs 15-24y); participants with low level of education were more likely to use active transport than were those of high education level (RRR = 1.73 (1.28–2.33); while participants residing in rural areas were more likely to use active transport (RRR = 1.27 (0.97–1.67)) and less likely to use public transport than those residing in urban areas (RRR = 0.71 (0.52–0.97)).

3.3. Anthropometric and metabolic markers associated with mode of transport

Descriptive statistics for WC, BMI and obesity by transport mode are shown in Fig. 4. The regression models showed gender differences in the associations between the anthropometric measures and transport mode (Table 2). BMI was associated with transport mode among males and females, however, WC and obesity were associated with transport mode only among males. Among males. these associations were significant ($p < 0.001$) in the crude model (1), age-adjusted model (2) and in the fully adjusted model (3). Men using active transport showed an odds ratio (OR) estimated by model (3) of 0.53 (0.35–0.81) of being obese compared with motor vehicle users. WC was 5.20 cm (3.29–7.11) smaller and BMI was 1.90 kg/m^2 (1.14–2.65) lower among male active than motor users. Similar significant associations were found among males when comparing public versus motor vehicle transport in the fully adjusted model (3). Among females, active transport was associated with significantly lower mean BMI ($\beta = -0.84$ (-1.67 to -0.02)) than motor vehicle transport in the fully adjusted model (3). Additional analyses pooling both genders showed similar associations to those described among males (see Table 1, Supplemental Digital Content 1, which shows the regression coefficients with their 95% CI for all persons).

Higher levels of vitamin D were found among females of both age groups using active transport compared with public transport when the fully adjusted model (3) was used ($\beta = 2.71$ mg/dL (0.74–4.67) for those aged <50y and $\beta = 2.85$ mg/dL (0.56–5.15) for those aged ≥65y). Higher levels of vitamin D were found among males and females aged ≥65y using active transport compared with motor vehicle ($\beta = 3.98$ mg/dL (1.46–6.50) for males; $\beta = 2.69$ mg/dL (0.61–4.77) for females). Total cholesterol was lower among

Table 1
Sample characteristics. Chile, ENS 2016–2017.

Variable	Category	n[a]	% or mean (95% CI)
Sociodemographic characteristics			
Gender	Males	2,262	48.9% (46.6–51.1)
	Females	3,851	51.1% (48.9–53.4)
Age (y)	$\bar{x}$	6,113	43.0 (42.2–43.8)
	15–24	831	19.1% (17.3–20.9)
	25–44	1,794	37.4% (35.0–39.8)
	45–64	2,028	30.5% (28.5–32.6)
	≥65	1,460	13.1% (11.8–14.5)
Zone	Urban	5,136	88.8% (87.3–90.1)
	Rural	977	11.2% (9.9–12.7)
Educational level (years of formal education)	Low (<8)	1,425	16.3% (14.4–18.3)
	Medium (8–12)	3,272	55.5% (52.6–58.4)
	High (>12)	1,362	27.6% (24.8–30.7)
	missing	54	0.5% (0.3–0.9)
Anthropometric measures			
Waist (cm)	$\bar{x}$	5,382	93.2 (92.6–93.9)
BMI (kg/m^2)	$\bar{x}$	5,385	28.5 (28.3–28.8)
Metabolic markers			
Vitamin D (ng/mL, males ≥65y)	$\bar{x}$	447	21.3 (19.8–22.8)
Vitamin D (ng/mL, females <50y)	$\bar{x}$	1580	20.1 (19.3–20.8)
Vitamin D (ng/mL, females ≥65y)	$\bar{x}$	792	17.7 (16.8–18.6)
Total cholesterol (mg/dl)	$\bar{x}$	3,471	177.3 (175.0–179.6)
ALT (U/L)	$\bar{x}$	3,619	25.6 (24.5–26.7)
GGT (U/L)	$\bar{x}$	3,631	30.5 (28.6–32.5)

[a] Non-weighted sample sizes. Weighted estimation with 95% confidence intervals (95% CI).

males using active and public transport than motor vehicle (β = −13.78 mg/dL (−21.3 to −6.26) and β = −8.58 mg/dL (−16.99 to −0.18), respectively); the opposite was seen among females when comparing active transport versus motor vehicle (β = 8.07 mg/dL (1.10–15.04)). Among males, active and public transport users had lower levels of ALT when compared to motor vehicle users (β = −5.81 U/L (−9.61 to −2.03) and β = −5.18 (−9.37 to −1.00), respectively); among males, GGT showed lower levels among public transport than motor vehicle users (β = −9.89 U/L (−15.92 to −3.87)) (see detailed results in Table 2).

4. Discussion

This analysis from a large representative sample of the Chilean adult population indicates that around 41% were using public transport, 38% motor vehicle and 21% active modes (cycling and walking) as the main modes of transport in Chile during 2016–2017. We found higher levels of active transport among males, younger groups, less educated and rural populations. This pattern has also been reported in other countries (Nehme et al., 2016; Reis et al., 2013; Sá et al., 2018; Titze et al., 2014). Our results on active transport are consistent with those reported by Aguilar-Farias et al. (2019) using the Chilean National Environment Survey (CNES) 2014 and 2015, where cycling prevalence was 7%, with higher use among youth and participants of low socioeconomic status. According to the CNES2015, females tended to walk more than males, however, the overall prevalence of active transport was similar by gender (Ministerio del Medio Ambiente de Chile, 2018). This study broadens the evidence obtained by the transportation sector, where trips rather than prevalence were studied. The Chilean Origin-Destination Survey (EOD) 2012 showed that around 30% of the trips in Santiago were made by public transport, another 30% by motor vehicle and around 40% were made walking or cycling (SECTRAUniversidad Alberto Hurtado, 2014). Our results showed that Santiago had higher use of public transport (around 50%) and lower of active transport (20%). However, these differences between EOD and ENS are expected, because the questions were different. ENS asked about the transportation mode most frequently used (at least once a week) in a sample aged ≥15y while EOD described total trips in a given week-day and a weekend day with no age restrictions.

Our study showed that anthropometric benefits are associated with active and public transport in males: we found lower WC, BMI and obesity than in motor vehicle users. We also found lower BMI among females using active transport than motor vehicles, but the magnitude of the association was 58% smaller than among males (0.9 versus 1.9 kg/m^2 for females and males, respectively). We ran three models to analyse the associations and the effects of potential confounders. The likelihood of being obese was lower for male active travellers compared with motor vehicle travellers. This held after adjusting for fruit-vegetable, alcohol and water consumption as well as physical activity and smoking. Other benefits were associations with decreased levels of hepatic enzymes, lower total cholesterol and a higher level of serum vitamin D. Our study described a dose-response relationship with transport modes. Increased health benefits were seen among active transport users (cycling or walking), followed by mid benefits among public transport users when compared with motor vehicle users. According to our fully adjusted model, WC, BMI, obesity, total cholesterol and hepatic enzymes were significantly lower among male public transport than motor vehicle users.

Our results are in line with the beneficial associations of active transport on BMI described in Chile by Steell et al. (2018) using ENS 2010. They reported that 30 min increase in active transport measured by the Global Physical Activity Questionnaire (GPAQ) was associated with lower odds for obesity, with an OR of 0.93 (95% CI 0.88, 0.98). We found a stronger association between transport and obesity in the fully adjusted model: OR = 0.67 (0.52–0.86) for obesity when comparing active vs motor travel among males. Steel et al. merged public and motor vehicle transport into a single category. We highlighted the importance of differentiating the analysis between public and motor vehicle users. For instance, we found an OR for obesity among males of 0.64 (0.43–0.96) when comparing public with motor vehicle use. Steel et al. adjusted for gender but did not show stratified results. Our findings showed stronger

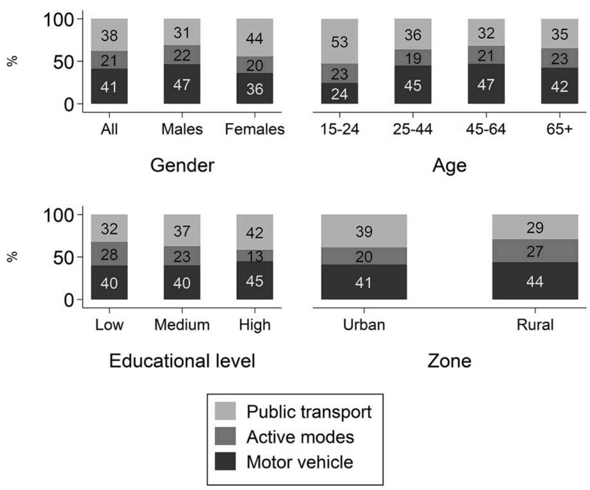

Fig. 1. Type of transport by gender, age, educational level, urban or rural zone. Chile, ENS 2016–2017*.
*Educational level (years of formal education): Low (<8), Medium (8–12) and high (>12).

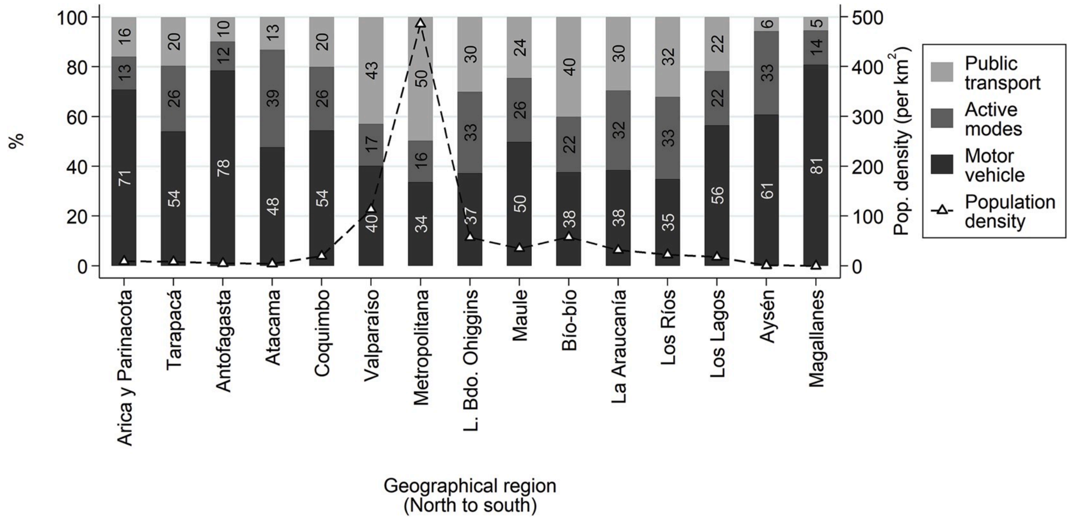

Fig. 2. Transportation modal share by each geographical region Chile, ENS 2016–2017*.
*The regions have been organized in the same order they are located geographically, from north to south with the densest ones located at the centre of the territory.

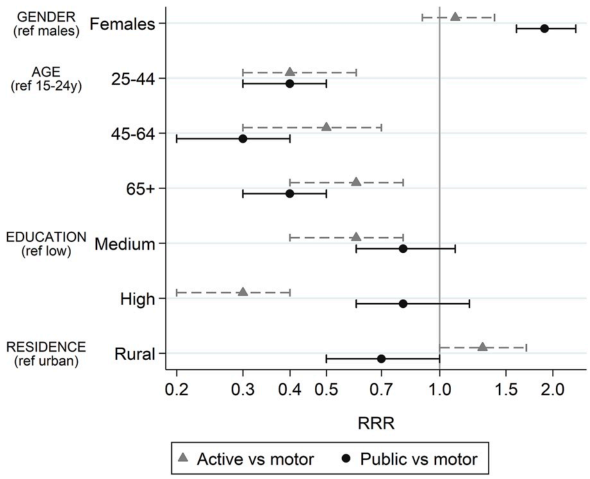

Fig. 3. Multinomial regression of associations between gender, age, educational level, place of residence and transport modes. Chile, ENS 2016–2017*.
*RRR = Relative Risk Ratio. RRR were calculated using multinomial logistic regression. Models were gender and age-adjusted. The reference category for the outcome was motor vehicle. Educational level (years of formal education): Low (<8), Medium (8–12) and high (>12).

associations between transport and anthropometry in males, pointing out the relevance of gender-specific analyses. This gender difference has been described by others (Falconer et al., 2015). Potentially, males tend to travel longer distances and perform more vigorous physical activity than females. This may be a plausible hypothesis for Chile, given the results obtained from the analysis of the GPAQ transport questions included in the ENS 2016–2017 (not shown) where males and females using active transport reported 79 and 58 min of transport-based physical activity, respectively. Associations of transport with vitamin D has been described in Chile recently by Solis-Urra et al. (2019), using ENS 2016–2017 in women, but some concern arises with the absence of complex sampling design on their variance estimation: variances are underestimated when complex sampling design is not considered. For instance, using the complex sample design for variance estimation we did not find a significant association between transport and Vitamin D among females aged ≥65y after adjusting for the confounding variables described by Solis-Urra (i.e. age, menopausal status, achieved education level, geographical region, dairy consumption and sunlight exposure). According to our fully adjusted model for females ≥65y, we found an association between transport and vitamin D, but after region, BMI and menopause were included in this model, significance was lost (results available on request). According to a meta-analysis based on prospective cohorts, active commuting was significantly related to lower incidence of coronary events, stroke and heart failure (Dinu et al., 2019). This decrease in cardiovascular risk could be partially explained by the improvement on the lipid profile. Aligned with our results, Zwald et al. (2018), using the U.S.

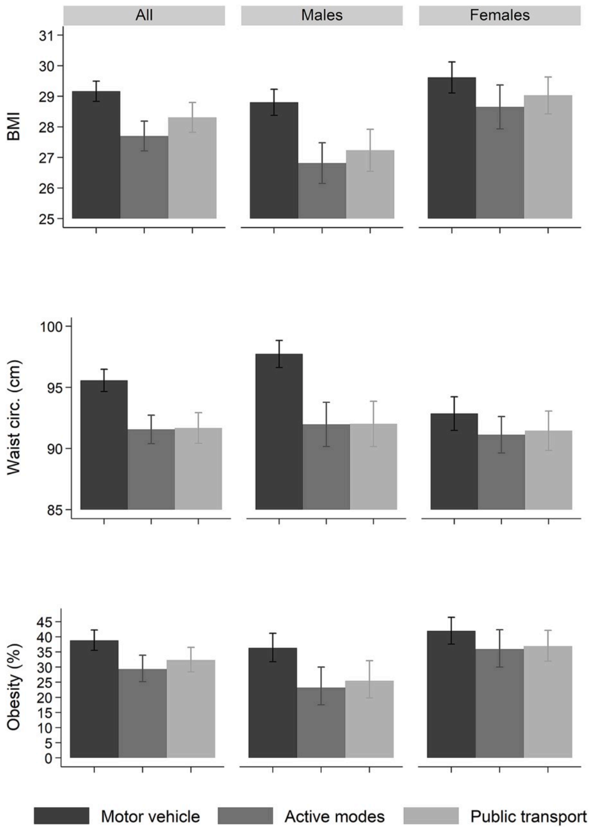

Fig. 4. Mean waist circumference, mean BMI and obesity (%) by type of transport and gender. Chile, ENS 2016–2017.
*BMI: Body Mass Index (kg/m^2), Obesity: BMI≥30 kg/m^2.

National Health and Nutrition Examination Survey (NHANES) 2007–2016, found lower LDL cholesterol among active transport users.

Active and public modes of transport could decrease WC, BMI and obesity by mechanisms related to higher energy expenditure (Besser and Dannenberg, 2005; Voss et al., 2016). Mechanisms by which active modes of transport could reduce hepatic inflammatory markers and improve the lipid profile are still greatly unknown, but physical activity linked to transport could decrease hepatic fat and in this way reduce hepatic inflammation (Farzanegi et al., 2019) and could also enhance the use of lipids by skeletal muscles, reducing plasma lipid levels (Wang and Xu, 2017).

In recent decades Chile has shown a systematic drift of trips from active and public transport to the automobile. Only recently, few cities have seen an encouraging growth of bicycle trips, most noticeably Santiago. Interventions aiming to increase more active modes of transport are described as major opportunities for the improvement of public health (Celis-Morales et al., 2017). Our associations suggest that incidental physical activity related to mass population transport could have a major role in public health. Our results may contribute to the formulation of policies or investments to shift modal share towards more active modes of transport, since on the one hand, they describe the baseline distribution of the main type of transport modes and, on the other hand, they describe the magnitude of anthropometric and metabolic benefits linked to differentiated modes of transport. This study underpins active modes promotion policies where walking and cycling could be promoted serving as feeders for the transportation system, particularly in small and mid-sized cities, where public transport is less available. Variations in patterns of use of active modes in Chile by geographical regions highlight the need for appropriate local policies allowing for a range of climates and geographic features. For instance, the southernmost region of Chile (XII-Magallanes) had the least use of active transportation modes, which is congruent with its cold and windy climate and high levels of obesity compared to other Chilean regions. However, authorities from Magallanes have recently invested in 17.5 km of new bike routes and announced 60 km more to be added. In Magallanes, reinforcing public transport could also serve as a health-enhancing local policy. Specific populations such as the less educated, females, rural and older groups would benefit greatly from cycling and pedestrian-inclusive policies which may help to tackle socioeconomic health inequalities (Gao et al., 2017). Also, investment in infrastructure could help to increase active modes (Langlois et al., 2016).

Some of this study's strengths are the use of a big, nationally-representative sample of the adult general population, including all socioeconomic groups from urban and rural areas; use of objective measures of health (i.e. not self-reported); analysis of public transport as a separate transport mode (and not included with non-active modes) and adjusting for lifestyle risk factors (i.e. current smoker, water intake, reduced-fat dairy consumption, fruit-vegetable consumption, alcohol use disorders and physical inactivity during leisure time). However, our study has some limitations. The cross-sectional nature of the sample limits causal inferences, as

Table 2
Mode of travel associations with anthropometric and metabolic markers by gender. Chile, ENS 2016–2017.

		Males				Females			
Outcome	Travel mode	Sample size#	β Model 1	β Model 2	β Model 3	Sample size#	β Model 1	β Model 2	β Model 3
Anthropometry									
Waist (cm)	Active vs MV	1,958	−5.76***	−5.33***	−5.20***	3,418	−1.73*	−1.13	−1.14
	Public vs MV		−5.72***	−4.02***	−3.91***		−1.41	−0.79	−0.96
	Public vs active		0.04	1.31	1.29		0.32	0.34	0.18
BMI (km/m²)	Active vs MV	1,956	−1.99***	−1.91***	−1.90***	3,423	−0.97**	−0.82*	−0.84**
	Public vs MV		−1.57***	−1.25***	−1.22***		−0.59	−0.44	−0.51
	Public vs active		0.42	0.67	0.67		0.37	0.38	0.34
Obesity (OR)	Active vs MV	1,956	0.53***	0.54***	0.53***	3,423	0.80	0.81	0.80
	Public vs MV		0.60***	0.64**	0.63**		0.82	0.84	0.82
	Public vs active		1.13	1.20	1.20		1.03	1.04	1.03
Metabolic markers									
Vitamin D (ng/m) [<50y]	Active vs MV	N/A	N/A	N/A	N/A	1,577	1.99**	2.00**	2.00**
	Public vs MV		N/A	N/A	N/A		−0.85	−0.85	−0.75
	Public vs active		N/A	N/A	N/A		−2.85***	−2.85***	−2.75**
Vitamin D (ng/m) [≥65y]	Active vs MV	446	2.10	2.02	3.99***	792	2.42**	2.33*	2.56**
	Public vs MV		2.17	2.22	2.07		−0.05	−0.14	−0.26
	Public vs active		0.07	0.20	−1.92		−2.46**	−2.47**	−2.82**
Total Cholesterol (mg/dL)	Active vs MV	1,256	−16.45***	−15.26***	−13.78***	2,210	4.75	7.24**	8.07**
	Public vs MV		−13.35***	−9.44**	−8.58**		−1.65	0.93	1.77
	Public vs active		3.09	5.83	5.20		−6.40*	−6.31*	−6.30*
ALT (U/L)	Active vs MV	1,321	−6.31***	−6.37***	−5.82***	2,293	−2.06	−1.76	−2.08
	Public vs MV		−5.33**	−5.54**	−5.18**		−1.01	−0.71	−0.98
	Public vs active		0.98	0.83	0.64		1.06	1.05	1.09
GGT (U/L)	Active vs MV	1,325	−4.52	−3.54	−2.57	2,301	−3.88	−2.52	−2.06
	Public vs MV		−13.63***	−10.44***	−9.89***		−4.85**	−3.48	−3.86*
	Public vs active		−9.11**	−6.90*	−7.32*		−0.98	−0.96	−1.80

Note: *p<0.1, **p<0.05, ***p<0.01. Linear regression coefficients (β) for the association between transport mode and waist circumference, Body Mass Index (BMI), vitamin D, total cholesterol, Alanine transaminase (ALT) and Gamma-Glutamyl transferase (GGT). Logistic regression Odds Ratio (OR) for the association between transport mode and obesity (BMI ≥30 kg/m²). Model 1: non-adjusted; Model 2 adjusted for age and gender; Model 3: adjusted for age, gender, smoking, water intake ≥6 glasses/day, reduced-fat dairy consumption, fruit and vegetable consumption ≥5 portion/day, alcohol (AUDIT score) and frequency of physical activity during leisure time sedentarism. Vitamin D model 3 results were also adjusted for sunlight exposure (self-reported as "little" or "a lot" in the last week). MV: Motor Vehicle; N/A: non-available data. #Model 1, 2 and 3 used the sample with valid data in model 3.

reverse causality and survival bias could be affecting our results. Moreover, other unobservable variables could affect our results (e.g. motivation or availability of time), potentially introducing a bias towards rejecting the hypothesis of no association. Health status may also influence transport modes (healthier people choose more active modes): we did not adjust by health status, but we did adjust by healthy lifestyles and benefits were seen both in healthy and unhealthy lifestyle populations. Nevertheless, our findings on obesity, BMI and WC were consistent with population-based prospective longitudinal research, as reported by Flint et al. (2016) using the UK Biobank data and by Qin et al. (2012) using the longitudinal China Health and Nutrition Survey data.

Chile has recently implemented policies for increasing the use of active transport modes, which is positive for health. The focus has been in adding bicycle routes mostly in capital cities of each region and affluent areas of Santiago. From 2013 to 2018 the number of bicycle lanes in Santiago increased 20-fold, from a total of 20 km of paths to 400 km, representing 10% of the cycling lanes in Latin America (Ríos et al., 2015). Some other big cities, noticeably Rancagua, have followed this lead. Traffic calming areas, with maximum speeds of 30 km/h, have been implemented in a few areas of Santiago (Ministerio de Transportes y Telecomunicaciones de Chile, 2014). INE, 2018, a new law regulating the flow of different modes in a road was passed. The law reduced the maximum speed of cars from 60 to 50 km/h and ordered cyclists to use the road unless its cycling conditions were considered unsafe (Ministerio de Transportes y Telecomunicaciones de Chile, 2018). Finally, pedestrianised streets have increased in business districts of a few Chilean cities, but they are still quite insignificant. Including the same transport question in the next ENS will be key for surveillance of the health impacts of transport policies and investments in transportation infrastructure. Including this question may be a low-cost surveillance method that could be used by other countries. Future research using longitudinal data from the Chilean population would help to clarify the causality of the associations between transport and objective measures, particularly if examined only among participants who were healthy at baseline, and thus did not base their mode choice on pre-existing impairments, and to understand the gender inequities we found.

The evidence to support transport planning decisions in local communities is growing in Latin America, as part of the broader spectrum of planning decisions that lead to healthy communities. There is no doubt that health is strongly related to the built environment people live in (Koehler et al., 2018) and transport is a very important component of this environment and vice versa.

5. Conclusions

In Chile, both active transport (cycling and walking) and public transport use were associated with multiple nutritional and metabolic benefits such as lower BMI, lower waist circumference, less obesity, higher vitamin D, lower cholesterol and lower hepatic inflammation. Stronger benefits were seen in males than in females. These findings are important evidence for transport planning policies and a great opportunity for the local design of population-wide preventive strategies to tackle chronic diseases, decrease gender, regional and socioeconomic inequities and to improve the quality of life of the population.

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CRediT authorship contribution statement

Álvaro Passi-Solar: Methodology, Formal analysis, Investigation, Data curation, Writing - original draft. **Paula Margozzini:** Methodology, Investigation, Writing - original draft, Supervision. **Andrea Cortinez-O'Ryan:** Writing - original draft, Writing - review & editing. **Juan C. Muñoz:** Methodology, Writing - original draft. **Jennifer S. Mindell:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jth.2019.100819.

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