



Transport-related physical activity in Brazil: an analysis of temporal trends using VIGITEL data

Atividade física de deslocamento no Brasil: uma análise de tendências temporais com dados do Vigitel

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ABSTRACT

Introduction: Transport-related physical activity (TRPA) in urban areas can offer benefits for health, sustainability, and the right to the city, but studies investigating associated inequities are still lacking. Considering the inequalities among Brazilian macro-regions, it is necessary to understand how sociodemographic factors influence TRPA over time. **Objectives:** Evaluate the temporal trends of TRPA in Brazilian macro-regions and assess its potential association with sex, age, educational level, and race/ethnicity. **Methods:** Data from the VIGITEL telephone survey of 623,193 adults (≥ 18 years) living in Brazilian capitals and the Federal District between 2009 and 2023 were used. Individuals who achieved ≥ 150 minutes/week of TRPA were classified as physically active. To assess the variables of interest, logistic regression models with non-linear functional forms were applied, with nodes positioned in the years 2015, 2020, and 2021. **Results:** The proportion of individuals active in commuting decreased from 17.9% (95% CI: 17.2; 18.7) in 2009 to 12.5% (95% CI: 11.5; 13.6) in 2023. All macro-regions showed a downward trend, with the lowest prevalence in the Central-West and the highest in the Southeast. Women, the elderly, white individuals, and individuals with both higher (12 or more years) and lower (0-4 years) educational levels showed lower levels of TRPA throughout the series. **Conclusion:** Given the declining trend in TRPA, which is differently related to sociodemographic factors, the need for policies that expand its access as a choice, considering its determinants more comprehensively, is reinforced.

Keywords: Active mobility; Active commuting; Urban areas; Socioeconomic factors; Public policies.

RESUMO

Introdução: A atividade física (AF) de deslocamento em meio urbano pode apresentar benefícios para a saúde, sustentabilidade e no direito à cidade, porém, ainda carecem de estudos que investiguem as iniquidades associadas. Considerando as desigualdades entre as macrorregiões brasileiras, faz-se necessário compreender como fatores sociodemográficos influenciam a prática de AF de deslocamento ao longo do tempo. **Objetivos:** Avaliar a tendência temporal da AF de deslocamento nas macrorregiões do Brasil e sua potencial associação com as variáveis sexo, faixa etária, escolaridade e raça/cor. **Métodos:** Foram utilizados dados do inquérito telefônico Vigitel, compreendendo 623.193 adultos (≥ 18 anos) residentes das capitais brasileiras e do Distrito Federal, entre 2009 e 2023. Foram classificados como ativos os indivíduos que atingiram ≥ 150 minutos/semana de AF de deslocamento. Para avaliar as variáveis de interesse, foram aplicados modelos de regressão logística com formas funcionais não-lineares, com nós posicionados nos anos de 2015, 2020 e 2021. **Resultados:** A proporção de indivíduos ativos no deslocamento diminuiu de 17,9% (IC 95%: 17,2; 18,7) em 2009 para 12,5% (IC 95%: 11,5; 13,6) em 2023. Todas as macrorregiões apresentaram tendência de redução, com a menor prevalência no Centro-Oeste e a maior no Sudeste. Mulheres, pessoas idosas, brancas e com maior (12 ou mais anos) e menor (0-4 anos) escolaridade apresentaram menores níveis de AF de deslocamento durante toda a série. **Conclusão:** Diante da tendência de declínio de AF de deslocamento, a qual está diferentemente relacionada a fatores sociodemográficos, reforça-se a necessidade de políticas que ampliem o seu acesso como escolha, considerando os seus determinantes de forma mais abrangente.

Palavras-chave: Mobilidade ativa; Deslocamento ativo; Áreas urbanas; Desigualdades sociais; Políticas públicas.

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Introduction

The relationship between low levels of physical activity (PA), the incidence of non-communicable diseases, and mortality is well-documented in the field of epidemiology¹. Against this backdrop, the World Health Organization proposed a global plan in 2018 to expand actions and policies aimed at reducing the prevalence of physical inactivity by 10% and 15% by 2025 and 2030, respectively². However, trend analyses indicate that global levels of physical inactivity have remained unchanged over the years^{1,3}.

Although PA is predominantly discussed from a leisure perspective^{1,2}, available evidence has highlighted the importance of transport-related physical activity (TRPA), a domain that remains under-explored. This domain, which encompasses the ways individuals actively travel from one place to another particularly when motivated by free choice rather than necessity⁴, offers potential health benefits. These arise not only from increased PA levels themselves but also from reductions in air and noise pollution and a decrease in traffic-related mortality. Furthermore, promoting TRPA as a choice correlates with promoting the “right to the city,” especially for social groups historically excluded from leisure activities⁵.

In Brazil, however, choices regarding PA practice remain conditioned by inequalities among social groups. The greater exposure of women to the “double burden” of work or the limited access of lower-income individuals to urban leisure spaces, for example, influence the choices these populations can make regarding leisure-time PA. These inequities, notably more pronounced in lower-income countries⁴, are repeatedly perpetuated rather than driving the formulation of equitable public policies, thereby deepening barriers to PA based on individual choice for certain groups⁶. Salvo et al.⁷ found that levels of TRPA are inversely proportional to income categories defined by the World Bank. Across all these categories, however, women and individuals with higher educational levels tend to engage in lower levels of TRPA, likely affected differently by the interplay between choice and the need for active commuting.

The Surveillance System for Risk and Protective Factors for Chronic Diseases via Telephone Survey (*Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico* - Vigitel) is an annual survey conducted by the Brazilian Ministry of Health that collects various relevant indicators regarding the

health of the national population, including time spent on active commuting. Previous studies using Vigitel data have focused on identifying linear trends in PA levels over time. Although this is a valid and easily interpretable analysis, relevant non-linear patterns, present during periods of significant disruption to daily habits and lifestyles, such as during and after the COVID-19 pandemic, may go unnoticed. Therefore, this study aimed to determine the temporal trend of TRPA across Brazil's macro-regions using available Vigitel data, as well as the associations with sex, age group, educational level, and race/ethnicity, by employing non-linear strategies capable of capturing the impact of the COVID-19 pandemic.

Methods

Study design and sample

This study reports an analysis of the level of TRPA using Vigitel data. Vigitel employs probability sampling methods, covering adults aged 18 years or older⁸. Only data from the 2009–2023 period were considered, due to changes made to the PA questionnaire in 2009. Detailed information regarding the sampling process has been reported previously⁹. Vigitel received approval from the Ministry of Health's National Research Ethics involving Human Beings Commission (CAAE: 65610017.1.0000.0008).

Descriptive and exposure variables

For regional comparison purposes, the 26 state capitals and the Federal District were grouped into five macro-regions: Central-West, Northeast, North, Southeast, and South. The sociodemographic variables used were sex (male; female), age group (18–24 years; 25–34 years; 35–44 years; 45–54 years; 55–64 years; 65 years or older), Educational level (0–4 years; 5–8 years; 9–11 years; 12 years or more), and race/ethnicity. Regarding the race/ethnicity variable, the “white”, “brown” and “black” groups were used in the main analysis. The “indigenous” and “asian” groups were excluded due to extremely low prevalence rates (< 2%), which resulted in unstable estimates with high variability. However, a graph showing all race/ethnicity groups is presented in Supplementary Figure 1. All variables in Vigitel are obtained through the self-reports of participants who answered the standardized questionnaire used in the survey.

Transport-related Physical Activity

To assess TRPA, were used questions regarding PA

performed via walking or cycling during commutes between home and work or home and the place of study. To calculate the total weekly TRPA, Vigitel uses the midpoint of each response category (e.g., 20 to 29 minutes is calculated as 24.5 minutes) and sums the commute times for both work and study locations. A key distinction in our approach is that, until 2023, Vigitel did not account for activity bouts of less than 20 minutes. In line with the latest recommendation that any duration of PA should be considered valid, our calculation counted the responses “Less than 10 minutes” and “10 to 19 minutes” as 4.5 and 14.5 minutes of PA, respectively. Following this calculation, individuals achieving a total TRPA of ≥ 150 minutes/week (equivalent to 30 minutes/weekday) were classified as active commuters. Therefore, it should be noted that slight differences may exist between our estimates and those found in previous Vigitel reports.

Statistical analysis

Descriptive analyses and inferential models accounted for the sampling weight assigned to each individual, provided in the Vigitel database via the *pesorake* variable. Continuous descriptive variables were presented as mean and standard deviation, while categorical variables were presented as percentages (weighted proportions). To analyze the temporal trend of active commuters, logistic regression models were used, with the outcome being the individual's classification as active or inactive in commuting and the predictor variable being the year. Given the possibility of non-linear variations over the period, models with linear and non-linear functional forms were compared using the Akaike Information Criterion (AIC; lower value) and likelihood-ratio tests. Given the superior fit of the restricted cubic spline (RCS) nonlinear models, these were adopted for visualizations and inferences, with knots placed at the years 2015, 2020, and 2021 to account for the inflection points observed in the estimated proportions and the potential effect of the COVID-19 pandemic on the proportion of active commuters. Furthermore, a directed acyclic graph (DAG) was created to visualize the interrelationships among the variables analyzed in the study, in order to provide further insight for interpreting the results (Supplementary Figure 2).

The proportion of active commuters and the trend over the years were also estimated according to the following strata: sex, age group, educational level, and race/ethnicity. For the race/ethnicity variable, individ-

uals who answered “Don't know” or “Refused to answer” were excluded from the analysis. The variables were included as interaction with the year in the logistic regression models, and the significance of the terms was assessed using likelihood-ratio tests.

All analyses used an alpha value of 5% set a priori. Data analysis was performed using R 4.2.2 software (R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2022). The code used to reproduce this analysis can be found on the following GitHub page: <https://github.com/gp-esteves/Dados-Vigitel>.

Results

Table 1 presents descriptive data on 623,193 participants studied over 14 years of Vigitel follow-up. A decrease in the number of participants evaluated over the years is evident. The proportion of female to male participants remained stable over time. The most common age groups were 25–34 and 45–54 years. The race/ethnicity subgroups most frequently reported throughout the years were white and brown. The most common educational level across the years was 9 to 11 years. The Southeast and Northeast macro-regions accounted for the highest proportion of responses over the years.

When comparing the regression models used to analyze the temporal trend of active commuters, the nonlinear model with RCS demonstrated greater explanatory power regarding the data compared to the linear model (difference in AIC values = -813; $p < 0.001$ in the likelihood-ratio test) and was therefore selected for analysis. The effect of the year was significant ($p < 0.001$), and Figure 1 illustrates the temporal trends of active commuters over time. A downward trend is observed in the percentage of active commuters at the national level (Figure 1A), falling from 17.9% (95% CI: 17.2; 18.7) in 2009 to 12.8% (95% CI: 12.1; 13.8) in 2015. The rate remained relatively stable until the onset of the COVID-19 pandemic, when there was another drop, reaching 10.8% (95% CI: 9.8; 11.9) in 2021. Finally, the most recent data available, from 2023, indicate an upward trend in the proportion of active commuters, reaching 12.5% (95% CI: 11.5; 13.6).

The model incorporating the macro-region variable showed a significant effect of year ($p < 0.001$), macro-region ($p < 0.001$), and the interaction between year and macro-region ($p < 0.001$), indicating distinct trends for each region of the country. Figure 1 illustrates a downward trend in levels of TRPA across all macro-regions between 2009 and 2023. Throughout

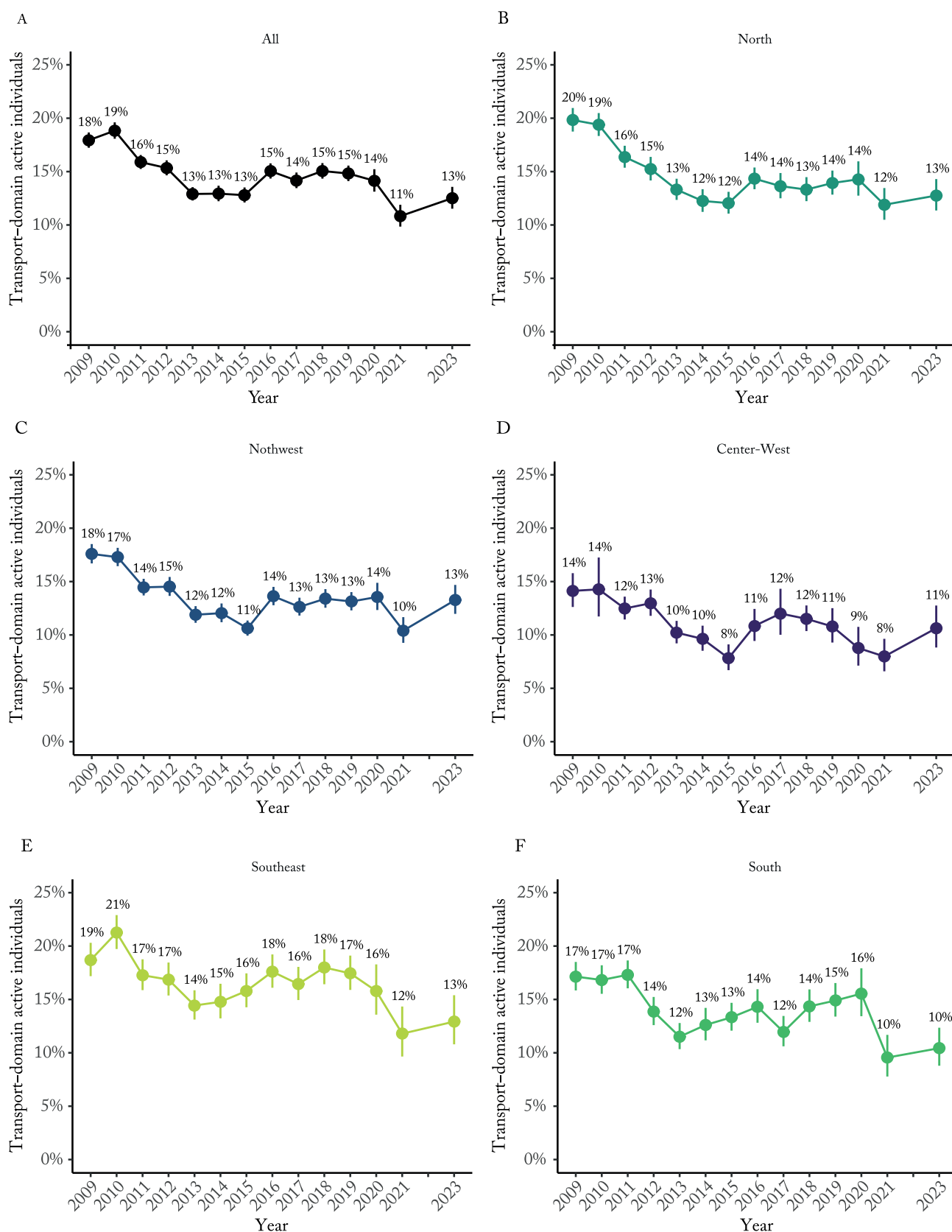


Figure 1 – Commuting workforce across Brazil's macro-regions. The points represent weighted proportions, with vertical lines indicating 95% confidence intervals. The line and shaded area represent the trend estimated via a logistic regression model incorporating a non-linear functional form for the year, along with its 95% confidence interval. Macro-region-specific lines were estimated by including an interaction term between year and macro-region.

the time series, the Southeast region showed the highest percentage of active commuters, while the Central-West showed the lowest. When evaluating the 2020–2021 period, marking the onset of the pandemic,

the South region exhibited the sharpest decline in the prevalence of active commuters (from 15.5% to 9.5%), whereas the Central-West region showed the least pronounced drop (from 8.7% to 7.9%). From 2021 to

Table 1 – Sample characterization adjusted for sample weight

Variables	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2023
Sample size	54.367	54.339	54.144	45.448	52.929	40.853	54.174	53.210	53.034	52.395	32.443	27.077	27.093	21.687
Body weight (kg)	69.8 (14.8)	70.3 (15.0)	70.9 (15.1)	71.6 (15.5)	71.7 (15.6)	71.8 (15.3)	72.5 (15.7)	72.5 (15.6)	72.7 (15.7)	73.0 (16.1)	73.1 (16.0)	73.9 (16.1)	73.8 (16.2)	75.1 (17.1)
Height (cm)	166.4 (9.9)	166.4 (10.2)	166.5 (10.0)	166.8 (10.0)	166.8 (10.3)	166.5 (10.3)	166.6 (10.3)	166.7 (10.3)	166.9 (10.3)	166.7 (10.2)	166.7 (10.3)	166.7 (10.2)	166.6 (10.0)	166.7 (10.2)
Sex (%)														
Male	46.1	46.1	46.1	46.1	46.1	46.1	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
Female	53.9	53.9	53.9	53.9	53.9	53.9	54.0	54.0	54.0	54.0	54.0	54.0	54.0	54.0
Age group (%)														
18–24 years old	17.5	17.1	16.7	16.4	15.9	15.6	15.2	14.8	14.5	14.1	13.8	13.4	13.3	12.9
25–34 years old	25.4	25.4	25.4	25.2	25.3	25.3	25.2	25.2	25.2	25.1	25.0	25.0	25.0	24.9
35–44 years old	20.2	20.1	20.0	19.9	19.7	19.6	19.4	19.3	19.1	19.0	18.8	18.7	18.6	18.3
45–54 years old	16.3	16.4	16.6	16.8	16.9	17.1	17.3	17.4	17.6	17.7	17.9	18.0	18.1	18.3
55–64 years old	10.7	10.9	11.1	11.4	11.6	11.8	12.1	12.3	12.6	12.8	13.1	13.4	13.5	13.8
Over 65 years old	9.9	10.1	10.2	10.4	10.5	10.6	10.8	10.9	11.1	11.2	11.4	11.5	11.6	11.8
Race/ethnicity (%)														
White	39.2	40.0	43.5	40.6	41.5	39.7	45.8	43.6	45.0	44.4	43.6	43.4	40.7	39.5
Brown	52.8	52.4	40.7	36.6	36.1	36.0	38.4	36.6	39.7	41.6	42.5	41.9	42.8	44.2
Black	7.3	7.0	10.5	10.7	10.1	10.5	9.0	9.6	11.6	10.9	11.3	11.1	13.6	13.4
Asian	0.5	0.4	2.4	2.9	2.3	2.7	3.2	1.6	1.3	1.2	0.9	1.0	1.1	1.3
Indigenous	0.0	0.1	1.8	1.9	1.5	1.4	1.7	1.7	1.4	1.2	1.2	1.8	0.8	0.9
Don't know	0.1	0.1	1.1	7.0	8.4	9.5	1.3	6.2	0.9	0.6	0.5	0.5	0.6	0.4
Don't want to inform	0.1	0.0	0.1	0.4	0.2	0.2	0.7	0.6	0.2	0.1	0.1	0.1	0.4	0.3
Educational level (%)														
0–4 years	18.0	16.8	17.3	16.1	15.2	14.9	13.9	13.6	13.2	13.0	12.8	11.8	11.9	11.1
5–8 years	24.0	23.8	21.5	20.7	21.4	21.1	20.7	18.9	17.6	17.3	16.0	15.6	14.8	14.7
9–11 years	35.8	35.8	36.7	38.5	37.3	38.1	38.1	35.9	37.3	38.0	38.4	39.1	40.0	41.3
12 years or more	22.2	23.6	24.5	24.7	26.0	25.9	27.3	31.6	31.9	31.8	32.8	33.5	33.3	32.9
Macro-regions (%)														
Central-West	11.2	11.2	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.7	11.7	11.8	11.8	11.9
Northeast	25.5	25.0	25.1	25.1	25.1	25.1	25.1	25.2	25.2	25.2	25.2	25.3	25.3	25.3
North	15.0	15.2	15.3	15.3	15.3	15.4	15.4	15.5	15.5	15.6	15.6	15.7	15.7	15.8
Southeast	39.8	40.3	40.2	40.1	40.0	39.9	39.8	39.7	39.6	39.5	39.4	39.3	39.2	38.9
South	8.5	8.2	8.2	8.1	8.1	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.0
Works (%)	64.2	65.3	65.7	65.9	64.5	64.0	62.6	64.6	64.1	64.0	63.6	63.2	59.8	62.0
Attends school/courses (%)	28.9	27.7	28.2	26.1	26.4	26.5	27.1	28.6	27.2	29.0	28.1	25.6	21.9	25.5
Walks (%)	57.1	56.4	54.7	56.2	54.9	55.3	55.4	55.8	55.7	54.3	54.5	54.2	51.3	47.1
Commutes on foot/by bike (%)														
Entire journey	22.3	20.4	19.9	19.2	19.4	18.8	19.3	16.9	17.5	16.1	17.2	17.0	19.2	17.9
Part of the journey	23.7	23.2	24.1	24.1	21.4	22.5	21.2	23.7	21.3	21.6	22.3	22.7	17.4	17.4
No	54.1	56.3	56.0	56.7	59.2	58.7	59.6	59.4	61.2	62.3	60.5	60.4	63.4	64.7
Active Commuters (%)	17.9	18.8	15.9	15.3	12.9	12.9	12.8	15.0	14.2	15.1	14.8	14.1	10.8	12.5

Data presented as percentage of individuals or mean (standard deviation), estimated using raking pesorake.

2023, the first year with available post-pandemic data, an upward trend in the prevalence of active commuters was observed across all regions. The Northeast and Central-West macro-regions showed the largest increases (from 10.4% to 13.2% and from 7.9% to 10.6%, respectively), followed by the Southeast (from 11.7% to 12.9%), North (from 11.8% to 12.7%), and South (from 9.5% to 10.4%).

Figure 2 presents the prevalence of active commuters, stratified by sex, age group, educational level, and race/ethnicity for each year of the time series. A significant year effect was observed for all sociodemographic variables ($p < 0.001$), with the exception of race/ethnicity. The analysis also revealed a significant effect of sex ($p = 0.004$), suggesting mean differences between men and women regarding the level of TRPA (Figure 2, panel A), although there was no significant interaction between sex and year ($p = 0.41$).

A significant effect of age group was observed (p

< 0.001), with the group aged 65 and older being the least active overall (Figure 2B). Furthermore, there was an interaction between year and age group ($p = 0.0009$), indicating distinct changes in trends across age groups over time. Although they recorded the largest reductions over the years, the younger groups remained among the most active commuters in 2023.

A significant effect of educational level was observed ($p < 0.001$). Individuals with 0–4 years of schooling generally showed the lowest prevalence of active commuters, followed by the group with 12 or more years (Figure 2C). The interaction between year and educational level ($p < 0.002$) indicated distinct patterns of change over time across the groups. After periods of fluctuation, the groups with the highest and lowest levels of TRPA in 2023 were, respectively, those with 9–11 years of schooling (15%) and those with ≥ 12 years (9.5%).

Finally, a significant effect of race/ethnicity was ob-

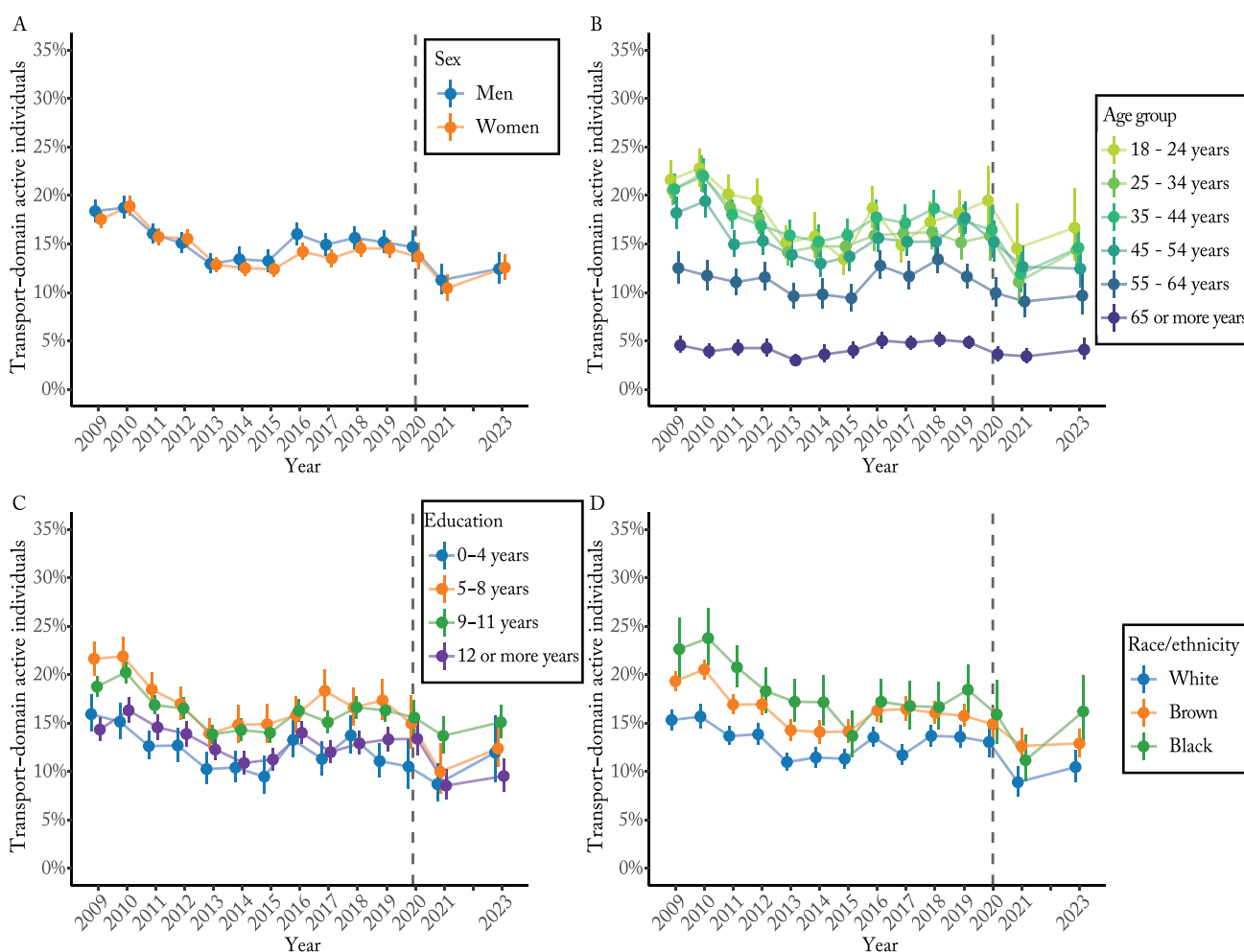


Figure 2 – Active commuters according to sociodemographic variables: sex, age group, educational level, and race/ethnicity. The points represent weighted proportions, and the vertical lines indicate 95% confidence intervals. The vertical dotted line at the year 2020 marks the onset of the COVID-19 pandemic.

served ($p < 0.001$). Overall, black individuals showed the highest proportions of active commuters, followed by brown and white individuals (Figure 2, panel D). In 2023, the proportions of active commuters by race/ethnicity were: 16.2% black, 12.9% brown and 10.5% white. Numerical data on the weighted proportions can be found in Supplementary Table 1.

Discussion

The study's main findings indicated a general downward trend in the proportion of active commuters over the years, with sharp declines observed between 2009 and 2015 and between 2020 and 2021. Differences across macro-regions were also noted regarding both the proportion of active commuters and the temporal trend of TRPA. Significant interactions between temporal trends and the variables of age group and educational level were identified, with the greatest reductions observed among younger individuals and those with 5 to 8 years of schooling. Furthermore, men and Black individuals exhibited higher levels of TRPA throughout the time series.

Previous time-series analyses of Vigitel data have already documented a reduction in TRPA in Brazil. Consistently, Bastone et al.¹⁰ observed a decline between 2010 and 2019, with inequalities based on age group, educational level, and race/ethnicity, as well as varying trends across capital cities. Our findings not only corroborate this scenario but also indicate that this reduction follows non-linear patterns and has intensified in more recent years. In contrast to earlier approaches based on traditional⁸ or segmented¹⁰ linear models, the non-linear models used in the present study offered greater explanatory power and enabled an analysis of the impact of transport sector events, macroeconomic fluctuations, and the COVID-19 pandemic in the country, revealing a sharp decline in the post-2020 period and a potential rebound to higher levels of TRPA in the final year of the series, 2023.

The downward trend in TRPA observed over the time series appears linked to the pattern of Brazilian urbanization, which is predominantly characterized by territorial sprawl and a transport structure centered on the use of private motor vehicles¹¹. Data from the Institute for Applied Economic Research reveal a significant shift in urban mobility patterns between 2001 and 2020. The fleet of private motor vehicles grew by 331% during this period, coinciding with a decline in the demand for bus travel in the country's major urban

centers¹². Meanwhile, studies employing various experimental designs have shown that public transport usage rates are positively associated with the population's level of TRPA, given that trips to and from public transport stops are typically made using active modes of travel^{11,13}.

Fiscal incentives and the declining appeal of public transport reinforce the use of private motor vehicles, thereby perpetuating an inefficient and unsustainable mobility system^{12,14}. The impacts of this model include environmental and public health issues, evidenced by rising levels of traffic congestion, air pollution, the formation of heat islands, physical inactivity, and traffic accidents, with pedestrians and cyclists historically among the primary victims¹². Furthermore, inadequate infrastructure for walking and cycling tends to empty the streets and increase crime rates¹⁵, fostering a cycle of dependence on private motor vehicles and mandatory adoption of public transport and TRPA.

The initial downward trend in levels of TRPA across Brazilian macro-regions was interrupted by a period of stability between 2015 and 2020. During this time, Brazil faced a severe economic recession that led to declines in employment rates and household income¹⁶, likely contributing to reduced use of private motor vehicles, which are known to be more costly¹². In this context, the observed stability in both bus usage rates¹⁷ and national levels of TRPA likely stemmed from the population's diminished ability to choose between urban mobility options. With the onset of the pandemic, national levels of TRPA, along with other modes of urban travel, declined due to social isolation policies. The adoption of remote work and study models, as well as the trend of shifting from brick-and-mortar to online retail¹¹, developments that were contemporaneous with the pandemic but not necessarily caused by it, are possible secondary factors contributing to the reduction in travel during this period.

Regarding the macro-regions, the highest and lowest proportions of individuals engaging in active transport throughout the study period were observed in the Southeast and Center-West, respectively. Urban, socioeconomic, cultural, and geographic factors (such as climate and terrain), as well as those related to transport infrastructure, may help explain the differences found in levels of TRPA¹⁸. Trends observed in the Southeast region, such as the extensive public transport infrastructure and the high motorization rates, help explain, respectively, the higher levels and sharp declines in

TRPA over the historical period.

Fluctuations in levels of TRPA show an inverse relationship with age. Young adults, despite being more active, exhibited the greatest variations, possibly due to greater susceptibility to instability in work, study, and living arrangements. Older adults, in turn, remained stable at low levels, likely due to poorer health status and lower labor market participation¹⁹.

Regarding educational level, the distinction between the groups with 0–4 and 5–8 years of schooling revealed discrepancies in TRPA between the two groups that had not been previously observed in other studies. A prior study using Vigitel data identified an inverse relationship between TRPA and educational level, but, like Vigitel, that study defined the lower-education group as those with 0–8 years of schooling²⁰. Consequently, the higher level of TRPA observed in that earlier study for the lower-education group likely stems from the high levels exhibited by the subgroup with 5–8 years of schooling, given that in our study, the 0–4 years group, along with the group having 12 or more years of schooling, showed the lowest levels of TRPA across the series.

The findings regarding the race/ethnicity variable reinforce previous results²¹ indicating higher levels of TRPA among black and brown individuals compared to white individuals. Furthermore, in Brazil, self-reported race/ethnicity can be considered an indirect indicator of income, given that the average earnings of black and brown individuals correspond to 57% and 58.5%, respectively, of the average earnings of white individuals^{22,23}. Thus, the lower income associated with this group may contribute to lower rates of private motor vehicle ownership, greater reliance on public transport, and higher levels of compulsory TRPA.

Regarding sex-based differences, it is worth noting that the effect size was small, with similar estimates for men and women throughout the time series. However, as with other sociodemographic variables, the failure to distinguish between walking and cycling likely obscured valuable data on differences in travel patterns between women and men, given that women use to travel more on foot on average, whereas men use to make greater use of bicycles^{24,25}. Furthermore, by defining “commuting” solely as travel between home and work or school, the survey underestimates trips made for caregiving or grocery shopping, more frequently associated with women²⁵.

This study also presents other limitations that should

be considered. Two important points regarding the ≥ 150 minutes/week cutoff warrant mention: first, this categorization fails to capture small changes in the volume of TRPA, which may play a significant role in population health and well-being; furthermore, this cutoff is based on recommendations for total PA rather than being specific to the transport domain, which may introduce classification bias. Therefore, we recommend that future research analyze not only the binary classification of individuals based on whether they meet PA recommendations but also the continuous value, when available.

Other limitations associated with Vigitel include regional disparities in landline telephone coverage, the assessment of PA levels via self-reporting, the masking of social and structural inequalities regarding TRPA within cities, the failure to distinguish between choice and necessity as drivers for adopting active transport, and the lack of differentiation between walking and cycling. Furthermore, in some of the years analyzed, a significant proportion of individuals were unable to report their race/ethnicity. Although these cases were excluded from analyses stratified by race/ethnicity, their magnitude may have influenced the results related to this variable.

This study also presents positive aspects. Notable among them is the opportunity to observe trends in TRPA in Brazil over a 13-year period, considering both the national landscape and macro-regions, as well as the potential impacts of the COVID-19 pandemic. Unlike Vigitel, this study conducted non-linear trend analyses of TRPA, shedding light on the varying patterns of this behavior throughout the historical series. Additionally, distinguishing TRPA differences across Brazilian macro-regions allowed for a novel observation of regional trends during the COVID-19 pandemic, as well as regional variations based on sex, age group, educational level, and race/ethnicity.

There has been a declining trend in the proportion of active commuters in Brazil over the years, with non-linear variations manifesting differently across the country's macro-regions and among various sociodemographic groups. This decline in TRPA may be linked to factors such as rising motorization rates, the deterioration of public transport, and unfavorable urban environments, particularly in low-income neighborhoods characterized by poor infrastructure, crime, and adverse topographical or climatic conditions.

Research should investigate the regional specificities associated with variations in the prevalence of TRPA, considering environmental, structural, cultural,

and economic conditions, while seeking to understand inequalities in access to and the adoption of active modes of travel. In conclusion, it is essential to implement evidence-based public policies that create inviting environments and improve conditions for movement, thereby reducing the burden associated with TRPA and transforming it into a viable and enjoyable option, particularly in low-income and informal settlements neighborhoods. Such actions are crucial for fostering cities that are not only more active and healthier but also sustainable and socially just.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Author contributions

Cooper PP, Mondini DR, and Garcia MC: Conceptualization; Data analysis; Investigation; Provision of tools; Data curation; Project administration; Funding acquisition; Writing – original draft; Writing – review and editing; Approval of the final manuscript version. Esteves GP: Conceptualization; Methodology; Software development, implementation, and testing; Data and experiment validation; Data analysis; Provision of tools; Data curation; Data presentation design; Writing – review and editing; Approval of the final manuscript version. Longobardi I: Conceptualization; Provision of tools; Funding acquisition; Writing – review and editing; Approval of the final manuscript version. Alves RA, Silva LCB, Alvim RO: Conceptualization; Provision of tools; Writing – review and editing; Approval of the final manuscript version. Hallal PC and Florindo AA: Conceptualization; Provision of tools; Supervision; Writing – review and editing; Approval of the final manuscript version.

Declaration regarding the use of artificial intelligence tools in the article writing process

The authors did not use artificial intelligence tools in the preparation of the manuscript.

Availability of research data and other materials

The content is already available (<https://github.com/gp-esteves/Dados-Vigitel>).

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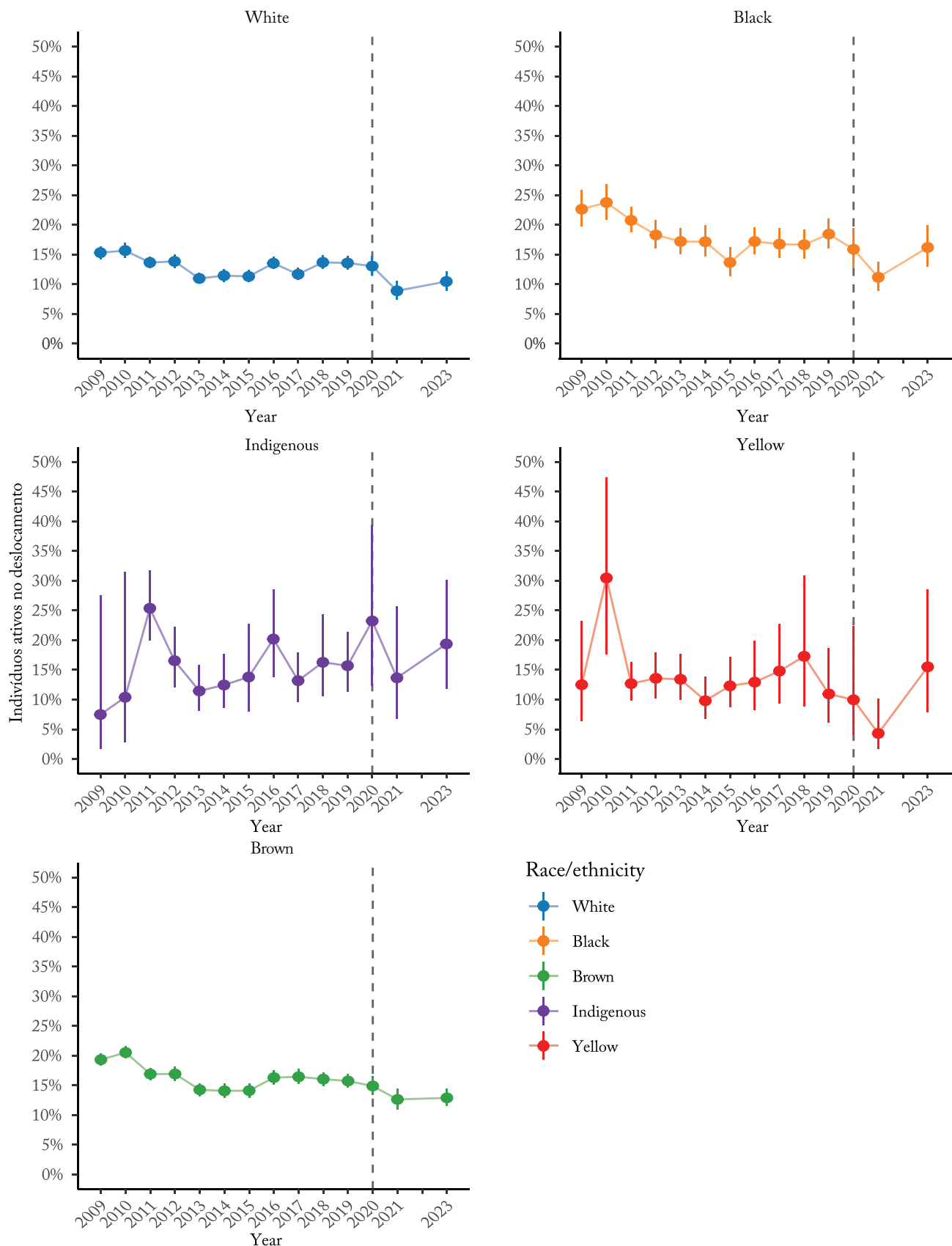
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Supplementary Material

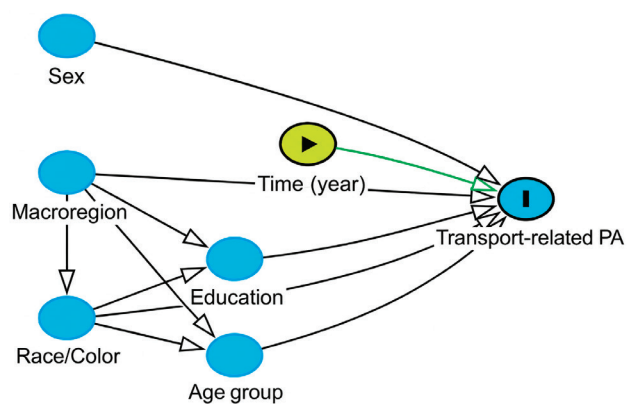
Supplementary Table 1 – Physical activity level during commuting, by sex, age group, and educational level.

Variables	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2023
Sex¹ (%)														
Male	18.4 (17.2; 19.6)	18.7 (17.6; 19.9)	16.1 (15.1; 17.1)	15.1 (14; 16.2)	13.0 (12; 14)	13.4 (12.3; 14.7)	13.2 (12.1; 14.4)	16.0 (14.9; 17.2)	14.9 (13.8; 16.1)	15.6 (14.5; 16.8)	15.2 (14.0; 16.4)	14.7 (13.2; 16.4)	11.3 (9.8; 12.9)	12.4 (10.9; 14.1)
Female	17.5 (16.7; 18.4)	18.9 (17.9; 19.9)	15.7 (14.9; 16.6)	15.5 (14.7; 16.5)	12.9 (12.1; 13.7)	12.5 (11.7; 13.4)	12.4 (11.6; 13.3)	14.2 (13.4; 15.1)	13.5 (12.6; 14.4)	14.6 (13.7; 15.5)	14.5 (13.6; 15.4)	13.7 (12.3; 15.1)	10.4 (9.2; 11.9)	12.6 (11.3; 13.9)
Age group² (%)														
18-24 years old	21.6 (19.7; 23.7)	22.8 (20.9; 24.8)	20.1 (18.3; 22.1)	19.5 (17.5; 21.7)	15.1 (13.5; 16.9)	15.8 (13.6; 18.2)	13.4 (11.8; 15.3)	18.7 (16.7; 20.9)	14.9 (13.1; 17)	17.3 (15.3; 19.4)	18.2 (16.1; 20.5)	19.5 (16.4; 23)	14.5 (10.9; 19.1)	16.7 (13.3; 20.8)
25-34 years old	20.6 (19.0; 22.2)	22.2 (20.4; 24.1)	18.8 (17.3; 20.4)	17.7 (16.1; 19.4)	14.1 (12.8; 15.6)	14.8 (13.1; 16.5)	14.7 (13; 16.6)	15.9 (14.3; 17.6)	16.1 (14.3; 18)	16.2 (14.5; 18.2)	15.2 (13.4; 17.1)	15.9 (13.2; 18.9)	11.1 (8.8; 13.8)	14.4 (12.1; 17)
35-44 years old	20.7 (19.1; 22.3)	22.0 (20.3; 23.8)	18.0 (16.6; 19.6)	16.9 (15.4; 18.5)	15.9 (14.4; 17.5)	15.2 (13.6; 17)	15.9 (14.4; 17.6)	17.8 (16; 19.6)	17.2 (15.4; 19)	18.7 (16.9; 20.6)	17.4 (15.8; 19.1)	16.5 (14.2; 19)	11.9 (10; 14.2)	14.6 (12.5; 17.1)
45-54 years old	18.2 (16.6; 19.9)	19.4 (17.8; 21.2)	15.0 (13.6; 16.4)	15.3 (13.9; 16.9)	13.9 (12.6; 15.3)	13.0 (11.7; 14.4)	13.7 (12.2; 15.4)	15.6 (14.2; 17.2)	15.2 (13.8; 16.8)	15.3 (13.9; 16.7)	17.7 (16.1; 19.4)	15.2 (13.2; 17.4)	12.7 (10.8; 14.8)	12.4 (10.5; 14.7)
55-64 years old	12.5 (11.0; 14.2)	11.7 (10.2; 13.4)	11.1 (9.8; 12.5)	11.6 (10.2; 13.1)	9.6 (8.4; 11)	9.8 (8.3; 11.5)	9.4 (8.1; 10.9)	12.8 (11.4; 14.3)	11.7 (10.3; 13.2)	13.4 (12; 15)	11.6 (10.4; 13)	9.9 (8.5; 11.6)	9.1 (7.5; 11)	9.7 (7.8; 12)
Over 65 years old	4.6 (3.7; 5.5)	3.9 (3.2; 4.8)	4.3 (3.5; 5.2)	4.3 (3.4; 5.3)	3.0 (2.4; 3.6)	3.6 (2.8; 4.6)	4.0 (3.2; 5)	5.0 (4.2; 6)	4.8 (4.1; 5.6)	5.1 (4.4; 5.9)	4.9 (4.2; 5.6)	3.6 (2.9; 4.5)	3.4 (2.7; 4.3)	4.1 (3.1; 5.4)
Educational level³ (%)														
0-4 years	15.9 (14.1; 17.9)	15.1 (13.4; 17.1)	12.6 (11.2; 14.1)	12.7 (11.0; 14.5)	10.2 (8.7; 12)	10.4 (8.9; 12.1)	9.5 (7.7; 11.6)	13.3 (11.5; 15.3)	11.3 (9.7; 13.1)	13.7 (11.9; 15.8)	11.1 (9.4; 12.9)	10.5 (8.2; 13.3)	8.7 (6.9; 10.8)	12.0 (8.9; 15.8)
5-8 years	21.6 (19.9; 23.5)	21.9 (19.9; 23.9)	18.5 (16.8; 20.2)	17.0 (15.3; 18.7)	13.9 (12.4; 15.5)	14.8 (13; 16.9)	14.9 (13; 17)	15.8 (14.0; 17.7)	18.3 (16.3; 20.6)	16.6 (14.7; 18.6)	17.3 (15.3; 19.6)	14.9 (12.4; 17.9)	10.0 (7.7; 12.9)	12.4 (10.5; 14.6)
9-11 years	18.8 (17.7; 19.8)	20.2 (19.1; 21.4)	16.9 (15.9; 17.8)	16.5 (15.4; 17.6)	13.8 (12.9; 14.8)	14.3 (13.1; 15.5)	14.0 (13.0; 15.0)	16.3 (15.1; 17.5)	15.1 (13.9; 16.3)	16.6 (15.5; 17.8)	16.3 (15.2; 17.5)	15.6 (13.9; 17.3)	13.7 (11.9; 15.7)	15.1 (13.5; 16.9)
Race/ethnicity⁴														
White	15.3 (14.3; 16.4)	15.7 (14.5; 16.9)	13.7 (12.7; 14.7)	13.8 (12.8; 15.0)	11.0 (10.1; 11.9)	11.4 (10.4; 12.6)	11.3 (10.3; 12.4)	13.5 (12.5; 14.6)	11.7 (10.7; 12.8)	13.7 (12.6; 14.8)	13.6 (12.5; 14.8)	13.0 (11.5; 14.8)	8.9 (7.4; 10.6)	10.5 (8.9; 12.2)
Brown	19.3 (18.3; 20.4)	20.5 (19.5; 21.6)	16.9 (15.9; 17.9)	16.9 (15.8; 18.1)	14.3 (13.2; 15.4)	14.1 (12.9; 15.3)	14.1 (12.9; 15.4)	16.3 (15.1; 17.5)	16.4 (15.2; 17.8)	16.1 (14.9; 17.2)	15.7 (14.6; 16.9)	14.9 (13.4; 16.6)	12.6 (11; 14.5)	12.9 (11.5; 14.4)
Black	22.6 (19.7; 25.8)	23.8 (20.9; 26.8)	20.8 (18.7; 23)	18.3 (16.1; 20.8)	17.2 (15.1; 19.5)	17.1 (14.7; 19.9)	13.7 (11.4; 16.2)	17.2 (15.1; 19.5)	16.7 (14.4; 19.4)	16.6 (14.3; 19.2)	18.4 (16.1; 21)	15.9 (12.9; 19.5)	11.2 (9; 13.8)	16.2 (13.0; 20.0)

1 Significant effect of year ($p < 0.001$) and sex ($p = 0.004$), but not of the year: sex interaction ($p = 0.41$). 2 Significant effect of year ($p < 0.001$), age group ($p < 0.001$), and the year: age group interaction ($p < 0.001$). 3 Significant effect of year ($p < 0.001$), educational level ($p < 0.001$), and the year: educational level interaction ($p = 0.002$). 4 Significant effect of year ($p < 0.001$), race/ethnicity ($p < 0.001$), and the year: race/ethnicity interaction ($p = 0.27$). The values in the table are proportions and their respective 95% confidence intervals, adjusted for sample weights across the years. P-values were obtained via logistic regressions adjusted for sample weights, incorporating the predictor variable “year” (modeled with a restricted cubic spline functional form), the stratification variable (sex, age group, or educational level), and its interaction with the year.



Supplementary Figure 1 – Active commuters by race/ethnicity, including the Indigenous and Asian categories. Points represent weighted proportions, and vertical lines represent 95% confidence intervals. The vertical dotted line at the year 2020 marks the onset of the COVID-19 pandemic.



Supplementary Figure 2 – Directed acyclic graph (DAG) demonstrating the interrelationship between the analyzed variables.

Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

- Was any indication of plagiarism observed in the manuscript?
No
- Did the authors provide clarification regarding the ethical procedures adopted for conducting the research?
Partially

Comments to the authors

Dear authors,

Thank you for submitting your manuscript entitled "Commuting Physical Activity in Brazil: an analysis of temporal trends using VIGITEL data" (Code 66628) to RBAFS. After careful consideration, I noted that the work addresses a relevant and interesting scientific topic within the field, fitting the scope of the journal. However, I see the need for a deeper discussion that encompasses aspects relevant to the theme, such as the trade-off between choice versus necessity of commuting physical activity within the sociodemographic con-

text of the Brazilian population, especially considering the urban, cultural, and social differences across the country's regions.

Furthermore, it seems that the analysis lacks sufficient robustness to advance the current state of the art, requiring a more elaborated justification and more recent and coherent bibliographic references related to the topic. I have provided several comments, listed in detail in the attached document, to clarify my concerns regarding the current proposal. I encourage the authors to submit a revised version of the manuscript addressing the points raised during the review process (see attached document).

Sincerely,
Reviewer

Final recommendation (decision)

- Major revisions required.

Reviewer B

The publication of the review was not authorized.