

Universidade de São Paulo
Faculdade de Saúde Pública

**Como estamos indo? Estudo do deslocamento
ativo no Brasil.**

Thiago Hérick de Sá

**Tese apresentada ao Programa de Pós-
Graduação em Nutrição em Saúde
Pública para obtenção do título de
Doutor em Ciências.**

**Área de Concentração: Nutrição em
Saúde Pública**

**Orientador: Professor Titular Carlos
Augusto Monteiro**

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EPÍGRAFE

“O seu avô, Thiago, morava na Chapadinha, uma pequena serra a uns 30 quilômetros de Niquelândia, no interior de Goiás. Sempre que tinha de ir à cidade, ele gostava e fazia questão de ir a pé. O problema é que os carros que passavam pela estrada insistiam em oferecer carona. Como recusar favor por aquelas bandas era desfeita, toda vez que o velho Ribamar ouvia o barulho do motor não pensava duas vezes: se escondia no mato!”

Eliam Brito de Sá, minha mãe

DEDICATÓRIA

Ao mestre, com carinho.

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A toda a minha família, que vive e não tem a vergonha de ser feliz.

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RESUMO

Sá TH. Como estamos indo? Estudo do deslocamento ativo no Brasil [tese de doutorado]. São Paulo: Faculdade de Saúde Pública da USP; 2016.

Resumo

Introdução: O deslocamento ativo tem estreita relação com problemas de saúde pública da atualidade e sua promoção pode contribuir para melhorias quanto à mobilidade urbana, estado de saúde e proteção do meio ambiente. Entretanto, a maior parte das pesquisas sobre o tema tem sido desenvolvida em países de renda alta. A presente tese busca ampliar a investigação sobre o deslocamento ativo no Brasil. **Objetivos:** i) Descrever a frequência, a distribuição e a variação temporal de indicadores do deslocamento ativo em populações brasileiras; ii) Avaliar o impacto de mudanças no padrão de transporte da população sobre o deslocamento ativo, o tempo sedentário e desfechos de saúde em populações brasileiras. **Métodos:** Tese composta por sete manuscritos. O primeiro apresenta revisão sistemática de estudos com informações sobre a prática de deslocamento ativo na América Latina e Caribe; o segundo descreve estimativas representativas da população brasileira sobre a prática de deslocamento ativo para o trabalho; o terceiro e o quarto descrevem a frequência e tendência temporal do deslocamento ativo na Região Metropolitana de São Paulo (ciclistas e escolares); o quinto discute a questão da mobilidade urbana e do direito à cidade em São Paulo; o sexto e o sétimo avaliam o impacto de mudanças no padrão de mobilidade da metrópole paulistana sobre a prática de deslocamento ativo, tempo não-ativo de deslocamento e tempo total de deslocamento, bem como sobre a poluição do ar e saúde da população. **Resultados:** A prevalência mediana de deslocamento ativo encontrada em diferentes locais do Brasil foi de 12%, variando entre 5,1% em Palmas (Tocantins) a 58,9% em Rio Claro (São Paulo) (*Manuscrito 1*). Um terço dos homens e das mulheres desloca-se a pé ou de bicicleta de casa para o trabalho no país. Em ambos os sexos, esta proporção diminui com o aumento da renda e da escolaridade e é maior entre os mais jovens, entre os que residem em áreas rurais, e na região Nordeste. Em todas as regiões metropolitanas estudadas, o quinto das pessoas de menor renda apresenta uma maior frequência de deslocamento ativo (*Manuscrito 2*).

Entre os anos de 2007 e 2012, observamos redução no número de ciclistas em São Paulo e diferenças expressivas na proporção de ciclistas entre homens e mulheres (9,7 por mil habitantes versus 1,4 por mil habitantes em 2012) (*Manuscrito 3*). Também verificamos uma queda na proporção de crianças que se deslocam ativamente para a escola entre os anos de 1997 e 2012 (*Manuscrito 4*). O cenário epidemiológico do deslocamento ativo no país é resultante da disputa pelo direito à cidade, com repercussões na transição de mobilidade humana e na saúde e qualidade de vida da população, como podemos observar no caso de São Paulo (*Manuscrito 5*). A construção de uma São Paulo mais inclusiva, com menores distâncias para os deslocamentos cotidianos e maior frequência de caminhada e bicicleta, levaria à substancial redução do tempo total e do tempo sedentário despendidos nos deslocamentos, sem diminuir a duração do deslocamento ativo (*Manuscrito 6*). Traria também ganhos à saúde da população, sobretudo pelo aumento da prática de atividade física e da redução da poluição do ar (*Manuscrito 7*). Conclusões: A prática de deslocamento ativo no Brasil apresenta marcadas diferenças segundo região e características sociodemográficas. De um modo geral, esta prática vem diminuindo no país, o que deve contribuir negativamente para a saúde da população. A promoção de cidades mais inclusivas e compactas, com o favorecimento a modos ativos de deslocamento, pode contribuir para reverter esta preocupante tendência.

Descritores: Saúde Urbana. Cidade Saudável. Caminhada. Bicicleta. Atividade Motora. Poluição do Ar. Acidentes de Trânsito. Doenças Crônicas. Transportes. Veículos Automotores. Planejamento de Cidades.

ABSTRACT

Sá TH. How are we going? Study of active commuting in Brazil [doctorate thesis]. Sao Paulo: School of Public Health, USP; 2016.

Abstract

Introduction: Active commuting is closely related to current public health issues and its promotion can contribute to improvements in urban mobility, health and environmental protection. However, research on the subject is largely concentrated in high-income countries. This thesis aims to expand research on active commuting in Brazil. **Objectives:** i) To describe the frequency, distribution and time trend of active commuting indicators in Brazilian populations; ii) To assess the impact of travel pattern changes on active commuting, sedentary time and health outcomes in Brazilian populations. **Methods:** The thesis consists of seven manuscripts. The first manuscript is a systematic review of studies with information on active commuting practice in Latin America and the Caribbean; the second describes nationally representative estimates about active commuting to work in Brazil; the third and fourth describe active commuting frequency and time trends in São Paulo metropolitan area (cyclists and schoolchildren); the fifth discusses the issue of urban mobility and the right to the city of São Paulo; the sixth and seventh assess the impact of changes in São Paulo travel pattern on active commuting, non-active commuting and total travel time as well on air pollution and population health. **Results:** The median prevalence of active commuting found in Brazilian settings was 12%, ranging from 5.1% in Palmas (Tocantins) to 58.9 % in Rio Claro (Sao Paulo) (*Manuscript 1*). One-third of men and women walk or cycle for commuting to work in Brazil. In both sexes, this proportion decreases with increasing income and education and is higher among younger people, those living in rural areas, and in the Northeast. In all Brazilian metropolitan areas studies, people in the lowest quintile of income had a higher frequency of active commuting (*Manuscript 2*). Between 2007 and 2012, we observed a decreasing number of cyclists in São Paulo and marked sex differences in the proportion of cyclists (9.7 per thousand inhabitants for men versus 1.4 per thousand inhabitants for women in 2012) (*Manuscript 3*). We also found a decrease in the proportion of children who are actively commuting to school between 1997 and

2012 (*Manuscript 4*). The epidemiological scenario of active commuting in Brazil is the result of a historical dispute for the right to the city, with repercussions for human mobility transition and people's health and quality of life, as can be seen in the case of São Paulo (*Manuscript 5*). Building a more inclusive São Paulo, with shorter distances and more walking and cycling, would lead to substantial reductions of total and sedentary commuting time, without reducing active commuting time (*Manuscript 6*). It would also result in improvements for people's health, particularly due to the increasing physical activity and decreasing air pollution (*Manuscript 7*). Conclusions: Active commuting in Brazil shows marked regional and socioeconomic contrasts. Overall, this practice has decreased, which should contribute negatively to the health of Brazilians. The promotion of more inclusive and compact cities, favoring active travel, can help reverse this worrying trend.

Subject Headings: Urban Health. Healthy City. Walking. Bicycle. Motor Activity. Air Pollution. Traffic Accidents. Chronic Diseases. Transportation. Motor Vehicles. City Planning.

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ABREVIATURA

95% CI	-	95% Confidence Interval
ACM	-	All-cause mortality
Adj PR	-	Adjusted Prevalence Ratio
AP	-	Air pollution
AT	-	Active travel
BAU	-	Business-as-usual
CET	-	Companhia de Engenharia de Tráfego
CETESB	-	Companhia Ambiental do Estado de São Paulo
CH ₄	-	Metano
CO	-	Monóxido de carbono
CO ₂	-	Dióxido de carbono
DALY	-	Disability adjusted life year
DCNT	-	Doenças crônicas não transmissíveis
DRF	-	Dose-response function
EC	-	Expanded Centre
FAPESP	-	Fundação de Amparo à Pesquisa do Estado de São Paulo
FSP	-	Faculdade de Saúde Pública
GPS	-	Sistema de Posicionamento Global
HC	-	Hidrocarbonetos totais
HEAT	-	Health and Economic Assessment Tool
HTS	-	Household Travel Survey
IBGE	-	Instituto Brasileiro de Geografia e Estatística
IC 95%	-	Intervalo de Confiança de 95%
IPAQ	-	Questionário Internacional de Atividade Física
IPEA	-	Instituto de Pesquisa Econômica Aplicada
IQR	-	Interquartile range
ITHIM	-	Integrated Transport and Health Impact Modelling Tool
LAC	-	Latin American and the Caribbean region
LSHTM	-	London School of Hygiene and Tropical Medicine
MDG	-	Millennium Development Goals
Med	-	Median
MeSH	-	Medical subject heading

MET	- Metabolic Equivalent of Task
METRÔ	- Companhia do Metropolitano de São Paulo
MP	- Material Particulado
NA	- Not applicable
NCD	- Non-communicable diseases
NOx	- Óxidos de nitrogênio
NR	- Not reported
OD	- Pesquisa Origem e Destino
PA	- Physical activity
PB	- Peripheral Belt
PM2.5	- Particulate matter
PNAD	- Pesquisa Nacional por Amostra de Domicílios
PNS	- Pesquisa Nacional de Saúde
PRISMA	- Preferred Reporting Items of Systematic Review and Meta-analyses
PTUMA	- Proyecto de Transporte Urbano para Áreas Metropolitanas
RMSP	- Região Metropolitana de São Paulo
RR	- Relative risk
SAT	- Sistema de Acidentes de Trânsito
SGD	- Sustainable Development Goals
SO2	- Dióxido de enxofre
SP	- São Paulo
SPMA	- São Paulo Metropolitan Area
SRTS	- Safe Routes to School
USP	- Universidade de São Paulo
VIGITEL	- Sistema de Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico
WHO	- World Health Organization
YLD	- Years of healthy life lost due to disability
YLL	- Years of healthy life lost

APRESENTAÇÃO

A presente tese apresenta parte dos resultados da pesquisa “Como estamos indo? Estudo do deslocamento ativo no Brasil”, cuja motivação principal era ampliar o conhecimento sobre a prática de deslocamento ativo no país e sua relação com a saúde da população. A tese é composta por sete manuscritos, sendo os quatro primeiros relacionados ao primeiro objetivo da tese (descrever a frequência, a distribuição e a variação temporal do deslocamento em populações brasileiras), e os três últimos, relacionados ao segundo objetivo, (avaliar o impacto de mudanças no padrão populacional de deslocamentos sobre o deslocamento ativo, o tempo sedentário e desfechos de saúde em populações brasileiras).

O primeiro manuscrito, “*Prevalence of active transportation among adults in Latin America and the Caribbean: a systematic review of population-based studies*”, apresenta revisão sistemática de estudos que analisaram a prática de deslocamento ativo na América Latina e Caribe. Neste manuscrito procuramos comparar resultados obtidos no Brasil com resultados obtidos em outros países latino-americanos.

O segundo manuscrito, “Diferenças socioeconômicas e regionais na prática do deslocamento ativo no Brasil”, utiliza dados do Suplemento sobre Saúde da Pesquisa Nacional por Amostra de Domicílios de 2008, o único levantamento nacional sobre a prática do deslocamento ativo até então^a, para aprofundar a investigação sobre a epidemiologia daquela prática e contrastes socioeconômicos e regionais.

O terceiro e o quarto manuscritos, ainda relativos à epidemiologia (ou f e d) da prática de deslocamento ativo, utilizam os dados das Pesquisas Origem e Destino de São Paulo de 1997, 2007 e 2012, executadas pelo setor de transportes (Secretaria dos Transportes Metropolitanos do Estado de São Paulo e Companhia do Metropolitano de São Paulo). Com isto, fizemos uso de um conjunto de dados pouco utilizado no estudo do deslocamento ativo no país e focalizamos a região metropolitana e o município de São Paulo, que são os *loci* dos artigos seguintes sobre a relação entre o deslocamento ativo e a saúde da população.

^a A Pesquisa Nacional de Saúde de 2013 é o levantamento de saúde mais recente com dados nacionalmente representativos. Os dados sobre atividade física, que incluem informações sobre a prática de deslocamento ativo, foram disponibilizados recentemente e não puderam compor a presente tese.

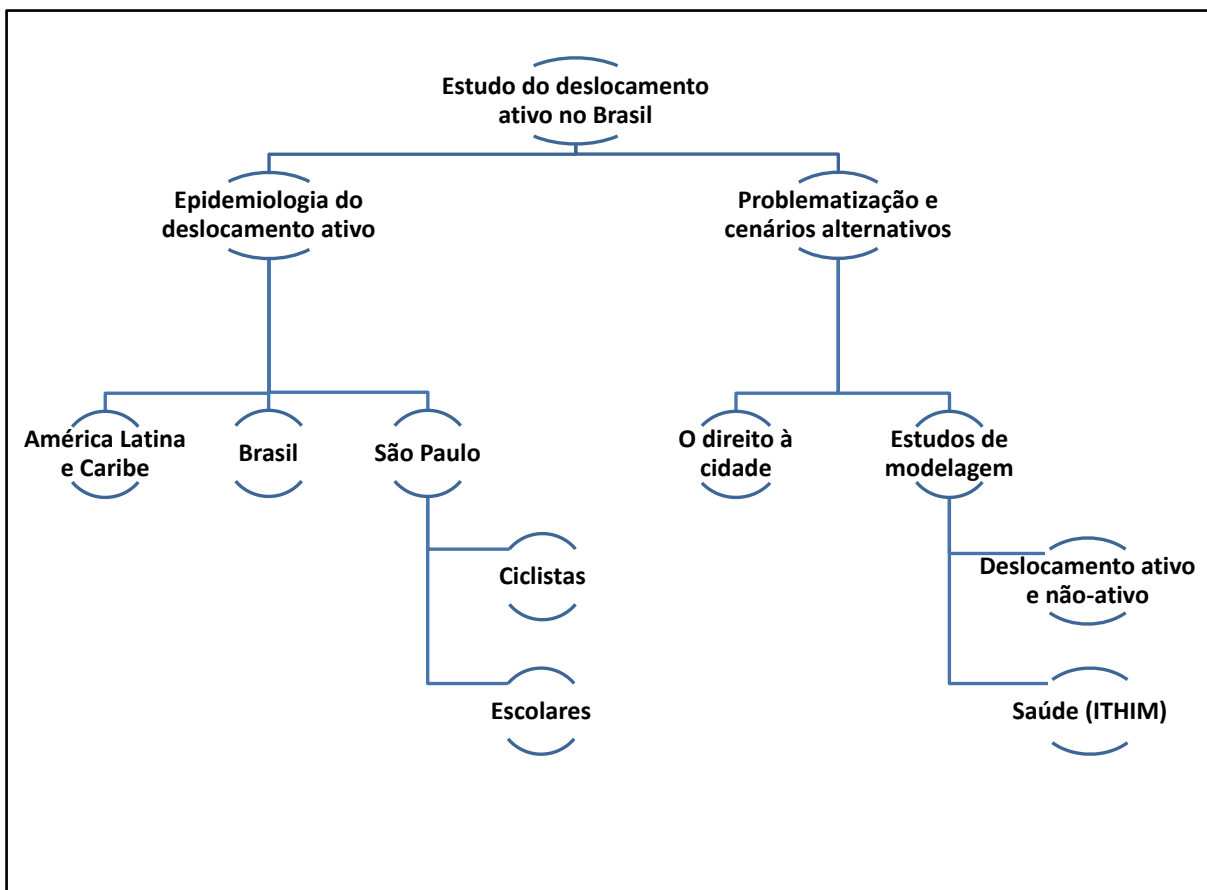


Diagrama ilustrando a organização dos manuscritos da tese.

Diante da escassez de informações detalhadas sobre o transporte por bicicleta em São Paulo e, de modo geral, em todas as cidades brasileiras, o terceiro manuscrito, *“Correlates, travel patterns and time trends of bicycling in São Paulo, Brazil, 1997-2012”*, descreve a frequência e a distribuição dos paulistanos que utilizam bicicleta para se transportar em 2012 bem como sua evolução temporal entre 1997 e 2012.

O quarto manuscrito, *“Changes in travel to school patterns among children and adolescents in the São Paulo metropolitan area, Brazil, 1997-2007”*, apresenta o padrão geral de deslocamentos da população de crianças e adolescentes residente na área metropolitana de São Paulo.

O quinto manuscrito, *“Who has the right to the city? The example of transport and the case of São Paulo”*, problematiza a mobilidade urbana e o direito à cidade em São Paulo, à luz das manifestações populares de junho de 2013, ocorridas durante a realização da tese.

O sexto manuscrito, *“Impact of travel mode shift and trip distance on active and non-active transportation in the São Paulo metropolitan area in Brazil”*, avalia o impacto de mudanças na mobilidade da metrópole sobre a prática de deslocamento ativo e tempo não-ativo de deslocamento.

Finalmente, o sétimo manuscrito, *“The São Paulo we want? Health impact modelling of different travel patterns for São Paulo, Brazil”*, avalia o impacto sobre a saúde da população paulistana da adoção de diferentes padrões de mobilidade.

1. INTRODUÇÃO

(Partes desta seção da tese foram publicadas no livro “A cidade em equilíbrio: contribuições teóricas ao 3º Fórum Mundial da Bicicleta - Curitiba 2014”, Editora Proec/UFPR)(Sá e Monteiro, 2014a; b).

O que é deslocamento ativo

O deslocamento ativo – também denominado transporte ativo, viagem ativa ou atividade física como forma de deslocamento – pode ser realizado de muitas maneiras, incluindo o uso de canoas, cavalgadas, skates e patins, muito embora a opção mais frequente para a maioria das pessoas fique entre a caminhada e o emprego de bicicletas. Por isso mesmo, caminhada e bicicleta são as modalidades mais comumente avaliadas em estudos sobre o tema e também são frequentemente entendidas como sinônimo de deslocamento ativo (Merom *et al.*, 2010; Buehler *et al.*, 2011; De Nazelle *et al.*, 2011; Hallal *et al.*, 2012; Woodcock, Givoni e Morgan, 2013; Mueller *et al.*, 2015), muito embora não haja uma definição precisa na literatura sobre o conceito de deslocamento ativo.

Parte da falta de precisão quanto à definição do que seria deslocamento ativo tem a ver com a ausência de um ponto de corte mínimo para a intensidade da atividade física necessária para se considerar determinado tipo de deslocamento como sendo ativo. Ainda assim, considera-se que a grande maioria dos deslocamentos ativos são atividades físicas que alcançam intensidade leve a moderada (Ainsworth *et al.*, 2000) e que, se realizados com regularidade, podem contribuir para o cumprimento das recomendações gerais para a prática de atividade física (Ainsworth *et al.*, 2000; Haskell *et al.*, 2007; Shephard, 2008). Importante destacar que o uso de motor como elemento auxiliar ao deslocamento não necessariamente descaracteriza o deslocamento ativo, como podemos observar no caso da bicicleta elétrica (Simons, Van Es e Hendriksen, 2009; Louis *et al.*, 2012) e da canoa de rabeta (Figura 1), principal modo de transporte nos igarapés amazônicos, no qual o condutor manipula um pesado motor sobre um eixo móvel.



Figura 1: Canoa de rabeta e bicicleta elétrica, modos ativos de deslocamento auxiliados por motor. Foto 1: Thiago H. de Sá / Foto 2: Reprodução do The Wall Street Journal.

Frequência, distribuição e variação temporal do deslocamento ativo no Brasil e no mundo

Em sua maioria, os estudos sobre a frequência, distribuição e variação temporal do deslocamento ativo têm sido realizados em países de alta renda e tratam do conjunto dos deslocamentos ou apenas daqueles realizados para ir e voltar do trabalho. A grande heterogeneidade entre os estudos, tanto na forma de estimar quanto de classificar os deslocamentos ativos, dificulta as comparações entre seus resultados.

No geral, o que se observa é uma ampla variação na prática de deslocamento ativo entre os países, com o predomínio da caminhada sobre os demais modos ativos de transporte (Hallal *et al.*, 2012). Nos países de renda alta, a proporção de deslocamentos ativos (realizados a pé ou de bicicleta) é bem mais frequente em países europeus (mais de 30% em países como a Dinamarca, Alemanha, Espanha e Lituânia, chegando a 47% na Holanda) do que nos Estados Unidos (10%). Diferenças substanciais entre países também são encontradas quando considerados apenas os deslocamentos para o trabalho: por exemplo, 15% de viagens ativas na Irlanda contra 8% no Canadá e 6% na Austrália (Bassett *et al.*, 2008). Em estudo sobre as regiões metropolitanas da América Latina, também foi possível observar diferenças substanciais na proporção de viagens realizadas ativamente, variando de 9% em Buenos Aires a 37% em Guadalajara (Corporación Andina de Fomento,

2011). A variação é menor entre as capitais brasileiras: Curitiba (35%), Belo Horizonte (35%), São Paulo (34%) e Porto Alegre (27%) (Corporación Andina de Fomento, 2011). Entretanto, é preciso cautela na interpretação de resultados advindos do emprego de indicadores nos quais o denominador é o total de viagens realizadas, uma vez que um mesmo indivíduo pode ter contribuído com inúmeras viagens. Além disso, nem todos os países e cidades possuem um sistema regular de informações sobre o padrão de viagens, o que, de certa forma, limita a comparação entre os estudos.

Na Região Metropolitana de Sydney, 16,5% dos adultos afirmaram caminhar ao menos 30 minutos por dia nos deslocamentos diários em geral (Merom *et al.*, 2010) enquanto, em Shangai, esta prevalência é superior a 79% (Matthews, Charles E. *et al.*, 2007). Embora não numerosos, os estudos sobre o tema realizados na Ásia sugerem que esta região apresenta as maiores frequências de deslocamento ativo no mundo (Matthews, Charles E. *et al.*, 2007; Trinh *et al.*, 2008).

Internamente aos países, é possível observar diferenças importantes na prática de deslocamento ativo. Entre os estados e maiores cidades dos Estados Unidos, observou-se variação considerável na prevalência de adultos que se deslocam ativamente para o trabalho, com valores oscilando entre 1% e 15% (Pucher *et al.*, 2010). Estudo brasileiro sobre a prática de caminhada e bicicleta no deslocamento em três grandes cidades brasileiras identificou uma prevalência maior de uso da bicicleta para o transporte no Recife (16,0%) quando comparado com as prevalências observadas em Curitiba (9,6%) ou Vitória (8,8%) (Reis *et al.*, 2013).

Ainda existe uma grande carência de estudos sobre o deslocamento ativo no Brasil, havendo uma concentração de estudos em populações do Sul e Sudeste do país, e, particularmente, em alguns municípios, como Pelotas e Goiânia (Santos *et al.*, 2009). O primeiro estudo sobre a frequência de deslocamentos ativos para o trabalho no Brasil, feito com base na Pesquisa Nacional por Amostra de Domicílios (PNAD) de 2008, foi publicado em 2011. Este estudo estimou em 10,5% a frequência de brasileiros maiores de 14 anos ativos no deslocamento para o trabalho, sendo maior esta frequência no Nordeste do país (15,4%) (Knuth *et al.*, 2011). O estudo considerou como ativos no deslocamento para o trabalho os indivíduos empregados que costumam ir a pé ou de bicicleta de casa para o trabalho, totalizando no trajeto 30 minutos ou mais somando ida e volta. Valendo-se de critérios semelhantes, um segundo estudo, restrito ao conjunto das capitais dos

26 estados brasileiros e Distrito Federal, encontrou frequência de 11,7% de adultos ativos no deslocamento para o trabalho em 2006. Esta frequência foi maior entre homens (14,2%) e bastante menor entre indivíduos acima dos 65 anos (3,1%) (Florindo *et al.*, 2009).

Estudos sobre a variação temporal da prática de deslocamento ativo são escassos, mais recentes e igualmente concentrados em países de alta renda (Hallal *et al.*, 2012). Em alguns países estudados, como nos Estados Unidos, Suíça e Canadá, foi observada uma queda na prática de deslocamento ativo nas últimas décadas (Hallal *et al.*, 2012). Variações temporais do deslocamento ativo no Brasil têm sido estimadas, sobretudo, a partir do Sistema de Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico (VIGITEL) (Hallal *et al.*, 2011; Mielke *et al.*, 2014; Sá *et al.*, 2015). De um modo geral, observa-se expressiva redução na prática de deslocamento ativo no conjunto das 26 capitais brasileiras e Distrito Federal desde 2006, ano do início da implantação deste sistema (Hallal *et al.*, 2011; Mielke *et al.*, 2014; Sá *et al.*, 2015). Estudos anteriores sobre a variação de prática de atividade física no Brasil valeram-se da versão curta do Questionário Internacional de Atividade Física (IPAQ), trabalhando, portanto, apenas com estimativas globais da prática de atividade física (Knuth *et al.*, 2010; Matsudo *et al.*, 2010).

Deslocamento ativo, mobilidade urbana e saúde

Os padrões de deslocamento dos indivíduos e populações apresentam estreita relação com suas condições de saúde, seja pela influência direta das consequências do modo de transporte, seja por ações indiretas dos padrões de deslocamento sobre determinantes de saúde, como as relações sociais e o estímulo ao uso dos espaços públicos (Kohl *et al.*, 2012).

Duas recentes revisões sistemáticas de estudos que trataram da relação entre deslocamento ativo e desfechos de saúde (Wanner *et al.*, 2012; Saunders *et al.*, 2013) – uma delas contendo apenas estudos longitudinais (Saunders *et al.*, 2013) – encontraram resultados semelhantes, mostrando benefícios da prática de deslocamento ativo, embora as evidências sejam limitadas. Ambas as revisões também destacaram que há pouca evidência empírica especificamente sobre a

relação entre deslocamento ativo e obesidade (Wanner *et al.*, 2012; Saunders *et al.*, 2013).

Estudo longitudinal com adultos dinamarqueses indicou, por exemplo, que a taxa de mortalidade entre trabalhadores que pedalavam para o trabalho foi 28% menor do que a mesma taxa para os demais trabalhadores (Andersen *et al.*, 2000). Similarmente, estudo de coorte chinês com seguimento médio de 5,7 anos (67 mil mulheres) encontrou redução no risco de morte prematura em mulheres que caminhavam ou pedalavam como forma de transporte (Matthews, C. E. *et al.*, 2007).

O deslocamento ativo apresenta-se também como um importante aliado no combate à pandemia de doenças crônicas não transmissíveis (DCNT). Uma meta-análise de estudos prospectivos demonstrou efeito protetor do deslocamento ativo (caminhada e bicicleta) sobre o risco de doenças cardiovasculares da ordem de 11% (Hamer e Chida, 2008). Este achado é similar ao encontrado por outra revisão sistemática restrita à relação entre caminhada exclusivamente de lazer e risco de doenças cardiovasculares, sugerindo não haver grandes diferenças entre caminhadas no lazer e no deslocamento (Boone-Heinonen *et al.*, 2009). Em crianças, a relação entre deslocamento a pé ou de bicicleta para a escola e excesso de peso tem sido investigada com maior regularidade, muito embora também faltem estudos com delineamento apropriado (Lee, Orenstein e Richardson, 2008; Wanner *et al.*, 2012; Saunders *et al.*, 2013).

Estudo ecológico sobre frequência da caminhada ou do uso da bicicleta como formas de deslocamento e prevalência de obesidade em países europeus, Estados Unidos e Austrália encontrou relação inversa entre as duas variáveis (Bassett *et al.*, 2008). Esta mesma relação inversa foi encontrada em estudos realizados com a população dos Estados Unidos (Gordon-Larsen *et al.*, 2009), Dinamarca (Smith, L. V. H., Borch-Johnsen, K. e Jorgensen, T., 2007) e Brasil (Peixoto, Benicio e Jardim, 2007), muito embora estes estudos possam ter sido afetados por confundimento residual em virtude do não ajuste por algumas importantes variáveis, como consumo alimentar (Gordon-Larsen *et al.*, 2009), demais tipos de atividade física (Smith, L. V., Borch-Johnsen, K. e Jorgensen, T., 2007) ou ambos (Peixoto, Benicio e Jardim, 2007). Limitações semelhantes podem ser observadas em estudos que encontraram associação inversa entre tempo de uso de automóvel (Frank, Andresen e Schmid, 2004; Dunton *et al.*, 2009) ou posse de veículo (Parra *et al.*, 2009) e excesso de peso. Além disso, há evidências do

papel benéfico do deslocamento ativo para outras doenças, como o diabetes (Pucher *et al.*, 2010), para a aptidão física de crianças (Voss e Sandercock, 2010) e para os níveis globais de atividade física tanto em crianças (Lee, Orenstein e Richardson, 2008) quanto em adultos (Pucher *et al.*, 2010).

Finalmente, por sua natureza abrangente, o deslocamento ativo pode se relacionar a diversos aspectos da saúde das pessoas e do seu ambiente. Ações de promoção do deslocamento ativo tem o potencial não só de aumentar sua prática, mas também de impactar positivamente em outros determinantes sociais de saúde, como a preservação dos recursos naturais ou o incremento da autonomia das pessoas, estabelecendo assim um ciclo virtuoso na melhoria das condições de saúde da comunidade (Dora *et al.*, 2014). Por exemplo, os contatos incidentais promovidos pelo hábito de caminhar e pedalar parecem influir positivamente na comunidade, pois estão relacionados com o fortalecimento do senso de pertencimento (Wood, Frank e Giles-Corti, 2010). Mais ainda, é possível observar uma associação direta entre a interação com espaços e pessoas e experiências diárias positivas, como a felicidade, especialmente entre os mais velhos (Oishi *et al.*, 2011). Presumivelmente, a prática do deslocamento ativo, em comparação com qualquer outro modo de deslocamento, tem o maior potencial de favorecer a familiarização com um lugar e a relação entre diferentes pessoas. Este “repovoamento” dos espaços comuns tem o poder de devolver a estes espaços a condição de lugares públicos (Augé, 1995), elementos propulsores da prosperidade urbana (Un-Habitat, 2013) e espaço para o exercício da cidadania (Harvey, 2003; Harvey *et al.*, 2013).

Além do papel benéfico direto da prática de atividade física durante os deslocamentos cotidianos, é preciso considerar os benefícios indiretos do deslocamento ativo no contexto da mobilidade urbana (Dora *et al.*, 2014). O transporte motorizado movido à queima de combustíveis fósseis é o modo mais usado de transporte da maioria da população – principalmente nos países de renda alta ou média – e responde por parcela considerável da emissão de material particulado sólido na atmosfera. A redução na qualidade do ar tem participação importante na carga de DCNT, sobretudo com relação a doenças respiratórias crônicas (Cooper *et al.*, 2009) e a doenças cardiovasculares (Frank *et al.*, 2006).

Se, por um lado, a substituição de modos motorizados por modos não motorizados de transporte trariam benefícios com relação à poluição atmosférica e à

emissão de gases do efeito estufa, é preciso considerar um possível incremento da exposição à poluição atmosférica nos indivíduos que optam pelo transporte não motorizado, tema de intensa discussão na literatura científica recente, ainda sem evidências conclusivas (Rank, Folke e Jespersen, 2001; Briggs *et al.*, 2008; Tsai, Wu e Chan, 2008; Boogaard *et al.*, 2009; Morabia *et al.*, 2009; Morabia *et al.*, 2010; Zuurbier *et al.*, 2010). Em que pese os desafios metodológicos, a hipótese mais aceita é a de que a exposição à poluição do ar entre praticantes de deslocamento ativo e usuários dos principais modos de transporte difere pouco, principalmente quando ciclistas e pedestres deslocam-se por vias menos movimentadas (Boogaard *et al.*, 2009; Morabia *et al.*, 2009; Morabia *et al.*, 2010; Zuurbier *et al.*, 2010).

Tendo em vista que o prejuízo causado pela poluição do ar é relativamente linear, ao contrário dos benefícios advindos da atividade física, cuja curva dose-resposta segue uma forma exponencial, é possível que, em determinado momento, a exposição à poluição do ar seja capaz de anular os ganhos da atividade física. Também é preciso, portanto, considerar o benefício líquido da prática de deslocamento ativo em diferentes níveis de poluição atmosférica. Uma análise preliminar realizada como complemento a esta tese indica haver um benefício líquido positivo da prática de deslocamento ativo mesmo quando são elevadas as concentrações de poluição do ar. Esta prática deixa de ser desejável apenas em condições extremas de poluição, encontradas em poucas cidades do globo em determinadas épocas do ano (Anexo 2).

Outro importante fator de risco à saúde relacionado com a prática de deslocamento ativo são os óbitos e lesões ligados ao trânsito. No Brasil, a taxa de mortalidade relacionada ao trânsito manteve-se em torno de 23 por 100.000 habitantes entre 1998 (ano da criação do novo Código Nacional de Trânsito) e 2007, sendo o pedestre a principal vítima ao longo de todo o período (Reichenheim *et al.*, 2011). Em 2007, a mortalidade de pedestres foi de 6,2 por 100.000 habitantes, o que correspondeu a 34,6% de todos os óbitos ligados ao trânsito, envolvendo, principalmente, indivíduos com mais de 40 anos de idade (Reichenheim *et al.*, 2011). Chama a atenção, também, o aumento contínuo da mortalidade de ciclistas no período entre 1996 e 2007 (Reichenheim *et al.*, 2011).

Ainda assim, segundo evidências recentes, a substituição do transporte motorizado por formas ativas de deslocamento parece trazer benefícios substancialmente maiores do que prejuízos, tanto no plano social quanto no

individual (Hartog *et al.*, 2011). Além disso, esta substituição reduz o número de quilômetros viajados por modo motorizado, o que também contribui para a redução do risco e gravidade de lesões de trânsito (Mueller *et al.*, 2015). Note-se, ainda, que, independentemente da substituição de modos de transporte, há evidências do aumento da segurança no trânsito a partir do aumento na frequência de deslocamentos ativos, o que pode ser explicado pelo efeito “*safety-in-numbers*”, ou seja, à medida que mais pessoas caminham e pedalam, menor se torna a chance de haver um acidente envolvendo pedestres ou ciclistas (Jacobsen, 2003). Em outras palavras, o aumento da exposição ao fator de risco no plano individual acaba por promover uma redução daquela exposição sobre o risco populacional de ocorrência do evento negativo.

Por fim, é cabe destacar que o transporte motorizado também é responsável por parcela significativa da poluição sonora nos centros urbanos, fator associado a diversos problemas de saúde, como distúrbios do sono, irritabilidade, estresse, fadiga, risco cardiovascular aumentado e problemas auditivos (Ising e Kruppa, 2004; Pirrera, De Valck e Cluydts, 2010). Aqui, é importante considerar o papel central dos transportes de massa (ônibus e trens) para a geração do ruído de fundo das cidades (apesar de serem opções melhores do que o transporte motorizado individual quando se consideram outros problemas de saúde).

Fontes de dados para o estudo do deslocamento ativo

Pesquisas de saúde

As principais fontes de dados para o estudo do deslocamento ativo têm sido os inquéritos de saúde e os sistemas de vigilância. Em ambos, o deslocamento ativo entra como um dos domínios de prática de atividade física, sendo comumente investigado enquanto hábito ou costume. Em nível nacional, é possível destacar três fontes para o estudo em adultos: o sistema VIGITEL, operado pelo Ministério da Saúde anualmente desde 2006; o Suplemento de Saúde da Pesquisa Nacional por Amostra de Domicílios da PNAD 2008, primeiro levantamento sobre prática da atividade física representativo de toda a população brasileira; e a Pesquisa Nacional

de Saúde (PNS) de 2013, a maior e mais detalhada pesquisa de saúde já realizada no país, também representativa de toda a população brasileira. Infelizmente, os microdados sobre deslocamento ativo da PNS 2013 não foram disponibilizados publicamente a tempo de serem analisados para esta tese.

O sistema VIGITEL estuda todos os anos, em cada uma das capitais dos 26 estados brasileiros e no Distrito Federal, amostras probabilísticas da população de adultos (18 ou mais anos de idade) residentes em domicílios servidos por pelo menos uma linha telefônica fixa ^b. O questionário do sistema, coleta informações sobre o costume de prática de deslocamento a pé ou de bicicleta para o trabalho desde 2006 e, a partir de 2009, também para a escola. Além disso, indaga-se das pessoas a duração total do percurso total (ida e volta do destino). A validade concorrente e a reprodutibilidade das estimativas de deslocamento ativo geradas pelo sistema VIGITEL foram avaliadas como satisfatórias (Monteiro *et al.*, 2008).

A PNAD 2008^c envolveu o estudo de uma amostra probabilística de 150.591 domicílios onde residiam 391.868 pessoas, entre crianças e adultos. O procedimento de amostragem da PNAD 2008 foi estruturado para permitir estimativas representativas do país como um todo, das 5 macro regiões (Norte, Nordeste, Sudeste, Sul e Centro-Oeste) e de todas as unidades da Federação. No caso do país e das grandes regiões, a amostra permite, ainda, estimativas representativas para domicílios na situação urbana e na situação rural. O questionário da PNAD 2008 pergunta se os indivíduos costumam ir a pé ou de bicicleta para o trabalho e, caso afirmativo, o tempo gasto no deslocamento. Estas questões foram respondidas apenas por indivíduos com idade igual ou superior a 14 anos e que não tivessem problemas de saúde que acarretassem dificuldades para andar cerca de 100 metros ou para fazer compras de alimentos, roupas e medicamentos sem ajuda.

Pesquisas origem e destino

^b Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Secretaria de Gestão Estratégica e Participativa. Vigitel Brasil 2010: vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico / Ministério da Saúde, Secretaria de Vigilância em Saúde, Secretaria de Gestão Estratégica e Participativa. Brasília: Ministério da Saúde, 2011. 152 p.: il. – (Série G. Estatística e Informação em Saúde)

^c IBGE. Um Panorama da Saúde no Brasil: acesso e utilização dos serviços, condições de saúde e fatores de risco e proteção à saúde 2008. Disponível em http://www.ibge.gov.br/home/estatistica/populacao/panorama_saude_brasil_2003_2008/default.shtm

Embora crescentemente utilizadas para avaliar o deslocamento ativo em vários países (Coogan e Coogan, 2004; Merom *et al.*, 2010), as pesquisas do setor de transportes – comumente conhecidas como Pesquisas Origem e Destino ou *Household Travel Surveys* – não têm sido devidamente exploradas para este fim no Brasil. As Pesquisas Origem e Destino (OD) buscam caracterizar a dinâmica dos deslocamentos diários feitos em determinada região com o objetivo de planejar a expansão ou reestruturação da rede de transportes. Com sua realização, obtém-se um conjunto de dados sobre o modo empregado nos deslocamentos das pessoas (motorizado / não motorizado / misto; individual / coletivo), a distância percorrida e o tempo gasto em cada deslocamento, sua origem e destino, e o propósito da viagem.

No Brasil, é cada vez maior o número de municípios e/ou regiões metropolitanas que realizam ODs periodicamente, como Porto Alegre, Curitiba, Belo Horizonte, Rio de Janeiro, Goiânia, Brasília, Natal, Fortaleza, Recife, Salvador, São Paulo, Campinas e Baixada Santista. A restrição das ODs aos grandes conglomerados urbanos também ocorre em outros países, como a Austrália, por exemplo, muito embora a maior parte dos países de renda alta também possuam ODs nacionalmente representativas (Stopher *et al.*, 2011).

Ainda que os dados sobre deslocamento ativo tenham sido frequentemente relegados a um papel secundário nas ODs (Coogan e Coogan, 2004), sua utilização com foco em questões de interesse da saúde pública pode trazer importantes contribuições ao entendimento de agravos à saúde relacionados à inatividade física (Bassett *et al.*, 2008; Grize *et al.*, 2010; Merom *et al.*, 2010; Pucher *et al.*, 2010). As ODs talvez sejam as fontes de dados que nos ofereçam as estimativas mais confiáveis da prática de deslocamento ativo, pois tradicionalmente analisam as viagens realizadas pelos indivíduos no dia anterior à entrevista, e não um hábito ou costume de se deslocar ativamente, como o fazem a maioria das pesquisas sobre condições de saúde da população. Mais ainda, as ODs buscam compreender todos os propósitos que motivaram os deslocamentos, e não apenas os propósitos de ir e voltar para o trabalho e escola. Ao coletar dados sobre todos os modos de transporte, as ODs também favorecem a investigação da prática de deslocamento ativo considerando as outras viagens realizadas pelo indivíduo, sejam elas de carro, moto ou transporte público. Um dos maiores desafios para a operacionalização do uso das ODs na pesquisa em saúde é a transposição da unidade de interesse das viagens para o indivíduo. Ao fazê-la, torna-se possível estimar, por exemplo, o

número ou a proporção de pessoas que se deslocam por determinado modo, informação mais relevante para o setor saúde do que o número ou a proporção de viagens realizadas por este modo de transporte (Merom *et al.*, 2010). Também é possível estimar o tempo acumulado de deslocamentos por habitante em cada modo, o que facilita a avaliação do efeito de políticas públicas do setor de transportes sobre a saúde da população (Woodcock *et al.*, 2009; Buehler *et al.*, 2011). É preciso ponderar, contudo, que as ODs são realizadas principalmente em capitais e grandes regiões metropolitanas, razão pela qual têm havido esforços recentes para o desenvolvimento de estratégias de pesquisa mais simples e baratas aplicáveis a municípios menores ou comunidades específicas (Forsyth *et al.*, 2012).

Muito embora as ODs ofereçam perspectivas promissoras para o estudo do deslocamento ativo, são muito poucos os estudos que avaliaram a validade do uso de seus dados, tanto com relação aos indicadores de atividade física (p.e., duração, intensidade) quanto aos indicadores de deslocamento (p.e., número de viagens, locais de origem e destino, horas de saída e chegada, modo e motivo da viagem) (Agrawal e Schimek, 2007; Krizek, Handy e Forsyth, 2009).

Estudo de validação da *Sydney Household Travel Survey (HTS)* observou que os respondentes subnotificaram o número de viagens em aproximadamente 7%, além de relatarem menores valores para as distâncias e maiores valores para a duração das viagens. Este estudo utilizou como medida critério uma estratégia combinada de uso do Sistema de Posicionamento Global (*Global Positioning System – GPS*) seguido de um recordatório de reconstrução das viagens baseado em mapas e tabulações extraídas do próprio dispositivo GPS, aplicado entre uma e duas semanas após o dia de referência (Stopher, Fitzgerald e Xu, 2007). Em estudos americanos, em estudos de validação com estratégia similar, podemos observar uma ampla variação na proporção de subnotificação de viagens, de 11% na *Saint Louis HTS* a 81% na *Laredo HTS* (Wolf, 2004). Mais recentemente, alguns autores tem avaliado a possibilidade não apenas de validar, mas de coletar os dados sobre as viagens, inclusive o modo e o motivo, por meio desta estratégia de coleta usando os dados do GPS e ferramentas de georreferenciamento, em substituição à entrevista domiciliar ou telefônica (Wolf, Guensler e Bachman, 2001; Wolf, 2004; Bohte e Maat, 2009).

Outra limitação das ODs é a falta de uma definição clara e padronizada sobre o conceito de viagem, sobretudo no que diz respeito às viagens a pé (Agrawal e

Schimek, 2007; Krizek, Handy e Forsyth, 2009). Diferentes estratégias de coleta de dados podem ou não captar viagens como (1) caminhar de uma loja a outra em uma mesma rua, (2) caminhar duas quadras até o ponto de ônibus ou, simplesmente, (3) dar uma volta no quarteirão. Como exemplo, podemos citar a OD da Região Metropolitana de Campinas de 2011, que considerou como viagem exclusiva a pé apenas deslocamentos superiores a 500m para outros motivos de viagem que não o trabalho ou a escola (Empresa Paulista De Planejamento Metropolitano, 2004). Neste caso, nenhuma das viagens ilustradas anteriormente teria sido captadas. Além disso, é possível que o próprio entrevistado não reconheça viagens tão curtas a pé como sendo viagens e que haja um viés de memória maior para viagens curtas realizadas a pé ou de bicicleta em comparação com outros modos de transporte, tendo em vista não apenas a brevidade destas viagens, mas também a menor preparação envolvida em sua realização (Agrawal e Schimek, 2007). Isto faz com que ODs tendam a subnotificar viagens realizadas a pé e de bicicleta (Agrawal e Schimek, 2007; Pucher *et al.*, 2011; Forsyth *et al.*, 2012), razão pela qual diversas pesquisas tradicionais tem promovido uma série de melhorias em suas estratégias de coleta de modo a refinar os dados sobre deslocamentos ativos, como a estadunidense *National Household Travel Survey*, desde 2001 (Pucher *et al.*, 2011), e a OD da Região Metropolitana de São Paulo, desde 1997 (Companhia Do Metropolitano De São Paulo, 2008).

Com relação à validação dos indicadores de intensidade de atividade física estimados por meio de ODs, observa-se que a maior parte dos estudos ainda se debruça sobre os aspectos metodológicos da integração de diferentes tecnologias, como o GPS, o acelerômetro e sistemas de georreferenciamento (Duncan e Mummery, 2007; Duncan, Badland e Mummery, 2009; Oliver *et al.*, 2010). Isto se dá pelas limitações inerentes a cada instrumento para o estudo da caminhada e da bicicleta no contexto dos deslocamentos urbanos (Krenn *et al.*, 2011). Com efeito, apenas com triangulação de instrumentos de coleta de dados sobre os deslocamentos dos indivíduos é possível a construção de uma medida critério capaz de validar o questionário de coleta das ODs no que diz respeito à intensidade dos deslocamentos ativos (Krenn *et al.*, 2011).

Pesquisa origem e destino da Região Metropolitana de São Paulo (OD/RMSP)

Realizada a cada dez anos pela Companhia do Metropolitano de São Paulo (METRÔ), desde 1967, a OD da Região Metropolitana de São Paulo (RMSP) é a mais antiga série histórica deste tipo no país. A RMSP é constituída por 39 municípios, que estão agregados em sete sub-regiões (Centro, Norte, Nordeste, Leste, Sudeste, Sudoeste e Oeste). As OD/RMSP contem informações sobre os domicílios, as famílias, os moradores e as viagens realizadas por eles. Outra característica importante destas pesquisas é que elas permitem a localização espacial das origens e destinos das viagens realizadas pela população em determinado período de tempo, graças ao zoneamento prévio da área de estudo, que leva em conta os limites dos setores censitários, os limites de municípios e de distritos no município de São Paulo, e a comparabilidade com o zoneamento das OD/RMSP de anos anteriores. A partir da OD/RMSP de 1997, passam a ser coletados dados mais detalhados sobre as viagens feitas a pé e de bicicleta, razão pela qual utilizaremos nas análises deste projeto as pesquisas realizadas em 1997 e 2007. A coleta da OD/RMSP97 foi realizada entre agosto e novembro de 1997 e a da OD/RMSP07, entre agosto e novembro de 2007, com complementação no período de fevereiro a abril de 2008.

Os dois levantamentos utilizaram plano amostral complexo, a partir do cadastro das companhias distribuidoras de energia elétrica na região, cuja cobertura é superior a 98%. O uso de um cadastro domiciliar praticamente universal como base para o processo de amostragem busca superar as dificuldades de um cadastro universal e atualizado de indivíduos para uma eventual amostragem aleatória simples. Ao se fazer a amostragem por conglomerados (no caso, o domicílio), temos um barateamento no custo por elemento amostrado, por conta de um menor gasto na elaboração de cadastros e na localização de indivíduos. Por outro lado, esta estratégia implica uma maior complexidade na análise estatística e, geralmente, um incremento na variância dos estimadores utilizados, com conseqüente diminuição da precisão do estudo (Cordeiro, 2001). A solução encontrada para diminuir o efeito da amostragem por conglomerado sobre a variância foi a análise estratificada por faixas de consumo de energia elétrica.

Primeiramente, toda a RMSP foi dividida em zonas. Em seguida, procedeu-se ao sorteio da amostra de domicílios em cada zona, com reposição, estratificado por faixas de consumo de energia elétrica (quatro faixas: até 100 kwh/mês, 100 a 200 kwh/mês, 200 a 300 kwh/mês e mais de 300 kwh/mês). A estratificação por faixas de consumo de energia elétrica buscou garantir a precisão das estimativas com um menor tamanho amostral, uma vez que o consumo de energia elétrica tem relação estreita com a renda familiar e com o número de viagens do domicílio (Companhia Do Metropolitano De São Paulo, 2008). Para algumas poucas zonas, onde não foi possível a criação de estratos, adotou-se a amostragem casual simples, por meio do arrolamento dos domicílios. A zona de pesquisa é a unidade geográfica a partir da qual existe representatividade estatística dos dados. O tamanho total da amostra para os dois anos foi dimensionado em 30.000 domicílios. Foram consideradas válidas as entrevistas completas realizadas em endereços residenciais sem problemas de identificação ou que não estivessem vagos / fechados. A Tabela 1 apresenta as principais características das duas últimas OD/RMSP (1997 e 2007).

Tabela 1: Características das Pesquisas Origem e Destino da Região Metropolitana de São Paulo em 1997 e 2007. São Paulo, 2013.

Pesquisas Origem e Destino / Região Metropolitana de São Paulo		
Variáveis	OD/RMSP 1997	OD/RMSP 2007
Zonas	320	460
Domicílios	23841	29957
Pessoas	98780	91405
Viagens	163541	169665

Entrevistas domiciliares completas foram aquelas em que todos os moradores forneceram pessoalmente informações sobre suas viagens no dia anterior à entrevista. Para tanto, o entrevistador retornava ao domicílio quantas vezes fosse necessário até que todos os indivíduos fossem entrevistados. A Tabela 2 apresenta detalhes sobre perdas e recusas para a OD/RMSP 2007:

Tabela 2: Perdas e recusas na Pesquisa Origem e Destino da Região Metropolitana de São Paulo em 2007. São Paulo, 2013.

Resultado da Entrevista no Domicílio	Total	%
Recusa	9549	17,5
Fechado	6081	11,1
Vago	2419	4,4
Incompleto	641	1,2
Problemas c/ endereço*	5920	10,9
INVÁLIDAS	24610	45,1
VÁLIDAS	29961	54,9
TOTAL	54571	100

Fonte: Metrô/SP

* Endereço não localizado, incompleto ou comércio.

Infelizmente, não há informações sobre perdas e recusas com o mesmo nível de detalhamento para a OD/RMSP 1997, muito embora a posição oficial do Metrô seja a de que estes indicadores têm sido muito similares desde 1987.

Tanto na OD/RMSP 1997 quanto na OD/RMSP 2007 foram coletados dados socioeconômicos da família (número de pessoas, condição de moradia, quantidade de bens de consumo e renda familiar) e dos indivíduos (idade, sexo, escolaridade, status de estudo, status ocupacional, renda individual e número de viagens), bem como informações sobre as viagens realizadas pelos residentes no dia anterior à entrevista, sempre um dia útil da semana (modo dos trechos da viagem, motivo na origem e no destino, hora de partida e chegada, número de transferências, dia da viagem, duração e distância). Além disso, para a OD/RMSP 2007, foram georreferenciados todos os endereços: domicílio, trabalho, escola, pontos de origem, de destino e de transferência.

Outras fontes de dados para o estudo da relação entre deslocamento ativo e saúde

A avaliação da relação entre deslocamento ativo e saúde prescinde do uso de informações sobre outros fatores de risco relacionados ao transporte com grande potencial de dano (Mueller *et al.*, 2015), como a poluição do ar e as lesões de

trânsito. Infelizmente, ainda não há um conjunto de informações suficientemente detalhado para outros fatores, como, por exemplo, a poluição sonora e o ambiente alimentar.

Os dados sobre lesões de trânsito e poluição do ar em São Paulo foram obtidos por meio do Sistema de Acidentes de Trânsito da Companhia de Engenharia de Tráfego (SAT-CET) e pelos informes anuais da Companhia Ambiental do Estado de São Paulo (CETESB), respectivamente.

O SAT-CET é um sistema construído a partir de diferentes fontes de informação do poder público, dentre as quais os registros policiais, os laudos do Instituto Médico Legal e registros da própria CET (Companhia De Engenharia De Tráfego, 2014). O sistema apresenta, a cada ano, um conjunto detalhado de informações sobre os acidentes de trânsito com vítimas graves ou mortas para o município de São Paulo, com dados sobre as pessoas e veículos envolvidos, bem como a localização, data e hora do evento. Após sucessivas melhorias no sistema, o SAT-CET apresenta consistência metodológica e maior similaridade no conjunto das informações coletadas sobretudo a partir de 2009.

Os sistema de informações da CETESB coleta dados sobre diversos poluentes atmosféricos, dentre os quais o monóxido de carbono (CO), óxidos de nitrogênio (NOx), hidrocarbonetos totais (HC), metano (CH₄), dióxido de enxofre (SO₂), dióxido de carbono (CO₂) e material particulado (MP). Estes dados são obtidos pela rede de monitoramento da qualidade do ar, presente em todo o Estado de São Paulo. Além disso, o sistema apresenta informações meteorológicas detalhadas para os dias de coleta. Maiores detalhes sobre os dados da CETESB, a metodologia de coleta e análise de dados e o inventário das fontes de poluição podem ser obtidas nos relatórios oficiais da companhia (Companhia Ambiental Do Estado De São Paulo, 2012; 2013).

A modelagem como ferramenta para o estudo da relação entre deslocamento ativo e saúde

Um modelo pode ser entendido como uma simplificação da realidade para responder uma pergunta específica (Simon Fraser University Complex Systems Modelling Group, 2010). A aplicação de modelos é recorrente em diversos setores e

particularmente interessante quando não há outros métodos disponíveis na busca por respostas ou quando estes métodos são custosos e demorados. No campo da saúde, modelos têm sido utilizados largamente, com aplicações distintas, como, por exemplo, no apoio à gestão de serviços de saúde, na avaliação de comportamentos de saúde e na predição da evolução de epidemias infecciosas (Simon Fraser University Complex Systems Modelling Group, 2010). Dado o grau de incerteza intrínseco ao processo de modelagem, é importante destacar que modelos servem mais como um indicativo da magnitude e direção esperados do que propriamente como uma evidência empírica (Parry e Stevens, 2001).

Dentre as diversas estratégias possíveis no processo de modelagem, a mais comumente utilizada para o estudo do impacto à saúde da prática de deslocamento ativo tem sido a combinação de técnicas computacionais com modelos matemáticos (Mueller *et al.*, 2015). Recente revisão sistemática de estudos de modelagem avaliando o impacto à saúde do aumento da prática de deslocamento ativo observou ganhos em saúde em 27 dos 30 estudos encontrados (Mueller *et al.*, 2015). Os benefícios estimados advieram principalmente do aumento dos níveis de atividade física, que compensaram os efeitos prejudiciais associados a lesões de trânsito e exposição à poluição do ar. Entretanto, 29 dos 30 estudos encontrados foram desenvolvidos em regiões de renda alta, historicamente com menores taxas de poluição do ar e de lesões de trânsito na comparação com regiões de baixa e média renda, como o Brasil.

De todo modo, o único estudo preditivo sobre diferentes cenários de mobilidade urbana (Woodcock *et al.*, 2009) envolvendo uma região de renda média-baixa (Nova Deli, Índia) encontrado naquela revisão projetou expressivos ganhos em saúde e redução na emissão de dióxido de carbono para o ano de 2030, no cenário que considerava a substituição de uma pequena parte das viagens feitas por transporte motorizado pelo deslocamento ativo. Esse cenário assume níveis de prática de deslocamento ativo similares aos já praticados em cidades do norte da Europa, como Amsterdã e Copenhagen.

A avaliação dos efeitos sobre a saúde da população de um modelo de cidade compacta aplicado a São Paulo, com melhoras na densidade e diversidade de uso do solo bem como a redução do uso de modos motorizados privados de transporte, também indicaram ganhos em saúde (Anexo 3). Os ganhos obtidos com o aumento da prática de atividade física e redução da poluição do ar superaram

expressivamente as perdas decorrentes do aumento nas lesões e mortes no trânsito. O ganho líquido em anos de vida ajustados para incapacidade foi de 420 por 100 mil habitantes (Intervalo de Confiança de 95%: 12; 1029). Além disso, os anos de vida ajustados para incapacidade perdidos em lesões e mortes no trânsito poderiam ser virtualmente eliminados com um aumento na infraestrutura peatonal e cicloviária que seja capaz de promover um grau de separação entre modos motorizados privados e pedestres/ciclistas de aproximadamente 5% no total de quilômetros viajados (Anexo 3).

2. OBJETIVOS

- i) Descrever a frequência, a distribuição e a variação temporal de indicadores do deslocamento ativo em populações brasileiras;
- ii) Avaliar o impacto de mudanças no padrão de transporte da população sobre o deslocamento ativo, o tempo sedentário e desfechos de saúde em populações brasileiras.

3. MANUSCRITOS

Manuscrito 1: Prevalence of active transportation among adults in Latin America and the Caribbean: a systematic review of population-based studies

Título corrido: Active transportation among adults in Latin America and the Caribbean
Artigo original submetido à Revista Panamericana de Saúde.

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ABSTRACT

Objective: to conduct a systematic review of the literature on the prevalence of active transportation in the Latin American and the Caribbean region (LAC).

Methods: twelve electronic databases were searched for relevant abstracts and to identify papers eligible for full-text review. A study was included if two authors agreed

that it was conducted in an adult sample (≥ 18 y) designed to be representative of a region in LAC and reported at least one measure of active transportation. References of papers included in our study and of reviews retrieved in the search were also checked to identify additional candidate publications. 87 scientific experts and 42 government authorities were either contacted or had their website searched for the same purpose. Data were extracted independently by two authors. **Findings:** A total of 10,459 unique records were found; the full text of 143 was reviewed. 45 studies were included, with estimates for 72 LAC settings, most of which in Brazil, Argentina and Colombia. Estimates were available for walking, cycling or the combination of both, with a high degree of heterogeneity for all of them ($I^2 \geq 99\%$). The median prevalence of active transportation combining walking and cycling was of 12%, ranging from 5.1% in Palmas (Brazil) to 58.9% in Rio Claro (Brazil). Gender differences varied in magnitude and direction according to the active transportation type. **Conclusion:** Prevalence of active transportation in the Latin American and Caribbean region varied widely, with great heterogeneity and uneven distribution of evidence across countries.

Descriptors: urban health, healthy city, transportation, walking, motor vehicles.

Introduction

In September 2015, heads of state will join in the United Nations General Assembly to discuss the implementation of a new set of goals post-2015, the Sustainable Development Goals (SDG), which aim to build upon the health gains obtained from the Millennium Development Goals (MDG) experience ¹. This new agenda includes thematic areas, such as city development and energy, and key aspects capable of promoting holistic and integrated responses towards a healthier future, including “safe, affordable, accessible and sustainable transport systems for all” ¹.

Active transportation is a key component for the development of healthy sustainable environments as it provides health benefits with ancillary benefits on greenhouse gases emissions ^{2,3}. Moreover, increasing active transportation levels is a key population-wide strategy to reverse the pandemics of non-communicable diseases (NCD), given the great potential of tackling physical inactivity levels through the transport sector ⁴. This is particularly important for low-to-middle income countries

since the majority of NCD lies in those regions ⁵, reinforcing historical health inequities.

The Latin American and Caribbean (LAC) region is composed by low-to-middle income countries with important challenges in terms of transport and urban planning, given its historical process of poor and rapid urbanization ⁶. Moreover, despite being the most urbanized region in the world, with 80% of the population living in cities ⁷, LAC has countries at different levels of urbanization and at different stages in the mobility transition ⁶. In recent years, several settings within the LAC region have experienced attempts to improve attributes of urban environment and to reduce the social and spatial segregation against the marginalized population ^{6,8-10}. These initiatives have great potential to promote or sustain walking and cycling.

However, monitoring data on active transportation has been sparse in low-and-middle-income countries, particularly for walking and cycling, as these modes were traditionally relegated to a secondary role, both in health and transport databases ¹¹. Failing to promote and monitor walking and cycling levels as well as other forms of active transportation might jeopardize efforts around that agenda in the SDG era, as we already learned from MDG struggling with lack of information, including for targets linked with sustainable healthy environments (e.g., Target C of MDG 7: “Ensure Environmental Sustainability”)².

The LAC region has marked differences and varied capacity to promote changes in the transport systems and to provide representative estimates of active transportation. Despite some recent efforts to compile these estimates, particularly for cycling ¹², most information available is based on the proportion of trips (and not the actual population prevalence), which is not the best indicator for public health monitoring. So far, little is known about the prevalence of these two health practices in the region ⁶. Therefore, the main purpose of this study was to conduct a systematic review of the literature to obtain the prevalence of active transportation in LAC in the last ten years.

Methods

A systematic review of studies reporting the prevalence of any type of active transportation in the Latin American region was performed in accordance with the Preferred Reporting Items of Systematic Review and Meta-analyses (PRISMA) guideline ¹³ and with the Centre for Reviews and Dissemination Guidance for

Undertaking Reviews in Health Care ¹⁴. We defined active transportation as any self-propelled, human-powered mode of transportation.

Search strategy

We searched MEDLINE, *Excerpta Medica* (Embase), SportDiscus, Lilacs, MediCarib, Web of Science, OVID, CINAHL, Scopus, Google Scholar, National Transportation Library, TRIS/TRID from January 2003 to December 2014 for articles with at least a title and abstract in English, Spanish, or Portuguese. We chose to limit the time period to the previous decade in order to provide up to date estimates, more relevant for policy planning. Search terms included variations of the following words in the three languages previously mentioned: epidemiology, prevalence, rate, active travel, active transportation, active commuting, urban mobility, running, walking, pedestrian, cycling, bicycle, bike, paddling, rowing, travel survey, transport survey, demand survey, origin and destination, mobility survey, time-use survey, adult, men, women, Latin America, Central America, South America, Caribe, and names of Latin American and Caribbean countries. Searches took into account MeSH (medical subject heading) terms or equivalents, truncated and text word terms. The search strategy was adapted from the search of Saunders et al. (2013) ¹⁵ and then adapted for each database used (available from the corresponding author).

The reference list of all manuscripts selected was reviewed as well as of relevant reviews identified through the search and selection processes. 87 scientific experts and 42 government authorities were either contacted or had their website searched in order to find any study (including unpublished or ongoing studies) that could be relevant for our review. We removed duplicate records through EndNoteWeb® (Thomson Reuters, Carlsbad, CA, USA).

Study Selection

Two reviewers (THS; PMN) independently identified potentially relevant studies by reading titles and abstracts. Full-texts of the abstracts previously evaluated were selected based on the reviewers' consensus according to the following criteria: (i) the study reported original data of any active transportation type or of a combination of types (data from the first evaluation of longitudinal studies were included); (ii) the study was conducted in Latin America or Caribbean region (studies with Latin American or Caribbean populations living in other regions were

not included); (iii) the study had a sample designed to be representative of that given region; and (iv) the study reported estimates from the adult general population (≥ 18 y). Disagreements between the two independent evaluations were solved by a third reviewer (LFMR).

Data Extraction and Quality Appraisal

Two reviewers independently extracted data using a data collection form (LFMR; FA), which was tested on a sample of papers. Disagreements were discussed with a third reviewer (MCB). The form included information on study design, methodological aspects, outcomes (as prevalence, or proportion of trips; if these were not available or possible to estimate, other measures were extracted – e.g. mean time), population characteristics and setting for each study. Studies for which more than one paper was obtained had their data extracted from all manuscripts retrieved.

The same reviewers also evaluated the quality of the studies, based on a quality assessment protocol previously agreed upon (Appendix S1). The standardized checklist included whether the study presented a definition of active transportation; whether active transportation prevalence was one of the study main objectives; whether target population, sampling strategy, data collection and statistical analysis were well-defined / described; whether total population and response rates were reported; and whether the analysis included key estimates, namely confidence intervals or standard errors.

Data Analyses

The overall prevalence of active transportation from each study was presented in a forest plot. Prevalence of active transportation was also analysed stratified by commuting mode and sex. In case of multiple estimates for the same study population, only the most recent estimate was considered. Confidence intervals were calculated when this information was missing in the original publication using standard error or data on prevalence and sample size. High heterogeneity among studies was defined as an $I^2 > 50\%$. Characteristics and quality of the studies were presented in narrative form and in relative frequencies. All analyses were performed in Stata 12.0 (Stata Corp, College Station, Tex.).

Results

10,459 records were retrieved from the electronic database search and additional records were identified from reference lists (n = 13), scientific experts (n = 35), and government authorities (n = 8 published reports and n = 3 unpublished reports). 45 studies met the eligibility criteria (Appendix S2). Studies that included more than one location or more than one period of analysis were initially presented separately, which resulted in 72 units of analysis, as detailed in Table S1. Furthermore, studies that estimated the prevalence of active transportation for population subgroups (e.g. adults vs. elderly) and did not provide enough information for combining stratum specific estimates were also presented separately.

The characteristics of the 45 eligible studies are summarized in Table 1. Most studies were conducted in Brazil (62.2%, n=28), in urban area (80.0%; n=36), and between 2005 and 2009 (60.0%, n=27). With reference to methodological aspects, the majority of them had cross-sectional design (97.8%, n=44), sample size greater than 1000 individuals (71.1%, n=32), used ≥ 150 min/week as the criterion for defining active transportation (33.3%, n=15), and used IPAQ long version (48.9%, n=22). Response rate was not reported in 51.1% of the studies (n=23).

Table 1: Methodological characteristics and geographic location of the studies. São Paulo, 2015

		n	%
Country	Argentina	13	29.0
	Brazil	28	62.2
	Chile	1	2.2
	Colombia	2	4.4
	Jamaica	1	2.2
Urbanicity	Urban	36	80.1
	Rural	1	2.2
	Urban and Rural	2	4.4
	NR	6	13.3
Year of data collection	2005-2009	27	60.0
	2010-2014	18	40.0
Study design	cross-sectional	44	97.8
	longitudinal	1	2.2

(Continue Table 1)

Sample size	≤ 1,000	13	29.0
	> 1,000	32	71.0
AT criteria	no/yes	18	40.0
	≥ 10min/week	3	6.7
	≥ 150min/week*	15	33.3
	≥ 30 min/day	4	8.9
	Other	5	11.1
Data collection instrument	IPAQ (long version)	22	48.9
	GPAQ	2	4.4
	Vigitel questionnaire	6	13.3
	Travel diaries	13	29.0
	Other questionnaires	2	4.4
	Response rate		
	60-80%	11	24.4
	80-100%	11	24.4
	NR	10	22.2
	NA	13	29.0
Total		45	100.0

NR: Not reported. NA: Not applicable

* Seven studies in this category also reported estimates using other criteria (≥ 10 min/week)

We only found estimates for walking and cycling but not for any other form of active transportation, such as running or paddling. The prevalence of active transportation, combining walking and cycling modes, varied widely ($I^2 = 99.9\%$) and was available only for Brazilian studies. Most estimates for Brazilian settings (69%, $n=27$) came from the Surveillance System of Risk and Protective Factors for Non-Communicable Diseases by Telephone Interview (VIGITEL). The median prevalence of active transportation was 12%. The lowest prevalence was found in Palmas, north of Brazil (prevalence of 5.1%, 95% CI: 3.4 to 6.8), and the highest in Rio Claro, southeast of Brazil (prevalence of 58.9%, 95% CI: 54.5 to 63.3) (Figure 1).

Fewer studies reported mode-specific prevalence of active transportation ($n = 17$ for cycling and $n = 17$ for walking) and most data came from Argentinian studies ($n = 13$). Both cycling and walking prevalences were highly heterogeneous across studies ($I^2 \geq 99\%$). The median prevalence of cycling was 3.2%, ranging from 1.3%

(95% CI: 1.0 to 1.6) in Paraná, Argentina, to 16.0% (95% CI: 14.4 to 17.6) in Recife, northeast of Brazil (Figure 2). The median prevalence of walking was 15.5%, ranging from 8.9% (95% CI: 8.0 to 9.8) in Corrientes, Argentina, to 27.1% (95% CI: 24.7 to 29.5) in Bogotá, Colombia (Figure 3).

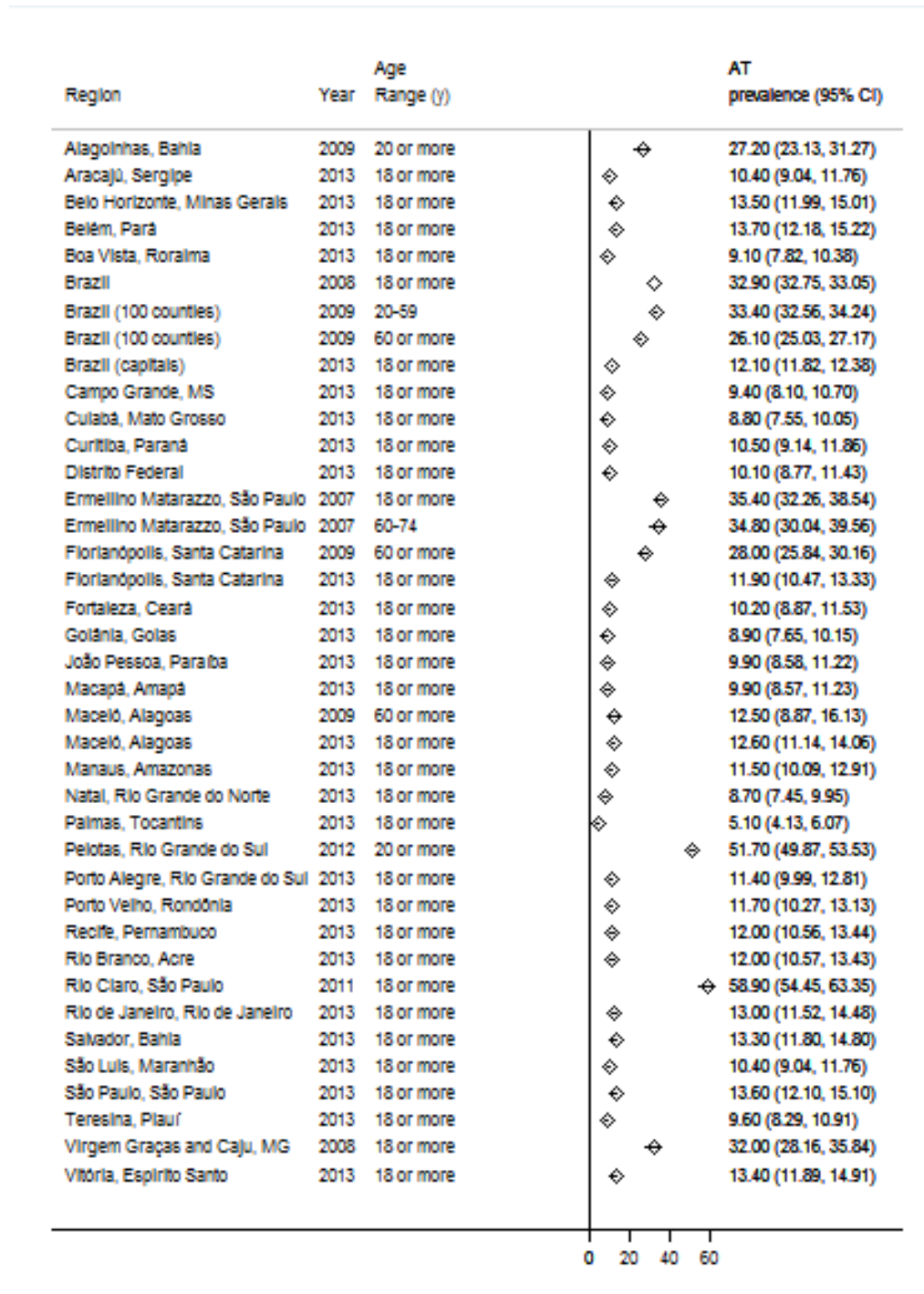


Figure 1: Prevalence of active transportation combining walking and cycling in the LAC region (only Brazilian settings). São Paulo, 2015.

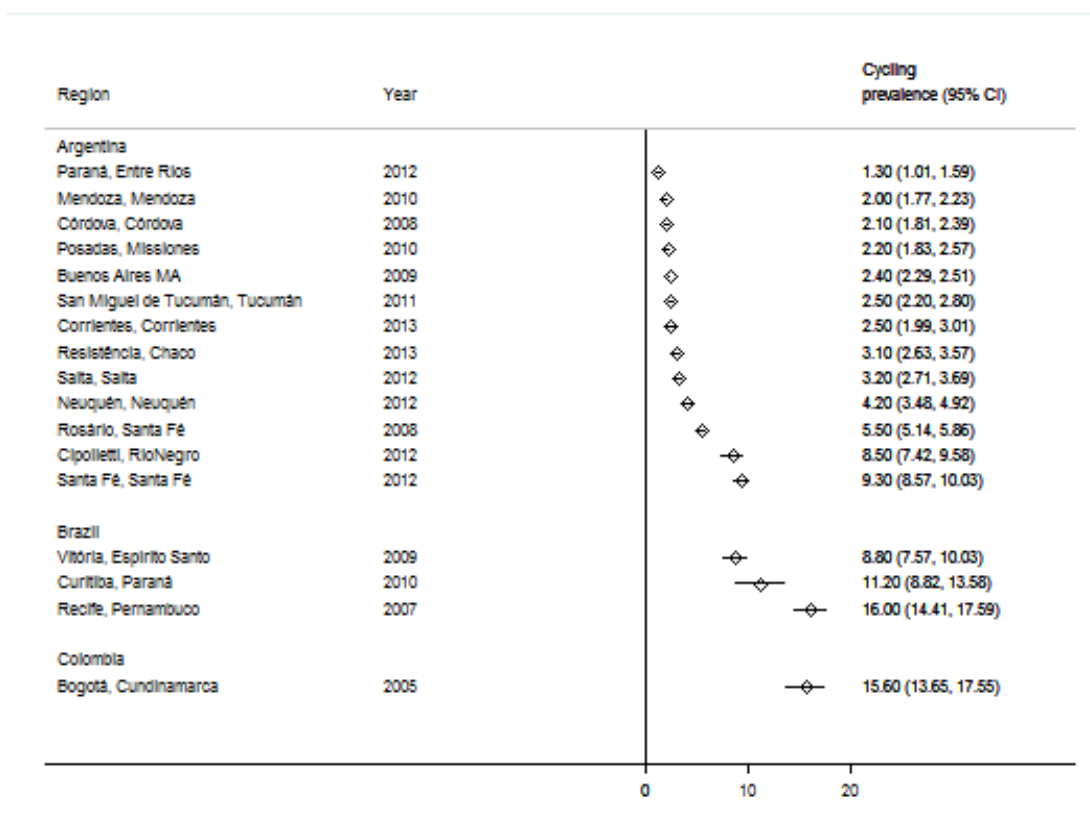


Figure 2: Prevalence of cycling in the LAC region. São Paulo, 2015.

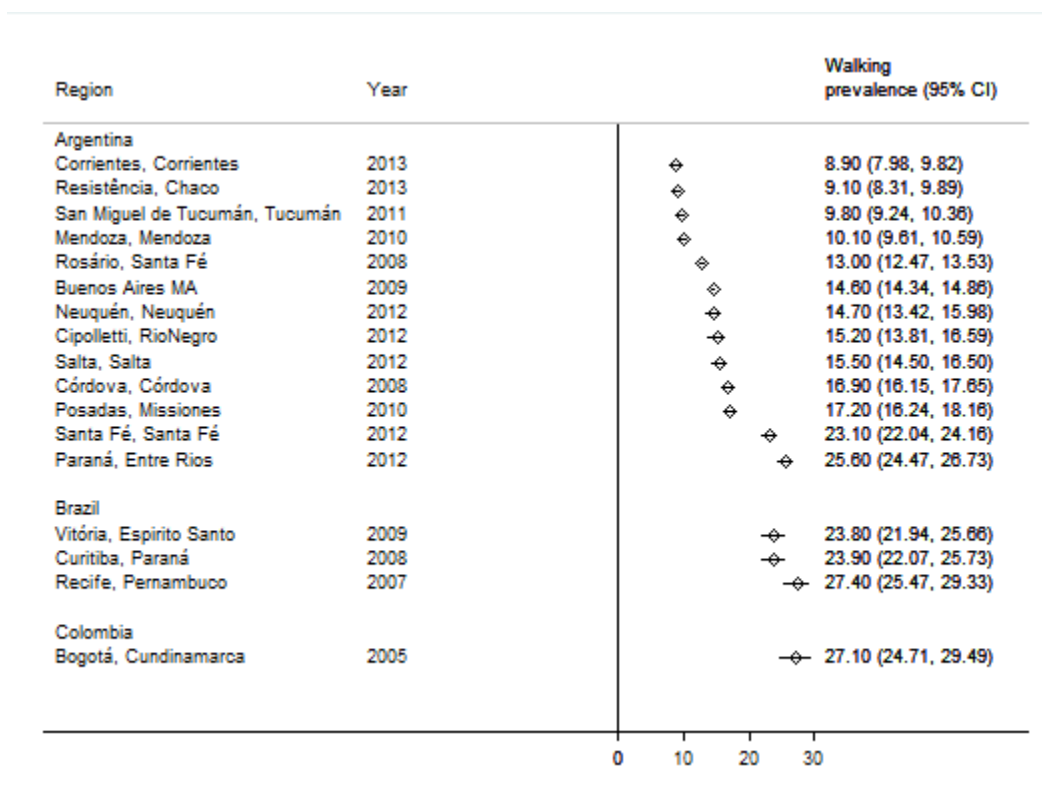


Figure 3: Prevalence of walking in the LAC region. São Paulo, 2015.

Pooled prevalences of active transportation were not estimated due to the high levels of heterogeneity across studies. In addition, direct comparison of active transportation prevalences from different settings is challenged by the multiple sources of heterogeneity among studies, including different cut-off points used to define active transportation (e.g. > 10 min/week vs. > 150 in/week).

In relative terms, gender gap varied broadly and in both directions for the estimates combining walking and cycling modes, with men-women prevalence ratio ranging from 0.7 in Porto Alegre and Cuiabá to 1.9 in Maceió and 2.7 in Virgem das Graças and Caju villages (Figure 4). Mode-specific prevalence of active transportation by sex was available only for Argentinian cities, showing consistently more walking among women and more cycling among men. All the estimates for Argentinian settings (n=13) came from the transport sector. Men-women prevalence ratio for cycling ranged from 1.4 (Cipolletti) to 8.8 (Posadas), respectively (Figure 5). Men-women prevalence ratio for walking ranged from 0.8 (Neuquén) to 0.5 (Salta and Córdoba), respectively (Figure 6). Age differences within studies were only available for walking and cycling separately and were systematically against the elderly population (Table S1).

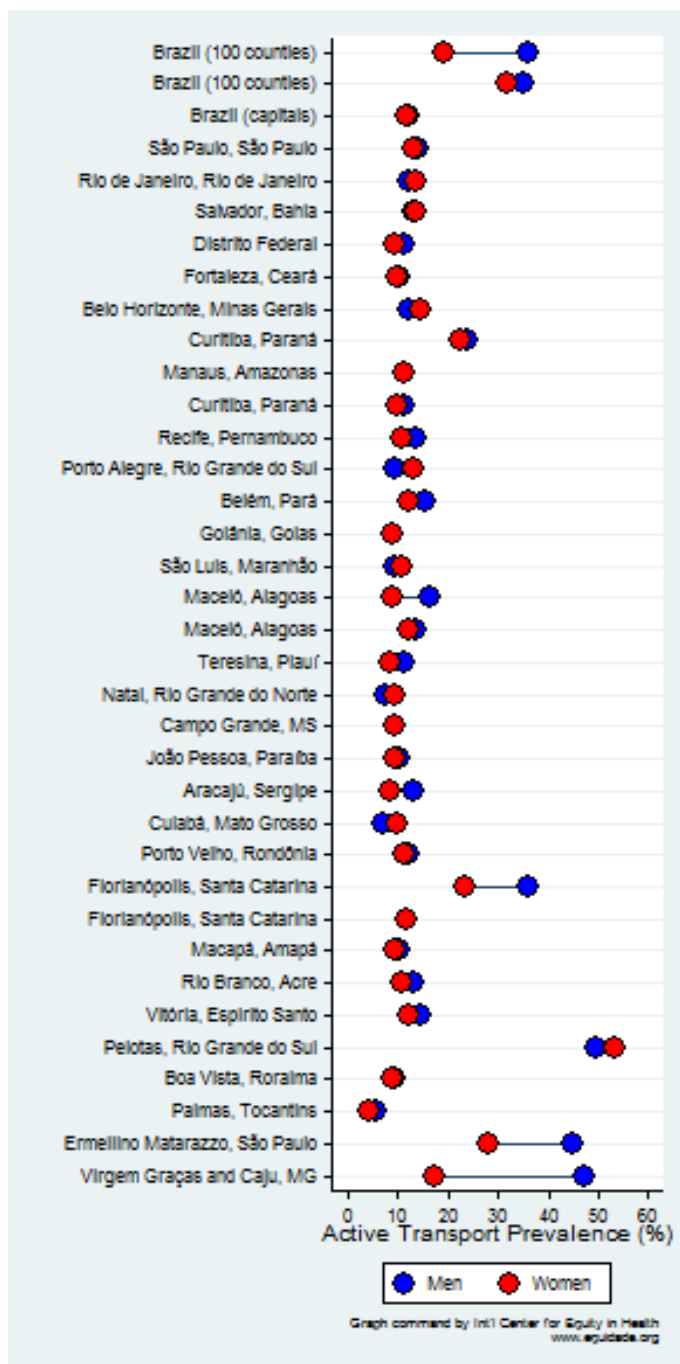


Figure 4: Men-women prevalence difference for active transportation combining walking and cycling in the LAC region (only Brazilian settings). São Paulo, 2015.

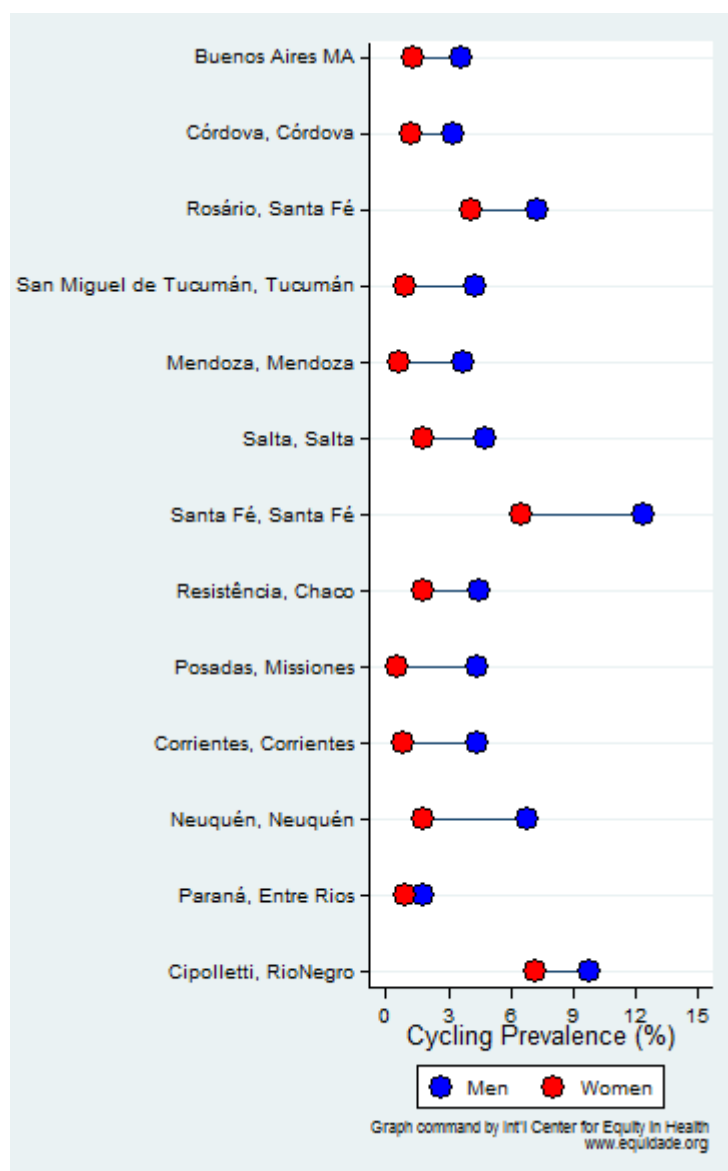


Figure 5: Men-women prevalence difference for cycling in the LAC region. São Paulo, 2015.

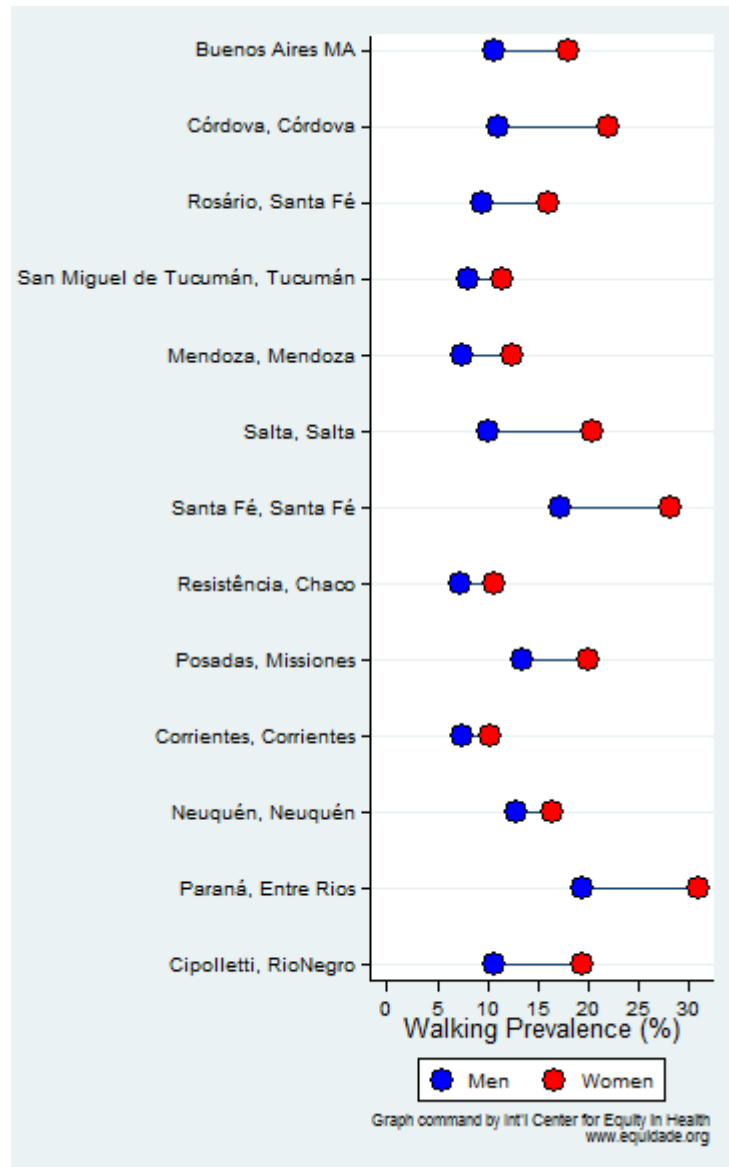


Figure 6: Men-women prevalence difference for walking in the LAC region. São Paulo, 2015.

Finally, quality appraisal showed that none of the included studies presented a definition of active transportation, 87.2% had active transportation prevalence as one of the study's main objective; 64.1% had not presented confidence intervals or standard errors for the prevalence estimates; around 30% had not reported or properly defined population, response rate and sampling strategy; 20% had not well described statistical analysis or reported total population (Table S2). Quality appraisal was not performed for five studies, which attended the eligibility criteria but did not have the full report published until July 2015.

Discussion

This study conducted an extensive review of the literature to estimate the prevalence of active transportation in the LAC region. Our findings show that estimates of active transportation and gender differences vary widely in the region for all forms of active transportation (walking, cycling and both combined). We also observed absence of information about active transportation for many LAC sites, with the available evidence concentrated in few countries. This is partly due to the remarkable examples of Brazil, for providing timely active transportation estimates through one of its health surveillance systems, and Argentina, for integrating the public health and transport sector agendas. We found substantial methodological variation across studies, mainly in the data collection instrument and the active transportation criteria used.

Overall, the median prevalence of active transportation in the LAC region is low (15.5% for walking; 3.2% for cycling; 12.0% combined) and inferior to the prevalence of active transportation in China and in most developed countries, even if considering only trips to work ^{16,17}. The LAC settings with higher prevalences are also far from the higher estimates present elsewhere (e.g., 16.0% for cycling in Recife, Brazil versus 63.6% in the Netherlands ¹⁷), except for the estimates combining walking and cycling. However, comparisons of information from other countries and settings are challenging because there is no standardization of instruments and indicators worldwide.

Gender differences in cycling and walking found in Argentinian cities might be explained by differences in trip characteristics, since women are more likely to make escort, multi-purpose, and/or encumbered trips, which are all less suited for cycling (and more suited for walking) than trips performed alone and unencumbered ¹⁸. The gender gap in cycling against women have been consistently observed in other places without a strong cycling culture ^{17,19}, and might be also related to infrastructural preferences and cultural norms, including greater risk aversion among women ¹⁸, out-group stereotypes, and experiences of marginalization ¹⁹. Higher car and motorcycle use by men, which is inversely correlated with active transportation in LAC settings ^{6,20}, also help to explain the gender gap in walking against men. As expected, age differences against the elderly were found both for walking and cycling, potentially reflecting the consequences of an environment less supportive for active transportation among vulnerable groups ^{21,22}.

Our study has several limitations. Despite our extensive search in 12 databases using the three most common languages in the region, we were unable to identify estimates from other LAC populations. Moreover, we had a very low response from government authorities (1 out of 42 contacts), however this single response provided estimates from 13 Argentinian cities, highlighting the potential for multisectoral work around the sustainable transport systems agenda. It was not possible to further explore the variability in the estimates through a multivariate meta-regression model due to scarcity of data and to redundancy of data sources, since most estimates for each active transportation outcome - walking, cycling or both combined - came from a single source. All studies failed to present an active transportation construct, which contributes to the difficulty in assessing the prevalence of people engaging in active transportation. Finally, quality of the retrieved studies varied substantially, which reinforces the need for better study design and transparency of reporting.

We recommend standardizing measures after the development of a construct for what constitutes active transportation, a challenge for public health and transportation researchers. Periodical large cross-sectional surveys, in both rural and urban populations, from more countries in the LAC region, would aid sustainable transportation planning in the upcoming SDG era, and help to understand how environmental changes influenced distribution of active transportation (natural experiment studies). Longitudinal studies examining determinants of active transportation in the region are also needed. Qualitative analyses investigating cultural norms, infrastructure preferences, and travel patterns would offer insight into equity issues and improvements in multisectoral collaboration.

Despite not being explicitly stated in any goal in the SDG finalized text ¹, walking, cycling and other forms of active transportation are indicators clearly integrating health and environmental sustainability ², cross-cutting a number of thematic areas, such as energy, city and sustainability. While several transport and urban planning interventions are taking place in the region with the potential to favour active transportation^{6,8-10}, we encourage LAC local authorities to build a comprehensive surveillance system upon existing sources of information, such as health systems and transport databases, in order to provide timely and detailed estimates of active transportation for policy planning and evaluation. This has the potential to leverage active transportation as a key component in the fight against the

NCD pandemics and climate change, two major health challenges for the LAC region in the 21st century.

Acknowledgments

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Supplementary Files

Table S1: Characteristics of LAC settings with estimates of active transportation between 2004 and 2014. São Paulo, 2015.

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Wome n (%)	Age Range (years)				
Secretaria de Transporte de la Nación ¹	Argentina	Buenos Aires Metropolitana Area	Urban	12985885	2009/2010	Cross-sectional	70321	Adults	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 15%, Men: 10.3%, Women: 19.3%; Walking elderly - Overall: 13.3%, Men: 11.5%, Women: 14.6%; Cycling adults - Overall: 2.7%, Men: 3.7%, Women: 1.7%; Cycling elderly - Overall: 1.6%, Men: 3%, Women: 0.4%	sex, age
								Elderly (57)					
PTUMA *	Argentina	Cipolletti, RioNegro	Urban	135499	2012/2013	Cross-sectional	2552	Adults (51) Elderly (56)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 16.1%, Men: 10.4%, Women: 21.5%; Walking elderly - Overall: 11.4%, Men: 12.2%, Women: 10.7%; Cycling adults - Overall: 9.6%, Men: 10.8%, Women: 8.5%; Cycling elderly - Overall: 3.4%, Men: 4.8%, Women: 2.2%	sex, age

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
PTUMA *	Argentina	Neuquén, Neuquén	Urban	312076	2012/2013	Cross-sectional	2954	Adults (52) Elderly (51)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 15.8%, Men: 13.9%, Women: 17.6%; Walking elderly - Overall: 7.7%, Men:6.4%, Women: 8.9%; Cycling adults - Overall: 4.3%, Men: 6.9%, Women: 2%; Cycling elderly - Overall: 3.3%, Men:6.3%, Women: 0.5%	sex, age
PTUMA ⁴	Argentina	Paraná, Entre Ríos	Urban	284695	2012/2013	Cross-sectional	5707	Adults (51) Elderly (61)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 27.2%, Men: 19.5%, Women: 34.5%; Walking elderly - Overall: 20.1%, Men:18.6%, Women: 21%; Cycling adults - Overall: 1.6%, Men: 2%, Women: 1.2%; Cycling elderly - Overall: 0.3%, Men:0.8%, Women: 0%	sex, age
PTUMA ⁵	Argentina	Posadas, Misiones	Urban	334059	2010	Cross-sectional	5940	Adults (55) Elderly (60)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 18.7%, Men: 14.5%, Women: 22%; Walking elderly - Overall: 10%, Men:8.1%, Women: 11.3%; Cycling adults - Overall: 2.5%, Men: 4.7%, Women: 0.7%; Cycling elderly -	sex, age

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
PTUMA*	Argentina	Resistencia, Chaco	Urban	362692	2013	Cross-sectional	5136	Adults (53) Elderly (57)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Overall: 0.9%, Men:2.3%, Women: 0% Walking adults - Overall: 9.9%, Men: 7.7%, Women: 11.8%; Walking elderly - Overall: 4.7%, Men:4.1%, Women: 5.1%; Cycling adults - Overall: 3.3%, Men: 4.7%, Women: 2.1%; Cycling elderly - Overall: 1.7%, Men:3.7%, Women: 0.2%	sex, age
PTUMA ⁶	Argentina	Rosario, Santa Fé	Urban	1305318	2008	Cross-sectional	15701	Adults (53) Elderly (58)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 13.6%, Men: 9.1%, Women: 17.6%; Walking elderly - Overall: 11.2%, Men:10.4%, Women: 11.7%; Cycling adults - Overall: 6.6%, Men: 8.4%, Women: 5%; Cycling elderly - Overall: 2.1%, Men:3.2%, Women: 1.3%	sex, age
PTUMA ⁷	Argentina	Salta, Salta	Urban	599011	2012	Cross-sectional	4987	Adults (51) Elderly (56)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 15.9%, Men: 10%, Women: 21.6%; Walking elderly - Overall: 13.2%, Men:10.5%, Women: 15.3%; Cycling adults -	sex, age

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
PTUMA ⁴	Argentina	Santa Fé, Santa Fé	Urban	515609	2012/2013	Cross-sectional	6057	Adults (50) Elderly (63)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Overall: 3.4%, Men: 4.7%, Women: 2.2%; Cycling elderly - Overall: 2.4%, Men: 5.1%, Women: 0.2%	sex, age
De Belaustégu i ⁸	Argentina	San Miguel de Tucumán, Tucumán	Urban	1069656	2011	Cross-sectional	10672	Adults (52) Elderly (57)	18 to 59; ≥ 60	Walked at least one trip (yes/no); Cycled at least one trip segment (yes/no)	Travel diary (day before the interview - only weekdays)	Walking adults - Overall: 10.6%, Men: 8.5%, Women: 12.6%; Walking elderly - Overall: 6.1%, Men: 5.4%, Women: 6.6%; Cycling adults - Overall: 2.7%, Men: 4.5%, Women: 1.1%; Cycling elderly - Overall: 1.6%, Men: 3.7%, Women: 0%	sex, age
IBGE ⁹	Brazil	Brazil	Urban and Rural	NR*	2008	Cross-sectional	391,868	NR*	≥ 18	Used to walk or cycle from home to work (yes or no)	PNAD questionnaire	32.9%\$	sex, age, region, years of schooling, per capita monthly income

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Madeira ¹⁰	Brazil	100 municipalities in 23 states	Urban	NR*	2009	Cross-sectional	12,116 (adults); 6,506 (elderly)	Adults (55) Elderly (59)	20 to 59; ≥ 60	Walking or Cycling for transport; Insufficiently active (10 to 149 min/week) or Active (≥150 min/week)	Long IPAQ (usual week)	Inactive adults - Overall: 32.6%; Insufficiently active adults - Overall: 34%; Active adults - Overall: 33.4% (32.6;34.7%), Men: 35.2%, Women: 32.0% Inactive elderly - Overall: 39.2%; Insufficiently active elderly - Overall: 34.7%; Active elderly - Overall: 26.1% (25.0%;27.2%), Men: 36.1%, Women: 19.1%	sex, age, skin colour, schooling, size of the municipality
Ministério da Saúde ¹¹	Brazil	26 capitals and Federal District	Urban	NR*	2013	Cross-sectional	52,929	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 12.1% (11.5%;12.7%), Men: 12.2% (11.2%;13.2%), Women: 11.9% (11.2%;12.7%)	sex, age, years of schooling
Hallal ¹²	Brazil	26 capitals and Federal District	NR*	NR*	2009	Cross-sectional	54,367	54	≥ 18	Walking or Cycling to/from work for at least 30 min/day	VIGITEL questionnaire	Overall: 14.4%, Men: 18.0%, Women: 11.5%	sex
Mielke ¹³ Hallal ¹² **	Brazil	26 capitals and Federal District	NR*	NR*	2008	Cross-sectional	54,353	54	≥ 18	Walking or cycling at least 30 minutes per day to/from work	VIGITEL questionnaire	Men: 10.3%, Women: 6.4%	sex, age, years of schooling
Mielke ¹³ Hallal ¹² **	Brazil	26 capitals and Federal District	NR*	NR*	2007	Cross-sectional	54,251	54	≥ 18	Walking or cycling at least 30 minutes per day to/from work	VIGITEL questionnaire	Men: 12.7%, Women: 9.1%	sex, age, years of schooling
Mielke ¹³ Hallal ¹² Florindo ¹⁴ **	Brazil	26 capitals and Federal District	NR*	NR*	2006	Cross-sectional	54,369	54	≥ 18	Walking or cycling at least 30 minutes per day to/from work	VIGITEL questionnaire	Men 13.5%, Women: 8.7%	sex, age, years of schooling

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Pitanga ¹⁵	Brazil	Alagoínhas, Bahia	NR*	138366	2009/2010	Cross-sectional	460	65	≥ 20	Walking or Cycling (≥150 min/week)	Long IPAQ (usual week)	Overall: 27.2% (19.6%;35.9%)	no
Ministério da Saúde ¹¹	Brazil	Aracajú, Sergipe	Urban	NR*	2013	Cross-sectional	1,942	61	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 10.4% (8.1%;12.6%), Men: 13% (8.7%;17.2%), Women: 8.3% (6.1%;10.4%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Belém, Pará	Urban	NR*	2013	Cross-sectional	1,955	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.7% (11.6%;15.8%), Men: 15.7% (12.1%;19.3%), Women: 12.0% (9.6%;14.3%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Belo Horizonte, Minas Gerais	Urban	NR*	2013	Cross-sectional	1,956	61	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.5% (11.5%;15.4%), Men: 12.3% (9.3%;15.3%), Women: 14.4% (11.9%;17%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Boa Vista, Roraima	Urban	NR*	2013	Cross-sectional	1,953	60	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 9.1% (6.8%;11.4%), Men: 9.5% (5.6%;13.3%), Women: 8.8% (6.2%;11.4%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Campo Grande, Mato Grosso do Sul	Urban	NR*	2013	Cross-sectional	1,949	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 9.4% (7.5%;11.2%), Men: 9.3% (6.5%;12.2%), Women: 9.4% (7%;11.8%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Cuiabá, Mato Grosso	Urban	NR*	2013	Cross-sectional	1,964	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 8.8% (7.1%;10.4%), Men: 7.3% (5%;9.5%), Women: 10.1% (7.8%;12.5%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Curitiba, Paraná	Urban	NR*	2013	Cross-sectional	1,951	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 10.5% (8.6%;12.3%), Men: 11.2% (8.2%;14.2%), Women: 9.8% (7.6%;12%)	sex, age, years of schooling
Reis ¹⁶	Brazil	Curitiba, Paraná	Urban	1746896	2010	Cross-sectional	697	52	18-65	Walking for transport (≥150 min/week)	Long IPAQ (usual week)	Walking in low-income and low-walkability areas: 21.1%; in high-income and low-walkability areas: 21.1%; in low-	income and walkability

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Kienteka ¹⁷	Brazil	Curitiba, Paraná	NR*	NR*	2010	Cross-sectional	677	53	18-65	Cycling (yes/no)	Long IPAQ (usual week)	Overall: 11.2% (9.0%;14.0%), Men: 19.1%, Women: 4.2%	sex, age, marital status, children, economic status, education, own bicycle, own car, quality of life, health perception, working status, physical activity, sex, age, education, marital status, car ownership, BMI, population density, neighbourhood income, public transport density, BRT tube station number, traffic lights number, entropy, residential area proportion, commercial area proportion, street density, block number, dead-end streets proportion, street intersection (≥ 4 or more segments) proportion, average slope, streets mean length, bike path density, distance to nearest bus stop, distance to
Hino ¹⁸	Brazil	Curitiba, Paraná	Urban	1851215	2008	Cross-sectional	1,206	62	35 to 54	Any walking for transport (≥ 10 min/week); Walking for transport at recommended levels (≥ 150 min/week); Cycling for transport (≥ 10 min/week)	Long IPAQ (usual week)	Walking (≥ 10 min/week) - Overall: 50.8%, Men: 45.7%, Women: 54.2%; Walking (≥ 150 min/week) - Overall: 23.1%, Men: 23.8%, Women: 22.7%; Cycling (≥ 10 min/week) - Overall: 9.6%, Men: 16.0%, Women: 5.2%	sex, age, marital status, children, economic status, education, own bicycle, own car, quality of life, health perception, working status, physical activity, sex, age, education, marital status, car ownership, BMI, population density, neighbourhood income, public transport density, BRT tube station number, traffic lights number, entropy, residential area proportion, commercial area proportion, street density, block number, dead-end streets proportion, street intersection (≥ 4 or more segments) proportion, average slope, streets mean length, bike path density, distance to nearest bus stop, distance to

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Reis ¹⁹	Brazil	Curitiba, Paraná	Urban	1851215	2008	Cross-sectional	2,097	63	≥ 18	Walking for transport at recommended levels (≥150 min/week) and Cycling for transport (yes or no)	Long IPAQ (usual week)	Walking (150 min/week): 23.9% (21.4%;26.4%); Cycling (yes/no): 9.6% (7.8%;11.4%)	no
Parra ²⁰	Brazil	Curitiba, Paraná	Urban	1797408	2008	Cross-sectional	2,097	63	≥ 18	Walking (any vs. none) or Cycling (any vs. none) for transport	Long IPAQ (usual week)	Walking: 55%; Cycling: 8%	Perceived environment: accessibility, quality, personal safety, traffic safety, destinations within 10-in walk
Ministério da Saúde ¹¹	Brazil	Florianópolis, Santa Catarina	Urban	NR*	2013	Cross-sectional	1,956	61	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 11.9% (9.9%;13.9%), Men: 11.8% (8.6%;15%), Women: 11.9% (9.5%;14.3%)	sex, age, years of schooling
Corseuil ^{21,22}	Brazil	Florianópolis, Santa Catarina	Urban	421,240 (44,460 ≥60 years)	2009/2010	Cross-sectional	1,656	64	≥ 60	Walking or Cycling: Inactive (<10 min), Low-active (10 to 149 min/week) or Active (≥150 min/week)	Long IPAQ, adapted and validated for the Brazilian elderly (usual week)	Inactive - Overall: 36.8%, Male: 31.1%, Female: 40.1% Low-active - Overall: 35.0%, Male: 32.8%, Female: 36.6% Active - Overall: 28.0% (25.8%;30.1%), Male: 36.1% (32.3%;40.0%), Female: 23.3% (20.8%;25.9%)	sex, age, schooling, monthly income per capita and several perceived environmental characteristics related to infrastructure, traffic, crime safety, weather, and social support

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Del Duca ²³	Brazil	Florianópolis, Santa Catarina	Urban	NR*	2009/2010	Cross-sectional	1,720	55	20-59	Walking or Cycling to/from work or school (yes or no)	VIGITEL questionnaire	Overall: 49.6% (45.2%;54.0%), Men: 43.1%, Women: 45.5%	sex, age, skin colour, current marital status, educational level, per capital family income
Ministério da Saúde ¹¹	Brazil	Fortaleza, Ceará	Urban	NR*	2013	Cross-sectional	1,977	60	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 10.2% (8.4%;12%), Men: 10.3% (7.4%;13.3%), Women: 10.0% (7.8%;12.3%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Goiânia, Goiás	Urban	NR*	2013	Cross-sectional	1,979	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 8.9% (7.2%;10.6%), Men: 8.9% (6.1%;11.7%), Women: 8.9% (6.9%;11%)	sex, age, years of schooling
Cunha ²⁴	Brazil	Goiânia, Goiás	Urban	NR*	2005	Cross-sectional	2,002	62	≥ 18	Walking or Cycling for transport (≥10 min/week)	VIGITEL questionnaire	Overall: 8.5%, Men: 8.4% (6.1%;11.4%), Women: 8.7% (6.7%;11.2%)	sex
Tribess ²⁵	Brazil	Jequié, Bahia	NR	NR*	2005	Cross-sectional	265	100	60-96	Mean active transport time	Long IPAQ (adapted for elderly)	Among those performing <150min/week: 80.5 min/week Among those performing ≥150min/week: 161.9 min/week	active transport level
Ministério da Saúde ¹¹	Brazil	João Pessoa, Paraíba	Urban	NR*	2013	Cross-sectional	1,953	64	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 9.9% (7.9%;11.8%), Men: 10.3% (7.1%;13.5%), Women: 9.5% (7.1%;12%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Macapá, Amapá	Urban	NR*	2013	Cross-sectional	1,949	61	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 12.6% (10.2%;15%), Men: 16.6% (12.4%;20.8%), Women: 8.8% (6.3%;11.4%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Maceió, Alagoas	Urban	NR*	2013	Cross-sectional	1,978	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 12.4% (10%;14.8%), Men: 13% (8.8%;17.2%), Women: 11.9% (9.1%;14.7%)	sex, age, years of schooling

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Mourão ²⁶	Brazil	Maceió, Alagoas	Urban	896965	2009	Cross-sectional	319	70	≥ 60	Walking or Cycling (≥150 min/week)	Long IPAQ (usual week)	Overall: 12.5%, Men: 13.4%, Women: 12.2%	sex, age, schooling, per capita monthly income, marital status, familiar composition, number of diseases, physical health, comparative physical health, mental health, comparative mental health
Ministério da Saúde ¹¹	Brazil	Manaus, Amazonas	Urban	NR*	2013	Cross-sectional	1,959	58	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 11.5% (9.5%;13.6%), Men: 11.5% (8.3%;14.8%), Women: 11.5% (9%;14.1%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Natal, Rio Grande do Norte	Urban	NR*	2013	Cross-sectional	1,956	64	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 8.7% (7%;10.4%), Men: 7.7% (5.1%;10.3%), Women: 9.5% (7.3%;11.8%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Palmas, Tocantins	Urban	NR*	2013	Cross-sectional	1,960	58	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 5.1% (3.4%;6.8%), Men: 5.8% (2.9%;8.6%), Women: 4.5% (2.6%;6.3%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Porto Alegre, Rio Grande do Sul	Urban	NR*	2013	Cross-sectional	1,949	64	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 11.4% (9.5%;13.3%), Men: 9.2% (6.5%;12%), Women: 13.2% (10.6%;15.8%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Porto Velho, Rondônia	Urban	NR*	2013	Cross-sectional	1,954	56	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 11.7% (9.4%;14.1%), Men: 12% (8.5%;15.4%), Women: 11.5% (8.5%;14.5%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Recife, Pernambuco	Urban	NR*	2013	Cross-sectional	1,951	65	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 12% (9.9%;14.1%), Men: 13.6% (9.8%;17.4%), Women: 10.8% (8.5%;13%)	sex, age, years of schooling

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Reis ¹⁹	Brazil	Recife, Pernambuco	Urban	1561659	2007	Cross-sectional	2046	56	≥ 18	Walking for transport at recommended levels (≥150 min/week) and Cycling for transport (yes or no)	Long IPAQ (usual week)	Walking (150 min/week): 27.4% (23.7%;31.1%); Cycling (yes/no): 16.0% (13.7%;18.4%)	no
Simões ²⁷	Brazil	Recife, Pernambuco	Urban	NR	2007	Cross-sectional	2038	63	≥ 16	Physical activity at transport - low (less than 485 metabolic-equivalent minutes per week) and moderate to high (485 or more metabolic-equivalent minutes per week).	Long IPAQ (usual week)	Overall: 28.7%, Men: 34.3%, Women: 24.1%	age, sex, skin colour, educational level, marital status, participation in the Academia da Cidade program (ACP), live near an ACP site, heard about or seen an ACP activity, self-reported health status
Ministério da Saúde ¹¹	Brazil	Rio Branco, Acre	Urban	NR*	2013	Cross-sectional	1,971	60	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 12% (9.4%;14.7%), Men: 13.2% (8.9%;17.4%), Women: 10.9% (7.7%;14.2%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Rio de Janeiro, Rio de Janeiro	Urban	NR*	2013	Cross-sectional	1,980	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13% (11.1%;14.9%), Men: 12.3% (9.3%;15.2%), Women: 13.7% (11.2%;16.1%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Salvador, Bahia	Urban	NR*	2013	Cross-sectional	1,960	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.3% (11.3%;15.3%), Men: 13.2% (10%;16.4%), Women: 13.4% (10.9%;15.8%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	São Luis, Maranhão	Urban	NR*	2013	Cross-sectional	1,942	63	≥ 18	Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 10.4% (8.2%;12.6%), Men: 9.6% (5.9%;13.3%), Women: 11.0% (8.5%;13.5%)	sex, age, years of schooling

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Ministério da Saúde ¹¹	Brazil	São Paulo, São Paulo	Urban	NR*	2013	Cross-sectional	1,999	61	≥ 18	Walking or Cycling to/from work or school (≥150 min/week) Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.6% (11.8%;15.4%), Men: 14% (11%;17%), Women: 13.2% (11%;15.4%) Overall: 9.6% (7.5%;11.7%), Men: 11.1% (7.2%;14.9%), Women: 8.4% (6.3%;10.5%) Overall: 13.4% (11.5%;15.4%), Men: 14.6% (11.4%;17.8%), Women: 12.4% (10%;14.9%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Teressina, Piauí	Urban	NR*	2013	Cross-sectional	1,954	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week) Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.6% (11.8%;15.4%), Men: 14% (11%;17%), Women: 13.2% (11%;15.4%) Overall: 9.6% (7.5%;11.7%), Men: 11.1% (7.2%;14.9%), Women: 8.4% (6.3%;10.5%) Overall: 13.4% (11.5%;15.4%), Men: 14.6% (11.4%;17.8%), Women: 12.4% (10%;14.9%)	sex, age, years of schooling
Ministério da Saúde ¹¹	Brazil	Vitória, Espírito Santo	Urban	NR*	2013	Cross-sectional	1,966	64	≥ 18	Walking or Cycling to/from work or school (≥150 min/week) Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 13.6% (11.8%;15.4%), Men: 14% (11%;17%), Women: 13.2% (11%;15.4%) Overall: 9.6% (7.5%;11.7%), Men: 11.1% (7.2%;14.9%), Women: 8.4% (6.3%;10.5%) Overall: 13.4% (11.5%;15.4%), Men: 14.6% (11.4%;17.8%), Women: 12.4% (10%;14.9%)	sex, age, years of schooling
Reis ¹⁹	Brazil	Vitória, Espírito Santo	Urban	320156	2009	Cross-sectional	2023	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week) Walking or Cycling to/from work or school (≥150 min/week)	Long IPAQ (usual week)	Walking (150 min/week): 23.8% (21.7%;25.9%); Cycling (yes/no): 8.8% (7.4%;10.1%)	no
Ministério da Saúde ¹¹	Brazil	Distrito Federal	Urban	NR*	2013	Cross-sectional	1,966	62	≥ 18	Walking or Cycling to/from work or school (≥150 min/week) Walking or Cycling to/from work or school (≥150 min/week)	VIGITEL questionnaire	Overall: 10.1% (8.3%;11.9%), Men: 11.1% (8.3%;13.9%), Women: 9.3% (7%;11.5%) Overall: 58.9%, Men: 50.0%, Women: 66.3%	sex, age, years of schooling
Teixeira ²⁸	Brazil	Rio Claro, São Paulo	Urban	187637	2011/2012	Cross-sectional	470	55	≥ 18	Walking (≥10 min/week)	Long IPAQ (usual week)	Overall: 58.9%, Men: 50.0%, Women: 66.3%	sex
Mendes ²⁹	Brazil	Pelotas, Rio Grande do Sul	Urban	~300000	2012	Cross-sectional	2,874	59	≥ 20	Walking or Cycling (≥10 min/week)	Long IPAQ (usual week)	Overall: 51.7% (48.7%;54.7%), Men: 49.6% (46.0%;53.1%), Women: 53.2% (49.7%;56.7%)	sex, skin colour, age, schooling, per capita income, city area, mild crimes, serious crimes, buying and sale of drugs, safety for physical activity during the day, safety for physical activity during the night)

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Martinez-Gomes ³⁰	Brazil	Pelotas, Rio Grande do Sul	Urban	NR*	2010	Longitudinal	3,469	51	18	Usual Walking or Cycling (yes / no)	Questionnaire	Men (88.3%), women (87.7%)	sex
Amorim ³¹	Brazil	Pelotas, Rio Grande do Sul	Urban	340000	2006	Cross-sectional	972	57	20-69	Walking or Cycling (≥ 150 min/week)	Long IPAQ (usual week)	Overall: 48.1% (44.9%;51.2%)	existence of sidewalks, existence of green areas, most streets plan, garbage accumulation, existence of sewage, difficulty for walking or cycling due to traffic, existence of cross-walks, existence of exhausted fumes, streetlights at night, safe to walk during the day, safe to walk at night, existence of crime, walk and sports events, weather limiting physical activity practice
Tribess ³²	Brazil	Uberaba, Minas Gerais	Urban	NR*	2010	Cross-sectional	622	65	60-97	Mean active transport time	Long IPAQ (adapted for elderly)	Men: 77.9 min/week (standard deviation (sd): 95.4), Women: 60.5 min/week (sd: 70.6)	sex
Bicalho ³³	Brazil	Virgem das Graças and Cajú, Jequitinhonha Valley, Minas Gerais	Rural	612	2008/2009	Cross-sectional	567	52	≥ 18	150 minutes of active transport per week	Long IPAQ, adapted to rural areas (usual week)	Overall: 32.0% (28.2%;35.8%); Male: 47.3%; Female: 17.5%	sex, age, schooling, health self-perception
Salvador ³⁴	Brazil	Ermellino Matarazzo, São Paulo, São Paulo	Urban	106731	2007	Cross-sectional	385	61	60-74	Walking: Inactive (<10 min), Insufficiently active (10 to	Long IPAQ (usual week)	Inactive - Overall: 15.6% (11.6%;20.6%), Men: 11.0% (6.4%;18.2%), Women: 18.7%	sex

First author	Country	Area	Urbanicity	Population size	Year of data collection	Type of study	Total sample (n)	Population Characteristics		Active Transport Criteria	Data collection tool / strategy (reference period)	Prevalence (CI 95%) or other active transportation estimate available	Subgroups
								Women (%)	Age Range (years)				
Sá ³⁵ Florindo ³⁶ **	Brazil	Ermellino Matarazzo, São Paulo, São Paulo	Urban	117000	2007/2008	Cross-sectional	890	59	≥ 18	149 min/week or Active (≥150 min/week)	Long IPAQ (usual week)	(13.5%;25.4%) Insufficiently active - Overall: 49.6% (42.0%;57.2%), Men: 44.0% (35.0%;53.4%), Women: 53.4% (43.9%;62.7%) Active - Overall: 34.8% (27.6%;42.8%), Men: 45.0% (34.4%;54.9%), Women: 27.9% (20.5%;36.7%) Inactive - Overall: 14.1%, Men: 16.1%, Women: 12.4% Insufficiently active - Overall: 48.1%, Men: 40.7%, Women: 54.1% Active - Overall: 37.8%, Men: 43.2%, Women: 33.5% 45.8 min/day (CI 95%: 42.5;49.1)	no
Ministerio de Salud ³⁷	Chile	Chile	Urban and Rural	12853027	2009/2010	Cross-sectional	5,434	59	≥25	Mean active transport time to work	GPAQ	45.8 min/day (CI 95%: 42.5;49.1)	sex, age, schooling, zone (urban or rural)
Sarmiento ³ Cervero ³⁹ **	Colombia	Bogotá, Cundinamarca	Urban	~7 million	2005	Cross-sectional	1,334	65	≥ 19	Walking for transport (≥150 min/week) and Cycling for transport (yes or no)	Long IPAQ (usual week)	Walking (150 min/week): 27.1%; Cycling (yes/no): 15.6%	no
Dugas ⁴⁰	Jamaica	Jamaica	Urban	NR*	2010/2011	Cross-sectional	517	50	25-45	Median active transport time to work	GPAQ	Men: 43.9 min/day (Interquartile Range (IQR): 100.0), Women: 30.0 min/day (IQR: 49.3)	no

Acre, Alagoas, Bahia, Ceará, Espírito Santo, Goiás, Maranhão, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondônia, Santa Catarina, São Paulo, Sergipe e Tocantins.

§ Prevalence estimated by the review's authors based on the weighted n from Table 4.2.

PTUMA: Proyecto de Transporte Urbano para Áreas Metropolitanas; IBGE: Instituto Brasileiro de Geografia e Estatística; NR: Not reported; NR*: Not reported in the study, but might be available somewhere else.

* Reports not published, estimates and information provided by the authors. ** Estimates presented are from the first author mentioned.

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Pitanga ¹⁵	no	yes	yes	no	yes	yes	no	yes	no	87.10%
Reis ¹⁶	no	yes	yes	yes	yes	no	yes	no	yes	66.40%
Kienteka ¹⁷	no	yes	no	no	yes	yes	no	yes	yes	66.40%
Hino ¹⁸	no	yes	yes	yes	NR*	yes	yes	yes	yes	NR*
Reis ¹⁹	no	yes	yes	yes	NR*	yes	yes	yes	no	yes (from 60.5% to 75.2%)
Parra ²⁰	no	yes	no	no	NR*	yes	yes	no	yes	NR*
Corseuil ^{21,22}	no	yes	yes	yes	yes	yes	yes	yes	yes	89.20%
Del Duca ²³	no	yes	no	no	no	yes	yes	yes	yes	85.30%
Cunha ²⁴	no	yes	NR*	NR*	NR*	yes	yes	yes	yes	73.10%
Tribess ²⁵	no	no	no	no	no	yes	no	no	no	no
Mourão ²⁶	no	yes	yes	yes	yes	yes	yes	no	yes	no
Simões ²⁷	no	yes	no	no	NR*	yes	yes	no	yes	64.50%
Teixeira ²⁸	no	yes	yes	yes	yes	yes	no	yes	yes	81.70%
Mendes ²⁹	no	yes	yes	yes	yes	yes	yes	yes	yes	86.40%
Martinez-Gomes ³⁰	no	yes	yes	yes	yes	yes	yes	no	yes	no
Amorim ³¹	no	yes	yes	yes	yes	yes	yes	yes	yes	90.70%
Tribess ³²	no	no	no	no	no	yes	no	no	no	no
Bicalho ³³	no	no	NR*	NR*	yes	yes	yes	yes	yes	92.60%
Salvador ³⁴	no	yes	yes	yes	yes	yes	no	yes	yes	no
Sá ³⁵	no	yes	yes	yes	NR*	yes	yes	yes	yes	yes (from 72.0% to 81.7%)
Florindo ³⁶	no	yes	yes	yes	NR*	no	yes	no	no	NR*
Ministerio de Salud ³⁷	no	yes	yes	yes	yes	yes	yes	no	no	85.00%
Sarmiento ³⁸	no	yes	yes	yes	yes	yes	yes	no	no	66.70%

Appendix S1: Methodological Quality Assessment Protocol

Active transportation construct defined

- Did the study present a construct for active transportation?

Active transportation set as an objective

- Did the study describe the prevalence of active transport as a main objective of the study?

Target population well defined/described

- Did the study describe the target population of the study?

“A sample provides the means to obtain information about a larger group, called the target population. The target population must be defined by shared characteristics assessed and measured accurately. Some of these characteristics include age, sex, language, ethnicity, income, and residency. Invariably, subsets of the target population are too expensive or difficult to enlist because, for example, they live in places that are inaccessible to surveys (eg, remote areas, native reserves, military bases, shelters) or they speak languages not accommodated by data collection. These excluded individuals need to be described and their number estimated as a proportion of the target population. The requirements to define the target population and to identify systematic exclusions are necessary to give research consumers a basis for judging the applicability of a study to their question.”

Boyle M. Guideline for evaluating prevalence studies. Evidence-Based Mental Health 1998;1(2):37-39

Sampling strategy well defined / described?

- Did the study well describe/define the sampling strategy performed?

“Probability sampling relies on the principle of randomization to ensure that each eligible respondent has a known chance of selection; it requires that members of the target population be identified through a sampling frame or listing of potential respondents. This listing must provide access to all members of the defined target population except for exclusions acknowledged by the study authors.”

Boyle M. Guideline for evaluating prevalence studies. Evidence-Based Mental Health 1998;1(2):37-39

Data Collection Well Described

- Did the study comprehensibly describe the protocol of the data collection in order to be a reliable method?

Boyle M. Guideline for evaluating prevalence studies. Evidence-Based Mental Health 1998;1(2):37-39

Statistical Analysis Well Defined/ Described

Did the study comprehensibly describe statistical analysis to estimate active transportation such as the use of weight in studies with complex sampling?

Overall Prevalence Active Transportation Estimative

Did the study include descriptive values in absolute numbers (n) AND/OR the prevalence (%) of active transportation?

Magliano ES, Guedes LG, Coutinho ESF, Bloch KV. Prevalence of arterial hypertension among Brazilian adolescents: systematic review and meta-analysis. *BMC Public Health* 2013;13:833

Analysis included 95% CI

- Did the study include confidence intervals (e.g. 95% CI) for the prevalence of active transportation?

“Confidence intervals quantify this closeness by telling us the chance, for example 95%, that the unobserved target population value will fall within a certain range of the observed sample value. Estimates in prevalence studies must be accompanied by confidence intervals or the information needed to calculate them.”

Boyle M. Guideline for evaluating prevalence studies. *Evidence-Based Mental Health* 1998;1(2):37-39

Subgroup Analysis

Did the study provide descriptive values in absolute numbers (n) **AND/OR** the prevalence (%) of active transportation in subgroups such as sex OR age OR race?

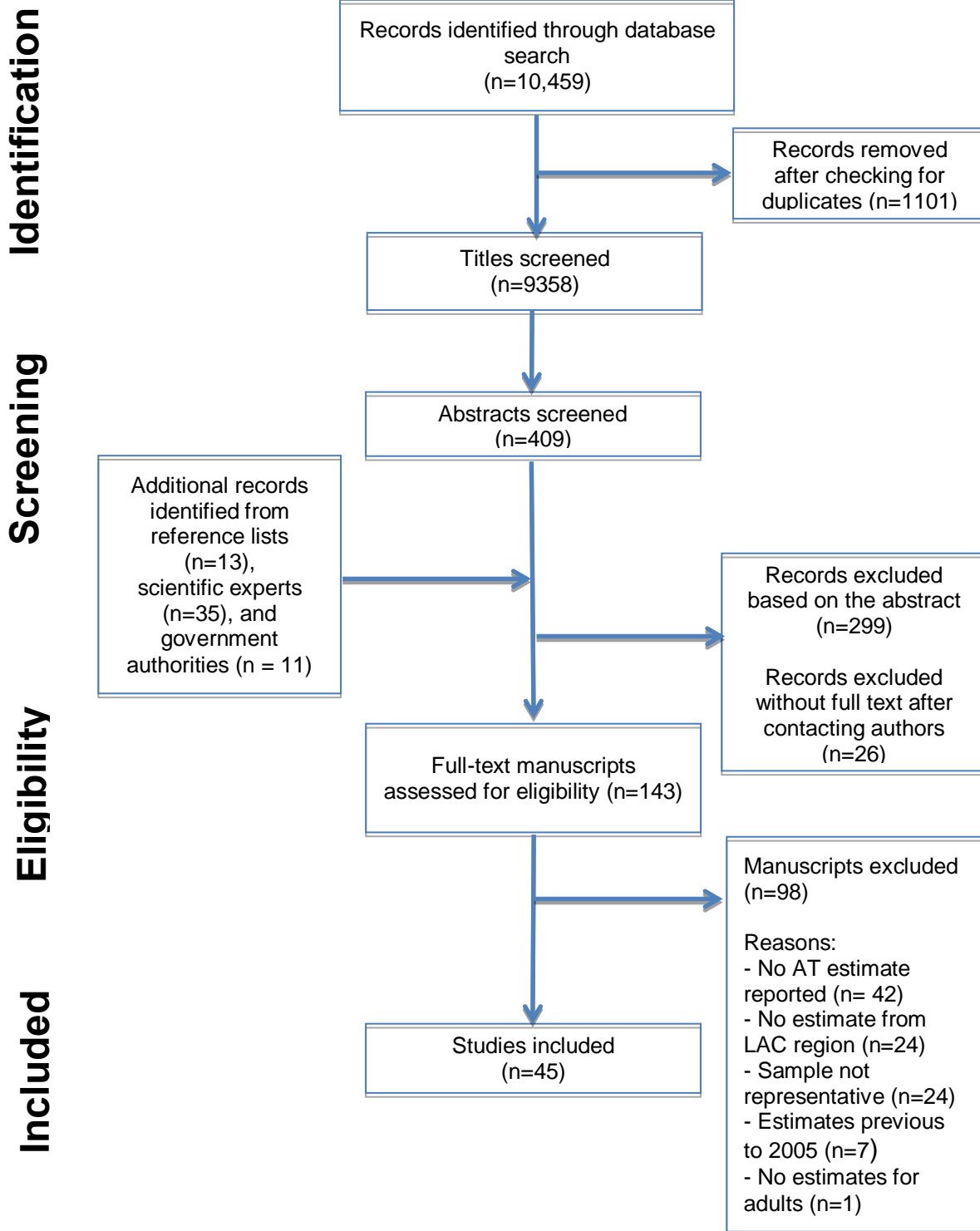
Sample matched target population (Response rate)

- Did the study provide the sample matched target population (response rate)? If yes, what was the final response rate?

“Non-response is the failure to enlist sampled individuals. If non-response is extensive and influenced by variables central to study objectives, it can lead to selection bias and estimates that deviate systematically from population values. When information is available on non-respondents, methods exist and should be used to evaluate selection bias. In the absence of such information, sample representativeness must be evaluated by comparing the socio-demographic characteristics.”

“The threshold for minimally acceptable response in prevalence studies should be set at 70% as long as the report shows that respondents and non-respondents, and/or the study sample and the target population, have similar important socio-demographic characteristics.”

Boyle M. Guideline for evaluating prevalence studies. *Evidence-Based Mental Health* 1998;1(2):37-39



Appendix S2: Flow Diagram.

Manuscrito 2: Diferenças socioeconômicas e regionais na prática do deslocamento ativo no Brasil.

Título em inglês: *Socioeconomic and regional differences of active commuting in Brazil.*

Título corrido: Deslocamento ativo para o trabalho no Brasil.

Artigo original aceito para publicação na Revista de Saúde Pública.

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Resumo

Introdução: O deslocamento ativo traz benefícios diretos à saúde do indivíduo e da população. Objetivo: Apresentar estimativas nacionais sobre o deslocamento a pé ou de bicicleta no trajeto casa-trabalho no Brasil e em suas principais regiões metropolitanas. Métodos: Utilizando dados do Suplemento sobre Saúde da Pesquisa Nacional por Amostra de Domicílios de 2008, estimamos a frequência e a distribuição de pessoas empregadas que se deslocam a pé ou de bicicleta no trajeto casa-trabalho, separadamente para homens e mulheres, segundo faixa etária, escolaridade, renda domiciliar per capita, residência em áreas urbanas ou rurais, regiões metropolitanas, e macrorregiões do país. Adicionalmente, estimamos a proporção desse indicador nos quintos da distribuição da renda domiciliar per capita em cada região metropolitana. Resultados: Um terço dos homens e mulheres desloca-se a pé ou de bicicleta de casa para o trabalho no Brasil. Em ambos os sexos, esta proporção diminui com o aumento da renda e da escolaridade e é maior entre os mais jovens, entre os que residem em áreas rurais, e na região Nordeste. Em todas as regiões metropolitanas, o quinto das pessoas de menor renda apresenta uma maior frequência de deslocamento ativo. Conclusão: O

deslocamento a pé ou de bicicleta para o trabalho no Brasil é mais frequente entre os mais pobres e entre pessoas que vivem em áreas e regiões economicamente menos desenvolvidas. A avaliação do deslocamento ativo no país traz informações importantes para a discussão de políticas públicas de mobilidade.

Descritores: Atividade motora. Caminhada. Transportes. Saúde Urbana. Planejamento das Cidades. Desigualdade em Saúde. Cidade Saudável. Regiões Metropolitanas.

Abstract

Introduction: Active commuting benefits directly the health of individuals and populations. Objective: To present national estimates about walking or cycling to work in Brazil and its main metropolitan areas. Methods: Using data from the Health Supplement of the National Research by Household Sample 2008, we estimated the frequency and distribution of workers commuting by walking or cycling in home-work trips, stratified by sex, age group, education, household per capita income, urban/rural areas, metropolitan region, and country region. We also estimated the proportion of this indicator according to quintiles of household per capita income in each metropolitan area. Results: One-third of men and women commute to work by walking or cycling. In both sexes, this proportion decreases as income and education attainment increase; and is higher among younger people, those living in rural areas, and in the Brazilian Northeast region. In all studied metropolitan areas, active commuting was more frequent among people in the lowest quintile of income. Conclusion: Walking or cycling to work in Brazil is more frequent among the poorest and those living in less economically developed areas. Assessing active transportation in Brazil provides important information for the discussion of national and local mobility policies.

Keywords: Motor Activity. Walking. Transport. Urban Health. Urban Planning. Health Inequality. Healthy City. Metropolitan Areas.

Introdução

A prática de formas ativas de deslocamento nas cidades, por meio da caminhada ou do uso da bicicleta, traz benefícios diretos à saúde do indivíduo,^{14,35,36}

além de benefícios à população, como a redução dos níveis de poluição atmosférica e de lesões no trânsito.^{8,28,35,36} Promover formas ativas de deslocamento poderia ter também um impacto econômico positivo, para além do impacto direto na saúde.¹⁷

A promoção do deslocamento ativo é favorecida com o conhecimento sobre a frequência e a distribuição desta prática no contexto onde se quer atuar. As formas mais comuns de deslocamento ativo, como os deslocamentos a pé e de bicicleta, estão relacionadas a uma variedade de fatores individuais (idade, sexo, renda, educação), ambientais (clima, topografia e ambiente construído) e características próprias de cada deslocamento, como a distância a ser percorrida, o motivo do deslocamento e seu custo.^{2,27} Em conjunto, esses fatores ajudam a entender porque a proporção de pessoas que se deslocam ativamente varia conforme países,^{3,13} regiões ou cidades,^{15,30} e estratos socioeconômicos da população.¹⁸ Estudos apontam ainda que o ambiente construído também determina a prática de deslocamento a pé ou de bicicleta,³³ além de promover maior segurança,²⁹ embora a magnitude desses efeitos varie conforme a renda e faixa etária.¹⁸

A promoção do deslocamento ativo no Brasil se ressentia da falta de estimativas nacionais sobre a frequência e distribuição dessa prática, já que grande parte da literatura no país limita-se a estudos de abrangência local, principalmente nas regiões Sul e Sudeste do país.³⁴ Como implicação prática da divulgação destes dados, poder-se-iam planejar políticas e programas de promoção que levassem em conta características regionais da prática de deslocamento ativo, bem como estratégias nacionais para a ampliação desta prática em determinados subgrupos populacionais. O objetivo desse estudo foi prover estimativas nacionais sobre a frequência e distribuição do deslocamento a pé ou de bicicleta no Brasil no trajeto casa-trabalho.

Métodos

Fonte de dados

Este estudo utilizou dados do Suplemento sobre Saúde da Pesquisa Nacional por Amostra de Domicílios (PNAD) realizada pelo Instituto Brasileiro de Geografia e Estatísticas (IBGE) em 2008. A PNAD é a única pesquisa amostral de representatividade nacional com informações sobre deslocamento casa-trabalho e cujos dados podem ser acessados publicamente¹⁶. O seu suplemento sobre saúde de 2008 investigou diversos temas relacionados à saúde da população, dentre os

quais a prática de atividade física em diferentes domínios (atividade física de lazer, deslocamento para o trabalho, atividade laboral e realização de limpeza pesada no ambiente doméstico).

Plano amostral e coleta de dados

A amostra da PNAD 2008 foi obtida por procedimentos de amostragem probabilística complexa, por conglomerados em dois ou três estágios: município, setor censitário e domicílio. Tanto no primeiro quanto no segundo estágio, as unidades (município e setor censitário, respectivamente) foram selecionadas com reposição e com probabilidade proporcional à população do Censo Demográfico de 2000. No terceiro estágio, as unidades (domicílios) foram selecionadas com equiprobabilidade, de acordo com o número de domicílios para cada setor censitário. Todos os moradores do domicílio foram entrevistados ou tiveram suas informações obtidas por meio de outro membro da família. Com o emprego de fatores de ponderação apropriados, os dados da PNAD 2008 permitem estimativas representativas para o total da população brasileira, para a população urbana ou rural e para a população das macrorregiões, Unidades Federativas e regiões metropolitanas do país.

O questionário da PNAD 2008 incluiu questões sobre se os indivíduos costumavam ir a pé ou de bicicleta para o trabalho e, em caso afirmativo, o tempo gasto neste deslocamento. Essas questões foram respondidas apenas por indivíduos com idade igual ou superior a 14 anos e que não tivessem problemas de saúde que acarretassem dificuldades para andar cerca de 100 metros ou para fazer compras de alimentos, roupas e medicamentos sem ajuda.

Variáveis do estudo e análise de dados

Com base nas respostas a essas questões, foi construído um indicador para a prática do deslocamento ativo para o trabalho, correspondente à proporção de pessoas empregadas com 14 anos ou mais de idade que se deslocam a pé ou de bicicleta da casa para o trabalho, independentemente do tempo de deslocamento. Este indicador e seu correspondente intervalo de confiança de 95% foram estimados separadamente para homens e mulheres, tendo em vista diferenças anteriormente observadas da prática de deslocamento a pé ou de bicicleta entre os sexos na população brasileira.^{10,19}

As estimativas foram calculadas para estratos da população masculina e feminina que levam em conta faixa etária (15-24, 25-34, 35-44, 45-54, 55-64 e ≥ 65 anos completos), escolaridade (1-3, 4-7, 8-10, 11-14 e ≥ 15 anos de estudo), macrorregião de residência (Norte, Nordeste, Sul, Sudeste e Centro-Oeste), residência em região metropolitana (sim/não), regiões metropolitanas (Belém, Belo Horizonte, Curitiba, Distrito Federal, Fortaleza, Porto Alegre, Recife, Rio de Janeiro, Salvador e São Paulo), residência em áreas urbanas ou rurais, e renda domiciliar per capita (em intervalos decilares).

Adicionalmente, para a população masculina e feminina residente em cada uma das nove maiores regiões metropolitanas do país ou no Distrito Federal, estimamos a distribuição do deslocamento a pé ou de bicicleta segundo quintos da distribuição da renda familiar per capita calculada em cada aglomerado urbano. A frequência e distribuição das pessoas que se deslocam a pé ou de bicicleta para o trabalho com trajeto de ida e volta igual ou superior a trinta minutos – indicador comumente descrito na literatura^{5,10,19,22,32} – estão disponíveis no Material Suplementar.

Foram consideradas estatisticamente significantes as diferenças observadas entre grupos quando a estimativa pontual de um deles não estivesse contida na estimativa intervalar do outro, no caso, o intervalo de confiança de 95%.²⁰ O estudo seguiu os princípios da Declaração de Helsinki e foi aprovado pelo Comitê de Ética em Pesquisa da Faculdade de Saúde Pública da USP. Os procedimentos analíticos deste estudo foram executados no aplicativo R (Versão 2.15.3) utilizando-se o pacote ‘*survey*’ de modo a considerar o desenho e os pesos amostrais da PNAD 2008.

Resultados

A Tabela 1 apresenta estimativas de deslocamento ativo entre homens e mulheres segundo situação do domicílio, região metropolitana e macrorregião. Cerca de um terço da população masculina e da população feminina do Brasil desloca-se a pé ou de bicicleta para o trabalho. Nas regiões metropolitanas do país, essa proporção cai para pouco menos de 20% tanto em homens como em mulheres. Em ambos os sexos, as maiores proporções de deslocamento ativo foram encontradas entre aqueles residentes na zona rural enquanto as macrorregiões Nordeste e Sudeste foram aquelas que apresentaram as menores proporções de deslocamento

ativo. Em geral, a proporção de homens e mulheres que se deslocam ativamente para o trabalho é similar em todos os subgrupos analisados, com exceção daqueles que residem na zona rural e na macrorregião Norte. Nos dois casos, a proporção de homens é consideravelmente maior que a das mulheres.

Tabela 1. Proporção da população com 14 anos ou mais de idade que se desloca a pé ou de bicicleta para o trabalho segundo variáveis sociodemográficas. Brasil, 2008.

Variáveis	Homens				Mulheres			
	n (milhares)	%	IC (95%)		n (milhares)	%	IC (95%)	
Situação do Domicílio								
Rural	5.271	53,4	50,8	55,9	2.666	45,2	42,7	47,9
Urbana	12.055	29,5	29,0	30,1	9.692	31,0	30,4	31,7
Região Metropolitana								
Não	14.556	40,4	39,4	41,3	10.178	40,0	39,1	40,9
Sim	2.769	18,9	18,3	19,6	2.181	18,7	18,0	19,4
Macrorregião								
Centro Oeste	774	24,2	22,7	25,7	615	26,5	25,0	28,1
Nordeste	6.365	46,9	45,2	48,5	3.859	40,5	39,0	42,0
Norte	1.644	39,5	35,9	43,2	922	35,8	33,4	38,3
Sudeste	5.669	26,7	26,0	27,5	4.505	28,1	27,1	29,2
Sul	2.648	33,8	32,0	35,6	2.291	37,2	35,5	38,9
TOTAL	17.325,1	34,2	33,5	34,9	12.358,5	33,3	32,6	34,0

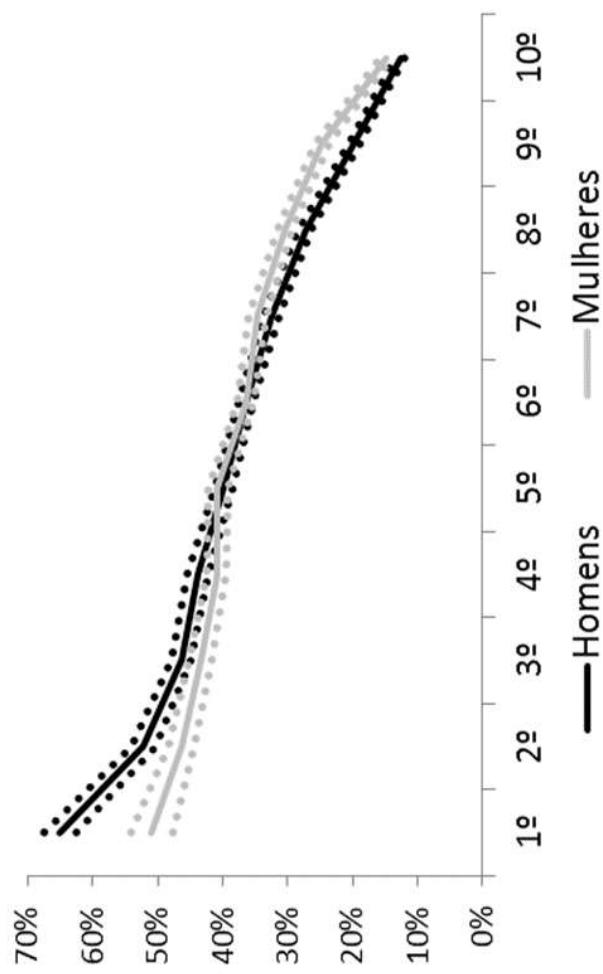
As figuras 1 a 3 apresentam a frequência da prática do deslocamento ativo para o trabalho entre homens e mulheres segundo decis de renda, escolaridade e faixa etária, respectivamente.

A proporção de pessoas que se deslocam a pé ou de bicicleta diminui com o aumento da renda e escolaridade em ambos os sexos (Figuras 1 e 2). Contudo, essa redução é mais pronunciada entre os homens, o que faz com que a prática do deslocamento ativo se torne mais frequente entre mulheres do que entre homens nos estratos de maior renda e escolaridade. Observa-se, também, uma maior frequência de deslocamento a pé ou de bicicleta para o trabalho entre os mais

jovens (14 a 19 anos de idade) e diferenças entre homens e mulheres apenas entre aqueles com idade igual ou superior a 55 anos, favorecendo os homens (Figura 3).

A figura 4 apresenta, para homens e mulheres, a proporção de pessoas que se deslocam a pé ou de bicicleta para o trabalho segundo quintos de renda domiciliar per capita nas dez regiões metropolitanas brasileiras estudadas. Em todos os aglomerados urbanos, o quinto das pessoas de menor renda apresenta uma maior frequência de deslocamento ativo. Entretanto, as diferenças entre estratos com rendas extremas variam consideravelmente entre homens e mulheres e nas várias regiões metropolitanas, sendo as maiores diferenças observadas na população masculina residente nas regiões metropolitanas do Norte e Nordeste do país. A menor frequência de homens e mulheres que se deslocam a pé ou de bicicleta foi encontrada no Distrito Federal, tanto entre os mais ricos (Q5) quanto entre os mais pobres (Q1). O Distrito Federal também apresenta a menor diferença entre pobres e ricos dentre todas as regiões metropolitanas (Figura 4).

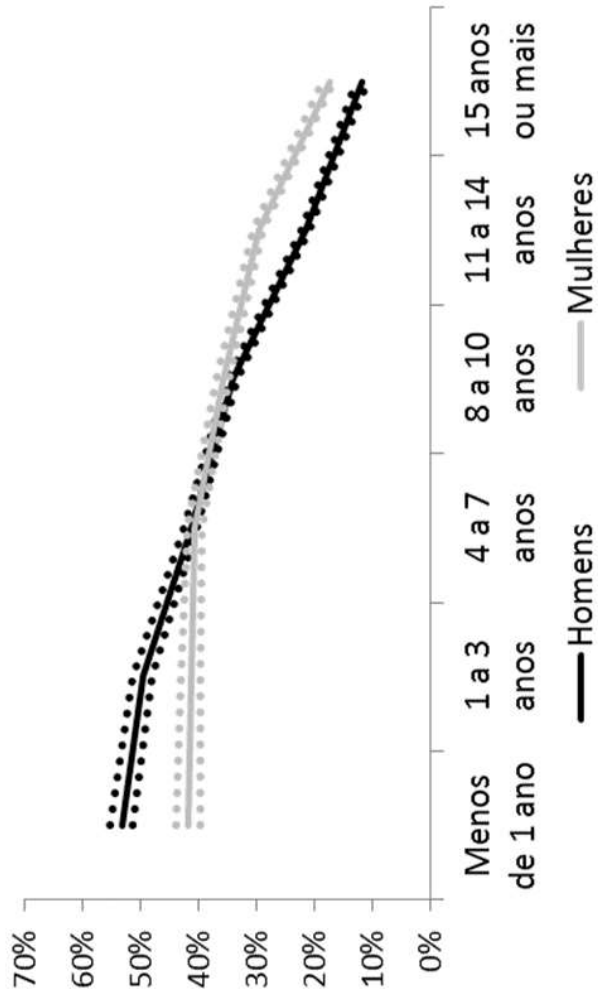
Figura 1 – Frequência (%) de deslocamento para o trabalho a pé ou de bicicleta entre homens e mulheres segundo decis de renda¹ – Brasil, 2008.



Fonte: PNAD (IBGE)

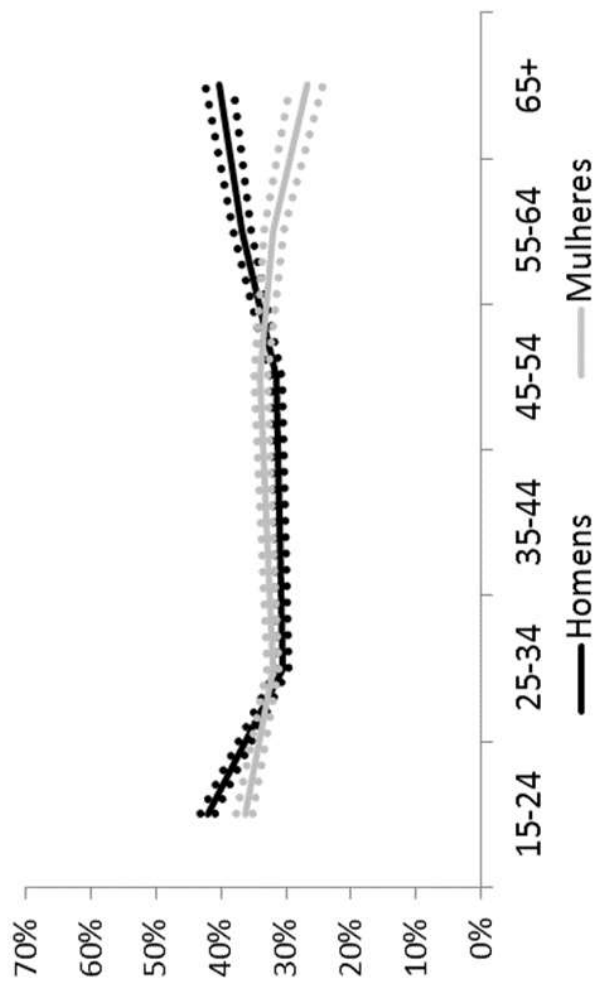
Nota: ¹ Quintis de renda domiciliar per capita

Figura 2 – Frequência (%) de deslocamento para o trabalho a pé ou de bicicleta entre homens e mulheres segundo anos de estudo – Brasil, 2008.



Fonte: PNAD (IBGE)

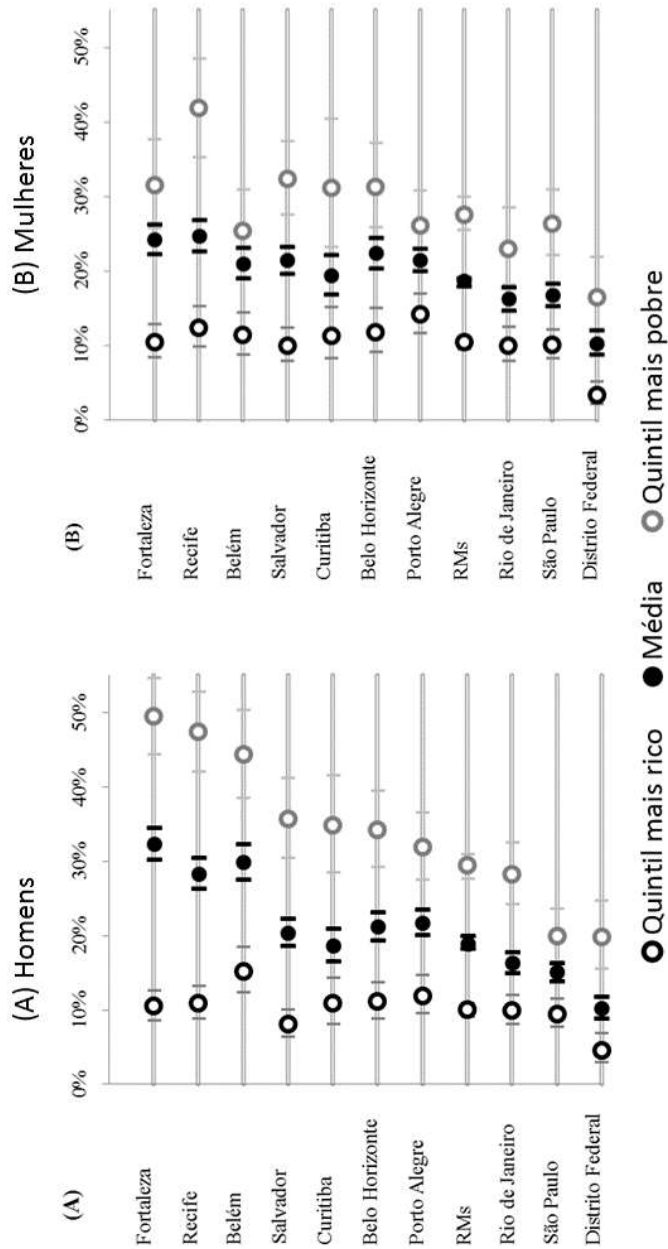
Figura 3 - Deslocamento casa-trabalho a pé ou de bicicleta entre homens e mulheres segundo faixa etária – Brasil, 2008.



Fonte: PNAD (IBGE)

Nota: ¹ Quintis de renda domiciliar per capita

Figura 4 - Proporção de pessoas ocupadas que se deslocam a pé ou de bicicleta para o trabalho, segundo sexo e quintil de renda¹ – regiões metropolitanas brasileiras, 2008.



Fonte: PNAD (IBGE)

Notas:¹ Quintis de renda domiciliar per capita

Discussão

Foram encontradas marcadas diferenças socioeconômicas e regionais na prática de deslocamento ativo para o trabalho no Brasil, sendo a prática mais frequente, em ambos os sexos, entre os mais pobres e nas áreas com menor renda (zona rural; regiões não metropolitanas; macro regiões Norte e Nordeste; e regiões metropolitanas de Belém, Recife e Fortaleza). Esta relação inversa entre renda e deslocamento ativo também foi encontrada em outros estudos brasileiros^{10,11,30,32} e internacionais,² embora essa relação seja menos acentuada em países desenvolvidos.

Sendo um dos raros exemplos de desigualdades em saúde favoráveis aos mais pobres, a associação inversa entre prática de deslocamentos para o trabalho a pé ou de bicicleta e nível de renda reflete a restrição orçamentária das famílias mais pobres, sua segregação espacial e a precariedade do transporte público, e não necessariamente uma prática guiada pelos benefícios socioambientais e de saúde.^{11,25,31,37} A segregação espacial existente nas metrópoles brasileiras aliada a um sistema público de transporte ineficiente contribui com o aumento do deslocamento a pé ou de bicicleta, pois aumenta o tempo necessário para alcançar o sistema de transporte público e realizar transferências dentro dele.³⁷

Ao compararmos as dez regiões metropolitanas do país, identificamos pouca variação na frequência de deslocamento ativo entre os 20% mais ricos da população (com exceção do Distrito Federal). Por outro lado, entre os 20% mais pobres, observa-se uma maior frequência de deslocamento a pé ou de bicicleta nas regiões metropolitanas mais pobres e onde os sistemas de transporte apresentaram significativas pioras nos últimos anos, como Belém, Fortaleza e Recife.²⁶ Supondo a manutenção da atual estrutura espacial das cidades e dos sistemas de transporte, concomitante à melhora nas condições de renda e de poder de compra dos mais pobres no Brasil,²³ espera-se que os níveis de deslocamento a pé ou de bicicleta da população diminuam e se aproximem do nível homogeneamente baixo observado entre os mais ricos. Quanto ao Distrito Federal, na comparação com outras regiões metropolitanas, a menor proporção de deslocamento ativo tanto entre os mais ricos quanto entre os mais pobres em ambos os sexos parece ser reflexo da singularidade do planejamento urbano de Brasília – pautado no deslocamento por automóveis – e das longas distâncias que boa parte da população precisa percorrer entre as cidades-satélite e a capital, onde se concentram a maior parte dos empregos.²¹

Outra razão para crer-se na piora do indicador é a crescente presença de veículos nos domicílios.¹³² O aumento da renda observado nos últimos anos no país foi acompanhado de um aumento mais do que proporcional nos gastos com transporte, sobretudo entre os estratos menores de renda, em virtude do aumento nas taxas de aquisição de motocicletas e automóveis.¹ Ademais, apesar do crescimento substancial das taxas de motorização, ocorrido em capitais do Norte e Nordeste nos últimos dez anos, estas taxas ainda correspondem à metade daquelas observadas nas demais regiões metropolitanas brasileiras, com potencial de contínua elevação na próxima década.²⁶ Embora ainda não haja séries temporais nacionalmente representativas para o deslocamento ativo, é possível observar uma redução de sua prática nos últimos anos na população das capitais brasileiras.²²

Situação semelhante pode ocorrer na zona rural, sobretudo por conta da aquisição de motocicletas.^{20,23} Apesar da falta de informações detalhadas sobre a evolução da motorização dos deslocamentos na zona rural, observa-se que o maior crescimento da frota entre 2001 e 2012 se deu em municípios de até 20 mil habitantes (aumento de aproximadamente 400%), bastante acima do crescimento observado para os automóveis (143%).²⁵ No entanto, políticas públicas de mobilidade focadas na melhora e integração de diversos modais podem aumentar as taxas de deslocamento a pé ou de bicicleta, como já mostrado em outros contextos.^{5,9,12}

Aproximadamente um terço dos homens e mulheres se desloca ativamente para o trabalho no Brasil, proporção similar àquela encontrada em países europeus, como França (34,9%) e Holanda (37,9%), e inferior àquela encontrada na China (46,1%)¹³. O deslocamento ativo para o trabalho é mais frequente entre os homens em apenas algumas regiões metropolitanas (Recife, Belém e Fortaleza), na zona rural e entre os mais velhos (a partir dos 55 anos); sendo superior entre as mulheres nos estratos superiores de renda e escolaridade. É possível que as diferenças segundo sexo nos estratos mais altos de renda sejam explicadas por questões relacionadas à adoção de hábitos mais saudáveis e diferenças em termos de posse de veículo dentro do domicílio.⁷ Tais diferenças segundo sexo podem, também, contribuir para explicar o menor ritmo de aumento da taxa de obesidade entre as mulheres com maior escolaridade em comparação com os homens igualmente escolarizados, algo não observado entre os mais pobres.²⁴ Estudos mais detalhados sobre as relações entre vida doméstica, mundo do trabalho e papéis de gênero na

determinação da prática de deslocamento a pé ou de bicicleta no Brasil são necessários para confirmar tais hipóteses.

Este estudo apresenta algumas limitações. Entre elas, a impossibilidade de inclusão do deslocamento a pé ou de bicicleta por outros motivos, que não somente para o trabalho. No entanto, deslocamentos para o trabalho respondem por aproximadamente 45% de todos os deslocamentos realizados em regiões metropolitanas brasileiras.⁴ Além disso, os dados da PNAD não permitem avaliar deslocamentos a pé e de bicicleta separadamente ou explorar, as distâncias percorridas nestes deslocamentos tampouco como sua prática varia em diferentes regiões dentro de uma mesma cidade. Essas questões seriam de extrema relevância para estudos sobre o impacto de políticas públicas que buscam ampliar a participação dos meios de transporte não motorizados no deslocamento diário da população.

Por outro lado, este é um dos primeiros estudos que utilizou as novas ponderações das PNAD, o que nos permitiu estimar o deslocamento a pé ou de bicicleta para toda a população brasileira, além de descrever as diferenças da prática segundo variáveis socioeconômicas e espaciais. Destacam-se, em particular, as diferenças observadas no deslocamento ativo entre homens e mulheres nos diferentes níveis de renda/escolaridade e entre as áreas urbanas e rurais, e entre algumas das metrópoles brasileiras.

As recentes mudanças socioeconômicas ocorridas no Brasil impactaram o acesso da população a bens de consumo, entre eles automóveis e motocicletas. No entanto, o acesso a serviços públicos de qualidade (por exemplo, transporte público) não ocorreu na mesma proporção e de forma equitativa entre as diversas regiões brasileiras. A avaliação do deslocamento ativo e suas diferenças regionais e socioeconômicas contribuem com a área de estudo de desigualdades em saúde existentes no país. Ademais, nosso estudo traz elementos para a atual discussão de políticas públicas de mobilidade focadas na integração de modais e com incentivos para o deslocamento a pé ou de bicicleta, considerando as importantes diferenças socioeconômicas e as particularidades regionais e urbanísticas das cidades brasileiras.

⁴ Corporación Andina de Fomento. Desarrollo urbano y movilidad en América Latina. Cidade do Panamá: CAF - Observatório de la Movilidad Urbana; 2011.

A prática de deslocamento a pé ou de bicicleta no trajeto casa-trabalho apresenta marcadas diferenças regionais e socioeconômicas no Brasil. Políticas nacionais e regionais em andamento, como a Política Nacional de Mobilidade Urbana ⁴ e a revisão dos planos diretores municipais, poderiam utilizar estes achados, e, assim, contribuir com a ampliação da proporção da população que se desloca a pé ou de bicicleta. Ademais, tais políticas devem garantir a manutenção dos níveis de deslocamento ativo entre os mais pobres, à medida que ocorre a desejada melhoria das condições de vida dos brasileiros menos favorecidos.

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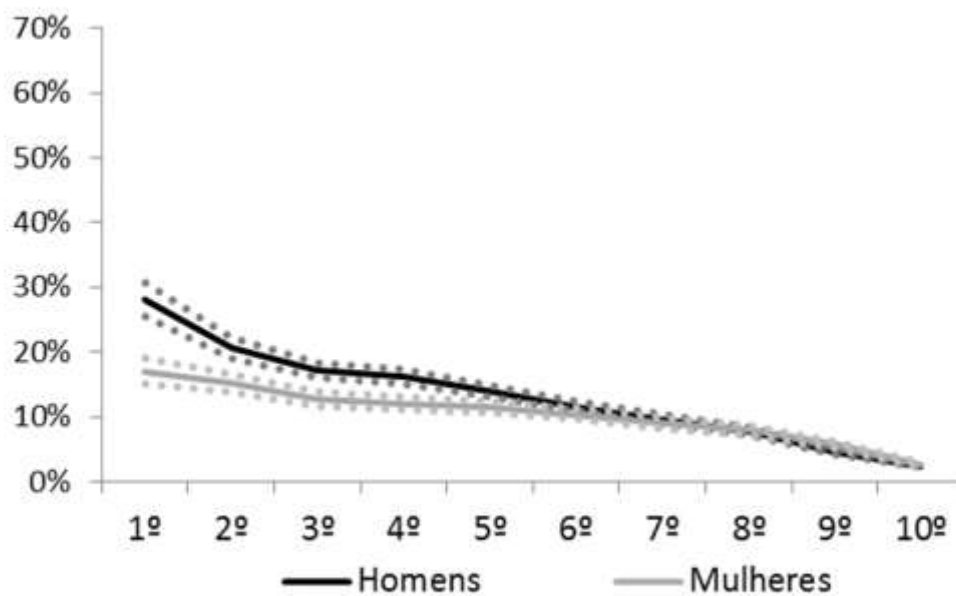
Material Suplementar

Tabela S1. Proporção (%) de homens e mulheres cujo deslocamento a pé ou de bicicleta para o trabalho é igual ou superior e 30 minutos segundo variáveis sociodemográficas. São Paulo, 2014.

Variáveis	Homens			Mulheres		
	%	IC (95%)		%	IC (95%)	
Situação do Domicílio						
Rural	16.3	14.7	18.0	10.0	9.1	11.1
Urbana	10.3	9.9	10.7	9.0	8.6	9.4
Região Metropolitana						
Não	13.5	12.9	14.2	11.0	10.5	11.6
Sim	6.3	6.0	6.7	5.1	4.7	5.4
Macrorregião						
Centro Oeste	6.0	5.3	6.8	5.3	4.7	6.0
Nordeste	17.9	16.8	19.2	11.6	10.8	12.5
Norte	13.4	11.2	15.8	9.3	8.1	10.6
Sudeste	8.8	8.3	9.3	8.3	7.7	8.9
Sul	8.6	7.9	9.3	8.9	8.1	9.8
TOTAL	11.5	11.0	12.0	9.2	8.8	10.0

Figura 5S

Figura 5 – Proporção de deslocamentos ativos cujo trajeto é igual ou superior a 30 minutos segundo sexo e decis de renda¹ – Brasil, 2008.

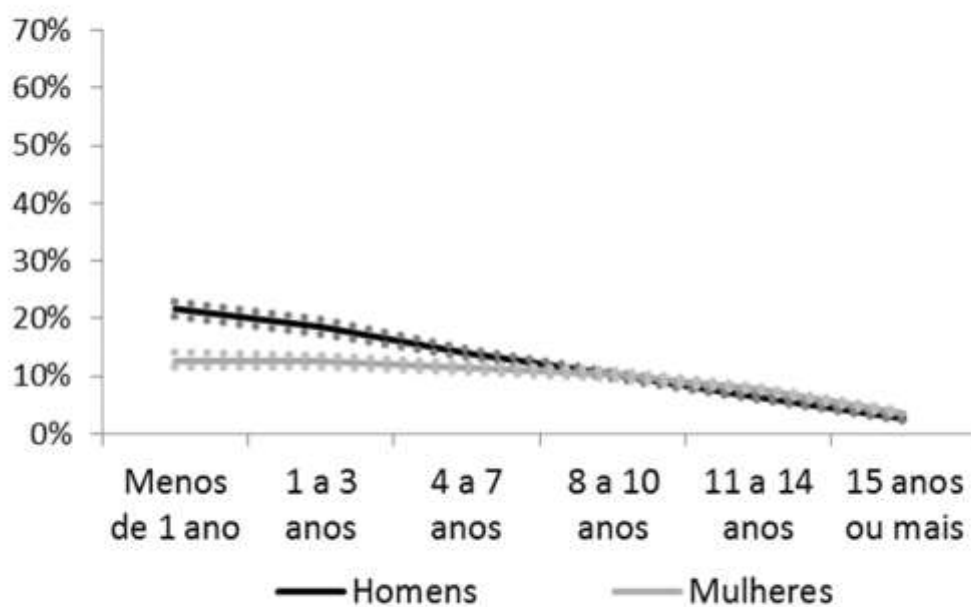


Fonte: PNAD (IBGE)

Nota: ¹ Quintis de renda domiciliar per capita

Figura 6S

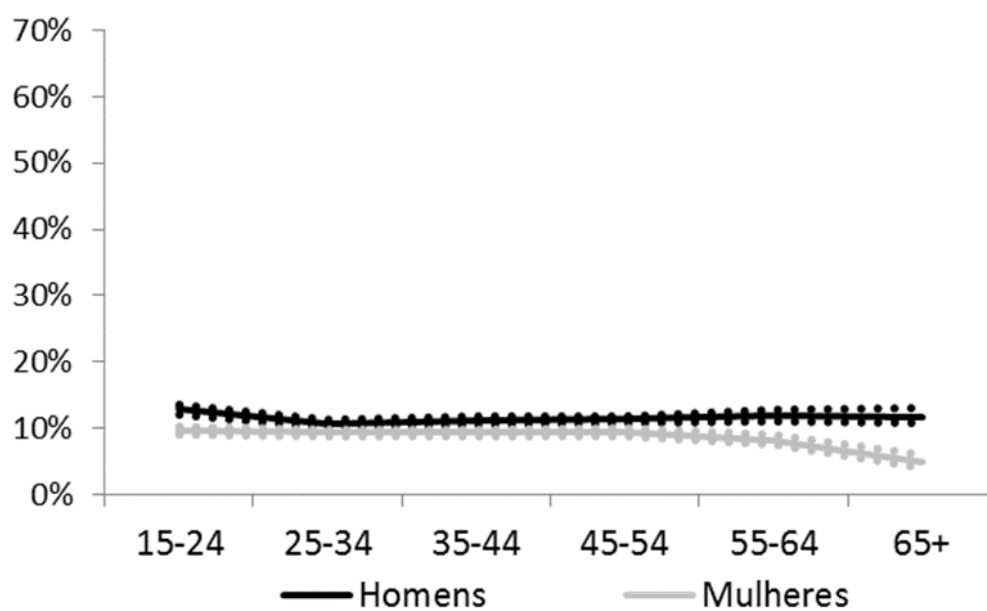
Figura 6 – Proporção de deslocamentos ativos cujo trajeto é igual ou superior a 30 minutos segundo sexo e anos de estudo – Brasil, 2008.



Fonte: PNAD (IBGE)

Figura 7S

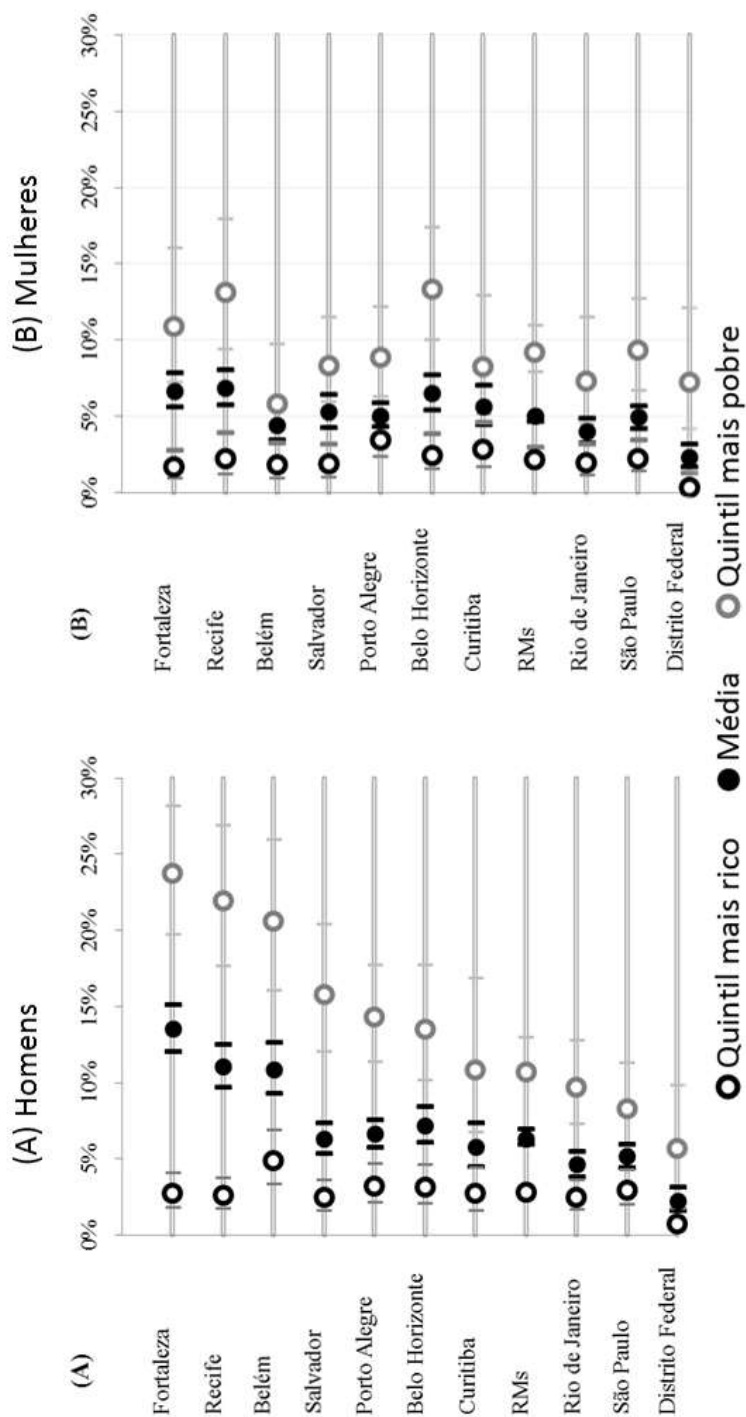
Figura 7 – Proporção de deslocamentos ativos cujo trajeto é igual ou superior a 30 minutos segundo sexo e faixa etária – Brasil, 2008.



Fonte: PNAD (IBGE)

Figura 8S

Figura 8 - Proporção de deslocamentos ativo cujo trajeto é igual ou superior a 30 minutos segundo sexo e quintil de renda¹ – regiões metropolitanas brasileiras, 2008.



Fonte: PNAD (IBGE)

Notas: ¹ Quintis de renda domiciliar per capita

Manuscrito 3: Correlates, travel patterns and time trends of bicycling in São Paulo, Brazil, 1997-2012.

Título corrido: Bicycling in São Paulo, Brazil, 1997-2012.

Artigo original submetido ao periódico *International Journal of Public Health*.

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Abstract

The purpose of the study was to describe bicyclists and bicycling trips, and to explore correlates and time trends of bicycling in São Paulo, Brazil from 1997-2012. Cross-sectional analysis using repeated São Paulo Household Travel Surveys (HTS). We used representative data of 1,174 bicyclists and 214,719 people. Poisson regressions for individual correlates were estimated using the entire 2012 HTS sample. Men were 6 times more likely to bicycle than women. We found increasing rates of bicycle use among the richest quartile but the total bicycling rates dropped from 1997 to 2012 due to decreasing rates among the poor.

Keywords: Transportation; Motor Activity; Bicycling; Health Promotion; Brazil; Urban Health; Healthy City.

Highlights

- Analysis using São Paulo Household Travel Surveys from 1997-2012
- Bicycling rates increased between 1997 and 2007 but decreased in 2012
- Between 2007 and 2012, bicycling rates decreased among the 25% poorest and increased among the 25% richest segments of the population.
- Younger men who did not own a car or a motorcycle and lived close to work/school were more likely to bicycle
- Strong age and gender inequalities were observed.

Introduction

The transport sector contributes to population level physical activity by facilitating active modes of travel, such as bicycling¹⁻³. Replacing motorized trips with bicycling is a promising strategy to help tackle the global burden of non-communicable diseases (NCDs) due to the many positive health effects of physical activity^{4,5} and the public health and environmental co-benefits^{6,7}. Enabling and facilitating bicycling are key improvements in transport systems^{8,9} towards healthier and more equitable cities^{7,10}.

Sao Paulo municipal government has implemented a few initiatives to facilitate bicycling, amidst a growing trend of similar policies across Latin America¹¹. Public bike hiring schemes, exclusive network route for bicycling on Sundays and holidays, and 'bicyclable paths' are part of a plan to be fully implemented by 2016¹². On the other hand, Sao Paulo remains highly segregated. Poorer segments of the population live in the peripheral neighborhoods and have to commute farther to work^{13,14}.

Little is known about bicycling trends in the Sao Paulo Metropolitan Area (hereafter, just Sao Paulo), as well as the characteristics of bicyclists. Most of the available data on active transportation combine walkers and bicyclists, though these two groups tend to have different socioeconomic characteristics¹⁵. Using data collected by large household representative samples of Sao Paulo residents, we aimed to analyze the correlates, travel patterns, and time trends of bicycling in the region.

Methods

We used data from the Sao Paulo Household Travel Survey (HTS), an ongoing household travel survey conducted every ten years, comprising the 39 municipalities in Sao Paulo metropolitan area – the largest metropolitan area in the country (8,500 km², approximately 21 million people)¹⁶. Given the rapid changes occurring in the region, a smaller HTS was also conducted in 2012 (8,115 households; 24,534 people; 46,861 trips), using the same strategy as for the HTS from 1997 (26,278 households; 98,780 people; 163,541 trips) and 2007 (29,957 households; 91,405 people; 169,665 trips). *Further details* concerning HTS methods *can be obtained elsewhere*¹⁷. Briefly, to select the households, Sao Paulo territory

was divided into contiguous traffic analysis zones, from which primary study units (households) were randomly selected according to three levels of electricity consumption — a proxy for the number of individuals in the household and income. For all surveys, a sampling strategy was based on the roll of consumers served by the city electric companies, covering 98.4% of the population ¹⁶.

Bicyclist was defined as any person for whom bicycling was the mode of transport for at least part of a trip (460 bicyclists in 1997; 595 bicyclists in 2007; 119 bicyclists in 2012). Household information included the number of family members, home ownership, income, and number of assets. Individual-level data included age, gender, education, employment status, and income. Trip-level data consisted of one-way trips undertaken on the day before the interview, and included origin and destination, mode of transport, number of mode transfers, trip purpose, and times of departure and of arrival. The 2007 and 2012 HTS provided geocoded location for work and study places, trip origin, destination as well as straight line distances for each trip.

Statistical analyses

Crude rates of bicyclists (per 1,000 residents) were estimated by individual characteristics for 2012 (Table 1). We used multivariate Poisson regressions to identify individual correlates of bicycling among travelers in 2012 (Table 1). Additionally, we estimated the person/day cumulative numbers of total and bicycle trips, total travel time and bicycling time, and total travel distance and bicycling distance for 2012 (Table 2). Rates of bicyclists (per 1,000 residents) for 1997, 2007, and 2012 were estimated by family income in quartiles (Figure 1). We considered statistically different rates when point estimates were not contained in the confidence interval of the rate of comparison ¹⁸.

Data were weighted to adjust for the selection probabilities at the individual level and to make the sample representative of the studied area. Analyses were conducted in 2015 using Stata 12.1. The University of Sao Paulo School of Public Health Ethics in Research Committee approved the study.

Results

Frequency and distribution of bicyclists

Table 1 shows the crude rates of bicyclists in Sao Paulo population as well as the adjusted prevalence ratios. Crude models showed that, in 2012, men were almost seven times more likely to bicycle than women. Individuals who worked or studied closer to home (5 km or less) were almost three times as likely to bicycle in their daily commutes. No clear trend was observed for education ($p = 0.402$) or income ($p = 0.394$) in 2012. All differences observed in the crude models remained statistically significant after controlling for age and sex. In the fully-adjusted model, there were no changes in the magnitude, direction or significance of any association. Most of the time and distance travelled by bicyclists on their daily travel was by bicycle (Table 2). Mean duration and distance of bicycling trips were 24.1 min (95%CI 21.3;27.0) and 3.8 km (95%CI 2.8;4.9), respectively. In all years, one quarter of bicycling trips started between 6 am and 7 am, and another quarter between 5 pm and 6 pm.

Time trend analyses showed an increase in the rate of bicyclists, from 3.9 (95%CI 3.2;4.6) per 1,000 residents in 1997 to 6.3 (95%CI 5.8; 6.8) per 1000 residents in 2007 but dropped to 5.4 (95%CI 3.9;6.9) in 2012. The overall decline in 2012 was caused by a sharp drop in the lowest income quartile from 2007 to 2012. However, the rate of bicyclists/1,000 individuals among individuals in the top income quartile increased from 1.2 (95% CI 0.6;1.8) to 4.5 (95%CI 2.0;6.5) (Figure 1).

Table 1. Crude rates of bicyclists in the São Paulo population and adjusted prevalence ratios according to sociodemographic characteristics. São Paulo, 2012.

Variable	Bicyclists (per 1,000 residents)	95% CI		Adj PR ^e	95% CI		p ^e	
Sex								
women	1.4	0.5	2.3	Ref	Ref	Ref		
men	9.7	6.7	12.6	6.5	3.6	11.8	>0.001	
Age (years)								
0-18	3.5	2.1	5.0	Ref	Ref	Ref	0.005 ϕ	
19-39	9.1	6.2	11.9	6.8	3.5	13.3	>0.001	
40-59	4.8	1.8	7.8	4.0	1.7	9.5	0.003	
≥60	1.1	0.0	2.2	2.8	1.0	8.1	0.049	
Education								
Less than high school	4.9	2.4	7.4	Ref	Ref	Ref	0.402 ϕ	
High school or some college	6.1	4.2	8.0	0.8	0.4	1.4	0.376	
College	4.0	0.9	7.0	0.7	0.3	1.9	0.489	
Quartiles of Family Income ^{\$}								
Lowest Q1 (< R\$ 1,572)	6.0	4.0	8.0	Ref	Ref	Ref	0.394 ϕ	
Q2 (R\$1,572 - R\$2,404)	6.4	3.6	9.3	1.0	0.7	1.4	0.997	
Q3 (R\$2,404 - R\$3,800)	4.0	1.7	6.2	0.8	0.5	1.2	0.230	
Highest Q4 (> R\$3,800)	4.3	2.0	6.5	0.9	0.4	1.7	0.665	
Distance to work or school ≤ 5km								
No	3.9	1.7	6.1	Ref	Ref	Ref		
Yes	10.6	7.5	13.8	3.3	2.0	5.5	>0.001	
Car ownership*								
No	8.3	5.9	10.7	---	---	---	---	
Yes	3.2	1.9	4.5	---	---	---	---	
Motorcycle ownership*								
No	5.3	3.7	6.9	---	---	---	---	
Yes	6.3	3.1	9.5	---	---	---	---	
Car or motorcycle ownership*								
No	8.4	5.9	10.9	Ref	Ref	Ref		
Yes	3.4	2.1	4.6	0.3	0.2	0.4	>0.001	
Bicycle ownership*								
No	0.7	0.2	1.3	Ref	Ref	Ref		
Yes	15.3	10.8	19.7	21.1	9.2	48.6	>0.001	

n=24,534; *n=24,295. \$ = As of January 2012, US\$ 1.00 = R\$ 1.83; e = Statistical significance if p<0.05. ϕ = p for Wald test.

Abbreviations: 95% CI: 95% confidence interval. Adj PR: Prevalence ratio from the fully adjusted model, including sex, age, education, income, distance to work / school ≤ 5km, car or motorcycle ownership, and bicycle ownership.

Table 2. Characteristics of travel patterns among bicyclists. São Paulo, 2012 (n=119).

Variables (per bicyclists/day)	mean	95% CI		median	IIQ (p25-p75)	
Total trips (n)	2.7	2.5	2.9	2.0	2.0	3.0
Bicycling trips (n)	2.2	2.0	2.3	2.0	2.0	2.0
Total travel time (min)	75.0	65.8	84.2	60.0	30.0	110.0
Bicycling time (min)	52.3	41.4	63.2	41.0	26.0	76.0
Total travel distance (km)	10.0	6.8	13.2	4.8	2.8	11.5
Bicycling distance (km)	7.9	4.7	11.1	4.0	2.0	8.9

Abbreviations: 95% CI: 95% confidence interval; IIQ(p25-p75): interquartile range

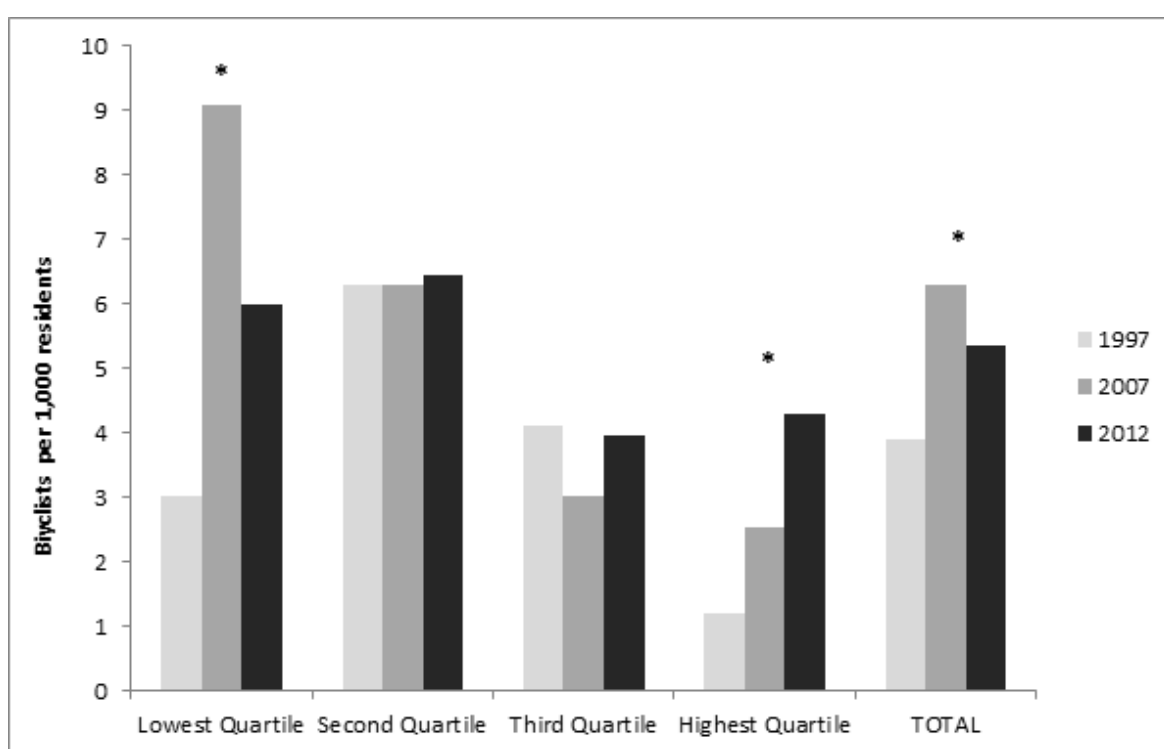


Figure 1. Crude rates of bicyclists (per 1,000 residents) according to quartiles of family income. São Paulo, 1997-2012. * Statistically significant differences.

Discussion

Using a representative sample from Sao Paulo, we found an increase in the number of bicyclists from 1997 to 2007, but a decline in 2012. In 2012, the 25% richest segment of the population experienced an increase in the rates of cycling whereas a decline was observed for the 25% poorest.

There are a number of potential explanations for the different trends observed by income quartile. Between 2007 and 2012, federal government decisions to foster the automobile and motorcycle industry (i.e. tax exemptions and loans for private vehicles purchase)¹⁹, contributed to an increase in car and motorcycle access in São Paulo and are associated with lower levels of active transportation in the region²⁰. Over this period, the proportion of families in the lowest quartile of income without a car or motorcycle dropped from 76.6% (95%CI: 75.3;78.0) to 71.3% (95%CI: 69.2;73.4) whereas the proportion of families in the highest quartile of income without a car or motorcycle increased from 4.4% (95%CI: 3.4;5.4) to 8.2% (95%CI: 6.2;10.2) (data not shown).

Additionally, we found that living closer to work/school increases the chances of being a cyclist, independent of income. In Sao Paulo, lower income individuals are more likely to live in the peripheral neighborhoods which means they have to travel long distances to work²¹. Two thirds of the jobs and less than 20% of the population live in the center in Sao Paulo¹⁴.

The poor have higher rates of informal working and are thus less likely to have their transportation costs subsidized by the employer²², and have less access to public transport. For instance, in 2007, poor public transport network and high cost were leading factors in respondents' choice to bicycle²³. Apart from its status, cars and motorcycles are necessary alternatives for the poor segment of the population to overcome either the absence of a good public transport network or the high costs associated with it.

Time spent on the daily commute from home to work is lower among the highest (quintile 5) income strata of the population (see appendix S1), since they can afford to live more centrally^{13,14}. However, bicycling remains more frequent among lower income and lower educated individuals, as well as men, young adults, and those who do not own a car. Similar results were shown for other cities in Brazil^{15,24-26}. In some European countries, a broad range of social groups bicycle for transportation,^{27,28} however figures are different in South^{15,26,29} and North America³⁰. In Bogota, where a large share of bike lanes has been implemented, users are mostly male younger adults who did not own a car²⁹. The wide age gap observed in São Paulo is particularly worrying considering the increasing net benefits of bicycling among older individuals³¹.

The gender gap in Sao Paulo is also noteworthy. While in the United Kingdom, women are twice less likely to bicycle than men ³², in Sao Paulo, we found that women were seven times less likely to bicycle than men. In some other European countries the gender difference is even less pronounced ²⁷. The same European countries also have some of the highest rates of bicycling among the overall population, ²⁷ suggesting that high levels of cycling might not be achieved without the development of a more inclusive cycling environment ³². We did not find studies that explored the reasons for such a wide gender gap in Brazil, although they might be expected to be similar to those of developed countries. Most women and men prefer not to cycle in busy traffic but women's preferences tend to be stronger. ^{33,34} When cycling is a minority activity it often comes with connotations of risky behavior and sport and these meanings may be less appealing to women ^{32,35}. Long distances commuted are other reasons that may explain the gender gap in Sao Paulo.

We found a very large contribution of bicycling on the daily commute of bicyclists, which may be associated with the lack of adequate transport mode integration. In 2007, one third of bicyclists reported they chose the bicycle as their mode of travel because of problems with the public transportation system (data not shown). Along with interventions to improve affordability, comfort and travel time in public transport, initiatives geared towards increasing the availability of bicycle parking infrastructure near subway and train stations and allowing the transportation of bicycles on the public transport could open up cycling to those going long distances. ³⁶ Irrespective of the reasons that would influence one to choose to use the bicycle, the reported number of bicyclists and bicycling trips in the city show substantial room for increase in all income strata and are favored by optimum local climate conditions year round.

Making bicycling more convenient, accessible and safer to all income levels is likely to result in higher bicycling rates across all income strata ³¹. Growing research linking environmental characteristics and bicycling in Latin America sheds a light on the environmental interventions that could help increase the number of bicyclists. Bicycle use has been associated with higher density of streets, lower rates of traffic collisions ³⁷ and residing in areas with a higher number of traffic lights and mixed-land use ²⁶. Desire for separation from fast or high volume motor traffic comes out very strongly from stated preference studies ³⁴. Recently evidence is emerging that

high quality cycling infrastructure does lead to more cycling if it access key destination and forms part of a connected network³⁸.

A strength of this study is the use of recent HTS data from the largest metropolitan area in Brazil. However, there are several limitations, including a smaller sample size and number of zones for 2012 in comparison to 2007 and 1997. Another limitation is the validity of self-reported data. Self-reported trip duration may limit its accuracy, especially for shorter trips like bicycling³⁹. The rounding that occurs in self-reports of duration may introduce additional measurement error⁴⁰.

We showed increasing rates of bicycling for transportation when 1997 and 2007 São Paulo, but a decline in 2012 driven by lower income individuals. A better understanding of the bicycling behavior in the city may be used to inform more effective policy decisions towards active transportation in Sao Paulo. Policies to reduce spatial segregation, improvements in bicycling infrastructure, and integrating the bicycle with the public transport system in neighborhoods of all income levels could put cycling back on an upward trajectory.

Acknowledgements

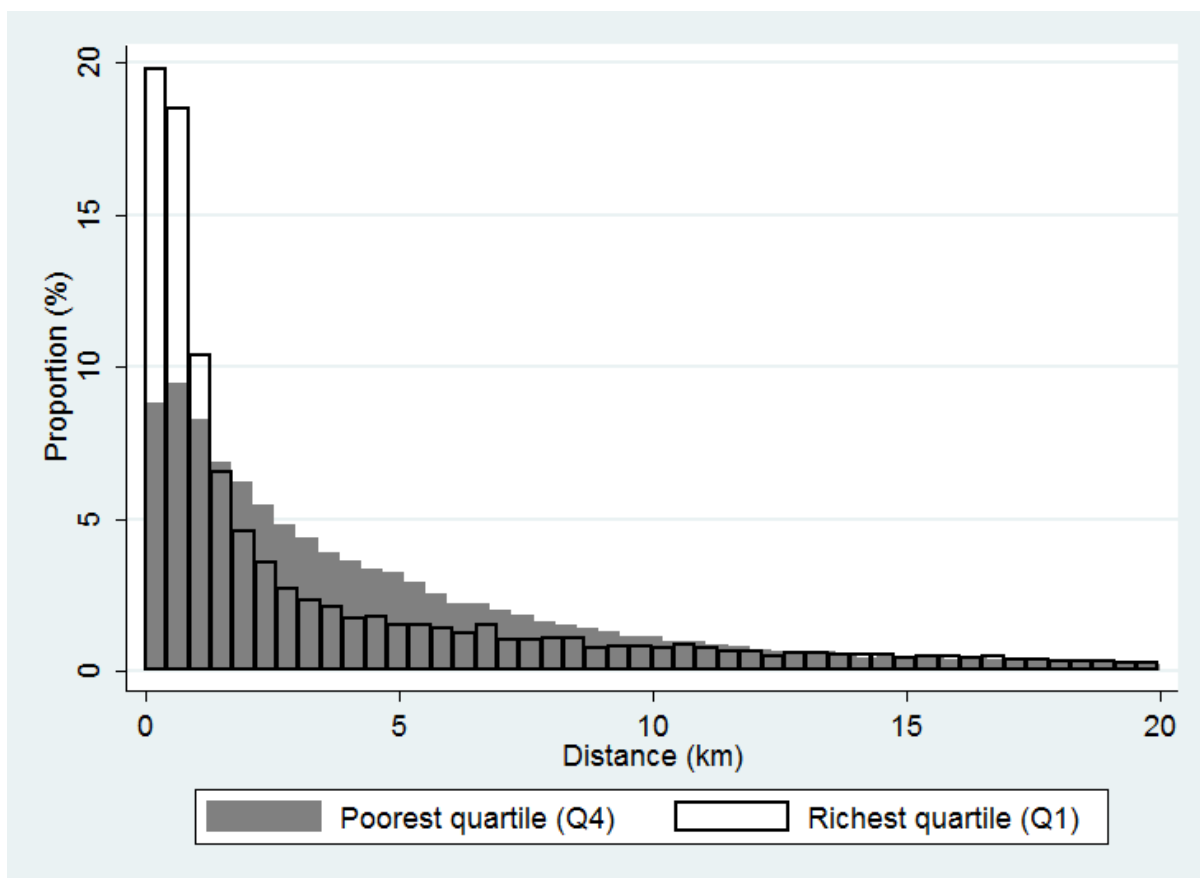
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Supplementary Files

Appendix S1. Distribution of bicyclists according to bicycling travel distance and family income. Sao Paulo, 2012.

Manuscrito 4: Changes in travel to school patterns among children and adolescents in the São Paulo metropolitan area, Brazil, 1997-2007.

Título corrido: Changes in children's travel to school in São Paulo, Brazil

Artigo original publicado no periódico *Journal of Transport and Health* (2015;2(2):143-50). A liberação dos microdados da Pesquisa de Mobilidade de 2012 durante o doutorado permitiu a atualização da tendência sobre o padrão de viagens de crianças e adolescentes para a escola em São Paulo. Esta atualização foi apresentada na forma de uma comunicação breve, em processo de avaliação por pares nos Cadernos de Saúde Pública (ver Apêndice A1, ao final deste manuscrito).

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ABSTRACT

This paper describes the changes in how children and adolescents travel to school in the São Paulo Metropolitan Area (SPMA), Brazil. Data were from children (6 to 11 y) and adolescents (12 to 17 y) who reported at least one trip to school at the SPMA Household Travel Survey for the years 1997 (15,491 people; 31,909 trips) and 2007 (11,992 people; 24,428 trips). We estimated: the proportion and respective 95% confidence interval, median interquartile range, and total trip time in each mode of travel (active, private, public transport) according to sex and quintiles of family income. The analysis was stratified by age group and weighted to make the sample representative of the studied population. Results suggest that the use of public transport and active transport in school travel decreased between 1997 and 2007, whereas the use of private transport increased, especially among children. An inverse relationship between median time in private transport and income was also observed for both children and adolescents. Median time of transport to school remained stable in the study period. This scenario suggests that little effort was put into improving independent mobility of children and adolescents to school by the local authorities. Policies focused on facilitating the acquisition of private vehicles implemented in the study period might have contributed to worsen the situation. Remodeling local environments (both built and social) to make them more suitable for children and adolescents' mobility might be part of a broader, long-term policy destined to enhancing the use and share of the cities' streets in a sustainable, equitable, and healthy way.

Keywords: Walking; Cycling; Motor vehicles; Transportation mode; Child; Urban health.

Introduction

Modes of travel have a crucial importance in the way cities and societies are organized and in people's quality of life and health. Despite this importance, few studies are investigating changes in modes of travel. Studies in high-income countries have shown a decrease in active transport in the last few years (Grize et al., 2010; van der Ploeg et al., 2008). However, extrapolation of the results from high-income countries to other contexts should be made with caution. For example, in Brazil there was a rapid change in the socioeconomic context, with direct consequences to the transport system. From 2000 to 2010, there was a 12% increase of the Brazilian population (Brazilian Institute of Geography and Statistics, 2014a), while in the same period there was an increase of around 140% in the number of vehicles in cities (Brazilian National Department of Transportation, 2014). Moreover, a 2006 federal policy stimulating vehicle purchases through tax reductions combined with an increase in the population's purchasing power help to explain the increase in car use.

A review study from de Nazelle et al. (2011) concluded that active travel policies have the potential to generate large population health benefits through increasing population physical activity levels, and smaller health benefits through reductions in exposures to air pollution in the general population. In this light, encouraging active transport is a potential method not only to improve health (Hamer and Chida, 2008; Saunders et al., 2013; Schoeppe et al., 2013), but also to improve traffic, social and ecological aspects (Hamer and Chida, 2008; Stone et al., 2014). Moreover, fostering active commuting of children and adolescents could promote empowerment through independent mobility and reinforce the role of streets as public spaces and drivers of health and prosperity in a city (United Nations Human Settlements Programme, 2013; Weiler et al., 2014).

Notwithstanding the well-recognized benefits of active transport, this practice consistently declined in the last decades among children and adolescents. Recently, a review reported data showing decline of active transport per decade in Australia (5 to 9 percentage points – p.p.), Brazil (16 p.p.), Canada (5 p.p.), China (11 p.p.), Switzerland (6 p.p.), and USA (9 p.p.) (Booth et al., 2014). Despite methodological differences among studies, patterns of consistent decline can be observed, probably due to car ownership and distance from home to school (Booth et al., 2014). Particularly in Brazil, data regarding modes of travel are scarce, especially time

trends, being worse when the focus is children and adolescents. In addition to the data from Florianópolis (Costa et al., 2012) included in the review, in Pelotas, also located in the South of Brazil, adolescents that reported walking or cycling to school decreased from 69% in 2005 to 56% in 2012 (16 p.p.) (Coll et al., 2014). There is no nationally representative time trend data of active travel to school in Brazil yet – in 2012, a National Adolescents School-based Survey showed that 38% of adolescents do not walk or cycle to or from school (Rezende et al., 2014).

Previous studies on transportation to school mainly have investigated only active transport (Coll et al., 2014; van der Ploeg et al., 2008). Despite its importance to public interventions and urban planning, we should understand transportation in a wider view. For example, active transport to school time could be decreasing because of better distribution of schools throughout neighborhoods or of improvements in the public transportation system, which are desirable ameliorations. Therefore, while active transport has decreased, we should learn how other forms of commuting are changing in order to improve the organization of the city and its transport system. Thus, the purpose of the present study is to describe changes in travel to school patterns among children and adolescents between 1997 and 2007, living in the São Paulo Metropolitan Area, Brazil.

Material and methods

We used data collected for the São Paulo Metropolitan Area Household Travel Survey (HTS), an on-going household travel survey carried out by the transport sector (*Companhia do Metropolitano de São Paulo - Metro*) every ten years since 1967. The past two HTS (1997 and 2007) comprised the 39 cities of the São Paulo Metropolitan Area (from now on, we will refer to the whole metropolitan area as São Paulo), the largest metropolitan area in South America, home to almost 21 million people, that comprises an area of 8,500 km² (Brazilian Institute of Geography and Statistics, 2014b). The proportion of people aged 5 to 19 years old in the São Paulo population in 1997 and 2007 were 28% and 24%, respectively (Seade Foundation, 2014). The education component of the Human Development Index increased in the region between 1991 and 2010 (from 0.421 to 0.725), resulting in a high proportion of people aged 6 to 14 years old attending school in 2010 (around 96%) (United Nations Development Programme, 2014).

For both surveys, the sampling plan followed a complex and stratified design to produce estimates representative of the São Paulo population. Sampling strategy was based on the roll of electricity consumers of the city electricity companies, which covers 98% of the area's population (Brazilian Institute of Geography and Statistics, 2014b). As part of the sampling process, São Paulo was divided in contiguous zones. Each zone was used to randomly select, with replacement, the primary study units (households) according to three levels of energy consumption – used as a proxy for household number of individuals and income. For both years, each zone had its sample size calculation, with the total sample size target for São Paulo of 30,000 households. In case of a not valid household (refusal to participate, without information from all residents, closed, empty or not found household), another household from the same zone and level of energy consumption would be randomly selected.

Data were collected for every household member using a face-to-face interview. In case of children younger than 10 years old who would not go alone to school, information was provided by the parents. Data collection took place in various days of the week to have all weekdays represented in the sample. Household-level data included the number of families and residential location. Several information from family and individuals was collected, including the number of members in the family, home ownership, family and individual income, age, gender, and education. Travel-level data was related to one-way trips undertaken on the day before the interview and included origin and destination, mode of travel, the number of times one changed the mode of travel, purpose and time of departure and arrival. Data were collected for the 1997 HTS from August 1997 through November 1997 from 98,780 people in 26,278 households, and include 163,541 trips. The 2007 HTS was conducted from August 2007 through April 2008 and contains data of 91,405 people in 29,957 households, and 169,665 trips.

In both years (1997 and 2007), we used information of children aged from 6 to 11 years old and adolescents aged from 12 to 17 years old (Centers for Disease Control and Prevention, 2014) who travelled to and from school at least once in the reference day. Trips originating in the school had the purpose defined as 'school'. Modes of travel were grouped into three categories: active transport (walking or cycling), private transport (car, motorcycle, taxi, school van, and charter bus) and public transport (public bus, public van, subway and train). In order to obtain

individual-level information of travel patterns, we aggregated travel-level data for each individual, estimating the person/day cumulative minutes spent on total travel, active, private, and public transport. We also classified subjects according to their mode of travel use: private transport users were those travelling by any private mode to school at least once on the reference day – same as for public transport users (the proportion of those who used both modes of travel were not presented due to low frequency – less than 1% in almost all cases). Active traveler was defined as those exclusively walking or cycling to school on the reference day.

Statistical analysis

Our entire analysis was stratified by age group (children and adolescents). For 1997 and 2007, we estimated the proportion and its respective 95% confidence interval as well as the median and interquartile range time of trips to school in each mode of travel (active, private, public transport) and in total according to sex and quintiles of family income. We considered population relevant estimate changes greater than 5% in the study period. Given the large sample size, all changes observed were statistically significant at a significance level of 0.05. Data were weighted to adjust for the selection probabilities at the individual level and to make the sample representative of the studied area. Analyses were conducted in 2014 using Stata 12.1 (StataCorp LP, College Station, TX, USA). The Institutional Ethics in Research Committee at the University of São Paulo School of Public Health approved the study.

Results

For 1997 we used data from 7,604 children (15,395 trips) and 7,887 adolescents (16,514 trips). For 2007 we used data from 5,795 children (11,662 trips) and 6,127 adolescents (12,766 trips). In 1997, the proportion of boys among children and adolescents was 53% (95% CI: 51 – 54) and 49% (95% CI: 48 – 50), respectively. In 2007, the proportion of boys was 52% (95% CI: 50 – 53) among children and 50% (95% CI: 49 – 51) among adolescents. The proportion of children and adolescents living in families with ≤ 2 minimum wages were 24% (95% CI: 23 – 25) in 1997 and 4% (95% CI: 3 – 5) in 2007. The minimum wage in 1997 and 2007 were R\$120 (US\$ 115) and R\$ 380 (US\$ 195), respectively.

General trends in transport patterns among children

Proportion of private transport increased between 1997 and 2007 due to a reduction in active and public transport trips (Figure 1).

The proportion of active transport decreased similarly among sex between 1997 and 2007. Among all income strata, the proportion of active transport decreased between 1997 and 2007, except in the lowest income quintile (Table 1). Between 1997 and 2007, the proportion of private transport increased for both sexes and income strata, except in the lowest income quintile (Table 1). Proportion of public transport decreased among in all quintiles of income and in boys and girls, although the reduction was more pronounced among the latter (Table 1).

In total, median time of transport to school remained stable between 1997 (median = 25 min, IQR: 20 – 40) and 2007 (median = 30 min, IQR: 20 – 50). The median time in private transport increased between 1997 and 2007, especially in boys and in the lowest and middle income quintiles (Table 2). Time spent in public transport remained similar between 1997 and 2007, except the second lowest quintile that increased in around 20 min (34%) (Table 2).

Table 2. Time spent by children in trips to school, according to mode of travel, sex, and income level. São Paulo, Brazil, 1997–2007.

Variables	Active transport ¹ (min/day)			Private transport ² (min/day)			Public transport ³ (min/day)											
	1997 (n = 4,999)	2007 (n = 2,999)	Med	1997 (n = 2,061)	2007 (n = 2,636)	Med	1997 (n = 642)	2007 (n = 222)	Med									
Sex																		
Girls	20	15	35	22	20	35	26	13	46	36	20	60	39	22	60	36	22	55
Boys	20	15	35	25	20	40	26	11	42	45	23	66	38	22	51	38	26	71
Income Quintile																		
1° (Lowest)	20	20	35	25	20	40	26	16	46	46	26	61	37	26	52	34	21	43
2°	25	18	36	20	20	35	33	11	53	46	23	63	36	20	75	55	30	95
3°	25	15	35	25	20	35	26	9	48	46	25	66	39	22	50	35	22	50
4°	20	15	30	20	12	30	23	8	42	38	21	61	34	18	52	35	23	56
5° (Highest)	20	10	25	20	15	30	21	13	41	33	19	56	45	30	56	50	23	71
Total	20	15	35	23	20	35	26	12	46	41	21	61	39	22	55	38	23	65

Notes:

n: number of trips considered in each mode and year; Med: median; IQR: interquartile range.

¹: among children who performed trips to school exclusively by walking and bicycle.²: among children who performed at least one trip to school by private transport (car, motorcycle, taxi, school transport and charter bus).³: among children who performed at least one trip to school by public transport (public bus or micro bus, subway or train).

Table 3. Proportion of adolescents going to school according to mode of travel, sex, and income level. São Paulo, Brazil, 1997–2007.

Variables	Active traveler ¹				Private transport user ²				Public transport user ³									
	1997 (n = 4,913)		2007 (n = 3,520)		1997 (n = 1,461)		2007 (n = 1,614)		1997 (n = 1,850)		2007 (n = 1,241)							
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI						
Sex																		
Girls	68	67	70	69	68	71	13	12	14	14	13	15	19	18	20	17	15	18
Boys	71	69	72	67	66	69	11	10	12	15	13	16	18	16	19	18	17	20
Income Quintile																		
1° (Lowest)	65	63	68	83	81	85	15	13	17	5	4	7	20	18	22	11	10	13
2°	80	78	82	80	77	82	4	3	5	7	5	8	16	14	18	14	12	16
3°	81	79	83	68	65	70	6	4	7	11	9	13	14	12	15	22	20	24
4°	72	69	74	58	55	61	8	6	9	20	18	23	20	18	22	22	19	24
5° (Highest)	48	46	51	35	32	38	30	27	32	45	42	49	21	19	24	19	16	22

Notes:

n: number of trips considered in each mode and year; %: proportion; 95% CI: 95% confidence interval.

¹: those performing trips to school exclusively by walking and bicycle.

²: those performing at least one trip to school by private transport (car, motorcycle, taxi, school transport and charter bus).

³: those performing at least one trip to school by public transport (public bus or micro bus, subway or train).

Some categories do not sum 100% because of the omission of the mixed user (those adolescents who used both private and public transports)

Table 4. Time spent by adolescents in trips to school, according to mode of travel, sex, and income level. São Paulo, Brazil, 1997–2007.

Variables	Active transport ¹ (min/day)			Private transport ² (min/day)			Public transport ³ (min/day)						
	1997 (n = 4,913)	2007 (n = 3,520)		1997 (n = 1,461)	2007 (n = 1,614)		1997 (n = 1,850)	2007 (n = 1,241)					
	Med	IQR	Med	Med	IQR	Med	IQR	Med	IQR				
Sex													
Girls	25	20 40	30	20	45	18	8 36	30	16 56	45	26 71	52	34 81
Boys	21	15 35	30	20	45	23	11 39	30	16 57	44	27 74	60	35 96
Income Quintile													
1° (Lowest)	25	20 35	35	20	50	19	10 41	53	26 80	46	26 74	60	35 90
2°	25	20 40	30	20	40	24	11 44	26	19 54	45	29 77	66	40 105
3°	25	15 40	30	20	45	31	16 48	30	15 60	45	26 74	57	36 91
4°	25	20 35	30	20	40	15	8 36	30	16 56	47	28 74	54	30 81
5° (Highest)	20	15 35	25	20	40	21	8 34	28	13 56	40	25 63	45	29 89
Total	25	20 37	30	20	45	20	8 36	30	16 56	44	26 73	55	34 90

Notes:

n: number of trips considered in each mode and year; Med: median; IQR: interquartile range.

¹: among adolescents who performed trips to school exclusively by walking and bicycle.²: among adolescents who performed at least one trip to school by private transport (car, motorcycle, taxi, school transport and charter bus).³: among adolescents who performed at least one trip to school by public transport (public bus or micro bus, subway or train).

General trends in transport patterns among adolescents

Proportion of private transport increased between 1997 and 2007 due to a reduction in active and public transport trips (Figure 1).

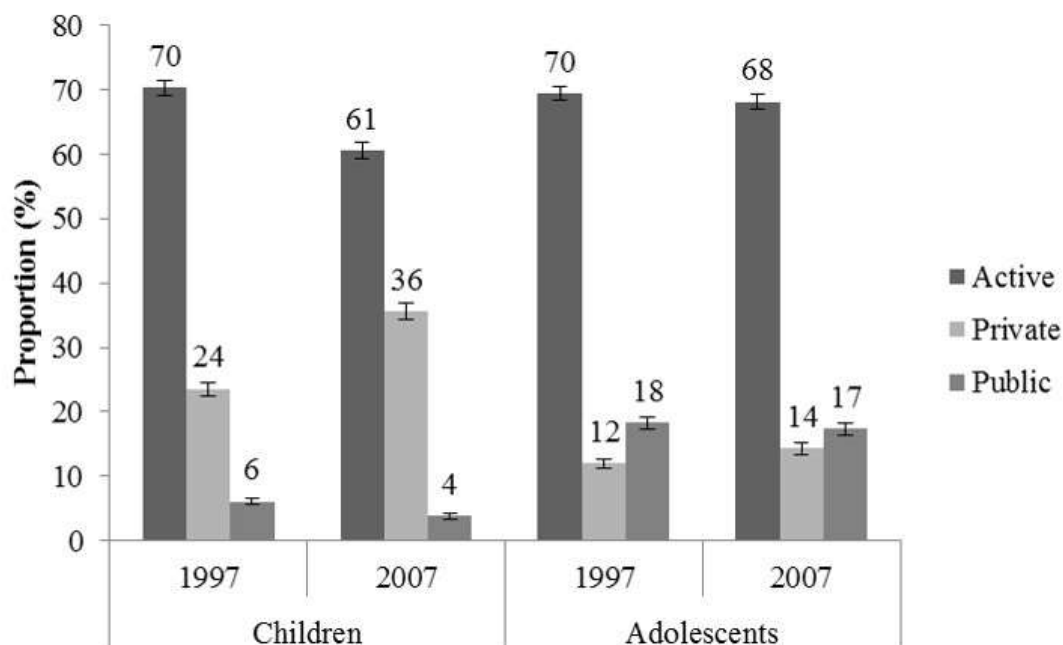


Figure 1 – Proportion of children and adolescents going to school according to mode of travel. São Paulo, Brazil, 1997–2007.

The proportion of active transport slightly decreased among boys and reduced among higher income strata between 1997 and 2007 (Table 3). The proportion of private transport increased among both boys and girls, whereas a sharp decrease in the lowest income quintile was observed (Table 3). The proportion of public transport slightly decreased among boys and in the lowest income quintile, with an increase in the middle income quintile (Table 3).

In total, median time of transport to school increased 10 minutes between 1997 (median = 30 min, IQR: 20 – 55) and 2007 (median = 40 min, IQR: 20 – 60). Among boys and the lowest income quintile, the median time of active transport increased 30% between 1997 and 2007 (Table 4). The median time spent in private transport increased 33% between 1997 and 2007 and this increase was higher among girls and in the lowest and second highest income quintiles. Time spent in public transport increased between 1997 (median = 44 min, IQR: 26 – 73) and 2007 (median = 55 min, IQR: 34 – 90). Median time of public transport was similar among sex in 1997, with a higher increase among boys from 1997 to 2007. Similarly, only in 2007, a

negative relationship between time spent in public transport and income level was found (Table 4).

Figure 2 presents the graphical distribution (histograms) of total median time spent in active, private and public transport for 1997 and 2007, for both children and adolescents.

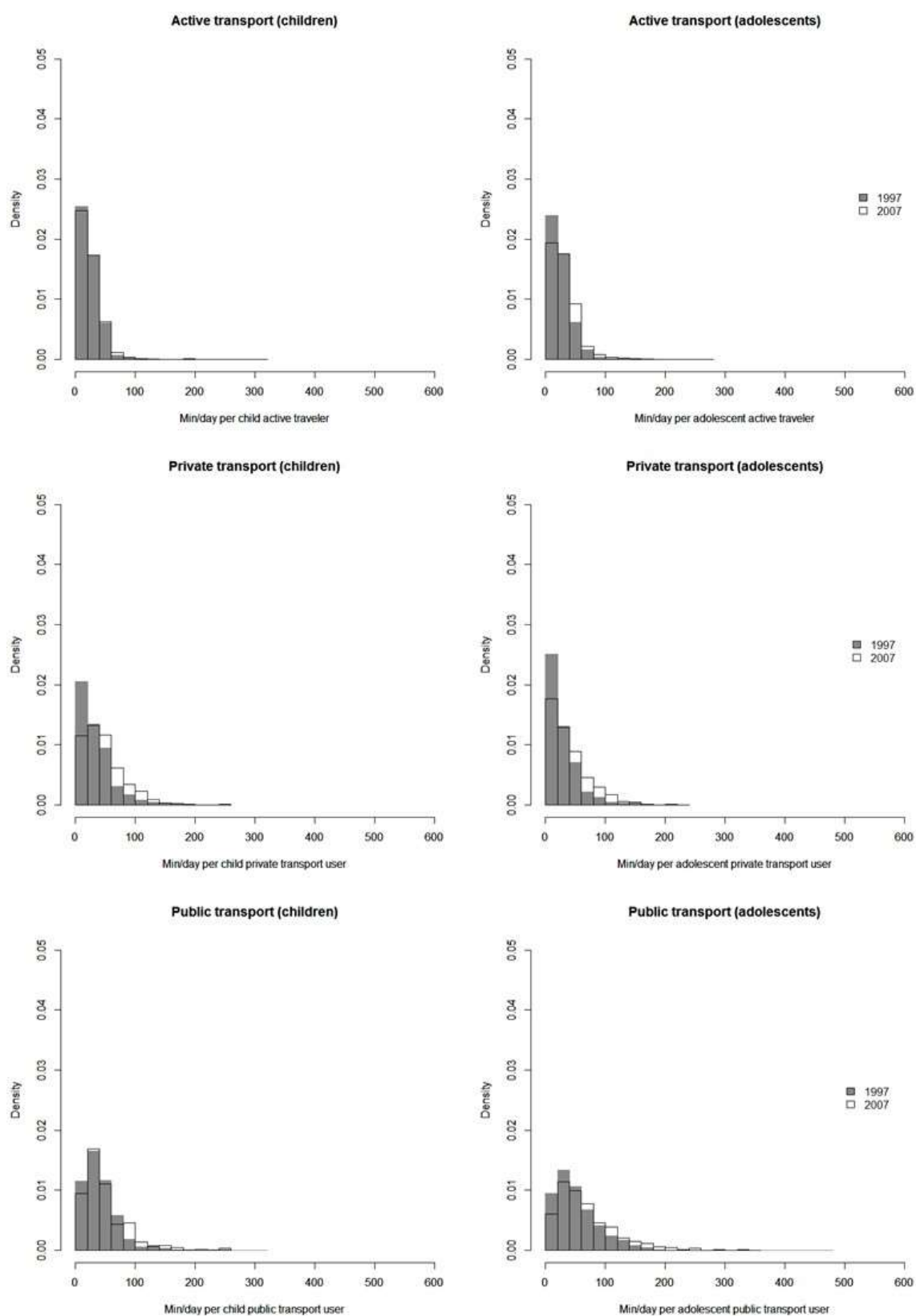


Figure 2 – Histograms of total median time spent in active, private and public transport by children and adolescents, considering only the users (40 min/day) of each mode. São Paulo, Brazil, 1997–2007. Active traveller: those performing trips to

school exclusively by walking and bicycle. Private transport user: those performing at least one trip to school by private transport (car, motorcycle, taxi, school transport, and charter bus). Public transport user: those performing at least one trip to school by public transport (public bus or micro-bus, subway or train).

Discussion

This study found that compared with the São Paulo travel to school patterns in 1997, the use of public and active transports decreased in 2007, whereas the use of private transport increased, especially among children. There was a slight increase in the median time of travel to school, which was more pronounced in trips made by private transport. Some disparities according to family income groups exist among both children and adolescents, such as an inverse relationship between median time in private transport and income. Finally, while the proportion of active travelers reduced – sharply among children – during the decade, the median time spent on active transport remained relatively stable.

The reduction in active transport to school due to increased private transport found in our study is a trend in several countries (Cui et al., 2011; Fyhri et al., 2011; Grize et al., 2010), and in other Brazilian cities (Costa et al., 2012). The substantial increase in the use of private transport might reflect what happened in Brazil in recent decades regarding economic growth and urban development. Concerning to the former, Brazilian purchasing power has been increasing in all socioeconomic strata, allowing more people to possess and use desired goods and services, including cars and motorcycles. As in other countries, in Brazil, the combination between individual's new economic capability and old desires play an important role in the private transport acquisition, not just for its instrumental value, but also for status symbol and affective factors (Steg, 2005). In addition, some federal government decisions fostered the automobile industry development, such as supporting tax exemptions and facilitating loans for private vehicles purchase.

The way urban sprawl took place in regions such as the São Paulo Metropolitan Area also helps to explain why active transport to school has become less attractive recently. The region has grown in an unplanned manner, with people settling down intensively and disorderly in peripheral areas before the needed infrastructure had arrived. For instance, between 1997 and 2007 the demographic density increased

28% in the periphery of the metropolitan area (*i.e.*, not considering São Paulo city) compared to 11% in São Paulo city (Department of Planning and Expansion of Metropolitan Transports, 2008). However, the density of jobs (Department of Planning and Expansion of Metropolitan Transports, 2008) and schools¹ did not follow the same trend. Particularly for schools, density increased 35% in the center against 6% in the other regions, shrinking in some areas¹.

It is plausible that this macro-environmental scenario has influenced meso and micro environmental aspects and, ultimately, the transport-related behavior. For instance, the quantity of cars in São Paulo state increased 31% from 1997 to 2007 (Brazilian National Department of Transportation, 2014) and, in the São Paulo Metropolitan Area, motorized trips increased 23% in the same period (Department of Planning and Expansion of Metropolitan Transports, 2008). Moreover, for decades transport policies focused on facilitating motorized traffic, thinking streets as roads instead of social places, trying to speed up traffic and minimize travel time (Banister, 2008; United Nations Human Settlements Programme, 2013). Evidence suggests that the number of cars in the household (Bringolf-Isler et al., 2008; Gropp et al., 2012) and pedestrian safety concerns (Bringolf-Isler et al., 2008; Carlson et al., 2014; Larouche et al., 2014; Pont et al., 2013) are strong correlates of non-active travel to school among children and adolescents. Regarding the unorganized urban sprawl patterns, consistent results indicate distance to school as an important barrier to active travel in this age (Carlson et al., 2014; Pont et al., 2013; Wong et al., 2011). Unfortunately, the available data does not allow us to analyze whether the distance to school increased in the period. Carver et al. (2014b) found that the territorial range among children residing in disadvantaged areas is generally restricted in less than 15 minutes when they are out alone, and is positively associated with the number of accessible destination types in the neighborhood. Recent evidences also suggest that community design and street network configuration can affect health (Marshall et al., 2014). Furthermore, other built environmental characteristics such as better walkability, street connectivity around home, residential density around home and school, percentage of streets with sidewalks, and total length of roads have showed to be important correlates of active commuting among children and adolescents living in high-income countries (Carlson et al., 2014; Gropp et al., 2012).

Children and adolescent's active commuting is also related to their parents' behaviours, attitudes, and perceptions (Babey et al., 2009; Bringolf-Isler et al., 2008;

Carlson et al., 2014). Parent's habitual active commuting can influence their children to actively travel to school (Carlson et al., 2014). Those aspects related to parents might also be viewed as intermediate variables in a framework that links macro-environmental scenario, such as the unorganized urban sprawl patterns, to active commuting. For instance, since school trips are commonly interlinked with parent's trips to work, an increase in private mode use in trips to work, due to increased distance from home, might also contribute to an increase in private mode use in their children's commute to school. Additionally, adolescents who frequently do not have an adult present after school and whose parents know little about their whereabouts after school are more likely to commute actively (Babey et al., 2009), which might help to explain why the decrease in active travel to school was not so strong when compared to children.

Other aspect is the parental safety concerns related to active transport to school, which decreases the probability of children using active commuting to go to school (Bringolf-Isler et al., 2008; Carlson et al., 2014). Regarding safety issues, a study conducted with Brazilian adolescents found that traffic and crime safety concerns were associated with non-active transport to school (Silva et al., 2011). A nationwide survey conducted in 2012 showed that 9% of students did not go to school in the 30 days preceding the survey because they did not feel safe on the way between home and school. This percentage was higher among public school students (10%), who are poorer than those from private schools (5%). In Brazil's Southeast region, where our study population is located, this proportion was 10% (Brazilian Institute of Geography and Statistics, 2013).

Policies that encourage active and safe transport to school, as well as policies aimed to inclusion of children in public and active transport, are of great importance to promote empowerment and independent mobility of children and adolescents. One public health effort that has been getting attention in this area is the Safe Routes to School program, initiated in Denmark in the late 1970s and that today is developed throughout Europe, United States, Australia, New Zealand, and Canada (National Center for Safe Routes to School, 2014). In the United States, where the program provides grants to local projects that support safe modes of active transport to school, a study found an increase of 37% in active transport after a 5-year period (Stewart et al., 2014). Unfortunately, programs of this type are scarce and not well documented in Brazil, where this kind of action could bring great benefits stimulating

safe and active transport to school. However, the imminent launch of the United Nations' Sustainable Development Goals brings new opportunities to discuss mobility-related topics, and to foster and implement programs that promote active transport to school and independent mobility for youth in several countries, including Brazil. Such discussions and programs have the potential to pervade several Sustainable Development Goals issues, like provision of safe, affordable, accessible and sustainable transport for connected and healthy communities; reduction of the environmental impact of cities; support of positive economic, social and environmental links within urban areas; reduction of road traffic deaths, and so on (United Nations, 2014).

Given the important impacts of active transport on health (Hamer and Chida, 2008; Schoeppe et al., 2013), the reduction of active transport observed among children and adolescents might have contributed to the increase of obesity and overweight rates both among these groups and adults (Conde and Monteiro, 2014). It also might help to explain the increase in the occurrence of asthma in the region (Solé et al., in press). Beyond the potential direct health effects, active transport to school by young people also reflects the empowerment and possibilities of street use, independent mobility, financial capacity, and other political and sociogeographic factors (Carver et al., 2014a; Fyhri et al., 2011; Schoeppe et al., 2014; Weiler et al., 2014). Indeed, according to the City Prosperity Index, developed by the United Nations Human Settlements Programme (2013), equity and social inclusion, including the promotion of street use by young people, especially through active modes of transport, are key aspects for the development of a more livable, healthy and prosperous São Paulo in the future (United Nations Human Settlements Programme, 2013).

Our study has some limitations. First, we were unable to evaluate whether trip duration increased due to a concomitant increase in the distance traveled since trip distance information was available only at the 2007 HTS. Additionally, HTS from both years suffer from the common limitations of self-reported data, which in this case tends to overestimate trip duration (Kelly et al., 2013). The rounding that occurs in self-reports of duration may also introduce additional measurement error (Yang and Diez-Roux, 2012). Nevertheless, the use of a unique and everyday trip purpose in this study (going to school) might have helped to reduce this error. Lastly, different data collection strategies among children according to their habit of going alone to

school could have introduced some report bias, unless we assume that the report from children going alone to school is as accurate as that of parents taking their children to school.

Conclusion

The results of this study suggest that from 1997 to 2007, São Paulo failed to improve independent mobility of children and adolescents to school, resulting in a reduction of public and active transport. In fact, it appears that policies focused on facilitating the acquisition and use of private transports made the present scenario worse for all, whereas the proportion and time use of private modes increased in the period. Remodeling local environments (both built and social) to make them more suitable for children and adolescents' mobility might be part of a broader, long-term policy destined to enhancing the use and share of the cities' streets in a sustainable, equitable, and healthy way. In this sense, São Paulo's most recent strategic urban plan – approved on June 30, 2014 – has goals related to reducing sociogeographic disparities, fostering urban life on neighborhood level, and reorganizing the transport system (São Paulo Department of Urban Development, 2014), which can change the city's current mobility scenario. Now it is necessary turn intention into action.

Footnote

¹ Calculated by the authors using educational census datasets freely provided by the Brazilian National Institute of Educational Studies and Researches at <<http://portal.inep.gov.br/basica-levantamentos-acessar>>.

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Apêndice A1 Aumento no uso de transporte motorizado privado no deslocamento das crianças para a escola na Região Metropolitana de São Paulo (1997- 2012).

Título corrido: Aumento do transporte motorizado privado nos deslocamentos das crianças

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Resumo

A Região Metropolitana de São Paulo apresentou, entre 1997 e 2007, tendência de aumento do uso transporte motorizado privado nos deslocamentos de crianças para a escola, com potenciais prejuízos à saúde da população. O objetivo deste estudo foi ampliar a análise desta tendência para 2012 e discutir potenciais estratégias para aumentar a proporção de crianças que andam, pedalam e usam o transporte público na região. A análise dos dados da Pesquisa de Mobilidade de 2012 indica não apenas a continuidade, mas a aceleração no aumento do uso transporte motorizado privado em deslocamentos de crianças entre 6 e 11 anos para a escola. O efeito de iniciativas em andamento sobre esta tendência, como os Planos de Mobilidade Urbana, só será devidamente compreendido com o devido monitoramento dos deslocamentos cotidianos e a avaliação do impacto destas ações sobre a saúde da população. Um pacote de políticas e programas voltados especificamente para a promoção e proteção da mobilidade a pé, de bicicleta ou por transporte público de crianças é imprescindível para garantir o deslocamento seguro, independente e ativo de crianças para a escola na RMSP.

Palavras-chave: criança; Caminhada; Bicicleta; Transportes; Ensino Fundamental e Médio.

Introdução

De acordo com os dados coletados em 1997 e 2007 pela Pesquisa Origem e Destino (OD) conduzida na Região Metropolitana de São Paulo (RMSP), aproximadamente 12% das crianças entre 6 e 11 anos trocaram a caminhada, a bicicleta e o transporte público pelo transporte motorizado privado nos seus deslocamentos para a escola ¹. Formas mais ativas de deslocamento trazem reconhecidos benefícios à saúde do indivíduo e da população ², sendo apontadas como um dos caminhos imprescindíveis para combater alguns dos maiores desafios atuais da saúde pública, como a pandemia de doenças crônicas não-transmissíveis e as mudanças climáticas ³. A opção pelo transporte público ou pela caminhada ou bicicleta para deslocamentos também traz importantes cobenefícios, como a redução da poluição atmosférica e de acidentes de trânsito ^{2,3}.

Além disso, o uso do transporte público, da caminhada ou da bicicleta para ir à escola implica fortalecimento da capacidade das crianças moverem de forma independente em sua cidade ⁴. Tal condição é fundamental tanto na sua formação como cidadão. É também um indicativo da percepção dos pais sobre os riscos fora de casa aos quais suas crianças estão submetidas ⁵. Mais ainda, garantir a participação de crianças nas vias e no sistema público de transporte favorece a diversidade e reforça o papel dos espaços públicos como condutores da saúde e da prosperidade das cidades ⁶.

A realização de nova coleta de dados pela Pesquisa de Mobilidade em 2012 permite estabelecer a variação recente dos modos de transporte para a escola utilizadas pelas crianças na RMSP. O objetivo desta comunicação é descrever a variação na proporção de crianças que andam, pedalam e usam o transporte público nos seus deslocamentos para a escola.

Métodos

Embora o número de domicílios e de pessoas estudados na Pesquisa de Mobilidade 2012 tenha sido inferior ao das pesquisas anteriores (Tabela 1), o processo de amostragem foi semelhante, sendo as unidades primárias de amostragem (zonas) de 2012 construídas como conglomerados das zonas de 2007, de modo que limites territoriais fossem respeitados e que o processo de zoneamento cobrisse todo o território dos 39 municípios da RMSP (Tabela 1). As estimativas para 2012 foram calculadas de modo idêntico ao empregado nas estimativas relativas aos

dois anos anteriores ¹. Foram consideradas diferenças estatisticamente significantes proporções cujas estimativas pontuais não estivessem contidas no intervalo de 95% de confiança (IC95%) da proporção a ser comparada ⁷ e populacionalmente relevantes diferenças de magnitude superior a dois pontos percentuais.

Resultados e Discussão

A análise dos dados da Pesquisa de Mobilidade de 2012 indica não apenas a continuidade, mas a aceleração da queda no número de crianças que andam, pedalam e usam o transporte público na RMSP (Figuras 1a e 1b). A mesma redução de aproximadamente dez pontos percentuais na proporção de crianças que se deslocam ativamente observada entre 1997 e 2007 (intervalo de dez anos) também foi encontrada entre 2007 e 2012 (intervalo de cinco anos), tanto em meninos quanto em meninas (Tabela S1). Em havendo continuidade desta tendência, até 2017, ano da próxima OD, a proporção de crianças que vão à escola por modos motorizados privados ultrapassará 50%. Entre os adolescentes (12 a 17 anos), a proporção de deslocamentos por modo de transporte permanece estável no período, com aproximadamente 67% dos adolescentes deslocando-se ativamente, 17% por transporte público e 15% por transporte motorizado privado, em meninos e meninas.

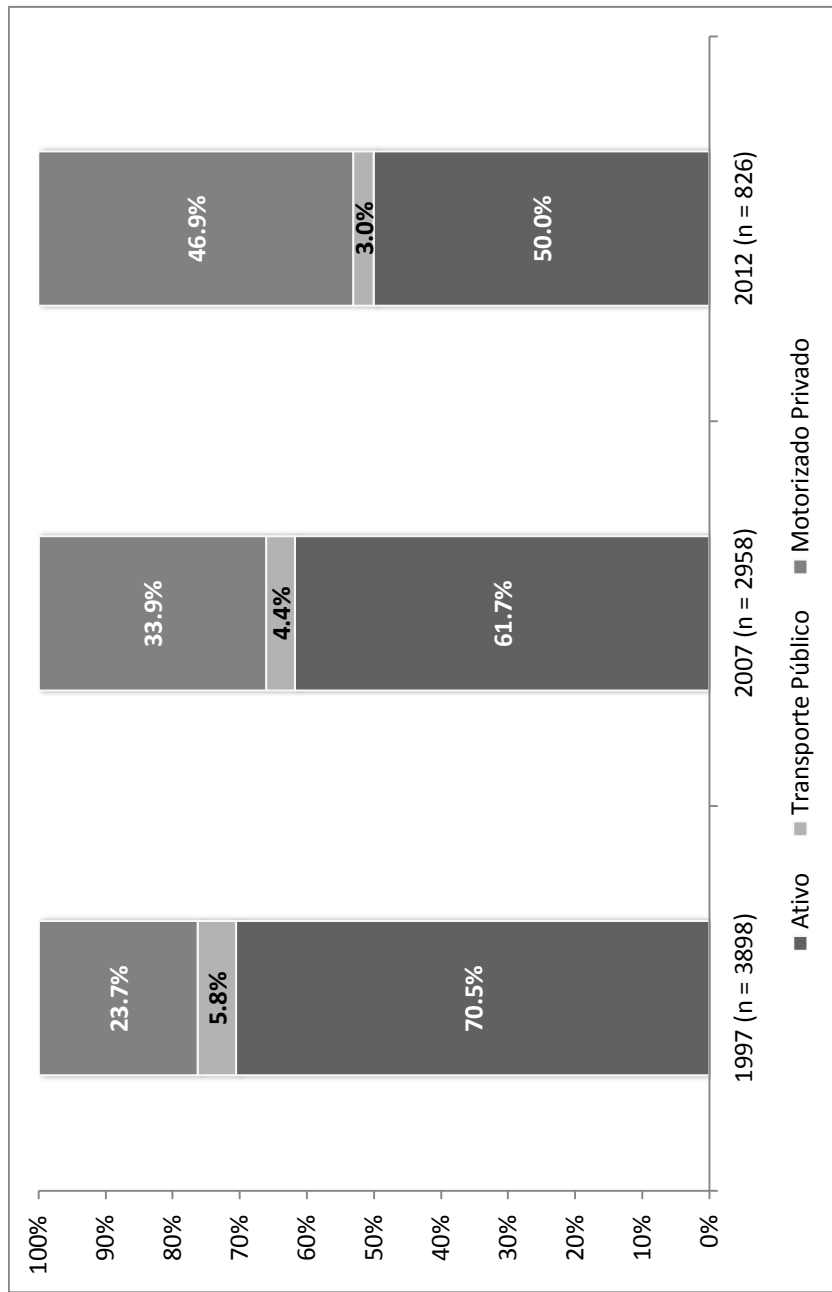
Apesar de existirem diferenças metodológicas entre as OD de 1997 e 2007 e a Pesquisa de Mobilidade de 2012, esses levantamentos nos parecem suficientemente comparáveis e capazes de prover estimativas do padrão de deslocamento da população da RMSP. Entretanto, o grande intervalo entre estas pesquisas, em contraponto à urgência de medidas para reverter esta tendência negativa, ilustra a necessidade de um sistema de monitoramento detalhado sobre o padrão de deslocamentos da população. Embora muito úteis para estudos em saúde pública, as OD têm propósito original distinto e apenas um planejamento multisetorial aprimoraria a coleta e uso das informações sobre mobilidade urbana e seus possíveis impactos na saúde pública.

Tabela 1. Detalhes sobre as pesquisas utilizadas para a avaliação da tendência de caminhada e uso da bicicleta nos deslocamentos para a escola. Região Metropolitana de São Paulo, 2016.

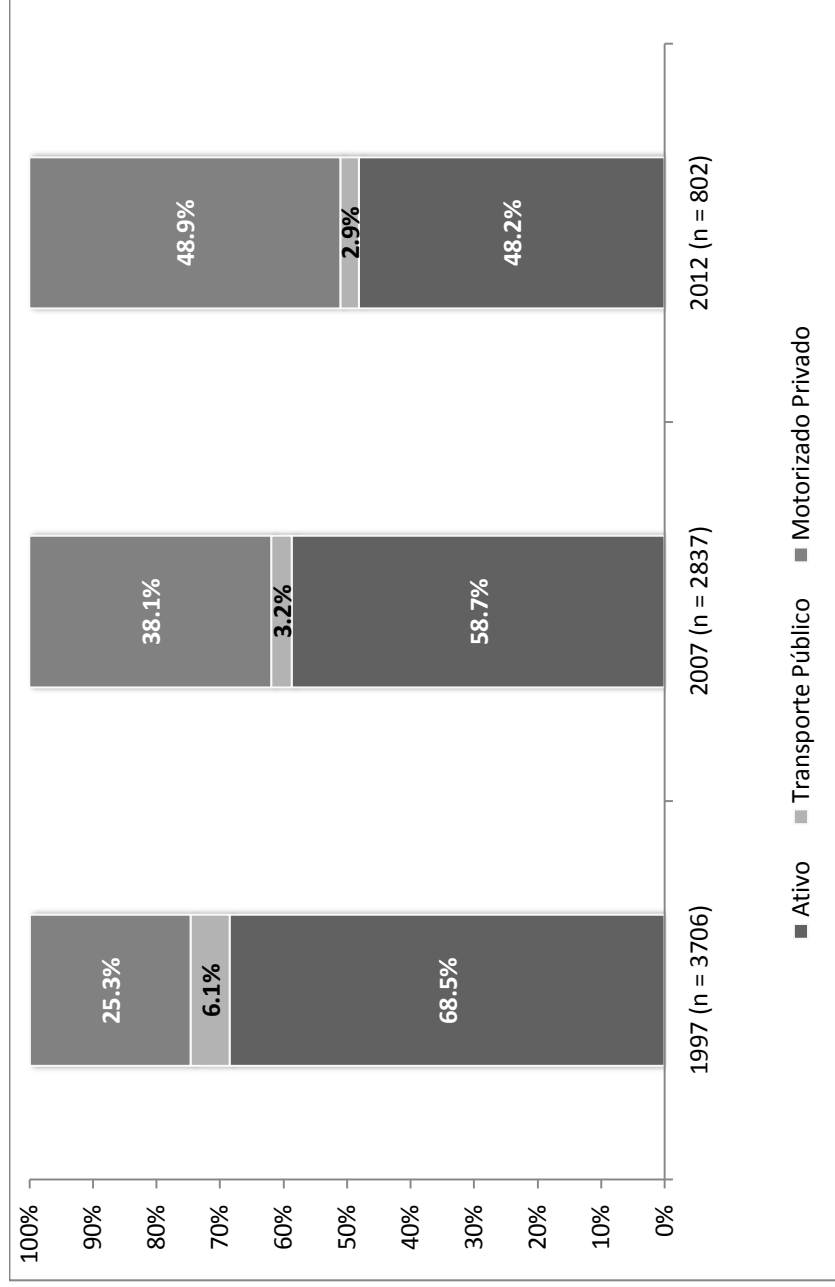
	1997	2007	2012
Nome da Pesquisa	Pesquisa Origem e Destino	Pesquisa Origem e Destino	Pesquisa de Mobilidade
Realização	Companhia do Metropolitano de São Paulo / Secretaria de Transportes Metropolitanos do Estado de São Paulo / Banco Nacional de Desenvolvimento Econômico e Social	Companhia do Metropolitano de São Paulo / Secretaria de Transportes Metropolitanos do Estado de São Paulo	Companhia do Metropolitano de São Paulo / Secretaria de Transportes Metropolitanos do Estado de São Paulo
População Estimada	16859712	19223930	19956590
Amostragem	Amostragem de domicílios, por conglomerado (zonas), estratificada pelo consumo domiciliar de energia elétrica, com reposição.	Amostragem de domicílios, por conglomerado (zonas), estratificada pelo consumo domiciliar de energia elétrica, com reposição.	Amostragem de domicílios, por conglomerado (zonas), estratificada pelo consumo domiciliar de energia elétrica, com reposição.
Total de zonas	389	460	31
Amostra total (domicílios)	98780 (26278)	91405 (29957)	24534 (8115)
Total de crianças (6 a 11 anos)	7604	5795	1628
Período de Coleta	1997	Agosto a novembro de 2007 e fevereiro a abril de 2008	2012
Estratégia de Coleta	Entrevistas domiciliares: questionário sociodemográfico + diário das viagens do dia anterior	Entrevistas domiciliares: questionário sociodemográfico + diário das viagens do dia anterior	Entrevistas domiciliares: questionário sociodemográfico + diário das viagens do dia anterior

Figuras 1a e 1b: Tendência temporal dos modos de transporte utilizados por crianças de 6 a 11 anos nos deslocamentos para a escola, RMSP, 1997-2012.

Meninos (1a)



Meninas (1b)



A piora observada na tendência também evidencia a necessidade de ações que estimulem o uso da caminhada, da bicicleta ou do transporte público para o deslocamento de crianças e adolescentes. Algumas iniciativas na região caminham nesta direção, como a isenção da tarifa para estudantes de escolas públicas nos serviços de transporte público estadual e de alguns municípios da RMSP, desde 2014. Em Londres, a isenção da tarifa para qualquer pessoa menor de 17 anos, implantada em 2005, contribuiu para aumentar em 26% o uso de transporte público entre os mais jovens, sem que tenha havido redução nos deslocamentos ativos ^{8,9}. A isenção da tarifa também normalizou o uso do transporte público e transformou a viagem de ônibus em importante espaço público de interação social para este grupo populacional ^{8,9}.

Outras ações têm o potencial de reverter a tendência observada na RMSP, como a revisão do Plano Diretor Estratégico do município de São Paulo e a elaboração dos Planos Municipais de Mobilidade Urbana, que têm como um dos princípios fundamentais a priorização do pedestre, do ciclista e do usuário de transporte público. Na contramão destas iniciativas, programas federais largamente responsáveis pelo aumento da motorização na região, como políticas de subsídio a veículos motorizados e programas habitacionais que reforçam a segregação espacial da cidade, seguem em curso. O real impacto destas iniciativas na motorização dos deslocamentos para a escola na RMSP só será melhor compreendido com o devido monitoramento e avaliação do impacto destas políticas à saúde pública ¹⁰.

Paralelamente aos planos citados, também é necessário um pacote de políticas e programas voltados especificamente para promoção e proteção da mobilidade a pé, de bicicleta ou por transporte público de crianças e adolescentes ¹⁰. A própria escola e a comunidade podem servir como elemento propulsor e lócus destas iniciativas, dada a evidência de efetividade da promoção de estilos de vida ativos a partir do ambiente escolar em regiões latino-americanas ¹¹. Um bom exemplo programa nacional consolidado de promoção da caminhada e do uso da bicicleta para a escola a partir do ambiente escolar é o *Safe Routes to School* (SRTS), iniciativa que envolve sociedade civil, escolas e governos, e que busca promover a saúde e qualidade de vida de crianças por meio do incentivo à caminhada ou uso de bicicleta para o deslocamento para escola (Nos Estados Unidos, desde 2005). Entre diversas ações, o SRTS examina as condições no

entorno da escola e desenvolve ações para melhorar acessibilidade e segurança, reduzir trânsito e a poluição e fortalecer o suporte comunitário aos deslocamentos ativos infantis. O SRTS apresenta evidências de efetividade no aumento da segurança ¹² e da caminhada ou uso de bicicleta para o deslocamento para a escola ¹³.

Os efeitos de longo prazo deste conjunto de ações podem ser observados no Japão, país que desenvolve uma “cultura de caminhada à escola” pelo menos desde 1953 ¹⁴. Algumas iniciativas se destacam, como a proibição da circulação de carros em zonas escolares durante o horário de entrada e saída de alunos, a forte participação comunitária e a educação das crianças desde o jardim de infância sobre noções de trânsito. Não por acaso, há raros deslocamentos para escola por modo motorizado (modos privados ou transporte público). A imensa maioria das crianças caminha, inclusive aqueles menores de oito anos de idade, sem o acompanhamento dos pais ¹⁴.

Exemplos como os citados acima devem ser adaptados à condição da RMSP e implementados para atenuar, e futuramente reverter, a tendência de motorização dos deslocamentos infantis. Para tanto, são fundamentais políticas integradas e ações multisetoriais, além da revisão e ampliação de programas já existentes, como o *Caminhos da Escola*, a fim de garantir o deslocamento seguro, independente e ativo de crianças para a escola.

Conclusão

No Brasil, é comum ouvirmos o discurso conservador de que “é preciso tirar as crianças das ruas”. Nosso entendimento é absolutamente distinto. A construção de uma cidade mais humana, justa e sustentável ³ passa por devolver não apenas as crianças às ruas, mas também seus pais, avós, amigos e vizinhos. São nas ruas que muitas das relações sociais e culturais acontecem e o deslocamento para a escola representa uma importante prática cotidiana da vida comunitária, com potencial para reinserção das crianças ao espaço público e à coletividade ¹⁰.

Agradecimentos

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Título: Aumento no uso de transporte motorizado privado no deslocamento das crianças para a escola na Região Metropolitana de São Paulo (1997- 2012).

Comunicação Breve – Material Suplementar

Tabela S1. Distribuição dos modos de transporte utilizados por crianças de 6 a 11 anos nos deslocamentos para a escola, Região Metropolitana de São Paulo, 1997-2012.

	1997 (n = 3898)	IC (95%)	2007 (n = 2958)	IC (95%)	2012 (n = 826)	IC (95%)
Meninos						
Ativo	70.5%	(68.2%; 72.8%)	61.7%	(59.1%; 64.3%)	50.0%	(46.2%; 53.9%)
Transporte Público	5.8%	(4.8%; 6.8%)	4.4%	(3.2%; 5.5%)	3.0%	(1.7%; 4.3%)
Motorizado Privado	23.7%	(21.4%; 25.9%)	33.9%	(31.4%; 36.4%)	46.9%	(43%; 50.8%)
Meninas						
Ativo	68.5%	(66.2%; 70.8%)	58.7%	(56%; 61.3%)	48.2%	(44.2%; 52.1%)
Transporte Público	6.1%	(5.1%; 7.2%)	3.2%	(2.3%; 4.2%)	2.9%	(1.5%; 4.3%)
Motorizado Privado	25.3%	(23.1%; 27.5%)	38.1%	(35.5%; 40.7%)	48.9%	(45%; 52.9%)

Manuscrito 5: Who has the right to the city? The example of transport and the case of São Paulo.

Título corrido: Right to the city in São Paulo.

Artigo original submetido ao periódico Transport Reviews.

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Abstract

This paper discusses the question about the right to the city and the implications of the dispute for the city to urban mobility, using Sao Paulo, Brazil's largest city, as a study case. We present the concept of the human mobility transition, which relates to the idea of large shifts in human mobility dynamics that have affected the constitution and development of urban settlements, the structure of the urban form, and the social network. We then argue that its latest stage is heavily influenced by the fact that cities have become both the arena for and the object of the political struggle between unsustainable economic growth and sustainable human development. Health consequences of the dispute for the city in the context of urban mobility are discussed. Final section uses the case of Sao Paulo to illustrate these arguments, focusing on changes that occurred from the end of the XIX century onwards.

Keywords: right to the city; transportation; city planning; urban health; human rights; Brazil.

Introduction

In June 2013, millions of people occupied the streets of over 100 Brazilian cities to protest against urban living conditions that jeopardize basic human rights (BBC News, 2015), such as the right to health, education, leisure, housing and freedom of movement (United Nations, 2015). Ultimately, our understanding is that they were claiming their right to the city, through democratic management, social organization,

and the full exercise of citizenship (Harvey, 2003; Sorensen & Sagaris, 2010). The current urban forms ⁵ of Brazilian cities, as of most of other cities around the globe (Brenner, Marcuse, & Mayer, 2009), are not random and are not natural. Predominately, they are the result of changes driven over the last century by powerful forces, including financial institutions, commercial corporations, and developers (Lynch, 1984; Vitali, Glattfelder, & Battiston, 2011), usually in partnership with the city authorities (Harvey, 2011; Jacobs, 2000; Sager, 2011). These forces work to modify and transform the urban form in order to fulfil their strategy to circumvent barriers to perpetual capital accumulation. This shapes everyday city life, almost always with a negative impact on quality of life, liveability, natural environment, and health (Jacobs, 2000; Karanikolos et al., 2013; Rydin et al., 2012; Sorensen & Okata, 2010).

This type of urban development and urbanization has become a key mechanism for capital reinvestment (Harvey, 2011), with social class segregation as the key mechanism to modify the urban form (Villaça, 1998). This seems to occur in all capitalist contemporary metropolises, being more visible or stronger in more unequal cities (Villaça, 1998). The concentration of money and power in private hands (Piketty, 2014; Vitali et al., 2011), enables the wealthiest institutions, corporations and individuals to dominate cities' political systems and thus to dominate people's everyday living, mainly through dispossession and debt (Harvey, 2011). In response to these forces, many social movements have emerged. They include the Healthy Cities, the World Social Forum, the Homeless People's Movement, the World Bike Forum, La Via Campesina, Occupy, and the Free Pass Movement. Internationally, there is a growing awareness and approximation of each movements' agenda and coordinated efforts, reinforcing the idea that "only a powerful social movement based on collective action at every level of society will deliver planetary health and, at the same time, support sustainable human development" (Whitmee et al., 2015), including in the urban context (Planetary Health (Whitmee et al., 2015) and Integral Ecology (Pope Francis, 2015) are concepts that

⁵Urban form is understood here as the "spatial arrangement of persons doing things, the resulting spatial flows of persons, goods and information, and the physical features which modify space in some way significant to those actions" (Lynch, 1984)(page 84)

highlight the strong interdependence between human health and human civilisation with flourishing natural systems).

The catalyst for the protests in Brazil in 2013 was the rise in the cost of public transport, however demonstrations were led by a network of social movements, not all directly dealing with transport issues (Harvey et al., 2013). This happened in a city with a long tradition of uprisings against the quality of the public transport system, in a country which was the first to include the right to the city in its Constitution in 1988 (UN-Habitat, 2010). The right to the city draws together many rights usually dealt with separately, working as a common cause for different and yet interlinked social determinants of healthy living (Sorensen & Sagaris, 2010). This paper focuses on the issue of mobility within the city, with special attention to Brazil's largest city, Sao Paulo, which with its suburbs in 2014 had approximately 20 million inhabitants.

Mobility transition

The re-creation of cities to promote the so-called urban advantage in health has to take into account the non-linear transitions that are occurring across urban settings, the mechanisms through which cities are being shaped, and the diversity and underlying tensions hidden within each of them (Harvey, 2003; Rydin et al., 2012). Since the urban form is strongly determined by human motion, understanding the constraints of human mobility is a key step to transform our cities. The current dispute for the city can be placed on the last stages of the human mobility transition.

The concept of the mobility transition relates to the idea of large shifts in human mobility dynamics that have affected the constitution and development of urban settlements, the structure of the urban form, and the social network. The economic, political and demographic forces driving the human mobility transition are also those promoting shifts in mortality, fertility and morbidity patterns, especially through changes in the everyday practices related to the diet, physical activity, energy use and environmental exposures. Since food and human movement are heavily interconnected, the mobility transition can be linked with the nutrition transition (Popkin, 1993) in many ways, providing an important framework to understand trends in human motion over history. Just as in the nutrition transition, the

pace of changes in mobility has accelerated in more recent decades through the actions of the powerful and wealthiest minority to privatize and 'commodify' everyday living. The mobility transition stages are synthesized in Figure 1 and briefly explored in the Box.

Its latest stage, which we call 'human urbanism', may be seen as a 'viable future' and relates to the changes observed in recent decades as a response to the failure of this acceleration and immobility condition, particularly in the urban context. Based on ideas such as the integral ecology (Pope Francis, 2015), '*buen vivir*' (Gudynas, 2011), planetary health (Whitmee et al., 2015) and human urbanism (Harvey, 2003; Harvey et al., 2013), this potential future seems an attempt towards more 'just' cities, with a renaissance of non-motorized modes, particularly walking and cycling, reductions in individual motorised modes of transport, development of renewable energy motorized modes and a global movement in favour of collective modes of transport. We will explore in further detail the mechanisms related to the two last stages of the human mobility transition as well as their health consequences in the next section.

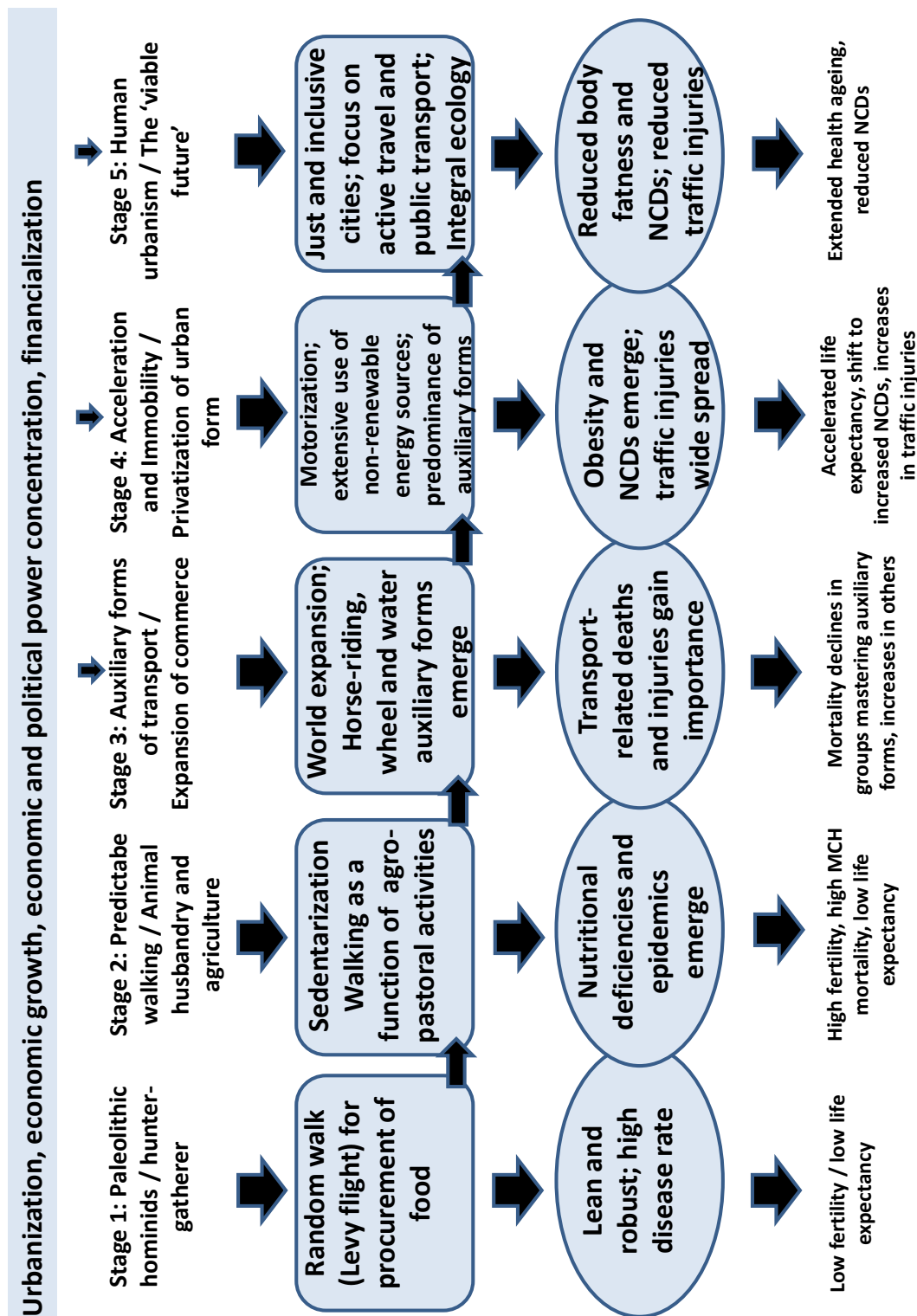


Figure 1: Stages of the mobility transition (adapted from Popkin, 1999)³³.

We will explore in further detail the mechanisms related to the two last stages of the human mobility transition as well as their health consequences in the next section.

Privatization of the urban form and its health consequences

Privatization of urban form

Travel is an intrinsic constituent of human beings, affecting the differentiation of our species (Kuliukas, 2002) and the genes we share today (Chakravarthy & Booth, 2004; Neel, 1962). Walking, the most ancient form of displacement, is simultaneously experienced as *“both biological embodied reality, and as socially constructed discursive activity, part of the symbolic repertoire at our disposal to communicate complex gendered, sexual, age, ethnic and sub-cultural identities”* (Green, 2009).

Liberty to travel has been understood as an imperative for the free development of a person⁶ and for full experience of urban advantages (UN-Habitat, 2013). From supranational (Dora et al., 2014; Haines, Alleyne, Kickbusch, & Dora, 2012) to street level (Harvey et al., 2013), changes in urban mobility in favour of active forms of travel and of universal public transport have been argued as vital for sustainable human development and for global health equity (Friel, Marmot, McMichael, Kjellstrom, & Vågerö, 2008). However, control of circulation through privatization of the urban form accelerating as from the past century has prevented the right to travel to the majority of the population living in cities.

The right to travel within the city is affected by the tensions between private interests and collective rights as the control of circulation is a determinant both for the capital reproduction and the realization of life. Impediments to travel include the following:

- Uncontrolled urban growth through housing and urban land speculation, leading to the continued expansion of slums and substandard housing to accommodate surplus of labour (Harvey, 2003; Sorensen & Okata, 2010; UN-Habitat, 2010; UN-HABITAT, 2012).
- Unregulated financialization of daily life including of home, city space and travel, leading to overreliance on individual responsibility, economic

⁶The Human Rights Declaration. [Accessed: Feb 03, 2015]
<http://www.un.org/en/documents/udhr/#atop>

disruptions and crisis. (Harvey, 2011; Karanikolos et al., 2013; Martin, Rafferty, & Bryan, 2008; van der Zwan, 2014).

- Unsustainable car-oriented transportation systems, unable to provide access to destinations for everyone, leading to inequity, injuries, pollution and economic inefficiency (Dora et al., 2014; UN-HABITAT, 2012; Vasconcellos, 1999, 2001).

Box 1. The mobility transition in human history.

Despite the challenges of characterizing the time-resolved location of individuals and populations in the past, the mobility transition throughout human existence can be understood in five broad stages: 1) Random Walk; 2) Sedentarization; 3) Auxiliary forms of transport; 4) Acceleration and Imobility; and 5) Human urbanism. Long before the development of *homo sapiens*, bipedality played a decisive role in the evolution of the first hominids (Kuliukas, 2002). In the first stages of human mobility, during the Late-Paleolithic era (50,000-10,000 BC), walking and running were the only forms of locomotion, much likely following a random walk pattern (Levy walk) (Raichlen et al., 2014), similar to that of other group mammals (Edwards et al., 2007; Viswanathan et al., 1999). The Levy walk pattern seems to optimize searching for, acquiring, processing, and transporting foods and is linked with variations in the availability of prey and gatherings (Edwards et al., 2007; Raichlen et al., 2014; Viswanathan et al., 1999). It might also have contributed to prevent the occurrence of epidemics although the Late-Paleolithic population would still suffer from high rates of mortality, mostly related to infectious disease. Even though conditioned by food availability, hunter-gatherers were able to move autonomously and relatively free to explore their surroundings (Raichlen et al., 2014). With the development of agriculture and animal husbandry (around 10,000 BC) (Wendorf & Schild, 1998), humans begin to settle, the first great wave of sedentarization of humankind (Tauger, 2011). Mobility becomes more predictable, influenced by place density and the number of intervening opportunities in a given area, although still strongly deterred by the costs (in time and energy) associated to physical distance. This sedentarization process brings famine, epidemics and endemic diseases, although with increases in fertility rates. At the same time, men and women became physically attached to their herds and crops.

Animal husbandry has not represented an immediate use of animal force for human mobility. Horse-riding – the first auxiliary form of transportation – was documented only 5,000 years later (around 4800 BC) in the steppe cultures in the centre of the Eurasian continent (Anthony, 2010). This new technology, together with a later development (around 3400 BC) of carts and chariots (the first wheeled vehicle designed for speed) allowed Proto-Indo-European speakers to overcome the boredom and isolation of grass steppes and the costs of physical distance in cattle management (Anthony, 2010). It also helped them to gradually wide spread their culture and language from India to Portugal (Anthony, 2010). Nevertheless, from that period until the end of the Middle-Age, auxiliary forms of human transport designed for speed, safety and convenience were almost exclusively for a minority of the population (the elite, the traders or the military personnel), a condition that remains throughout history until recently. Since distance-related costs reduce, human mobility becomes more dependent on the intervening opportunities in the journey, i.e., the number of opportunities between origin and destination able to satisfy the needs who gave rise to one's travel (Stouffer, 1940). Auxiliary forms of travel contributed for the elimination of many nutritional deficiency diseases as well as the dissemination of infectious diseases worldwide due to the ability to transport food and pathogens over large distances, especially after the development and expansion of maritime auxiliary forms. These have led to important mortality declines among populations who mastered auxiliary forms of transportation followed by striking mortality increases (in many cases, the complete extinction) among those who did not.

Dispossession from rural land first in Britain (Thompson, 1963) (most intensive in the 19th century) and in different parts of the world created a landless working surplus – providing the human workforce for the Industrial Revolution – who migrated to cities, accelerating urbanization (Thompson, 1963). The challenges of human mobility in this new environment (Virilio, 1986), intrinsic to the new economic system (Harvey, 2011), contributed to the development of motorised forms of transport, initially mass transit by road and rail and later by individual motorised modes. The bicycle also improved considerably along the 19th century to function as an auxiliary form of transportation more suitable for the modern urban environment, enabling increasing speed for individuals (Herlihy, 2006). Despite the fact that human mobility pattern in the urban context remains determined by place density and intervening opportunities (Noulas, Scellato, Lambiotte, Pontil, & Mascolo, 2012; Stouffer, 1940), the dissemination of motorised forms of transportation made auxiliary travels predominate in human mobility for the first time in history. It transformed mobility, with people moving less, in terms of movement and energy expenditure, and moving more and faster, in terms of displacement. Another novelty present in the Acceleration and Imobility stage is the reliance on non-renewable energy sources, namely fossil fuels, unlike traditional energy sources previously adopted, such as human and animal traction or natural forces (winds and sea currents, mainly). On the other hand, the inequality between those without access to the most technologically advanced auxiliary forms of transport and those with access were perpetuated in the urban context, with traffic-related morbidity and mortality rates strikingly higher among pedestrians, many of whom lacked other option to travel except for walking.

These all result from the commodification of cities – the conversion of cities to places for consumption and places to be consumed, undermining their social function. The spatial flows in the modern city are orientated around the use of motor vehicles, particularly private cars as they provide the speed necessary for capital accumulation both as a mode of transport, accelerating movements of goods and workers, and as a high added value product in a complex industrial chain. They also create the need for costly and complex urban interventions, such as roads and viaducts, through which surplus capital can be allocated. A hierarchy of daily travellers has long been established, with the wealthiest at the very top and the most deprived at the bottom. (UN-HABITAT, 2012; Vasconcellos, 1999, 2001) Public transport systems have been historically developed as ways for workers to commute – not necessarily to access the advantages of urban life (Harvey et al., 2013; UN-HABITAT, 2012; Vasconcellos, 1999, 2001). Cities have become a collective means of constant consumption, including the consumption of travel, with the cars as a social symbol of status. This is part of an ideology committed to systematic promotion of dispossession of public goods (Freudenberg, 2014). It changes the idea of the city, undervaluing its nature as a space for human exchange and replacing it as a space for the circulation of capital, both as supply and workforce (UN Habitat, 2013).

Health Consequences

The privatization of urban form in the last century has involved accelerated transition from non-motorised to motorised modes of transport. As cities commodify, daily mobility becomes increasingly dependent on an ability to pay for faster modes or for well-located homes. Those without such resources are forced to live farther out and to reallocate time from other daily activities to commuting, increasing their exposure to environmental pollution and traffic violence as well as disrupting their travel time budget and thus their everyday life (Metz, 2008; Mokhtarian & Salomon, 2001). Those able to afford their own cars or motorcycles spend a lot of time in traffic, losing the opportunity of physical activity and interaction with the urban environment. Thus people at all levels of resource and vulnerability suffer an environmental burden and also health problems. Hence, we now experience a double burden of problems related to transport in both extremes at a high human cost, a pattern similar to

several other contemporary health challenges, such as in the epidemiological and nutrition transitions.

The double burden of disease in the nutrition transition provides a powerful analogy for the corporate role in the production of health harms in the urban mobility context. Through their policies and practices, corporations have gradually increased the burden of obesity, first affecting the more affluent sectors of society, while under-nutrition remained a problem for the largest share of the population (Moodie et al., 2013; Swinburn et al., 2011).

Reductions in production costs given to technological advances and work exploitation, and increased awareness of the health damaging effect of these products in the original consumers, has pushed companies' marketing and retailing strategies towards the more vulnerable in such a way that obesity and undernutrition now coexist in several places worldwide. Similarly, major corporations in the car, oil, finance, media, construction and real estate sectors have had a decisive role in the shift in the transport profile of cities in the last century, from active travel to individual motorized modes of transport. The shift first occurred in the wealthiest segments of the population although, unlike in the nutrition transition, it affected simultaneously everyone as increases in car use represented an immediate increase in environmental pollution and traffic injuries for the vulnerable segments of society.

Just as with ultra-processed food and drink products, in rapid developing countries like Brazil, China and India, there is a striking increase in motorcycle (and car) use among the poorer segments of the population, causing higher levels of exposure to environmental hazards and lower levels of physical activity through daily commuting. For instance, motorcycling is, at the same time, an efficient, comparatively cheap way to overcome the large distances imposed by spatial segregation against poor and a particular damaging behaviour as it combines all the health harms above mentioned. Even though motorisation has reached new segments of the population, it did not necessarily represent a choice in urban mobility for them. At the same time, there is a reverse trend in driving, licensing and car ownership followed by increases in cycling in some population subgroups with more freedom to move within and across urban settings, starting in places like Denmark

and Holland in the 70s and later in other places such as Australia (Healy, Catchpole, & Harrison, 2012), Germany (Kuhnimhof, Buehler, & Dargay, 2011) and the United Kingdom (Kuhnimhof et al., 2011).

Finally, the 'acute' health consequences of the dispute for the city must also be taken into account. For instance, hundreds were injured in the protests of June in Brazil (mostly from police violence) and at least 13 were dead, 8 of which in direct conflicts between vehicles and protesters during street occupations ⁷.

All of the issues mentioned above are common to cities throughout the world. São Paulo is given as the case study in the next section, looking at the historical context of this mega-city, as well as recent changes in its urban form with direct influence in human mobility and the right to travel. The influence of historical conditions and policy decisions described below on shaping the city and its surroundings may be seen in different ways, of which the study below is one.

The case of São Paulo

Founded in 1554, São Paulo remained a relatively small city until the end of the 19th century, with a population of around 60,000 people in 1889, the year of the proclamation of Brazil as a republic. In 1900-1901 the first electric trams and the first municipal train station were installed⁸, a privilege for few people on those days. The pedestrians were mainly freed slaves who had the city streets as their territory (Fernandes, 2013; Rolnik, 1989). This retained the sense of inferiority in walking following the previous rural context; one more inheritance of Brazilian slavery culture (Fernandes, 2013).

In the following decades, the inner and a new outer city grew very fast, driven by the rise in the coffee industry and then other forms of industrialization. External migration, especially from European countries, was heavily promoted by the local and federal governments in an attempt to 'improve' and 'regenerate' the Brazilian people. (Diwan, 2007) (In 1920 one third of São Paulo residents were foreigners ^f).

⁷ Deaths in Brazil's protest in 2013: <http://midia independente.org/pt/red/2014/02/528893.shtml>

⁸Demographic History of São Paulo, Prefeitura de São Paulo:
http://smdu.prefeitura.sp.gov.br/historico_demografico/introducao.php

The black and admixed people living in well-located but poorly constructed slums were expelled in favour of migrants from Europe and elsewhere, and were in effect forced to live in a peripheral 'poverty belt' round the city (Rolnik, 1989) which still exists and continues to grow.

In this period there was intense debate and dispute on the principles underlying the development of the first city urban plans. These were needed to resolve problems partially derived from rapid urban growth, such as floods, infectious disease outbreaks, and increased traffic. Modernist and futurist ideas prevailed, with strong support from the fast expanding car industry. Francisco Prestes Maia (later São Paulo mayor), set out the master plan in his *Plano de Avenidas* (Plan of Avenues). This was inspired by the spectacular radial concentric master plans imposed on some major European cities, but with very troublesome exceptions. Rail and river transport was neglected. Rivers became increasingly polluted and in effect dead, parks, river valleys and green belts were ignored – most of the rivers were buried to give room for new avenues. The *Plano* marked the shift from rail to road transport and from public shared to private individual transport, with perpetual support for cars and motorists over other street users, and priority given to circulation over all other daily activities in public space.

This pro-private ideology was continued by successive administrations and intensified during the 1964-1985 military regime, reinforcing the idea of a 'middle class city' (Rolnik & Klintowitz, 2011; Vasconcellos, 2014), in which "the elite and the middle classes remain prisoners to their concept of life – clearly expressed in the growth of isolated, high-quality residential clusters while the poor and captive users of public or active transport struggle to survive" (de Vasconcellos, 2005). São Paulo reached nearly 6 million residents in 1970, after massive migration in the previous decades from less industrialized and more impoverished Brazilian regions. Between 1977 and 1997, ability to travel in the city became much harder for the poorest part of the population, with dramatic increases in the monthly cost of transport (from 9% to 41% of the minimum wage), reductions in public transport infrastructure (from 34 to 25 km/10 million population) and constant growth of peripheral slums. This contributed for more people walking (from 26% to 35% of all trips between 1977 and 1997) (de Vasconcellos, 2005) and also for high levels of traffic deaths of around 25

deaths per 100,000 residents, mostly of pedestrians (de Vasconcellos, 2005). In 2002, for the first time, private transport (53%) surpassed public transport (47%).

In recent decades some attempts have been made to address these crises. These include plans for public transport expansion and interconnection, bus and rail fleet renewals, and dedicated lanes for buses. However, São Paulo faced continuous delays in the expansion of the railway system by the state government. Moreover, public transport fares continued to rise above inflation whereas rises in expenditures for private travel (including acquisition and maintenance) were three times smaller than inflation between 2001 and 2012 (Carvalho et al., 2013). Federal programs and policies to address the global and financial crisis through increases in internal consumption also contributed to maintain vehicle dependency – for instance, tax breaks for car purchase contributed to an 18 per cent increase in cars in Sao Paulo between 2007 and 2012 (against a 2% increase in the population). Despite bringing evident improvements to the quality of life of the poor, now able to overcome the spatial segregation of the city, this Federal initiative – strongly influenced by car corporate – was a lost opportunity for the development of a more sustainable city.



Figure 2 - The latest stages of the mobility transition in São Paulo. In the first picture (above), São Paulo city centre at the end of the 19th century, with public space still shared by different forms of transport although auxiliary forms (still non-motorized), such as the chariot, exclusive for the rich. In the second picture (below), São Paulo at the beginning of the 21st century, with public space dominated by private motorized auxiliary forms of transport (AbovePhoto: Marc Ferrez; Below Photo: Oswaldo Corneti/ Fotos Públicas).

There has been some recent improvements in the bicycle and walking infrastructure, traffic-calming policies, and open street programs implemented, driven by the political agenda of the Municipal government. There has also been a slowdown in public transport fare rises, mainly forced by the protests of 2014. The city's Master Plan, including its Urban Mobility Plan, emphasizes the priority for pedestrians, cyclists and public transport users as well as the social value of property (Prefeitura de São Paulo, 2014). However, these initiatives do not amount to a shift in the ideology that favours private advantage over public goods, nor to human mobility conditions. The extent to which they will help to reverse negative health trends remains to be properly evaluated. Some of those trends include rises in obesity, reductions in active transport and in outdoor physical activity practice (de Sa, Garcia, & Claro, 2014; Schmidt et al., 2011), and the persistence of high levels of air pollution (Bell, Davis, Gouveia, Borja-Aburto, & Cifuentes, 2006) and traffic injuries (Companhia de Engenharia de Tráfego, 2012).

The current dispute for the city in São Paulo, of which the dispute for the right to freedom of movement summarised here is a leading example, illustrates tensions in the latest stages of the human mobility transition and its health consequences. Rather than a situation restricted to a given period and place, these stages of the human mobility transition and the tensions arising from the dispute for the city continue to illustrate the condition of different geographic and socioeconomic subpopulations around the globe (Brenner et al., 2009).

Conclusions

Cities round the world are divided, fragmented and prone to conflicts. They have become both the arena for and the object of the political struggle between unsustainable economic growth and sustainable human development (Harvey et al., 2013; Lynch, 1984; Sorensen & Okata, 2010). At the same time, since cities are the most radical experience of humankind into transforming its own reality, in ways that transform men and women and their families themselves, any discussion around the cities we want for the future is now intrinsically linked to the question of which society we aspire to become (Harvey, 2003). The right to the city goes beyond the individual

right to access its resources and advantages (UN-Habitat, 2010). It is a collective right to transform ourselves by transforming our cities upon the exercise of a collective power on the process that recreate the urban form to support human capabilities (Commission on Social Determinants of Health, 2008; Harvey, 2003; Lefebvre, 2001), and which improve and protect health and well-being. The 'viable future' that emerges from this new urban politics is neither determined nor necessarily positive but a result from the political struggle. At least in São Paulo, the effects of the demonstrations of June were largely in favour of healthier and more sustainable transport system, from the immediate effect of reversing raises in the public transport fare, to the impulse in the prioritization of urban mobility in the political agenda. This impulse contributed to the creation of new mechanisms for social appropriation of the public space, financial investments to facilitate non-motorized transport and enhance public transport quality, stronger efforts to tackle corruption and demand transparency in future transport contracts, and direct social participation in the development of policies, such as the São Paulo City Urban Mobility Plan.

Disclosure Statement

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Manuscrito 6: Impact of travel mode shift and trip distance on active and non-active transportation in the São Paulo metropolitan area, Brazil.

Título corrido: Impact of travel changes in São Paulo, Brazil.

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Abstract

Background: changes in urban mobility play a major role in transforming metropolitan areas into healthier places. This study quantified the impact of changes in travel mode shift and trip distance on active and non-active transportation of working age adult population of São Paulo. **Methods and Findings:** through different scenarios, we estimated the daily time spent in transportation per inhabitant (divided in active and non-active transportation time) and the proportion of inhabitants accumulating 30 minutes or more of daily active transportation. The replacement of individual for collective motorized modes in long distance trips (>1000m) in combination with the substitution of long for short trips positively impacted all outcomes. Compared to the current situation, there was an increase in the active transportation time (from 19.4 to 26.7 min/inhabitant), which also increased the proportion of adults active for transportation (from 27.6% to 35.4%). Additionally, the non-active transportation time decreased (from 67.0 to 26.2 min/inhabitant), which helped to reduce the total time spent in transportation (from 86.4 to 52.9 min/inhabitant). **Conclusion:** Transport and urban planning policies to reduce individual motorized trips and the number of long trips might produce important health benefits, both by increasing population levels of active transportation and reducing the non-active and the total time of daily trips.

Introduction

Between the 1950s and 1990s, Latin America faced a rapid and chaotic process of urbanization. This led to a current urbanization rate of almost 80% and the creation of large metropolitan areas, also known as megacities, such as Mexico City and São Paulo (UN-HABITAT, 2012). Urban mobility in these cities became reliant on individual motor vehicles, which led to environmental degradation of the natural and built environment and deterioration of public transport systems (Vasconcellos, 2001; WHO, 2011). This process increased social inequalities and created many health impacts still to be resolved (UN-HABITAT, 2012). Poor urbanization also reduces the access and opportunities for employment, education, protection from environmental risks, public services use, and other determinants of well-being (Commission on Social Determinants of Health, 2008). Thus, urban mobility improvements are needed to improve urban life and to tackle the burden of non-communicable diseases (Rydin et al., 2012; WHO, 2011).

Urban mobility, which is influenced by transport and land use planning, plays a direct role on health through daily travel time and travel modes (Hoehner et al., 2012; Stone et al., 2014). Poor urban mobility, such as that of the São Paulo Metropolitan Area, leads to longer trips in daily transportation, two thirds of which are non-active forms and involve either sitting or standing in private or public transportation vehicles (Companhia do Metropolitano de São Paulo, 2008). In this sense, transport and urban planning are closely related to physical activity, free time and sedentary behavior.

Although changes in urban mobility present great potential for increasing population levels of physical activity (Hoehner et al., 2012; Pratt et al., 2012), health-oriented modifications might be challenging. For instance, while increasing walking trips is a health-promoting strategy, long trip distances pose a significant barrier to achieve this goal (Hoehner et al., 2012). While distance is less of a problem for cycling in comparison to walking, there are several barriers of the urban environment in the context of Latin American cities (Mosquera et al., 2012), including high risks of traffic accidents and injuries (Garcia et al., 2013). Therefore cycling might still not be a feasible option for a significant proportion of people, particularly for women (Mosquera et al., 2012).

From the health effect point of view non-active transportation can be seen as a lost opportunity for physical activity and it can also impact health through sedentary

behavior. Non-active transportation can be seen as a proxy of sedentary behavior, an independent risk factor for obesity and abdominal obesity (Mummery et al., 2005). Longer commuting times, commonly found in large cities, have been associated with lower cardiorespiratory fitness and higher metabolic risk (Hoehner et al., 2012). Also, people who spend a large amount of time sitting in traffic have been found to display a lower sense of community and higher social isolation (Hart and Parkhurst, 2011). This is particularly problematic for Sao Paulo, where people spend an average of 1.6 hours per day in traffic (Rede Nossa Sao Paulo, 2013). Changes in transport and urban planning have to take into account this complex context in order to achieve a better balance that favors active transport and minimizes both non-active and total daily travel time, while considering the urban environment of large Latin American cities. Modelling these changes allow us to create alternative hypothetical scenarios that can help to determine the best-case alternative for the promotion of active travel and reduction of trip distance. Although not originally designed for health purposes, household travel surveys are a reliable but underused source of information that can provide input for time replacements in the transport context. Some studies have used travel surveys to study transportation and health outcomes (Maizlish et al., 2013; Rissel et al., 2012; Rojas-Rueda et al., 2012; Woodcock et al., 2009; Woodcock et al., 2013). To address this knowledge gap, we explored the impact of travel mode changes and trip distance on total travel, active transportation, and non-active transport time in working age adult population living in the São Paulo metropolitan area. For this aim we modelled three scenarios using information from the São Paulo Metropolitan Area Household Travel Survey.

Methods

Data source

The main data source of this study is the São Paulo Metropolitan Area Household Travel Survey (HTS), an on-going household travel survey carried out by the transportation sector every ten years. The 2007 HTS was conducted from August 2007 through April 2008 comprising the 39 cities of the São Paulo Metropolitan Area (hereafter, São Paulo), the largest metropolitan area of South America (19,161,048 and 20,128,227 inhabitants in 2007 and 2013, respectively) (SEADE Foundation, 2014).

The sampling plan of the HTS followed a complex and stratified design to produce estimates representative of the São Paulo population. The sampling strategy was based on the roll of electricity consumers of the city electricity companies, which covers more than 98.4% of the area's population (IBGE, 2011). To select the households, the São Paulo territory was divided into 460 traffic analysis zones, which were contiguous and compatible to the administrative boundaries of the metropolitan area, its cities and districts. The criteria to define the zones also took into account the trip generation and attraction, the transport and road structure, land use characteristics, and the existence of physical barriers and open areas. Each zone was used to randomly select the primary study unit (household) according to three levels of electricity consumption - a proxy for number of individuals in the household and income. For both years, each zone had its sample size calculation, with a total sample size target for São Paulo of 30,000 households.

In order to accomplish this sample size target, 54,571 households were visited (26.4% were either not a family residence, closed or empty household; 17.5% refused to participate; and 1.1% did not have information from all residents). In case of not valid household, another household from the same zone and level of energy consumption was randomly selected. HTS data was weighted to adjust for the selection probabilities at the individual level and to make the sample representative for the study area. The full HTS provides a comprehensive source of data for 29,957 households, 91,405 people, and 169,665 trips.

Data from HTS were obtained and recorded in a standardized manner for every household member through face-to-face interview on a weekday. Household-level data included number of families and residential location. Family information included number of members in the household, residence ownership, and number of house goods, including bicycles and vehicles. Individual-level data included age, gender, education, employment status, income, and place of work and study. Trip-level data is related to one-way trips undertaken on the day before the interview and includes origin and destination, travel mode, number of times one shifted the mode of transport, mode shift places, purpose, distance, and time of departure and arrival.

We used only information for working age adult population (age ≥ 18 y and ≤ 59 y), from a sample of 56,428 people. Out of the 116,947 trips performed by these people, 989 trips were removed due to lack of information about distance, with a remaining sample of 56,261 people and 115,958 trips. Data analysis was conducted

in 2013. Approval to conduct the research was obtained from the School of Public Health Ethics Committee (University of São Paulo).

Trip characteristics definitions

Trip duration was calculated from the difference between the arrival time at destination and the departure time at the origin. We calculated trip distance on the Google Maps street-network database using the trip origin and destination geographic coordinates. We considered short trips those with a distance shorter than or equal to 1000 meters ($\leq 1000\text{m}$). Mode of travel was defined as the type of transport used in each trip or trip segment. Active transportation modes were walking and cycling; individual motorized modes were car, motorcycle, and taxi; and collective motorized modes were subways, trains and buses. Purpose was determined based on the purpose of the trip's destination. If the destination was returning home, then purpose was based on the trip's origin. We considered three trip purposes: work, school, and others (shopping, health, leisure, looking for job, and personal errands).

Outcomes

Daily time spent in active transportation per inhabitant: sum of all individuals' hours spent walking or cycling in every trip (could be zero or the entire trip) divided by the total number of individuals in the population, including those who did not travel on the day before the interview;

Daily time spent in non-active transportation per inhabitant: sum of all individuals' time spent in motorized trips or trip segments divided by the population, including those who did not travel on the day before the interview;

Daily time spent in transportation per inhabitant: sum of the two previous indicators, i.e., the sum of the time spent in transportation divided by the entire population;

Proportion of working age adults active in transportation: proportion of individuals that accumulated 30 minutes or more of walking/cycling regardless of trip segment duration.

Creating the scenarios

Using the routine data from the HTS, we developed three scenarios for São Paulo and compared them to the real situation in 2007. The algorithms used for this calculation were the following:

Where t is an individual's trip time and T is the accumulated person time,

$$T_{\text{total/inhabitant}} = \sum (T_{\text{active}} + T_{\text{non-active}}) / N_{\text{inhabitants}}$$

where

$$T_{\text{total}} = T_{\text{active}} + T_{\text{non-active}}$$

$$T_{\text{active}} = \sum (t_{\text{active}}); t_{\text{active}} = t_{\text{walking}} + t_{\text{bicycling}}$$

$$T_{\text{non-active}} = \sum (t_{\text{non-active}}); t_{\text{non-active}} = t_{\text{individual motorized mode}} + t_{\text{collective motorized mode}}$$

In the first scenario (Scenario 1), the impact of the substitution of any motorized mode of travel by walking on short trips ($\leq 1000\text{m}$) was explored. For that, we recalculated the trip duration by multiplying its distance with the average walking speed of 13.3 min/km (approximately 4.5 km/h) (Ainsworth et al., 2011). Walking was the chosen active mode for substitution in all scenarios because it is a more feasible mode of transport for all populations when compared to cycling, and has an average speed that is less dependent on environmental conditions, such as slope.

Scenario 2, in combination with scenario 1, explored what would be the impact of the substitution of an individual motorized mode of travel by a collective motorized mode on long trips ($> 1000\text{m}$). For that, we assumed individuals would accumulate the mean time of active transportation associated with long-distance collective motorized trips per each individual motorized trip replaced. Also, we calculated the new total trip duration by adding the mean difference in total duration of collective motorized trips compared to individual motorized trips according to deciles of trip distance, since the mean difference in total trip duration between individual and collective motorized trips increases with longer travelled distance.

Finally, scenario 3, in addition to scenarios 1 and 2, focused on the impact of the substitution of 50% of long trips by short trips, as could be done in a more compact city where origins and destinations were closer to each other. For that, we considered that individuals would have an increase of 0.97 minutes in active transportation per each long trip replaced, since this is the difference between the mean active transportation time accumulated in long and short trips. To calculate the new mean total duration, we added, for each trip replaced, the difference in mean

total duration between collective motorized long-distance trips and walking short-distance trips. We have to note that, on scenario 3, after all the substitutions, no trip is now made using an individual motorized mode, whether they are short or long-distance trips. Thus, scenario 3 should be viewed as best case or maximum impact scenario which requires large changes in the location of residential and work places inside the city.

In our study, we assumed that everything else on São Paulo mobility patterns would remain stable except for what had been modified in the scenarios. We also assumed no synergy among the proposed changes.

Statistical analysis

Analyses were performed to describe the distributions of participants' sex, age, education and the presence of cars, motorcycles and bicycles at home, with their corresponding 95% confidence intervals (95% CIs). Descriptive analysis of the trips was also performed, identifying the frequency and distribution of trips according to trip characteristics (mode, purpose and distance), as well as median duration of the complete trips and median duration of the active segment (segment done by walking or cycling) of the trips with their respective interquartile range (p25 – p75). Data analyses were carried out using the STATA statistical package, version 12.0 (StataCorp, College Station, TX, USA), considering survey's weighting factors.

Results

Population and trips characteristics

The working age adult population São Paulo in 2007 was mostly female (53.0%). More than half of the sample completed at least high school level education (56.0%) (Table 1). Of that population, 72.3% of adults reported traveling on the reference day. The median number of trips performed per adult per day was 2 (interquartile range: 0 – 2), same as for the number of motorized trips (2; 0 – 2). The median number of trips with at least 10 minutes of walking per adult per day was 0 (0 – 1). The median distance accumulated in all trips per adult per day was 9.9 km (0 – 32.5).

Table 1. Sociodemographic distribution estimates^a of the adult population in the São Paulo Metropolitan Area (SPMA). Household Travel Survey (n=56261), August to November 2007 and February to April 2008.

Sociodemographic characteristics	SPMA 2007		
	%	CI (95%)	
Sex			
Male	47.0	46.6	47.4
Female	53.0	52.5	53.5
Age (years)			
18 – 24	19.5	19.0	20.1
25 – 34	27.0	26.2	27.7
35 – 44	23.2	22.5	23.8
45 – 54	21.7	21.1	22.3
55 – 59	8.6	8.1	9.1
School Grade			
No schooling or incomplete Elementary schooling	8.8	7.7	9.8
Elementary schooling/	16.8	15.9	17.6
Middle schooling	18.5	17.8	19.2
High schooling	42.4	41.3	43.5
Graduate schooling	13.6	12.2	14.9
Car at home			
None	44.7	42.9	46.5
One	40.5	39.2	41.8
Two or more	14.8	13.5	16.1
Motorcycle at home			
None	90.4	89.6	91.2
One	9.0	8.2	9.7
Two or more	0.6	0.5	0.8
Bicycle at home			
None	62.0	60.7	63.3
One	27.0	25.9	28.1
Two or more	11.0	10.2	11.8

^a Estimates based on sampling weighting factors.

Table 2 describes characteristics and duration of trips. Moreover, short-distance trips were mainly accomplished by walking (83.4%) or in individual motorized modes (14.0%), while long-distance trips were mainly completed in collective and individual motorized modes (47.8% and 38.9%, respectively). Cycling accounted for 1% of trips in both short and long-distance trips. Only 12.5% of trips to work and 31.5% of trips to school were short.

Impacts on daily time spent in transportation per inhabitant

In scenario 1, we quantified the impact of the substitution of any motorized mode by walking in short trips. This replacement had small impact on active, non-active, and total daily time spent in transportation per inhabitant (Table 3). Therefore, the proportion of adults engaging in active transportation remained stable compared to the real situation (increased 0.2 percentage points – pp).

In scenario 2, the additional replacement of individual by collective motorized modes in long trips largely increased the daily time of active transportation per inhabitant (6.7 minutes or 34.2% increase), which positively influenced the proportion of adults active through transportation (7.4 pp or 26.6% increase). However, this scenario also increased daily total and non-active transportation time per inhabitant (14.3 minutes or 16.6% increase and 7.6 minutes or 11.4% increase, respectively) (Table 3).

Table 2. Characteristics^a and duration of trips performed by adults in the SPMA according to trip mode, purpose and distance. Household Travel Survey (n=115,958), August to November 2007 and February to April 2008.

Trip characteristics	Trips (n)	%	Total median duration (minutes)	p25 – p75	Median duration of the trip's active stretch (minutes)	p25 – p75
Mode						
Predominantly collective motorized ^b	38,733	40.2	60	40 – 95	10	7 – 17
Predominantly individual motorized ^c	48,900	34.5	25	15 – 40	2	0 – 2
Exclusively cycling	1,089	1.0	20	15 – 30	20	15 – 30
Exclusively walking	27,236	24.3	15	10 – 20	15	10 – 20

(Continue Table 2)

Purpose							
Work	66,412	60.1	40	20 – 75	7	2 – 15	
School	22,227	19.3	20	10 – 40	10	2 – 15	
Others	27,319	20.6	30	15 – 50	5	2 – 15	
Distance							
≤ 1000 meters	96,217	16.8	10	5 – 15	5	10 – 15	
> 1000 meters	19,741	83.2	40	20 – 70	7	2 – 15	
Total	115,958	100.0	30	15 – 60	7	2 – 15	

^a Estimates based on sampling weighting factors.

^b Includes trips in which the larger stretch was performed by the following modes: bus, microbus, school bus, metro or train.

^c Includes trips in which the larger stretch was performed by the following modes: car (driver or passenger), motorbike and taxi.

^d Part of the trip performed by walking or bicycling.

Table 3. Indicators of transportation in the real situation and in the three alternative scenarios for the adult population of the SPMA. Household Travel Survey, August to November 2007 and February to April 2008.

	Active through transportation ^a	Daily time of transportation / inhabitant	Daily time of active transportation / inhabitant	Daily time of non-active transportation / inhabitant
	% (CI 95%)	Minutes (CI 95%)	Minutes (CI 95%)	Minutes (CI 95%)
Real Situation	27.6 (26.5 to 28.6)	86.4 (83.9 to 89.1)	19.4 (18.8 to 20.0)	67.0 (64.5 to 69.5)
Scenario 1 (Substitution of short-distance ^b individual motorized trips by walking)	27.8 (26.8 to 28.9)	86.2 (83.5 to 88.9)	19.6 (19.0 to 20.3)	66.4 (63.9 to 98.9)
Scenario 2 (Scenario 1 + Substitution of long-distance ^b individual motorized trips by collective motorized trips)	35.2 (34.1 to 36.4)	100.4 (97.7 to 103.1)	26.3 (25.6 to 27.0)	74.0 (71.4 to 76.5)
Scenario 3 (Scenarios 1 and 2 + Substitution of 50% of long trips by short trips)	35.4 (34.2 to 36.5)	52.9 (50.7 to 55.2)	26.7 (26.0 to 27.4)	26.2 (23.9 to 28.5)

^a Adults aged 18 to 59 years old which accumulated 30 minutes or more in walking or bicycling trips.

^b Short trips: ≤1000m; Long trips: >1000m.

Finally, in scenario 3, the combination of the two previous scenarios along with the substitution of 50% of long by short trips positively impacted all outcomes. The increase on the daily time of active transportation per inhabitant did not change from scenario 2 to scenario 3, which helped to maintain the level of active adults during transportation. Nevertheless, daily time of non-active transportation per inhabitant dropped substantially (-47.8 minutes or 64.6% decrease), consequently reducing the

total daily time of transportation per inhabitant (-47.4 minutes or 47.3% decrease) (Table 3).

Discussion

Using a representative sample of the largest metropolitan area in Brazil and testing various transportation scenarios, we found that only a combination of shorter trip distances, more walking and less car based transportation, could most influence population health by concomitantly reducing the total and the non-active daily commuting time and increasing active daily commuting time. This increase in active transportation could lead to a higher proportion of the population achieving the recommended levels of physical activity through transportation. These results are consistent with similar studies from large urban cities in Europe and North America (Maizlish et al., 2013; Rissel et al., 2012; Rojas-Rueda et al., 2012; Woodcock et al., 2009; Woodcock et al., 2013), thus the importance of exploring this topic in the Latin America region, which has particular urban and social characteristics.

The total proportion of short trips ($\leq 1000\text{m}$) was 25%, most of which are already made by active forms of transportation, mainly walking. According to the results from our scenario 1, the impact of a shift from motorized modes to walking in short trips on the mean proportion of active travel is still low, despite the fact that the adult effectively making the shift would add around 13 minutes of walking for each kilometer replaced. A potential solution to promote active transportation is to increase the number of trips that are done by collective public transport versus individual private means, as shown in scenario 2. In addition, non-active transportation time could be effectively reduced, according to scenario 3 by increasing the number of short trips within the city. This could also reduce sedentary time of the population by reducing the time spend sitting in car and public transport. Thus, improvements in the public transportation system and in urban planning in São Paulo are imperative (Haines et al., 2009; Hartog et al., 2011; Maizlish et al., 2013; Woodcock et al., 2013).

To our knowledge, this study is the first to model transport scenarios in order to evaluate the health determinants of changes in urban mobility in a Brazilian setting. Additionally, unlike most of the modeling studies, it aimed to estimate impacts not only in physical activity but also in sedentary behavior, by using non-active transport as a proxy. Both are important and independent health issues and risk

factors for obesity and other non-communicable diseases (Dunstan et al., 2012; Hoehner et al., 2012; Owen et al., 2010; Proper et al., 2007; Sugiyama et al., 2012; Thorp et al., 2010). Given the growing evidence on the impact of sedentary behavior on health outcomes, particularly on obesity and cardiovascular health (Hoehner et al., 2012; Mummery et al., 2005), our findings underscore the importance of not just increasing active transportation, but also reducing sitting time on daily commuting.

Transportation and urban planning sectors should be increasingly involved with public health in order to create coordinated and synergistic strategies for promoting active commuting and reducing sedentary behavior (Pratt et al., 2012). Another important implication from our study, as exemplified by scenario 3, is the fact that shorter trip distances and higher density and diversity compared to the status quo can increase the number of people meeting physical activity recommendations through transportation by a mean of 7 minutes in daily time of active transportation at the population level. Several land-use planning and community design alternatives such as Smart Growth and livable communities have emerged in recent years. Such movements call for a more integrated design of neighborhoods, with less fragmentation between residential and work places, thus facilitating active transportation, while making it safe and enjoyable (Degaspari, 2013; Fenton, 2005; Jerrett et al., 2013; Sykes and Robinson, 2014).

This study has some limitations. The 2007 HTS has the common limitations of self-reported data, in this case tending to overestimate trip duration (Kelly et al., 2013). Also, trips shorter than 500m whose purpose was not work or school were not reported, which could have underestimated the time of active transportation at baseline. Nevertheless, considering the short distance and the low proportion of trips for other purposes, the impact is likely small. We used a much less sophisticated modeling approach, which was unable to consider synergies among changes. Concerning distance calculation, another limitation is related to some inaccuracy in Google Maps in Brazil, especially in lower income areas (Davis Junior and de Alencar, 2011).

Notably, the finding that people spend a large amount of time travelling to work or school highlights the need for and supports the concept of a compact city where both walking and bicycling are more easily attainable. Unfortunately, economic drivers of megacities, such as housing and rentals prices, have historically forced people to live further away from their destinations and into the periphery of the urban

area (WHO, 2011), thus increasing commuting times and reducing opportunities to fully experience the city (Rydin et al., 2012; WHO, 2011). Nevertheless, the benefits of active commuting not only for individual and population health but also for environmental reasons (Maizlish et al., 2013; Woodcock et al., 2009) should be recognized by policy makers at local and global level, who should continue to implement policies, incentives and regulations that discourage private vehicle use (De Nazelle et al., 2011; Dora and Racioppi, 2003).

In fact, some plans have already been developed worldwide in favor of a more egalitarian, accessible and car-independent urban mobility system – similar to some of our scenarios. This includes São Paulo's plan to become a city in which every destination could be reached in not more than 30 minutes (Prefeitura de São Paulo, 2012) as well as recent changes in its Master Plan in 2014 (Prefeitura de São Paulo, 2014), including the development of its Urban Mobility Policy (Prefeitura de São Paulo, 2014). The conditions under which these changes are most likely to occur are uncertain, but it seems to be a combination of a social mobilization around the fight for political collective rights together with sustained pressure from the environment on society (Harvey et al., 2013; Köhler et al., 2009).

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Manuscrito 7: The São Paulo we want? Health impact modelling of different travel patterns for São Paulo, Brazil.

Título corrido: Health impact of travel patterns for São Paulo.

Artigo original não submetido.

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Abstract

Background: The city of São Paulo (Brazil) faces the challenge of overcoming the negative consequences of a chaotic and accelerated process of urbanization. In this study we sought to illustrate how different scenarios for future travel patterns in the city could lead to different consequences for health. **Methods:** This study uses the Integrated Transport and Health Impact Modelling (ITHIM) tool to evaluate the health impacts of different travel pattern scenarios for São Paulo adult population (around 9 million in year 2012). Four scenarios were generated; two assuming shifts to travel patterns of real settings in 2012, (i) SP expanded centre and (ii) London, and two others assuming travel patterns favouring private transport or active travel and public transport, (iii) SP California and (iv) SP 2040, respectively. For each scenario ITHIM estimated changes in exposure to air pollution, road traffic injury risk, and physical

activity. Health outcomes were illustrated with the disability adjusted life years (DALYs) measure. Sensitivity analyses were performed to identify the main sources of uncertainty. **Results:** This study found considerable health gains in the scenario that involved substantial increase in walking and cycling in combination with reductions in car and motorcycle use (SP 2040 scenario, combined effect of 85k DALYs avoided). In this scenario, 4.7% of deaths from ischemic heart disease would be avoided only by increases in physical activity. On the other hand, we found larger health losses in the scenario favouring private transport (SP California, combined effect of 53k DALYs lost), with a 23% increase in the number of deaths due to road transport. The functional form of the dose response relationship for physical activity and air pollution had a large impact on most scenarios in sensitivity analyses. **Conclusions:** Moving urban trips from car and motorcycle travel to walking, cycling and public transport can provide major health benefits in São Paulo as long as such changes are substantial and across the whole population. Seeking to extend the travel pattern from the central area (scenario i) seems a good starting point and existing policies a promising way forward on this. Strategies to mitigate the negative impact of public transport on air pollution would increase the benefits. The findings also indicate priorities for empirical and modelling research in order to model more accurately the health benefits of a shift to active travel.

Keywords: Walking, Bicycling, Physical activity, Transportation, Motor vehicles, Health impact assessment, Latin America, Urban Health.

Background

Persisting population growth and urbanization are projected to add 2.5 billion people to the world's urban population by 2050, with over 90 per cent of the increase concentrated in low-and-middle income countries (1). In Latin America and the

Caribbean – a region with an already high level of urbanization (80 percent) – increases in urban population have been followed by steep raises in motorization rates, particularly in large countries such as Brazil and Mexico (2). This poses a challenge for the development of sustainable, healthy, safe and equitable transportation systems, centred on active travel and public transport (3, 4). Adding to the local benefits of the development of sustainable transportation systems (5-7), reducing car and motorcycle dependency has also been suggested as an indispensable strategy to improve planetary health and to reverse climate change (3, 4).

Megacities in the Latin America and the Caribbean region have undergone a chaotic and accelerated process of urbanization in the last century (2, 8). In São Paulo, the largest Brazilian municipality, this process has produced a divided city (9, 10), with around 10% of the population living in a central wealthier area (hereafter, 'expanded centre' or EC) surrounded by the remaining 90% living in a poorer peripheral 'belt' (PB). Relative to PB, EC enjoys several features that would seem to favour more sustainable travel patterns. Some of these features include better infrastructure for walking and cycling, better offer of public transport, lower violence rates and more mixed land use. Despite this, travel among residents in EC has historically been dominated by car use (10, 11) while that among residents of PB is more reliant on public transport. This prominence of public transport in PB is, however, less a consequence of the quality of public transport and more a reflection of resource constraints and lack of transport alternatives among poor families in PB.

São Paulo's future travel pattern might well move in the direction of either travel pattern, becoming more alike in terms of mode share and travel distances, by following a number of policies and initiatives launched after the year 2010. At the city and regional level, policies supportive of a more sustainable transport system include the city's Master Plan revision, the development of a long-term plan "*SP 2040: the city we want*" and the discussions around the Municipal Urban Mobility Plan, all of which favour of a less car dependent and less segregated city (12-14). Related initiatives include the expansion of the cycling and walking infrastructure, the provision of free bus rides to children at school (elderly people already had free bus travel), and the introduction of strategies for speed reduction. On the other hand, the city travel pattern might also be affected by changes at the state and national level. On the former, the recurrent delays in the expansion of metro and trains beyond middle-class areas (15), despite the continuity of the same political party in the state of São Paulo for more than twenty years since 1995; on the latter, increases in purchasing power (particularly among the poor) (10, 11) as well as recent housing and macroeconomic policies, which have reinforced car dependency and the spatial segregation in Brazilian cities, including São Paulo (16, 17).

In past years the health benefits and risks of active travel have been extensively studied in international literature. In these studies the potential health and environmental gains from increases in active transport have been modelled in recent years using methods that integrate the benefits of physical activity with the harms from exposure hazards, mainly injury risk and air pollution (18), which change in a positive or negative direction. These studies have consistently found net benefits from active travel when modelling large population changes, although the vast

majority of the evidence comes from high-income cities (18), with only one study involving a low-and-middle income setting (Delhi, India) (5). Since calculation is considerably influenced by baseline levels of physical activity, road traffic injury risk, air pollution; by the distribution of physical activity, road traffic injuries, and air pollution exposure across age and gender; and by the population demographic profile, the net benefit from active travel in low-and-middle income settings remains unclear.

Therefore, our study aims to create alternative counterfactual scenarios for the city of São Paulo to understand the potential range of the magnitude of health impacts from changes in population travel patterns. To do so, we built two scenarios based on travel patterns from real settings and two scenarios based on hypothetical travel patterns, which will be detailed in below.

Methods

Description of scenarios

To explore the contradictions of the spatial segregation present in the city, we modelled the health impacts on the urban adult population of São Paulo, assuming i) shifts to travel patterns of those living in EC and PB, derived from real data. Results from shifts to travel patterns of PB were not presented as the area represents around 90% of the city. We also assumed ii) shifts to the travel pattern of London, which has high levels of public transport use for a high income city (although lower than in São Paulo). In comparison to São Paulo, London is a more motorized city, with similar constant travel time budget and size; better public transport, road and pedestrian infrastructure; and lower rates of violence and spatial segregation. The travel pattern

of London was also derived from real data. Finally, we assumed iii) SP California would be a city with similar levels of walking, car and public transport use to that observed in California (USA) combined with the current levels of cycling and motorcycling of São Paulo in 2012. The travel pattern of California used to build this scenario was obtained from Gotschi et al. (2015)(19); and iv) shifts to travel patterns of a visionary São Paulo (SP 2040), in which travel pattern would reflect aspirations from social movements and political commitments expressed in several official documents over recent years. We built quantitative estimates based on upon several official documents – including the municipality’s long term plan “*SP 2040: the city we want*” (14) – as well as social movements’ aspirations (13, 14, 20). SP 2040 would be a city in which the vast majority of destinations could be reached in no longer than 30 minutes (14); walking is the main travel mode for both genders and all age groups (13, 14); cycling accounts for 7% of total travel time (20), evenly distributed across gender and age (13), only declining in older age to 4.5% after age 70 and to 1.5% after age 80 (reductions equivalent to those observed in the Netherlands (19)); and 70% of travel time from motorised trips comes from public transport. We used the travel pattern from trips no longer than 30 minutes in São Paulo 2012 as a baseline distribution to build SP 2040 travel pattern. In order to facilitate comparison across scenarios, we used Sao Paulo 2012 baseline population also for SP 2040.

Integrated Transport and Health Impact Model

This study used the Integrated Transport and Health Impact Model (ITHIM) to model changes in population health due to changes in active travel time, exposures of air pollution and road traffic injury risk. ITHIM is an integrated assessment tool that has been used to estimate the health effects of transport scenarios and policies at the

urban and national level. Different versions of ITHIM have been applied for this purpose in large cities (5, 7), including one from a low-and-middle income region (5). Our analysis was conducted on ITHIM's most updated version, able to model the health impact of active travel through three pathways (physical activity, air pollution and traffic injuries) as well as the variability and uncertainty of parameters with Monte Carlo simulation (with 10000 iterations), already implemented in ITHIM's previous version (19). The model was implemented in Analytica version 4.6.1.30 (www.lumina.com) and available upon request. Data analyses were performed in Excel 2010 (Microsoft) and Stata 12 (STATA Corporation). A summary of data sources used to build the São Paulo ITHIM version is available at Table 1.

São Paulo Metropolitan Area Household Travel Survey

We used data collected for the São Paulo Metropolitan Area Household Travel Survey (SP-HTS) from 2012, which followed a complex and stratified sampling plan to produce estimates representative for the each of the cities in the São Paulo Metropolitan area, including São Paulo city itself. To select the households, São Paulo city was divided into 23 traffic zones, which are the smallest area level with statistical representativeness in the survey. The zones were contiguous and compatible with the administrative boundaries of the city as well as with the traffic zones from SP-HTS in previous years. We defined the EC as the merged area from five zones, corresponding to 20 central districts⁹ out of the 96 city districts. We chose to use zones to build EC and not the municipal official boundaries of the expanded central area because the zones are the primary sampling unit from the SP-HTS and

⁹Districts considered to be in the expanded centre: Bela Vista, Bom Retiro, Brás, Cambuci, Consolação, Liberdade, Pari, República, Santa Cecília, Sé, Água Rasa, Belém, Mooca, Jardim Paulista, Pinheiros, Campo Belo, Itaim Bibi, Moema, Saúde e Vila Mariana.

also represent territories ('districts') with local structures of governance (see Figure S1 for the geographical differences).

SP-HTS data were collected for every household member using a face-to-face interview on various days of the week to have all weekdays represented in the sample. Family information included the number of family members, income, number of assets, and number of cars, motorcycles and bicycles. Individual-level data included age, gender, education, employment status, and income. Trip-level data consisted of one-way trips undertaken on the day before the interview was held, and included trip purpose, origin and destination, time of departure and time of arrival, mode of transport, and the number of changes between transport modes during the trip. SP-HTS also provided the geocoded location for work and study places, trip origin and destination, and locations for changes in the mode of transport. More details about SP-HTS can be obtained elsewhere (21, 22).

Travel patterns

We compared the travel patterns of Sao Paulo in 2012 (SP 2012 - baseline) against the counterfactual scenarios in which the whole city adopted travel patterns i) from those living in EC (SP EC); ii) from London in 2012 (London 2012); iii) from a highly motorized São Paulo (SP California), with higher levels of car and motorcycle use and lower levels of walking, cycling and public transport; and iv) from a visionary São Paulo (SP 2040), with higher levels of walking and cycling and lower levels of car and motorcycle use. Details from the real settings (SP 2012 - baseline, SP EC and London 2012) can be seen in Table 2.

Travel patterns were modelled as changes based on travel time distribution by mode for each scenario applied to the constant total travel time of Sao Paulo in 2012. Travel behaviour was modelled as population wide distributions of travel times spent in different modes, stratified by sex and age groups for Sao Paulo 2012 baseline and each scenario. We assumed the total travel time budget to remain constant in all scenarios.

The health impact from physical activity changes due to changes in travel patterns was modelled using disease specific relative risks (RR) applied to both incidence and mortality. The same relative risks were assumed for estimating deaths, years of life lost (YLL), and years of healthy life lost due to disability (YLD) in each scenario. The dose-responses used were RR = 0.84 (standard deviation (sd) = 0.03) for stroke, ischemic heart disease, and other cardiovascular and circulatory diseases (23); RR = 0.83 (0.04) for type II diabetes(24); RR = 0.96 (0.02) for depression (25); RR = 0.72 (0.07) for dementia and Alzheimer's disease (26); RR = 0.94 (0.01) for breast cancer (27); and RR = 0.80 (0.08) for colon cancer in men (28) and RR = 0.86 (0.06) for colon cancer in women (28). See Gotschi et al. (2015) (19) for details.

There is uncertainty around the exact relationship between physical activity and health outcomes although some studies suggest it as curvilinear, flattening at higher levels of physical activity (29, 30). Given the absence of evidence on the exact shape of these disease specific dose-response curves, we assumed a log-linear relationship with power transformations ranging from 0.25 to 1 (19) and evaluated this assumption in a sensitivity analysis.

Non-travel related physical activity

Age (18+) and gender specific information on non-travel related physical activity was estimated in Metabolic Equivalent Tasks (METs) using the International Physical Activity Questionnaire (IPAQ) data from the São Paulo City Health Survey (ISA-Capital), which is representative of São Paulo city. We cleaned and analysed IPAQ data following the recommendations of the IPAQ scoring protocol (<http://www.ipaq.ki.se>), as previously done in other studies, in order to avoid overestimation (31, 32). We used the leisure domain to represent non-travel physical activity since most cohort studies from which relative risks were taken consider only this domain and walking alone. We also checked in the sensitivity analysis the potential impact of the non-travel related physical activity variation on the results. METs were converted into marginal METs by subtracting 1 MET (intensity of being at rest). Non-travel related physical activity was assumed not to be influenced by changes in the scenarios.

Road traffic injury

We analysed road traffic injury data from 2009 to 2013 obtained by the SAT-CET in the Police records and the Institute of Forensic Medicine. The SAT-CET is the official dataset of road traffic injuries in São Paulo. A 'fatal' injury is defined in the database as a death resulting from the collision (each year, around 93% of deaths occur up to 30 days after the collision). A 'non-fatal' injury is defined as any injury for which the victim needed medical assistance or was removed to a health service and had the injury reported in the police records. Given to the definition used by the SAT-CET, we assumed all 'non-fatal' injuries to be serious injuries. We used the mean fatal and non-fatal injuries between 2009 and 2013.

Table 1. Key data sources to build the scenarios for São Paulo

Survey	Household Travel Survey	Health Survey	Road Traffic Injury	Air pollution
Name	Pesquisa de Mobilidade 2012	Inquérito Domiciliar de Saúde (ISA-Capital)	Sistema de Acidentes de Trânsito - Companhia de Engenharia de Tráfego (SAT-CET)	Qualidade do Ar no Estado de São Paulo (2012) / Emissões Veiculares no Estado de São Paulo (2013)
Frequency	Every five years since 1997	2003 and 2008	Annually	Annually
Year(s) analysed	2012	2008	2009-2013	2012 (PM2.5 concentration) and 2013 (emissions by vehicle type)
Survey size (subjects)	24,534	2,691	Around 33,000 victims (1250 fatal) per year	...
Geographic coverage	São Paulo Metropolitan Area	São Paulo city	São Paulo city	São Paulo State
Survey method	Face to face interviews + 1-day travel diary	Face to face interviews. IPAQ* used for physical activity data	Data collection on Police records and at the Institute of Forensic Medicine.	Air quality monitoring network (15 stations for particulate matter in São Paulo city) / Emission inventory based on vehicle fleet, fuel source and emission factors
Age range analysed	18+	18+	Any	...

* IPAQ: International Physical Activity Questionnaire

For each victim we had information about age, gender, mode of transport, location and year. Injuries resulted either from a collision between a striking vehicle and a victim vehicle occupant (or pedestrian) or from a collision against no other vehicle. For collisions with multiple victims at different vehicles, we assumed the largest one

to be the striking vehicle for victims in any other vehicle or for pedestrians. For any victims in the largest vehicle we assumed the striking vehicle to be the second largest vehicle.

The number of injuries is modelled for each scenario based on changes to time travelled by both striking vehicle and victim modes. Gender differences in road traffic injury risks were maintained in the subsequent scenarios, with the impacts of these risks upon numbers of injuries changing in line with changes in travel patterns. Changes from baseline indexed by age, gender and victim mode are then scaled to the background burden from traffic injuries in São Paulo in terms of deaths, YLL, YLD, and disability adjusted life years (DALYs = YLL + YLD). We used empirical estimates from Elvik (33) to consider a potential safety in numbers effect of increases in time travelled by both striking vehicle and victim modes. The background burden from traffic injuries in São Paulo was estimated as a fraction of the Brazilian background burden from traffic injuries, obtained from the Global Burden of Disease (GBD) study 2013 (34), and adjusted to reflect São Paulo's population size, and age and gender distribution.

Air pollution

We obtained information on concentrations of particulate matter smaller than 2.5 micrometres (PM 2.5) and source apportionment (for primary PM) available for São Paulo (35). We also used published data on the relative contribution in PM 2.5 concentrations for each vehicle type (36). We then multiplied the time travelled by mode in each scenario to the relative contribution of each vehicle type in order to obtain the counterfactual PM 2.5 concentration. We assumed that the relative

contribution of each vehicle type would remain constant across all scenarios. For the São Paulo metro and train network, we took the mean value of PM 2.5 measures from platforms of different stations (37) and assumed they did not vary in the whole system. We also did not model the effect of changes in traffic congestion, speed and micro-climate on air pollution. The health impacts of changes in PM 2.5 exposure were modelled using the exposure response function for all-cause mortality recommended by the World Health Organization (WHO) (38).

Table 2. General aspects of São Paulo real settings.

Variable	São Paulo City	São Paulo Expanded Centre
Population (million)	10.2	1.1
Area (km ²)	1509	113
Population density (residents / km ²)	6757	9572
% with college degree	18.9	45.2
Family income (mean, R\$*)	3345	5884
Cars (per 100 families)	68	87
Motorcycle (per 100 families)	9	7
Bicycles (per 100 families)	38	40

Source for London Population and Area: <http://data.london.gov.uk/>

Source for São Paulo Area:

http://smdu.prefeitura.sp.gov.br/historico_demografico/tabelas.php

*R\$: Brazilian Reais (US\$ 100 = R\$ 200.9 in July 2012)

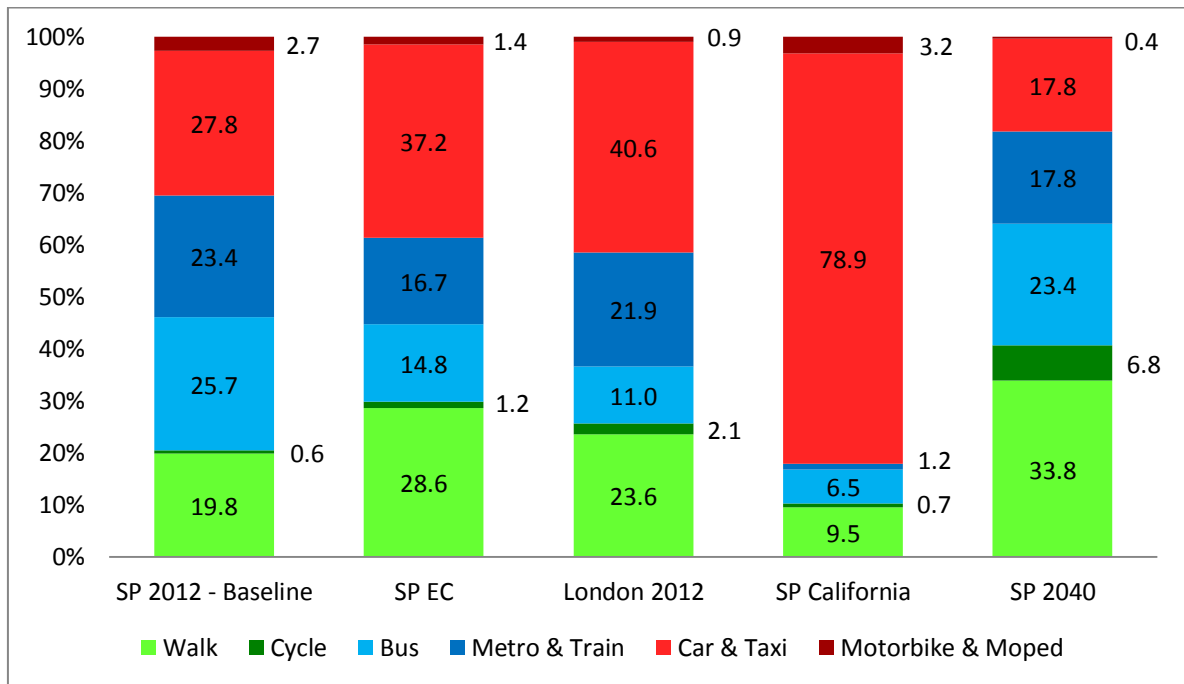
We also estimated the CO₂ equivalent greenhouse gases vehicle emissions (CO_{2eq}) for São Paulo city by multiplying the vehicle and fuel type fraction of São Paulo city fleet to the CO_{2eq} by mode of São Paulo Metropolitan Area (36). The report from which these data was obtained (36) used the following gases and weights to estimate CO_{2eq}: CO₂ (CO_{2eq} = 1); CH₄ (CO_{2eq} = 21); N₂O (CO_{2eq} = 310), based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (39). Changes in CO_{2eq}

from baseline were estimated based on changes in travel time by vehicle mode for each scenario.

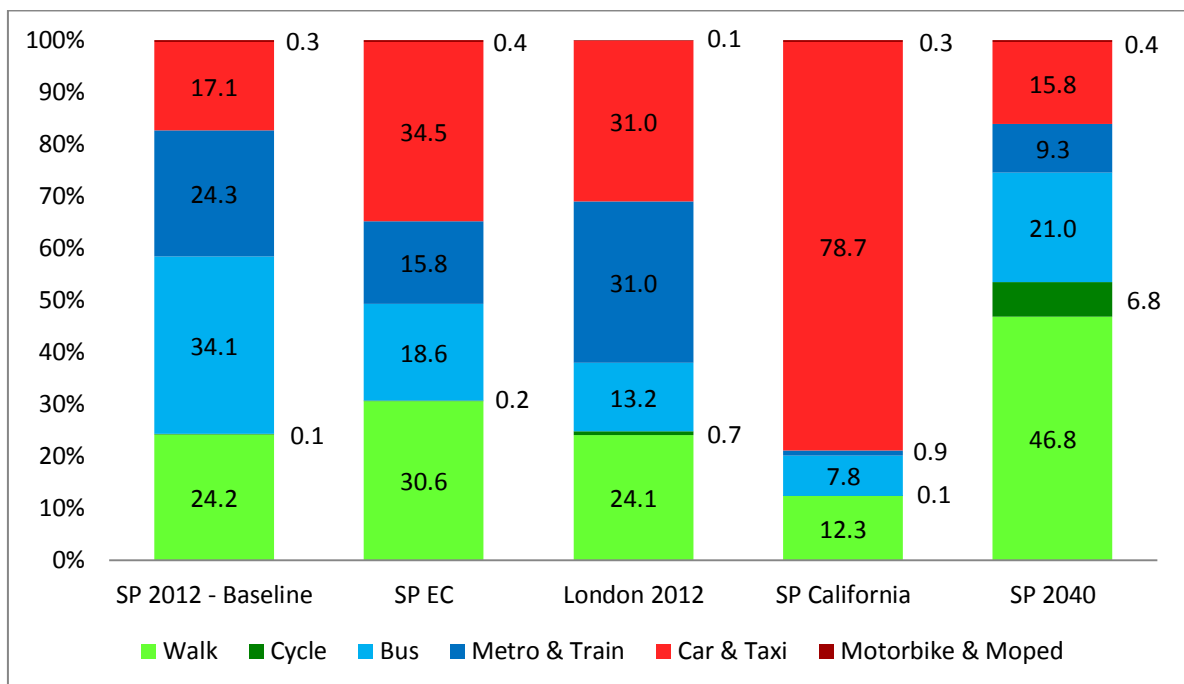
Sensitivity Analysis

We performed several sensitivity analyses to assess the robustness of our findings as well as the influence of key parameters of the model in each scenario. These parameters included the shape of dose-response curves for physical activity, as described above; the disease-specific RR for incidence and mortality; the levels of non-travel physical activity; the MET values assigned for walking and cycling; the exposure response function for PM 2.5; the fractions of PM 2.5 emissions by mode; the safety-in-numbers power values and the proportion of lifelong or underreported injuries. We also modelled the impact of physical activity directly on all-cause mortality instead of on individual diseases. For this, we used a dose-response function taken from a large cohort study (40), two different RR (for total physical activity and for walking alone) taken from a systematic review (30), and the RR for walking alone recommended for the WHO Health and Economic Assessment Tool (HEAT) (41).

1A



1B



Figures 1A and 1B. Percentage of daily average travel time by mode for each scenario by gender (1A: Men; 1B: Women). For absolute values, see Table S1.

Results

Travel Patterns

The travel pattern in the EC is closer to that of London (Figure 1). In both areas, car use accounts for over a third of total travel time and the relative contribution of public transport to total travel time is almost 20 percentage points lower than in São Paulo. This reflects the fact that in EC and London, income levels, car ownership and public transport offer are higher (Figure 1). Cycling levels in London are much higher than those from any existing São Paulo setting (EC or the entire city), and the gender gap in cycling is also narrower in London, although still substantial (male:female ratio of cycling 2.8 in London versus 9.1 in São Paulo). In SP California, almost 80% of all trips are performed by car whereas less than 10% are performed by public transport, both for men and women. In SP 2040, gender cycling inequity was completely eliminated, with an average of 4 min per day for both men and women. The absolute values for total travel time used to derive the travel patterns are presented in Table S1.

Age distributions of walking and cycling are particularly important for health modelling as changes in physical activity in different age groups might lead to substantially different health impacts. In all scenarios, levels of walking decline with increasing age (Figure S2). This decline is less steep London than in the Expanded Centre, given the lower levels of walking among people aged 18-29. Walking levels are low in SP California for any age group. SP 2040 is the scenario with the highest levels of walking among the elderly (60y or more), at around 35 min per day, similar to the current levels in Switzerland for this age group (19). Cycling levels also decline with increasing age from age group 30-44, being virtually absent in the elderly in any São

Paulo real setting or in SP California (Figure S3). SP 2040 is the scenario with the highest levels of cycling for any age group, with mean time per person per day around twice the current level in Switzerland and two thirds of the level in the Netherlands (19).

Health Impact Modelling

The health impacts for São Paulo population of adopting different travel patterns are presented in Figure 2 as DALY changes from baseline (since DALYs are human years lost, note that negative values for DALYs represent a health gain; full results in Table S2). We found health harms in London 2012 and SP California scenarios, mainly driven by increases in road traffic injury in both cases. However, when we stratified the results by gender we found net health benefits in London and smaller losses in SP California for women, due to their much lower road traffic injury risk (Table S2). EC and SP 2040 showed positive net benefits with consistent health gains overall as a result of increases in physical activity and reductions in air pollution and road traffic injury, both for men and women (Table S2).

Table 3. Health impact (deaths and DALYS) by disease and gender from changes in physical activity for each scenario.

	SP 2012 - Baseline	SP EC	London 2012	SP California	SP 2040
Male (Deaths)					
Stroke	2749	-6	-29	116	-98
Ischemic heart disease	4859	-14	-41	218	-171
Other cardiovascular and circulatory diseases	2934	-7	-25	133	-102
Type-2 diabetes	1058	-3	-11	47	-40
Colon cancer	723	-1	-4	17	-15
Breast cancer	7	0	0	0	0
Dementia and Alzheimer's disease	386	2	-6	8	-12
Depression	0	0	0	0	0
Total	12716	-29	-116	540	-438
Male (DALYs)					
Stroke	84216	-424	-528	4122	-2912
Ischemic heart disease	125115	-669	-611	6327	-4284
Other cardiovascular and circulatory diseases	47015	-268	-258	2387	-1591
Type-2 diabetes	53026	-329	-113	3091	-1812
Colon cancer	14039	-49	-44	392	-275
Breast cancer	242	-1	-1	6	-4
Dementia and Alzheimer's disease	14056	1	-196	362	-433
Depression	34620	-228	-228	-40	-525
Total	372329	-1966	-1980	16647	-11836
Female (Deaths)					
Stroke	2859	-5	-55	64	-177
Ischemic heart disease	3878	-8	-79	80	-243
Other cardiovascular and circulatory diseases	3267	-4	-67	63	-200
Type-2 diabetes	1273	-3	-27	28	-84
Colon cancer	868	-1	-6	9	-22
Breast cancer	1268	-2	-6	24	-37
Dementia and Alzheimer's disease	866	1	-20	0	-41
Depression	0	0	0	0	0
Total	14279	-21	-261	268	-804
Female (DALYs)					
Stroke	74795	-256	-953	2810	-4707
Ischemic heart disease	103831	-394	-1415	3756	-6623
Other cardiovascular and circulatory diseases	42133	-135	-520	1619	-2635
Type-2 diabetes	63461	-274	-634	2970	-4192
Colon cancer	15150	-25	-61	252	-381
Breast cancer	28445	-48	-59	702	-819
Dementia and Alzheimer's disease	17092	-19	-345	154	-872
Depression	51429	-131	-9	2532	-2349
Total	396336	-1283	-3996	14796	-22579

Table 4. Number of fatal and serious injuries by mode of travel and gender for each scenario (Median (% change from baseline)).

	SP 2012 - Baseline	SP EC	London 2012	SP California	SP 2040
Men, Fatal					
Pedestrian injury	332	336 (1%)	366 (10%)	347 (4%)	234 (-30%)
Cyclist injury	36	20 (-44%)	169 (365%)	35 (-3%)	339 (833%)
Motorcycle and mopeds injury	311	273 (-12%)	304 (-2%)	374 (20%)	11 (-96%)
Car, van, bus and truck injury	171	168 (-2%)	195 (14%)	300 (76%)	92 (-46%)
Other road and transport injury	1	1 (-15%)	1 (-4%)	1 (-10%)	2 (3%)
Total	852.0	799 (-6%)	1036 (22%)	1057 (24%)	677 (-21%)
Women, Fatal					
Pedestrian injury	147	153 (4%)	162 (10%)	156 (6%)	95 (-35%)
Cyclist injury	2	1 (-45%)	4 (148%)	1 (-31%)	9 (446%)
Motorcycle and mopeds injury	29	27 (-7%)	27 (-6%)	32 (12%)	1 (-96%)
Car, van, bus and truck injury	39	37 (-5%)	47 (21%)	71 (82%)	20 (-49%)
Other road and transport injury	0	0 (-9%)	0 (-1%)	0 (-1%)	0 (-21%)
Total	215.8	217 (1%)	240 (11%)	259 (20%)	125 (-42%)
Men, Serious					
Pedestrian injury	3572	4038 (13%)	4313 (21%)	4682 (31%)	2203 (-38%)
			12325		19850
Cyclist injury	1325	779 (-41%)	(830%)	1676 (26%)	(1398%)
Motorcycle and mopeds injury	14611	16179 (11%)	17053 (17%)	20395 (40%)	93 (-99%)
Car, van, bus and truck injury	7789	7798 (0%)	10273 (32%)	16704 (114%)	4390 (-44%)
Other road and transport injury	27	25 (-5%)	28 (5%)	31 (17%)	22 (-19%)
			43992	43489	
Total	27324.3	28819 (5%)	(61%)	(59%)	26558 (-3%)
Women, Serious					
Pedestrian injury	3203	3701 (16%)	3845 (20%)	4177 (30%)	1866 (-42%)
Cyclist injury	77	46 (-40%)	725 (840%)	98 (27%)	1114 (1346%)
Motorcycle and mopeds injury	2406	3176 (32%)	2751 (14%)	3123 (30%)	24 (-99%)
Car, van, bus and truck injury	5348	4846 (-9%)	6653 (24%)	9811 (83%)	3298 (-38%)
Other road and transport injury	5	5 (-4%)	6 (6%)	6 (19%)	4 (-19%)
			13979	17215	
Total	11039.0	11774 (7%)	(27%)	(56%)	6307 (-43%)

Physical activity

In 2012, around 768000 DALYs and 27000 lives were lost in São Paulo due to diseases affected by physical inactivity, used to build this model (cardiovascular diseases, breast and colon cancer, type-2 diabetes, dementia, and depression).

In any scenario, an important shift in the disease burdens for deaths and DALYs was observed for cardiovascular diseases – particularly ischemic heart disease – and type II diabetes both for men and women (Table 3). For instance, by assuming the travel pattern of SP California, São Paulo would have 808 extra deaths from reductions in physical activity, of which 674 from cardiovascular diseases. The changes in the disease burden favoured women in all scenarios, except for EC. In SP 2040, the health gains from physical activity among women are nearly twice that of men both for DALYs and deaths. The relative contribution of active travel (walking and cycling) on total marginal METh of physical activity are presented in Table S3.

Road traffic injuries

In only five years, between 2009 and 2013, São Paulo had the striking number of over 150,000 injured and 5000 dead from road traffic. For our baseline scenario (SP 2012), the estimates were 38,363 injured and 1068 dead, respectively, with burden higher among men for all modes of travel (Table 5). Gender differences in numbers of injuries and fatalities for cycling and motorcycling were substantial, possibly reflecting a much higher use of these modes among men (Figure 1 and Table S1). By contrast, the fact that the number of deaths among male pedestrians is twice that among females cannot be explained by gender differences in levels of walking and may be related to differences in traffic behaviour, such as more aversion to risk

among women and more walking in busy roads among men. Gender differences in road traffic injury were reflected in the subsequent scenarios, influenced by changes in travel patterns.

Changes in total deaths for the scenarios varied from -41% in SP 2040 to +20% in London 2012 (+1% for EC and +5% for SP California). As shown in Table 4, London 2012 scenario had the highest increases in deaths and injuries in comparison to the other scenarios, both for men and women, because of large increases in cyclist fatalities. In SP 2040, the substantial increases in deaths from cycling are also noticeable, reflecting higher bicycle use both for men and women. Changes in road traffic injuries varied from -35% in SP 2040 to +34% in London 2012 (+11% for EC and +15% for SP California) and followed a similar pattern than that of deaths for men and women, and across scenarios.

Table 5. Health impact (deaths and DALYS) by gender from changes in air pollution for each scenario.

	SP EC	London 2012	SP California	SP 2040
Male				
Deaths	-456	-447	-369	-629
DALYs	-19162	-18398	-18370	-26666
Female				
Deaths	-335	-118	-189	-470
DALYs	-15700	-5961	-13097	-22388
Male+Female				
Deaths	-791	-565	-558	-1099
DALYs	-34862	-24359	-31467	-49055
PM2.5 background concentration ($\mu\text{g}/\text{m}^3$)*	16.9	16.6	18.0	16.1

*Baseline PM2.5 background concentration: 18.5 $\mu\text{g}/\text{m}^3$

Air pollution

Since buses contribute more than cars or motorcycles to PM 2.5 concentrations in São Paulo, most scenarios showed reductions in background PM 2.5 concentrations of around $1.7 \mu\text{g}/\text{m}^3$ (see Table 6) as they involved reductions in total public transport by having more cars (SP California), more walking and cycling (SP 2040) or a combination of both (EC and London 2012). The large increase in car use for SP California compensated reductions in bus use which resulted in nearly same level of background PM 2.5 concentrations from baseline (Table 5).

Health gains from the reduction in PM 2.5 concentrations varied between scenarios due to different levels of exposure across age groups as a result of different travel patterns. For instance, exposure levels in London 2012 were higher in the elderly (60y or more) than in other scenarios, especially for women. This is a consequence of the fact that women in London spend more time in tube (Figure 1), which also helps to explain the lower gains among women in that scenario (Table 5). Had São Paulo adopted the travel pattern of SP 2040 – with twice the level of active travel and almost half the level of private transport and bus use – a total of 1099 deaths would be avoided per year, comparable to the number of deaths avoided from increases in physical activity (1242 deaths).

Had São Paulo adopted the travel pattern of SP California, 11.4 million tonnes of $\text{CO}_{2\text{eq}}$ emissions would be added to the current 7 million tonnes of $\text{CO}_{2\text{eq}}$ emissions in the city (163% increase). Increases in $\text{CO}_{2\text{eq}}$ emissions were also observed for EC and London scenarios (1.3 million tonnes and 2.1 million tonnes or 19% and 30%

increases, respectively). The only scenario with reductions in CO_{2eq} emissions was SP 2040 (-3.6 million tonnes or 51% reduction).

Sensitivity Analysis

The impact of changes to physical activity exposure modelled directly on all-cause mortality rather than modelling disease specific mortality is presented in Table S4. For any dose-response or RR used, DALY changes from physical activity were consistently larger when modelled directly on all-cause mortality. For instance, in the SP California scenario, DALY losses from physical activity at least doubled, being nearly five times higher when using the RR recommended for HEAT (41) (33.3k *versus* 157.1k). However, these changes were not large enough to reverse the net health impact of any scenario after combining the effects from the other two pathways (air pollution and road traffic injury), except for when using RR from Wen et al. (40) in the London 2012 scenario (Table S4).

Sensitivity of the model to key parameters was presented with tornado plots for each scenario (Figures S4 to S7), illustrating health impacts from replacing the key parameter of interest with the age-gender specific 97.5th and 2.5th percentile of the parameter distribution. The model was most sensitive to assumptions on the exposure response function for PM_{2.5}, safety-in-numbers power values, and the shape of the dose-response curves for physical activity, as these three parameters were among the four most influential parameters on most scenarios. The relative contribution of other parameters to model uncertainty varied depending on the scenario. The direction of net health impacts was always maintained. Other relevant contributors were the MET values assigned for walking, the fraction of total PM_{2.5}

from transport, the fraction of transport PM 2.5 assumed for buses and for cars, and uncertainties around the health harm of tube air pollution. The remaining parameters examined played a minor role.

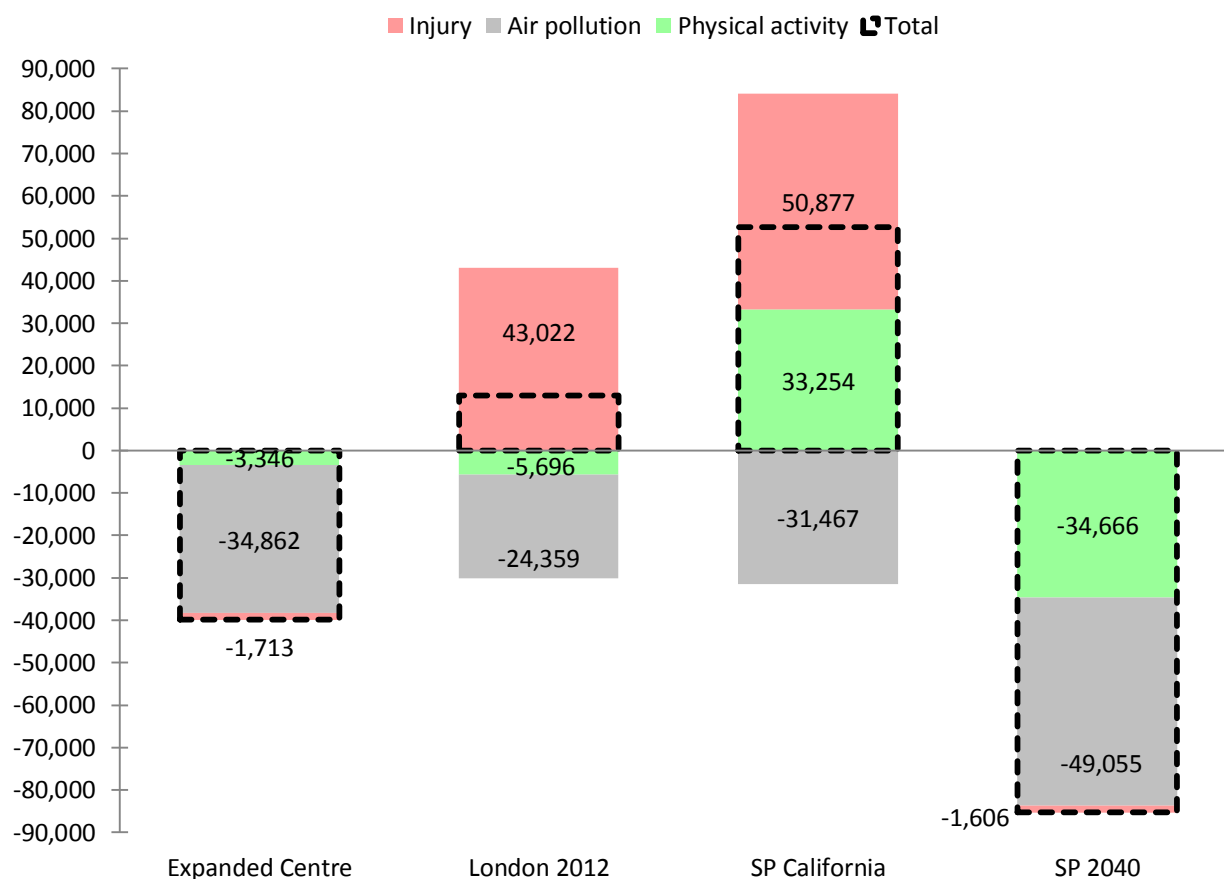


Figure 2. Changes in DALYs for each scenario, broken down into the proportions attributable to changes from air quality, physical activity and road injuries. Detailed results in Table S2.

Discussion

Principal Findings

In this health impact modelling study we observed substantial population health benefits in Sao Paulo following a shift to a travel pattern featuring considerably more active travel and less car and motorbike use (SP 2040). These modelled benefits

resulted from increasing physical activity and reducing air pollution and road traffic injury. Assuming the travel pattern of the expanded centre to the entire city would also represent health gains, mainly due to reductions in air pollution. Health effects differed by gender across scenarios, with a more favourable trade-off among women.

Our estimates also indicated that adopting the travel pattern of a more developed city (London), in terms of improved transport infrastructure but also more driving, would not necessarily generate health benefits for São Paulo. This highlights the importance of the local context when implementing changes. The current travel pattern in the wealthier and more developed area of the city seems to be a better starting point to look at while planning the city's future transport and urban systems.

Strengths and limitations

At present, ITHIM is the only model developed to assess the health impacts of transport changes that has been applied in any low- and middle-income setting (18), in which availability and quality of primary data tend to be lower than in high-income settings. Our study used the best available primary data for São Paulo to build the scenarios and to test effects of deviations in key parameters in sensitivity analyses. These analyses showed greater uncertainty for parameters still in debate in the literature (e.g. the functional form of dose-response curves) (30, 40) than for limitations in primary data, such as the proportion of lifelong injuries or a more accurate estimate of non-travel physical activity for São Paulo population.

The structure of ITHIM São Paulo allows checking the health impact of transport changes through physical activity, air pollution and road traffic injury, pathways most

commonly used in this type of assessment (18). However, some important transport-related exposure-outcome associations for low- and middle-income settings were not included, such as vehicle speeds, which could affect air pollution through reductions in congestion as well as the number and severity of traffic injuries (42); traffic noise, with repercussions in sleep duration and quality (43); and interpersonal violence related to travel behaviour (e.g., female sexual harassment (44) and road rage episodes of altercation and aggression (45)).

Additional strengths of ITHIM São Paulo include: the possibility of considering morbidity and not just all-cause mortality (except for air pollution); realistic population wide distributions by age and gender of travel times; the inclusion of non-travel physical activity and background diseases; and mode specific estimations of exposure to air pollution, based on time in traffic/metro and ventilation rates. Recent evidence supports the assumption that increased levels of active travel do not lead to a change in non-travel or leisure-time physical activity, at least in a high income setting (46). We limited our analysis from short to medium term health changes, i.e., we did not model the benefits of physical activity at younger ages in later life or the longer term effect of reduced air pollution, which may have led to an underestimation of the net health effects. Particularly for the SP 2040 scenario, heavily influenced by the municipality's long term plan "*SP 2040: the city we want*"(14), results may also be underestimated since we used the 2012 baseline population instead of the projections for 2040 in order to facilitate comparability across scenarios. In 2040, a larger proportion of people in older age groups is expected (Table S5), a group that benefits more from active travel in comparison to younger groups.



Figure 3. Cycle lane at the Paulista Avenue, São Paulo, built in 2015. Note motorcyclists trafficking between car queues, a common feature in São Paulo, and the dedicated bus lanes next to the sidewalks. Left, the remaining original vegetation that once were in the Paulista Avenue (Trianon Park); Right, the Museum of Arts of São Paulo (MASP). Photo: Marcelo Camargo/ AgênciaBrasil (FotosPúblicas).

The plausibility of our scenarios can be questioned. In SP 2040, we envisage remarkable cycling levels and the virtual elimination of age and gender inequities in cycling, similar to the Netherlands. Assuming those changes to occur between 2016 and 2040, a large cycling uptake would be needed, what has only been seen in places with strong policies and sustained investments in favour of that mode of travel, such as Portland, USA (5-fold increase in mode share in 19 years) (47). Evidence suggests that by itself an increase in the cycling level is not enough to reduce age and gender inequities (48), which makes reductions in inequities an even harder challenge. For instance, the Canadian Province of Quebec managed to triple the proportion of cyclists among people aged 55 y (also in 19 years) but age

inequities persisted (49). For modes other than cycling, the changes modelled in SP 2040 and in other scenarios are also sometimes relatively large but not different from those observed in several different settings. Moreover, measures to enable active travel and to reduce private transport use may reinforce themselves since access to a private vehicle is the most important factor associated with physical inactivity in transportation in São Paulo residents (50).

Comparison against other studies and models

The direction of changes observed for the scenario with increasing active travel and reductions in private transport in São Paulo (physical activity increase, air pollution and road traffic injury reduction) was similar to those found in Delhi (5), the only low- and middle-income setting for comparison. The magnitude of DALYS gained was also similar, with approximately 12.5k DALYS gained per million population in Delhi and 9.7k DALYS gained per million population in Sao Paulo.

The comparison with other studies that included these three health pathways (18) – all in cities from high-income countries – showed discrepancies in the direction of changes only for the road traffic injury pathway, with some studies reporting an increase (5, 7, 51-53) and some reduction in road traffic injuries (54-56) following changes towards more sustainable transport systems. All studies showing reductions in road traffic injuries, including ours, assumed a non-linearity of risks with increased active travel, e.g., by taking into account a safety-in-numbers effect or variations in the volume of travel by 'striking vehicle' modes (54-56). Also of note are the gender differences in road injury risks, which systematically disadvantaged men (smaller

gains or larger harms for men), similar to the observed in the Netherlands (57) but not in London (58). Unfortunately, very few studies assessing the health impact of transport and urban planning changes address health inequalities (18).

The relative contribution of air pollution to the net health impact of our scenarios was substantially larger in comparison to the observed in Delhi (5) and in most high income settings (5, 7, 51, 53-55), except for Dhondt et al. (56). In all those places, physical activity played a major role. For the comparison with high income settings, these may be related to the different stages in the epidemiological and physical activity transitions (59), and therefore higher levels of non-travel physical activity in São Paulo (Table S6), which reduces the relative contribution of active travel for total physical activity (60). On the other hand, there was little change to the estimates in sensitivity analyses applying much lower baseline levels of non-travel physical activity (Figures S4 to S7). For the comparison with Delhi, non-travel physical activity levels assumed for that city seemed noticeably low when compared to other estimates for the Indian population (60), with less than 5 MET hours per week among men and higher levels only among women aged 30 to 59 years (5). Other potential explanation is the use of a log-linear dose-response function for PM 2.5 in Delhi (unlike the use of a linear function for SP), as annual average concentrations in Delhi were substantially large (5).

Policy Implications

São Paulo should pursue the effective implementation and monitoring of several recent initiatives aiming to enable and facilitate active travel as well as to reduce car

and motorcycle use (12-14). Policies to tackle age and gender health disparities in transport, especially in cycling, are of particular relevance to achieve the substantial changes required for a positive health impact. Walking and cycling should be the safest, cheapest, most pleasant and convenient options for most everyday trips, which means shifting priority and investments from roads for motorists towards improvements in favour of active travel and mass transit.

A strong commitment towards sustainable transport would have the potential to half the CO_{2eq} emissions from road transport, which is the sector with the single largest contribution, and growing trend of CO_{2eq} emissions in the city (36). Such bold reduction is perfectly in accordance with the political commitment of a “drastic reduction in the greenhouse gases emissions”, stated in the “*SP 2040: the city we want*” long-term plan (14). At the national level, it could also contribute to the Brazilian State commitment to reduce in 43% the greenhouse gases emissions by 2030 (based on emissions from 2005) (61), given the important contribution of São Paulo to the national emissions.

Ongoing policies that seek to shift the city in the right direction should be encouraged, with proper evaluation to ensure that the expected transport and health benefits are realised. Such policies include the construction of dedicated cycling infrastructure, improvements in sidewalks, larger investments in mass transit, and strategies for traffic-calming and traffic law reinforcement. Other promising initiatives for which net health effects are less clear in low- and middle-income settings includes the intended expansion of the cycle hire system for the entire city as well as the vehicle inspection program, discontinued in 2014. Strategies to reduce the

contribution and mitigate the negative impact of public transport on air pollution, such as fleet renewal and changes in the energy matrix, could increase the benefits observed. Gender differences from road injury against men across scenarios point to the fact that, together with improvements in infrastructure and traffic conditions, it would be indispensable to foment a culture of peace in roads and streets, and to improve the work conditions of groups at very high risk, particularly courier motorcyclists (*'motoboys'*), who are majorly men (62).

A better designed and more compact, decentralised and diverse city would ease active travel uptake and the access to several other social determinants of health, such as education, work, leisure, green space, services, and health facilities. It would also generate large travel time savings (22), in a city with high levels of traffic congestion and daily accumulated travel time. To create this visionary city, São Paulo and its citizens would have to overcome the long history of segregation and dispossession against the poor population (9) and the privileges traditionally given to the middle class and the elite (63). Brazil has undergone remarkable reductions in social inequities in the last decade, with the eradication of hunger and improvements in housing, employment and health, particularly among the poorer. As the country's largest and richest city, São Paulo stakeholders could also lead a national debate and become a role model on how to improve people's wellbeing and quality of life in urban areas without reproducing the previous paradigm of unsustainable and car dependent cities (16, 17).

Unanswered questions and future research

Our study shed light on some unanswered questions and future research. Apart from uncertainties previously mentioned – such as the shape of dose-response functions – a number of parameters used came from high-income settings or populations, including the relation between daily and weekly travel behaviour for walking and cycling (19), the average YLD for lifelong and temporal road injuries (64), the mode-specific ventilation rates (58), and most of the relative risks used for the physical activity pathway (23-28). Although sensitivity analyses showed minor effects of these parameters to the model uncertainty, a sum of minor differences can still produce very different results.

Moreover, despite not being from a high-income setting, São Paulo and Delhi are still quite different in terms of travel patterns and urban planning, so that more studies on low- and middle-income settings would be very welcome. Modelling specific policies together with empirical research, in close coordination with the policymakers, would also allow a more refined analysis on how to best achieve context-specific changes in population travel patterns. Future research should aim to better understand the relation between travel patterns and other risk factors, such as noise, food behaviour, independent mobility and social isolation as well as other health-relevant issues, such as quality of life, happiness, violence and mental well-being. Finally, we were unable to better represent particularly vulnerable groups, such as children or people with chronic conditions, since basic information to feed the model was not available for them.

Conclusion

São has the challenge to overcome the negative consequences of a chaotic and accelerated process of urbanization, which involves the development of a healthier population travel patterns. Our results indicate that moving urban trips from car and motorcycle travel to walking, cycling and public transport can provide health benefits as long as such changes are substantial and across the whole population. Seeking to extend the travel pattern from the central area seems a good starting point. Many of São Paulo's existing plans and initiatives provide a promising way forward and we hope that future research can monitor the extent to which they achieve their aspiration to create a 'São Paulo we want'.

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Supplementary Tables and Figures

Table S1. Daily average minutes of travel by mode of transport and gender for each scenario (median values).

Male

	SP 2012 - Baseline	SP EC	London 2012	SP California	SP 2040
Walk	18.6	21.8	18.5	7.5	19.8
Cycle	0.6	0.9	1.6	0.6	4.0
Bus	24.1	11.3	8.6	5.2	13.7
Car & Taxi	26.1	28.3	31.8	62.4	10.4
Motorbike & Moped	2.5	1.1	0.7	2.5	0.2
Metro & Train	22.0	12.7	17.2	0.9	10.4
Total	93.9	76.1	78.5	79.1	58.4

Female

	SP 2012 - Baseline	SP EC	London 2012	SP California	SP 2040
Walk	19.6	20.8	20.5	9.0	26.9
Cycle	0.1	0.1	0.6	0.1	3.9
Bus	27.7	12.6	11.2	5.7	12.1
Car & Taxi	13.8	23.5	26.4	57.8	9.1
Motorbike & Moped	0.2	0.3	0.1	0.2	0.2
Metro & Train	19.7	10.8	26.4	0.6	5.3
Total	81.1	68.1	85.2	73.5	57.4

Table S2. Changes in DALYs for each scenario, broken down into the proportions attributable to changes from air quality, physical activity and road injuries.

	SP EC	London 2012	SP California	SP 2040
Men, DALYs				
Physical activity	-2062.3	-1699.2	18457.8	-12086.8
Air pollution	-19162.3	-18397.5	-18370.1	-26666.5
Injury	-1640.9	36193.0	42511.2	-203.8
Total	-22865.5	16096.3	42598.8	-38957.1
Women, DALYs				
Physical activity	-1283.4	-3996.5	14795.8	-22579.1
Air pollution	-15700.1	-5961.0	-13097.1	-22388.1
Injury	-71.7	6829.4	8366.1	-1402.5
Total	-17055.2	-3128.1	10064.8	-46369.7
Men and Women, DALYS				
Physical activity	-3345.7	-5695.6	33253.6	-34665.9
Air pollution	-34862.4	-24358.6	-31467.2	-49054.5
Injury	-1712.7	43022.4	50877.3	-1606.2
Total	-39920.7	12968.2	52663.6	-85326.7

Table S3. Relative contribution of active travel (walking and cycling) on total METh from physical activity for each scenario.

	Cycling	Walking	All other	Total
SP 2012 - Baseline				
Male	2.0%	36.1%	19.4%	57.5%
Female	0.2%	36.6%	5.7%	42.5%
Total	2.2%	72.7%	25.2%	100.0%
SP EC				
Male	3.2%	37.9%	17.7%	58.8%
Female	0.2%	35.9%	5.2%	41.2%
Total	3.4%	73.8%	22.9%	100.0%
London 2012				
Male	5.2%	34.7%	16.7%	56.7%
Female	1.8%	36.6%	4.9%	43.3%
Total	7.0%	71.3%	21.6%	100.0%
SP California				
Male	3.2%	27.0%	30.3%	60.5%
Female	0.3%	30.3%	8.9%	39.5%
Total	3.5%	57.2%	39.2%	100.0%
SP 2040				
Male	11.0%	27.5%	12.1%	50.6%
Female	10.9%	34.8%	3.6%	49.4%
Total	21.9%	62.4%	15.7%	100.0%

Table S4. DALY differences from baseline (SP 2012 - Baseline) if calculating physical activity impact from all-cause mortality according to different exposure-response functions.

	SP EC	London 2012	SP California	SP 2040
Sum of disease-specific calculations (Figure 2)	-39920.7	12968.2	52663.6	-85326.7
<i>From physical activity pathway</i>	-3345.7	-5695.6	33253.6	-34665.9
All-cause mortality from Woodcock et al. (2011)	-51668.6	9458.5	153773.4	-160690.0
<i>From physical activity pathway</i>	-15093.6	-9205.3	134363.4	-110029.2
All-cause mortality from Wen et al. (2011)	-49109.4	-5049.4	91296.8	-160891.5
<i>From physical activity pathway</i>	-12534.3	-23713.3	71886.8	-110230.7
Walking alone from HEAT (2011)	-53834.7	8978.2	176554.1	-176887.5
<i>From physical activity pathway</i>	-17259.7	-9685.6	157144.1	-126226.7
Walking alone from Woodcock et al. (2011)	-45753.8	11971.1	96483.7	-117010.5
<i>From physical activity pathway</i>	-9178.7	-6692.7	77073.6	-66349.7

Table S5. Age and gender distribution of the adult population of São Paulo in 2012 and projections for São Paulo in 2040 (# (% Total)).

	2012			2040		
	Men	Women	Total	Men	Women	Total
18-29	1050207 (12%)	1127303 (12.9%)	2177510 (24.8%)	919453 (9,1%)	872750 (8,6%)	1792203 (17.7%)
30-44	1258238 (14.4%)	1419940 (16.2%)	2678178 (30.6%)	1456845 (14,4%)	1410357 (14%)	2867202 (28.4%)
45-59	954353 (10.9%)	1154548 (13.2%)	2108901 (24.1%)	1335783 (13,2%)	1381643 (13,7%)	2717426 (26.9%)
60-69	393247 (4.5%)	569726 (6.5%)	962973 (11%)	646254 (6,4%)	729063 (7,2%)	1375317 (13.6%)
70-79	212166 (2.4%)	317510 (3.6%)	529676 (6%)	395512 (3,9%)	504456 (5%)	899968 (8.9%)
80+	114301 (1.3%)	192224 (2.2%)	306525 (3.5%)	167419 (1,7%)	277994 (2,8%)	445413 (4.4%)
Total	3982512 (45.4%)	4781251 (54.6%)	8763763 (100%)	4921266 (48,7%)	5176263 (51,3%)	10097528 (100%)

Table S6. Average non-travel physical activity by age and gender (marginal MET_h per week).

	Men	Women
18-29	14.9	7.6
30-44	9.0	3.9
45-59	4.0	3.2
60-69	4.6	3.4
70-79	4.1	2.4
80+	4.0	1.0

Figure S1. Geographic differences between the municipal official boundaries of the expanded central area and the area representing the expanded centre in the study.

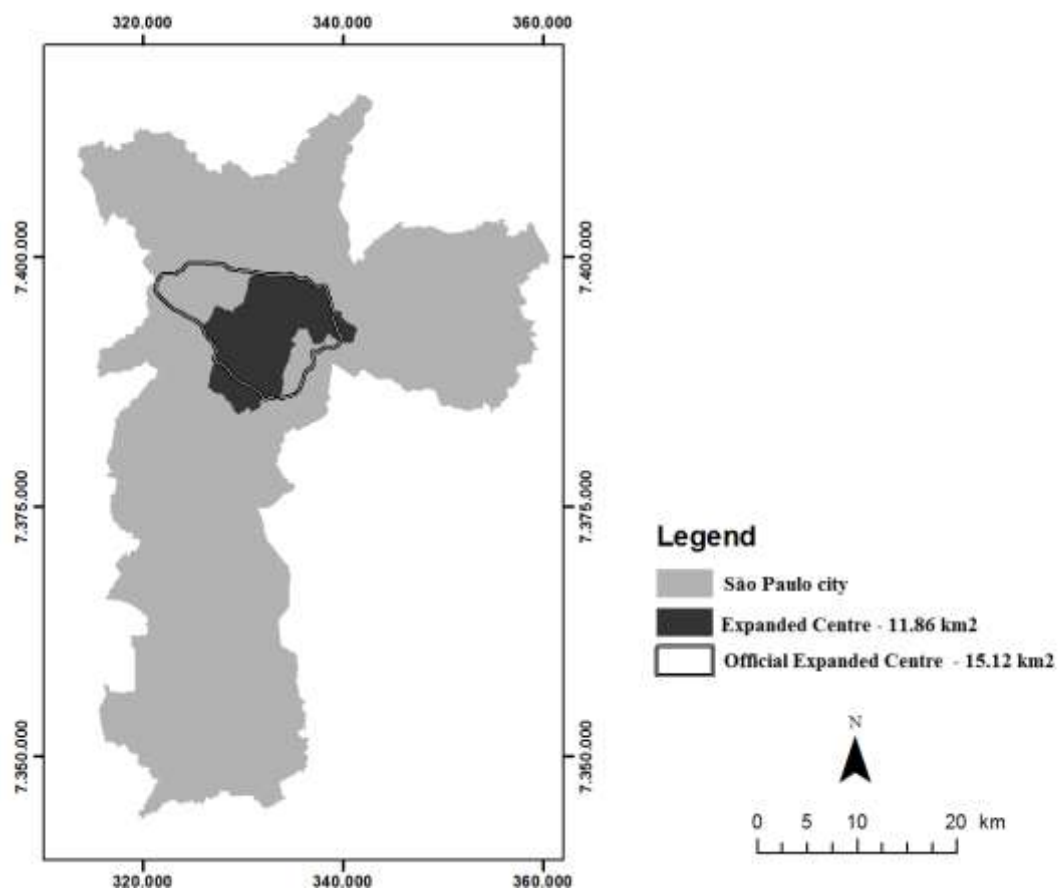


Figure S2. Average walking minutes per day by age groups and scenario

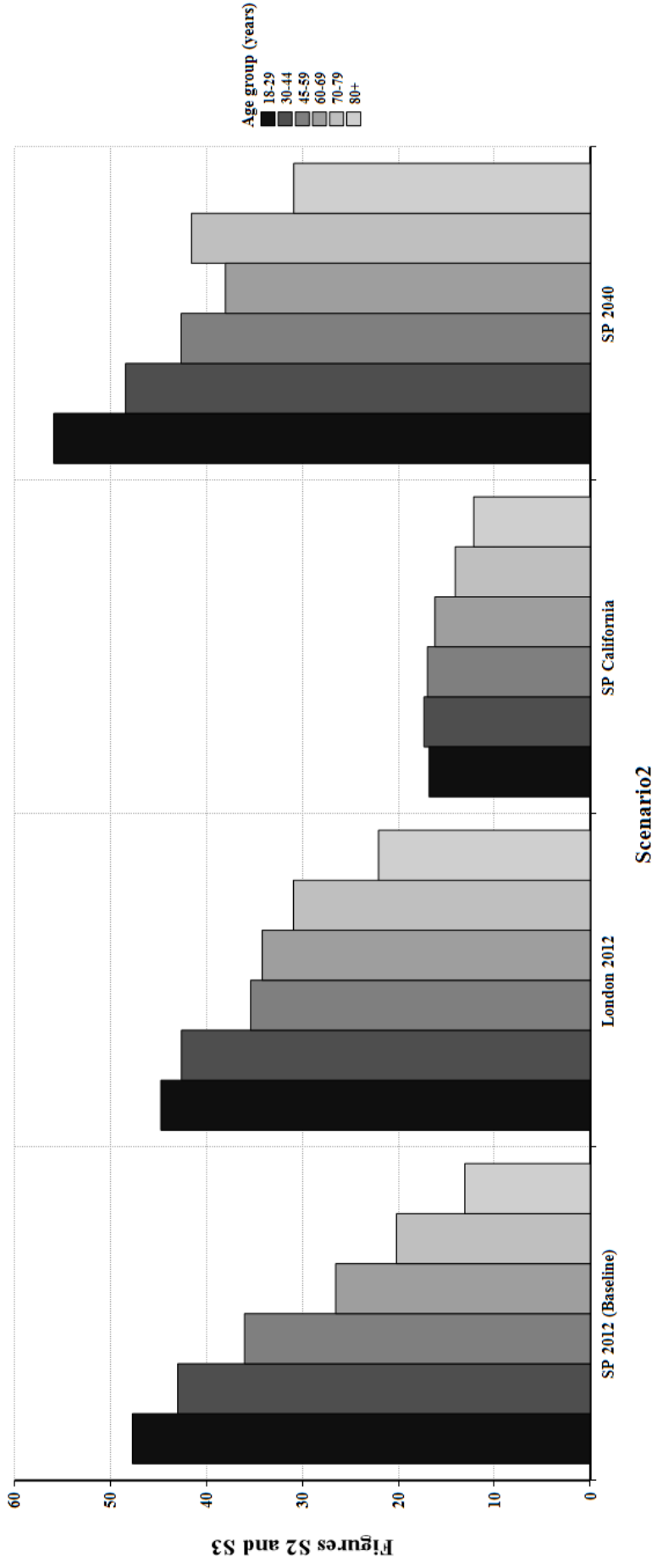
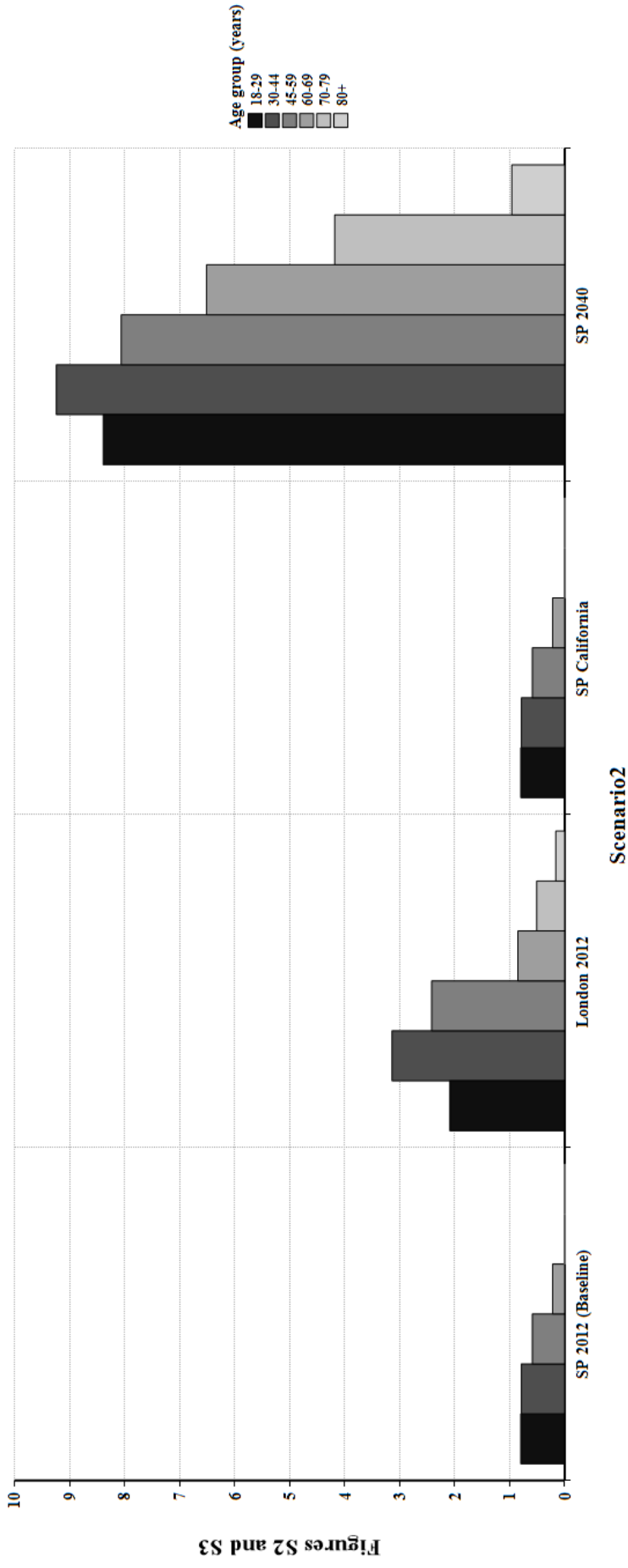


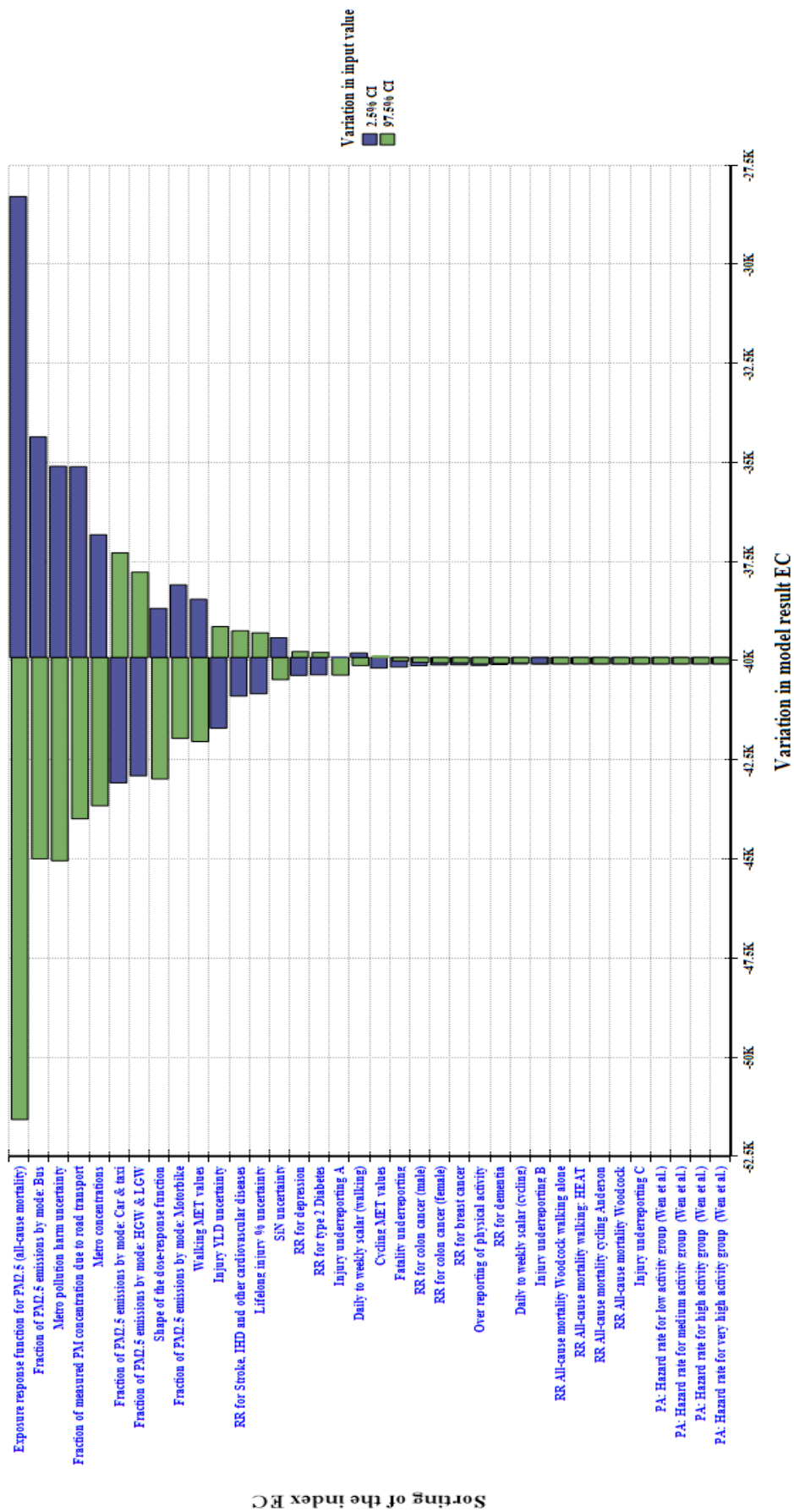
Figure S3. Average cycling minutes per day by age groups and scenario.



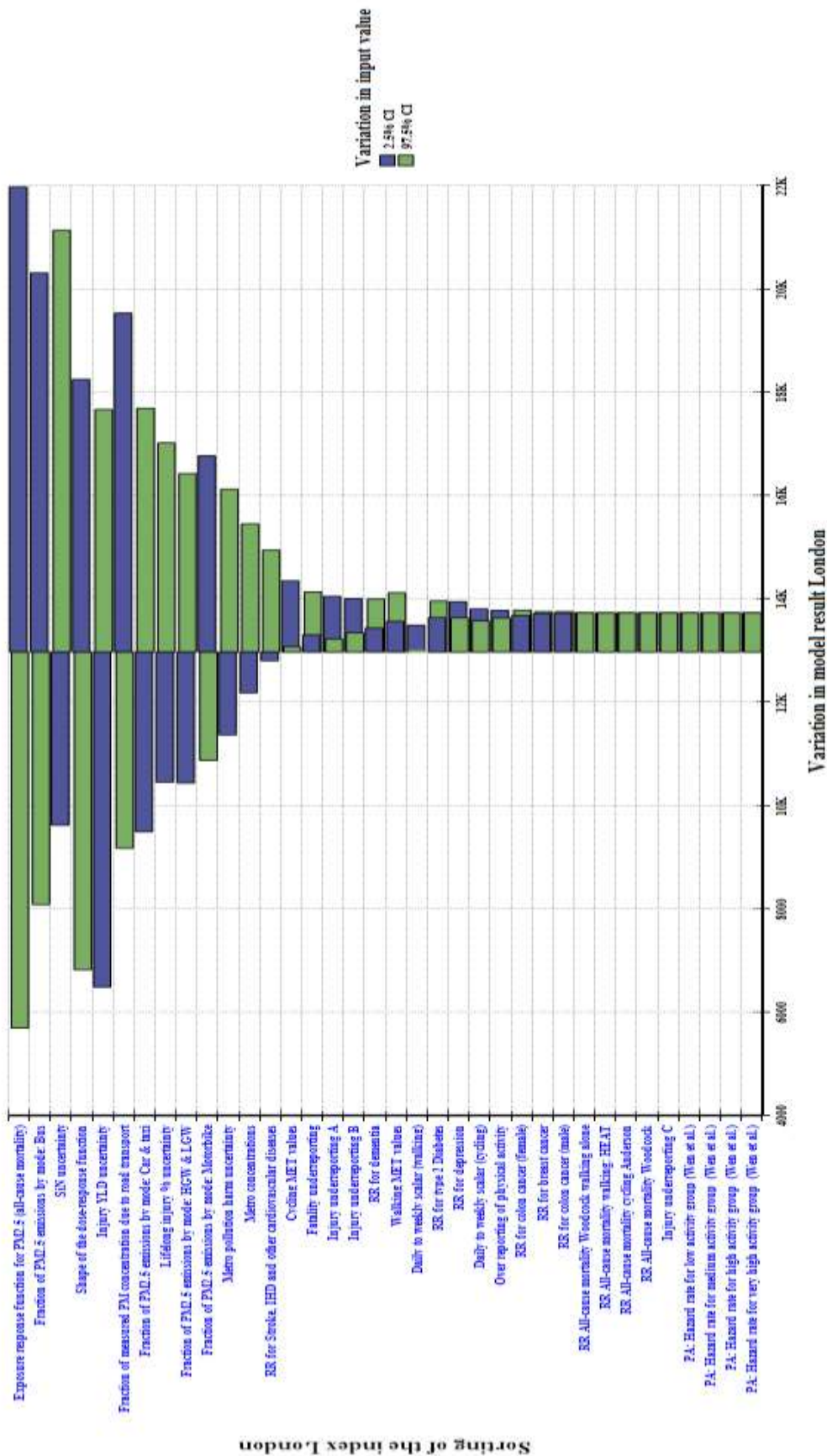
Figures S2 and S3

Figures S4 to S7. Tornado plots from sensitivity analysis.

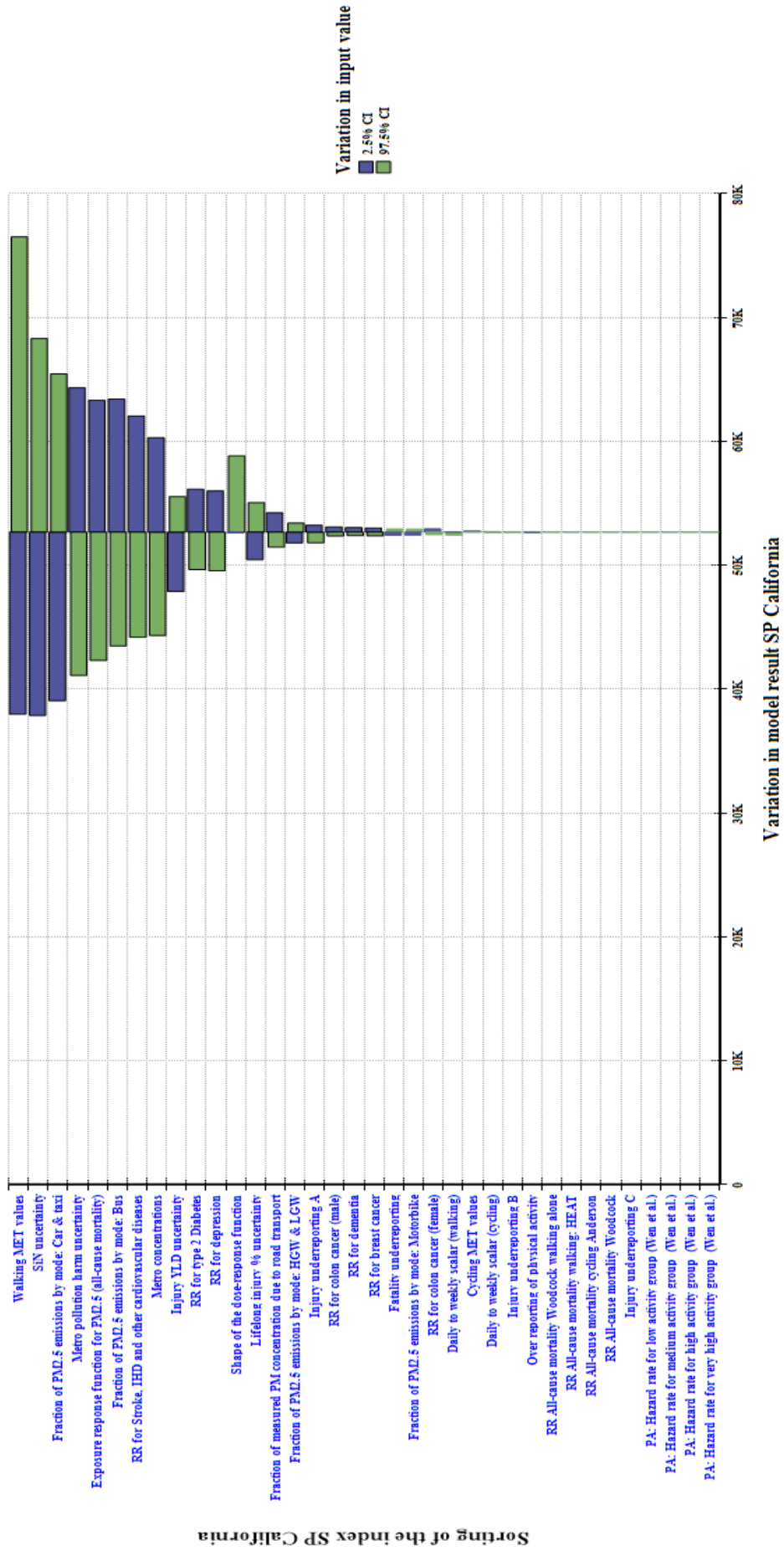
Figures S4. Tornado plot for the SP Expanded Centre scenario.



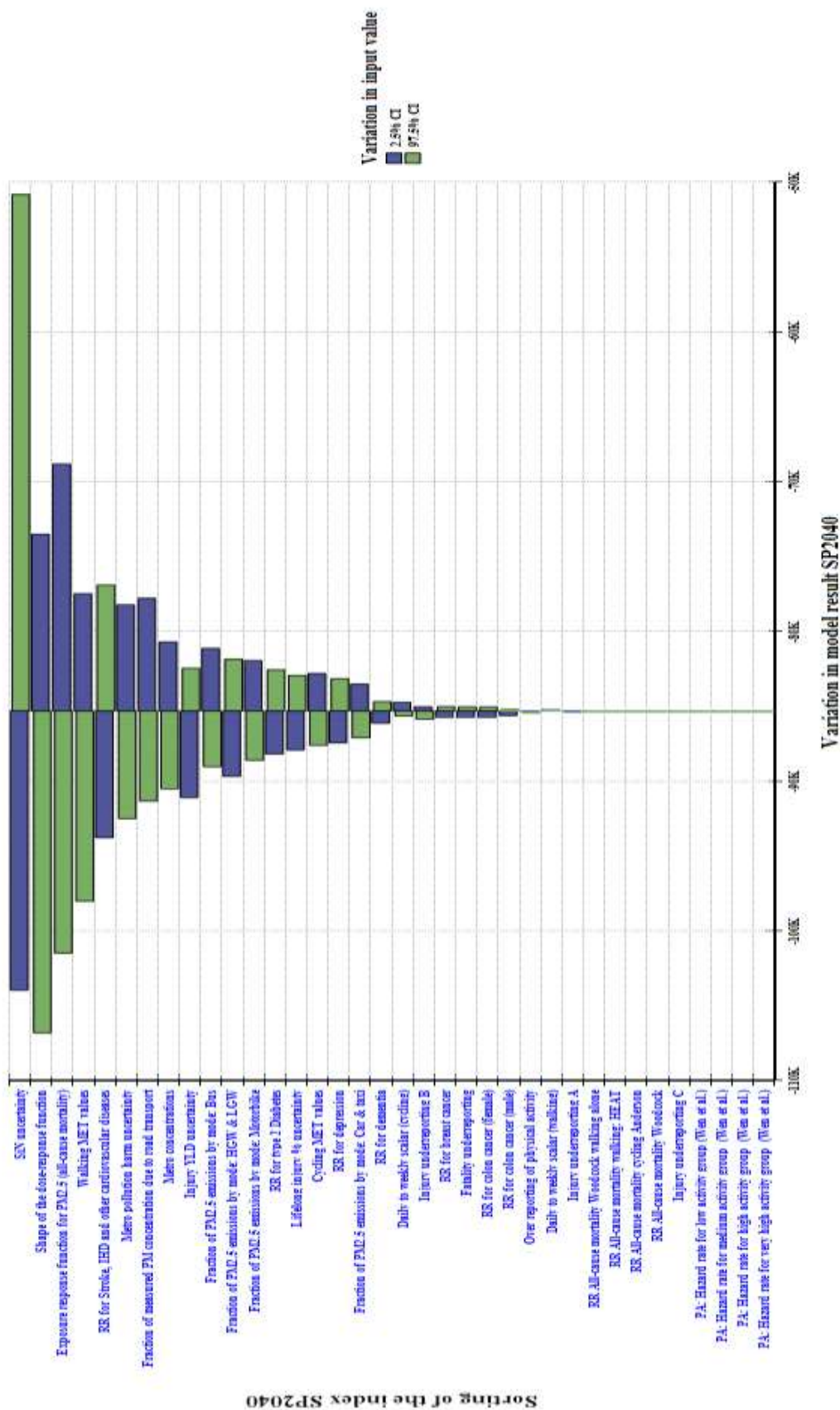
Figures S5. Tornado plot for the London 2012 scenario.



Figures S6. Tornado plot for the SP California scenario



Figures S7. Tornado plot for the SP 2040 scenario.



4. CONSIDERAÇÕES FINAIS

O conjunto de estudos apresentados nesta tese indica haver uma grande variação na prática de deslocamento ativo no Brasil em suas formas mais comuns (caminhada, bicicleta e a combinação de ambos), tanto em distintas regiões como em diferentes estratos sociodemográficos. Parte desta variação também é explicada pela heterogeneidade metodológica na geração destas estimativas.

A tendência de redução na prática de deslocamento ativo, observada no Brasil para o conjunto das capitais brasileiras, bem como para subgrupos vulneráveis como crianças e a parcela mais pobre da população, aponta para a necessidade de um pacote intersetorial de políticas públicas que tornem o deslocamento ativo a opção mais segura, agradável e conveniente para a maioria das viagens. Isso porque cenários de mobilidade favoráveis à prática de caminhada e bicicleta têm o potencial não apenas de contribuir para o aumento dos níveis populacionais de atividade física e para a redução do tempo inativo gasto nos deslocamentos cotidianos, como também de trazer ganhos populacionais em saúde, aí somados os ganhos decorrentes da redução nas lesões de trânsito e dos níveis de poluição do ar.

Ao contrário de outros países latino-americanos, há inúmeras fontes de informação sobre a prática de deslocamento ativo no Brasil que poderiam ser melhor exploradas. Ao mesmo tempo, faltam sistemas de monitoramento que ofereçam informações contínuas e detalhadas sobre o padrão de deslocamentos das metrópoles brasileiras, com ênfase nas formas ativas de deslocamento e no transporte público. A integração de fontes de informação já disponíveis e o uso de métodos de modelagem poderiam subsidiar o planejamento das mudanças necessárias para a construção de uma mobilidade humana mais saudável bem como uma melhor compreensão dos efeitos de políticas de transporte e de planejamento urbano sobre a saúde e o meio ambiente.

Também é preciso haver saúde em todas as políticas: o desenvolvimento de políticas públicas para promoção do deslocamento ativo será mais bem sucedido se considerar uma visão ampliada de saúde, que leve em conta não apenas a utilidade da atividade física ou seu caráter preventivo, mas também a relação do deslocamento ativo com os modos de viver e com a integração das pessoas com

seu meio ambiente, na perspectiva do desenvolvimento humano e urbano sustentável. Para isto, é necessária a devida reflexão sobre os modelos sociais e produtivos sob os quais está estruturada a sociedade brasileira.

Como estamos indo? A pergunta que inaugura a tese é desafiadora e de difícil resposta. Ainda temos bons níveis de uso da caminhada e bicicleta em regiões brasileiras, embora com marcadas diferenças regionais e sociodemográficas, e uma preocupante tendência de redução. Além disso, a maior parte do deslocamento ativo está amparada na pobreza e na falta de alternativas de transporte, principalmente nas grandes metrópoles do país. Há mudanças promissoras na direção da construção de sistemas de mobilidade urbana mais sustentáveis, acessíveis, confortáveis e seguros, embora ainda estejamos distante da transformação necessária para que alterações no padrão de mobilidade impactem de forma importante na saúde da população. Além disso, convivemos com níveis inaceitáveis de lesões e mortes no trânsito e poluição do ar. Entre idas e vindas, estamos na direção certa, a passos muito lentos.

O modelo de cidade mais compacta, diversa, inclusiva e bem desenhada é um promissor caminho para a promoção do deslocamento ativo e, por consequência, para a melhoria da saúde populacional e do meio ambiente. Transformar as cidades brasileiras nesta direção implica a superação de um histórico de urbanização caótico e acelerado, com larga tradição de segregação e dispossessão contra a população mais pobre, em benefício de interesses privados e das classes dominantes. Implica também a rediscussão sobre o direito à cidade e a prioridade dada a diferentes modos cotidianos de deslocamento. A condição em que essa transformação é mais provável permanece incerta, mas parece ser uma combinação entre forte mobilização social conjuntamente com uma pressão permanente dos limites do meio ambiente sobre a sociedade. Nas últimas décadas, o Brasil reduziu de forma notável a enorme desigualdade social do país e muitas cidades, como São Paulo, iniciaram suas reformas urbanas, na tentativa de superar o paradigma anterior de cidades segregadas, insustentáveis e dependentes de carros e motos. Em que medida essas iniciativas serão capazes de promover as necessárias alterações no padrão de deslocamentos de modo a trazer ganhos populacionais em saúde é uma questão a ser respondida.

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ANEXOS

Anexo 1 - Carta de aprovação do Comitê de Ética

Plataforma Brasil - Ministério da Saúde

Faculdade de Saúde Pública da Universidade de São Paulo

PROJETO DE PESQUISA

Título: Como estamos indo? O estudo do deslocamento ativo no Brasil

Área Temática:

Pesquisador: THIAGO HÉRICK DE SÁ

Versão: 1

Instituição: Faculdade de Saúde Pública da Universidade
de São Paulo - FSP/USP

CAAE: 01083312.2.0000.5421

PARECER CONSUBSTANCIADO DO CEP

Número do Parecer: 33920

Data da Relatoria: 13/04/2012

Apresentação do Projeto:

O projeto se insere em um contexto de mobilidade urbana e promoção da saúde, considerando alternativas de deslocamento ativo (como uso de bicicletas, caminhadas), tendo como hipótese que essa prática vem se ampliando na Região Metropolitana de São Paulo e que isso interfere positivamente em determinados indicadores de saúde.

Objetivo da Pesquisa:

Se propõe a investigar a frequência, distribuição e evolução temporal da prática de deslocamento ativo no Brasil bem como os efeitos dessa prática sobre as condições de saúde da população, de modo a subsidiar iniciativas de promoção de sua prática no Brasil. Também objetiva um estudo mais detalhado desses aspectos na Região Metropolitana de São Paulo.

Avaliação dos Riscos e Benefícios:

Não aborda seres humanos diretamente, trabalha com dados secundários produzidos e publicados por instituições públicas e apresenta benefícios no sentido de poder expor o crescimento do deslocamento ativo e interferências na saúde.

Comentários e Considerações sobre a Pesquisa:

Bastante interessante, factível e pertinente com relação ao atual problema mundial da mobilidade urbana na relação com a saúde.

Considerações sobre os Termos de apresentação obrigatória:

Não requer TCLE pois não envolve seres humanos, trabalha com dados e indicadores secundários.

Recomendações:

aprovar

Conclusões ou Pendências e Lista de Inadequações:

adequado para aprovação na forma como está.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Anexo 2 – Manuscrito “Can air pollution negate the health benefits of cycling and walking?”

Artigo original aceito para publicação no periódico Preventive Medicine

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f. Physical Activity for Health Research Centre (PAHRC), University of Edinburgh, UK.

Highlights

- Active travel (AT) is good for health because of increased physical activity (PA).
- Air pollution (AP) may reduce the health benefits of AT.
- We estimated risk-benefit trade-offs between PA from AT and AP.
- In typical urban AP situations benefits from PA clearly outweigh risks from AP.

Abstract

Objectives: Active travel (cycling, walking) is beneficial for health due to increased physical activity (PA). However, active travel may increase the intake of air pollution, leading to negative health consequences. We examined the risk-benefit balance between active travel related PA and exposure to air pollution across a range of air pollution and PA scenarios. **Methods:** The health effects of active travel and air pollution were estimated through changes in all-cause mortality for different levels of active travel and air pollution. Air pollution exposure was estimated through changes in background concentrations of fine particulate matter (PM_{2.5}), ranging from 5 to 200 µg/m³. For active travel exposure, we estimated cycling and walking from 0 up to 16 hours per day, respectively. **Results:** For the global average urban background PM_{2.5} concentration (22 µg/m³) benefits of PA by far outweigh risks from air pollution even under the most extreme levels of active travel. In areas with PM_{2.5} concentrations of 100 µg/m³, harms would exceed benefits after 2h 15 min of cycling per day or more than 10 h of walking per day. The results varied with different dose-response function (DRF) assumptions: with a non-linear DRF for PM_{2.5} and with linear DRF for PA, benefits of active travel outweighed the risks in all scenarios. **Conclusions:** Increasing active travel is beneficial for health in vast majority of cities and for vast majority of active travellers, even when harm caused by air pollution is taken into account.

Keywords: Physical activity; air pollution; bicycling; walking; mortality; Health Impact Assessment; Risk-Benefit Assessment.

Introduction

Several Health Impact Modelling (HIM) studies have estimated health benefits and risks of active travel (cycling, walking) in different geographical areas^{1,2}. In most of these studies, the general conclusion has been that the health benefits due to physical activity (PA) from increased active travel are significantly larger than the health risks caused by increases in exposure to air pollution.

Most of the existing active travel HIM studies have been carried out in cities in high income countries with relatively low air pollution levels^{1,2}. This raises the question on the risk-benefit balance in cities or areas where pollution levels are higher. Health risks of air pollution are usually assumed to increase linearly with increased exposure for low to moderate levels of air pollution, whereas the benefits

of PA increase curvy-linearly with increasing dose 3,4. Thus, at a certain level of background air pollution and of active travel, risks could outweigh benefits.

In this study we compare the health risks of air pollution with the PA-related health benefits from active travel across a wide range of possible air pollution concentrations and active travel levels. We use two thresholds to compare PA benefits and air pollution risks (Figure 1): At the “tipping point” an incremental increase in active travel will no longer lead to an increase in health benefits (i.e. max. benefits have been reached). Increasing active travel even more could lead to the “break-even point”, where risk from air pollution start outweighing benefits of PA (i.e. there are no longer net benefits, compared to not engaging in active travel).

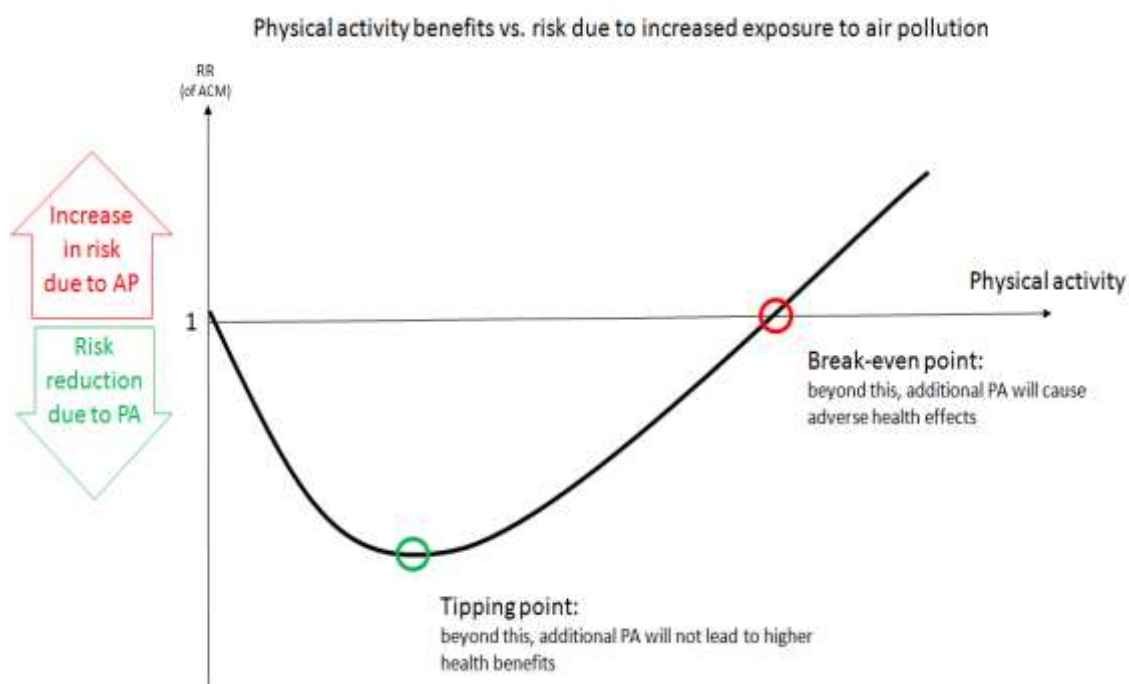


Figure 1: Definition of tipping point and break-even point as measured by the relative risk (RR) for all-cause mortality (ACM).

Methods

Our approach followed a general active travel HIM methodology^{1,2}. Air pollution exposure contrasts due to active travel were quantified by estimating changes in inhaled dose of fine particulate matter (PM_{2.5}) air pollution. We selected PM_{2.5} because it is a commonly used indicator of air pollution in active travel HIM studies^{1,2}, and because of the large health burden caused by PM_{2.5}. For both air

pollution and PA we used all-cause mortality as the health outcome because there is strong evidence for its association with both PM_{2.5} and PA₃.

The reduction in all-cause mortality from active travel was estimated by converting the time spent cycling or walking to Metabolic Equivalent of Task (METs) and calculating the risk reduction using dose-response functions (DRFs) adapted from Kelly et al.'s³ meta-analysis. From the different DRFs reported in Kelly et al.³ we chose the one with “0.50 power transformation” as a compromise between linear and extremely non-linear DRFs. Non-linearity in a DRF means that the health benefits of increased active travel would level out sooner and tipping points would be reached earlier than with more linear DRFs. See supplementary material for sensitivity analysis with different DRFs.

To convert cycling and walking time to PA we used values of 4.0 METs for walking and 6.8 METs for cycling. The walking and cycling levels used in this study are assumed to reflect long term average behaviour. The health risks of PM_{2.5} were estimated by converting background PM_{2.5} concentrations to travel mode specific exposure concentrations, and by taking into account ventilation rate while being active. For background PM_{2.5} we used values between 5 and 200 µg/m³ with 5 µg/m³ intervals. We also estimated tipping points and break-even for average and most polluted cities in each region included in the World Health Organization (WHO) Ambient Air Pollution Database⁷, which contains measured and estimated background PM_{2.5} concentrations for 1622 cities around the world.

The mode specific exposure concentrations were estimated by multiplying background PM_{2.5} concentration by 1.6 for cycling or 1.1 for walking. These factors are based on a review of studies that compared PM_{2.5} concentrations while cycling or walking to the background concentration of PM_{2.5}⁸. As the counterfactual scenario for time spent cycling or walking we assumed staying at home (i.e. in background concentration of PM_{2.5}). See supplementary file for sensitivity analysis with counterfactual scenarios where active travel time would replace motorized transport time. The ventilation rates differences while at sleep, rest, cycling and walking were taken into account when converting exposure to inhaled dose. For sleep, rest, walking and cycling we used ventilation rates of 0.27, 0.61, 1.37 and 2.55, respectively^{9,10}. Sleep time was assumed to be 8h in all scenarios and resting time was 16h minus the time for active travel.

For the PM_{2.5} DRF we used a relative risk (RR) value of 1.07 per 10 µg/m³ change in exposure⁴. We assumed that DRF is linear from zero to maximum inhaled dose. As a sensitivity analysis we used non-linear integrated risk function from Burnett et al.¹¹ (see supplementary material for details). The model used for all calculations is provided in Lumina Decision Systems Analytica format in supplementary file 2 (readable with Analytica Free 101, <http://www.lumina.com/products/free101/>), and a simplified model containing main results is provided in Microsoft Excel format in supplementary file 3.

Results

The tipping point and break-even point for different average cycling times per day and for different background PM_{2.5} concentrations are shown in Figure 2. For half an hour of cycling per day background PM_{2.5} concentration would need to be 125 µg/m³ to reach the tipping point. In the WHO Ambient Air Pollution Database less than 1% of cities have PM_{2.5} annual concentrations above that level⁷. The break-even point was over 200 µg/m³ for half an hour of cycling per day (Figure 2).

For half an hour of walking the tipping point and break-even point appear at a background concentration level above 200 µg/m³ (Figure S3, supplementary file). For the average urban background PM_{2.5} concentration (22 µg/m³) in the WHO database, the tipping point would only be reached after 11.5 hours of cycling and 16 hours of walking per day.

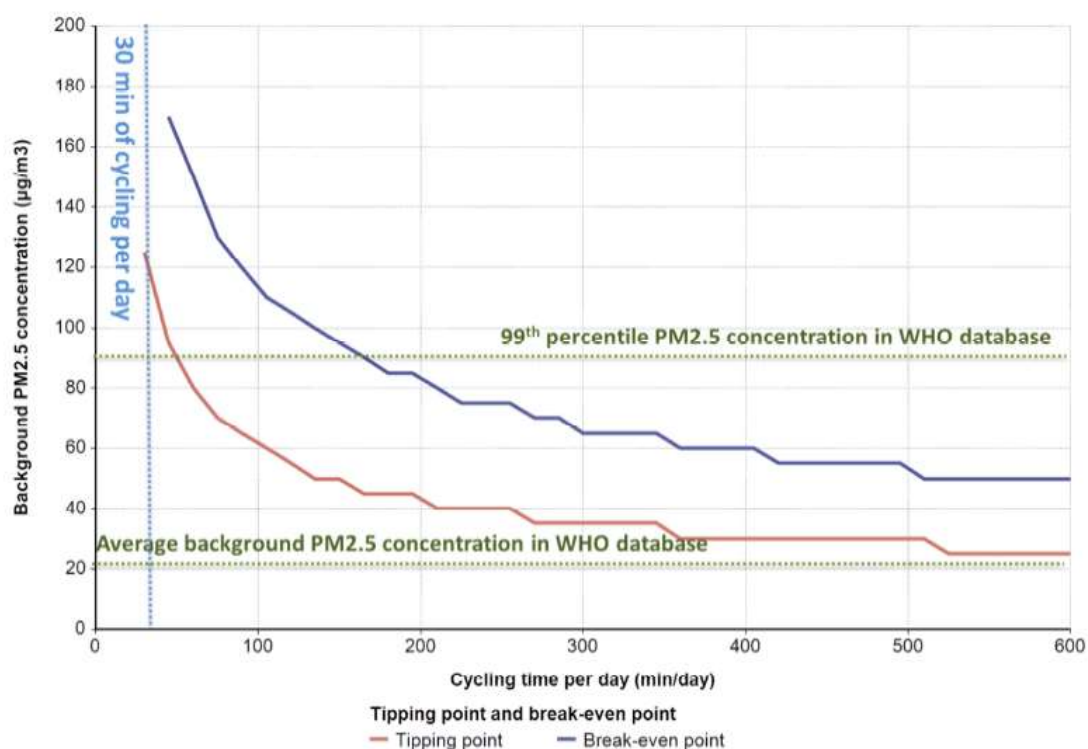


Figure 2: Tipping and break-even points for different levels of cycling (brown and blue lines, respectively) (minutes per day, x-axis) and for different background PM_{2.5} concentrations (y-axis).

Green lines represent the average and 99th percentile background PM_{2.5} concentrations in World Health Organization (WHO) Ambient Air Pollution Database⁷. Tables S1 and S2 (supplementary file) shows the tipping point for cycling and walking, respectively, in different regions of the world. In the most polluted city in the database (Delhi, India, background concentration of 153 µg/m³), the tipping and break-even points were 30 and 60 minutes of cycling per day, respectively (Table S1, supplementary file). In most global regions the tipping points for the most polluted cities (44 µg/m³ to 153 µg/m³) varied between 30 and 90 minutes per day for cycling, and 90 minutes to 6h 15mins per day for walking (Table S1, supplementary material).

Sensitivity analyses with different input values showed that the results are sensitive to the shape of the DRF functions. With the linear DRF for active travel the break-even point would never be reached for any background PM_{2.5} concentrations (Figure S4, supplementary material). With the most curved DRF (0.25 power) the

PM_{2.5} concentration where harms exceed benefits for 1h of cycling per day would drop from 150 µg/m³ to 130 µg/m³ (Figure S4, supplementary material). With a non-linear DRF for PM_{2.5} the break-even point was not reached in any background PM_{2.5} concentration when using “power 0.50” DRF for cycling and walking. Other input value modifications had small or insignificant impact to the results.

Discussions

This study indicates that, practically, air pollution risks will not negate the health benefits of active travel in urban areas in the vast majority of settings worldwide. Even in areas with high background PM_{2.5} concentrations, such as 100 µg/m³, up to 2h 15 min of cycling and 10h 45 min of walking per day will lead to net reduction in all-cause mortality (Figure 2 and Figure S3, supplementary material). This result is supported by epidemiological studies that have found statistically significant protective effects of PA even in high air pollution environments^{12,13}. However, it cannot be excluded that individuals engaging in extreme levels of active travel (i.e. bike messengers or professional athletes) may be exposed to air pollution related health risks, including short term effects⁶, when cycling in extremely polluted environments.

Some considerations of limitations and strengths of our study need to be applied when generalising these findings. In this analysis we took into account only the long-term health consequences of PA and PM_{2.5}. Assessing impacts of short-term air pollution episodes, where concentrations increase significantly above the average air pollution levels for a few days, would require additional analyses. However, it seems reasonable to assume that vulnerable subgroups suspending active transport during high air pollution episodes would yield greater benefits in terms of avoided short term respiratory symptoms than what would be gained from PA during these days.

For the health risks of air pollution we only estimated the increased risk during cycling and walking, not the overall health risk from everyday air pollution. Air pollution causes a large burden of diseases all over the world¹¹ and reducing air pollution levels would provide additional health benefits. Since transport is an important source of air pollution in urban areas, mode shifts from motorized transport to active travel would not only improve health in active travellers, but also help to reduce air pollution exposures for the whole population¹⁴.

The results are sensitive to assumptions of the linearity of dose-response relationships between active travel-related PA and health benefits, and between PM_{2.5} and adverse health effects. With linear DRFs for PA the benefits always exceeded the risks at all levels of PM_{2.5} concentrations. Evidence for a linear DRF for high PM_{2.5} concentrations is small and, for example, the Global Burden of Disease study applied non-linear, disease specific DRFs for PM_{2.5}. If the risks of PM_{2.5} level out after PM_{2.5} concentrations over 100 µg/m³, the health benefits of PA would always exceed the risks of PM_{2.5}.

Conclusions

The benefits from active travel generally outweigh health risks from air pollution and therefore should be further encouraged. When weighing long term health benefits from PA against possible risks from increased exposure to air pollution, our calculations show that promoting active travel is a viable option in the vast majority of settings (defined by the tipping points), and only very few extreme concentrations would call for recommendations against additional use of active travel (defined by break-even points).

Conflict of interest statement

The authors declare that there are no conflicts of interests.

Author contributions

MT made the calculations and drafted first version of the manuscript. AJN, TG, MJN, SK, THS, DRR and JW participated in designing the scope of the study. AJN and TG helped to clarify the message of the study. All authors contributed to the writing of this paper. All authors approved the final version to be submitted for consideration of publication.

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Supplementary data

Tainio et al. Can air pollution negate the health benefits of cycling and walking?

Methods -sensitivity analyses

Shape of dose-response function (DRF) for cycling and walking

In the main analyses we assumed the “power 0.50” shape for DRFs for cycling and walking as a compromise between linear and extremely non-linear DRFs. As a sensitivity analysis we also ran calculations with “log-linear” and “0.25-power transformed” DRFs. See Figure S1 below for illustration of different DRFs for cycling, and their impact to all-cause mortality.

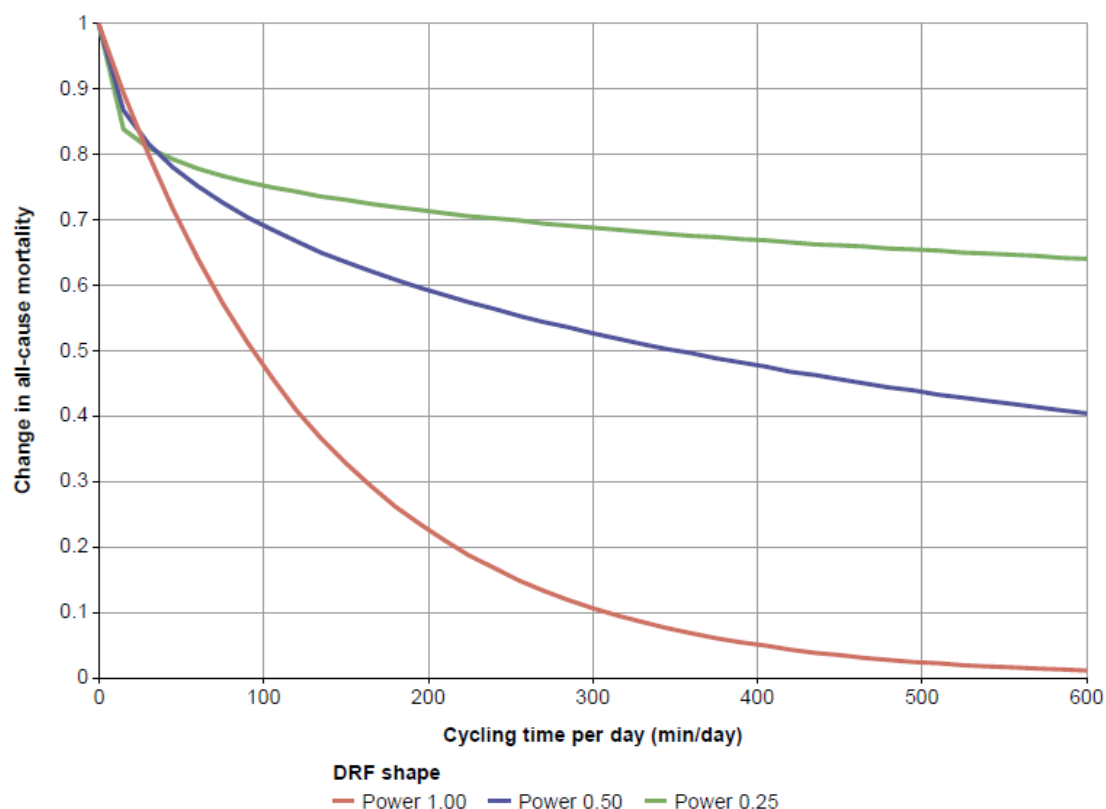


Figure S1: Different transformations for dose-response function (DRF) for cycling. “Power 0.50” was the main DRF used in the analysis. DRFs are adopted from (Kelly et al. 2014).

Air pollution adjusted DRF's

Studies examining the health benefits of physical activity (PA) underestimate the benefits because the participants of these studies are exposed to local air pollution. Kelly et al., previously calculated pooled relative risks for walking and cycling using random-effects meta-analysis of risk estimates at 11.25 METh/week from included prospective cohort studies. Rojas Rueda (2014 – unpublished work) adjusted the risk estimates for each cohort study by estimating air pollution (PM_{2.5}) exposure in each risk group. We re-calculated an air-pollution adjusted pooled relative risk for walking and cycling using random-effects meta-analysis of these adjusted risk estimates. See Table S1 (below) for comparison of adjusted and non-adjusted DRFs for cycling and walking for log-linear DRFs.

Table S1: RR for cycling and walking with and without adjustment for background air pollution

concentrations, based on reanalysis of Kelly et al. (2014) (95% confidence intervals in parenthesis). RR are per 11.25 METh/week change in cycling and walking. Log-linear DRF was assumed in these calculations.

RR	Cycling	Walking	
RR	0.903 (0.866-0.943)	0.886 (0.806-0.973)	
RR (adjusted)	0.901 (0.863-0.940)	0.884 (0.804-0.971)	

Counterfactual scenario from transport

In the main analyses we assumed that counterfactual scenario for cycling and walking is to stay at home. As a sensitivity analysis we also repeated the calculation assuming that increasing active travel would occur by changing the mode of travel e.g. from car to bicycle without changes in exposure concentration. In such scenario the change in exposure is based solely on the inhalation rate differences between driving and cycling/walking.

Shape of the DRF for PM2.5

In the main analyses the DRF for PM2.5 was assumed to be linear. As a sensitivity analyses we calculated the results by using the DRFs from (Burnett et al. 2014). Burnett et al. predicted nonlinear DRF for PM2.5 air pollution for different diseases. The DRF for stroke was the most non-linear with maximum harm reached around 300 $\mu\text{g}/\text{m}^3$ concentrations. We used Burnett et al.'s DRF for stroke as a hypothetical non-linear DRF for all-cause mortality to predict how non-linear PM2.5 DRF would change the results. See Figure S2 below for illustration of both DRFs for PM2.5.

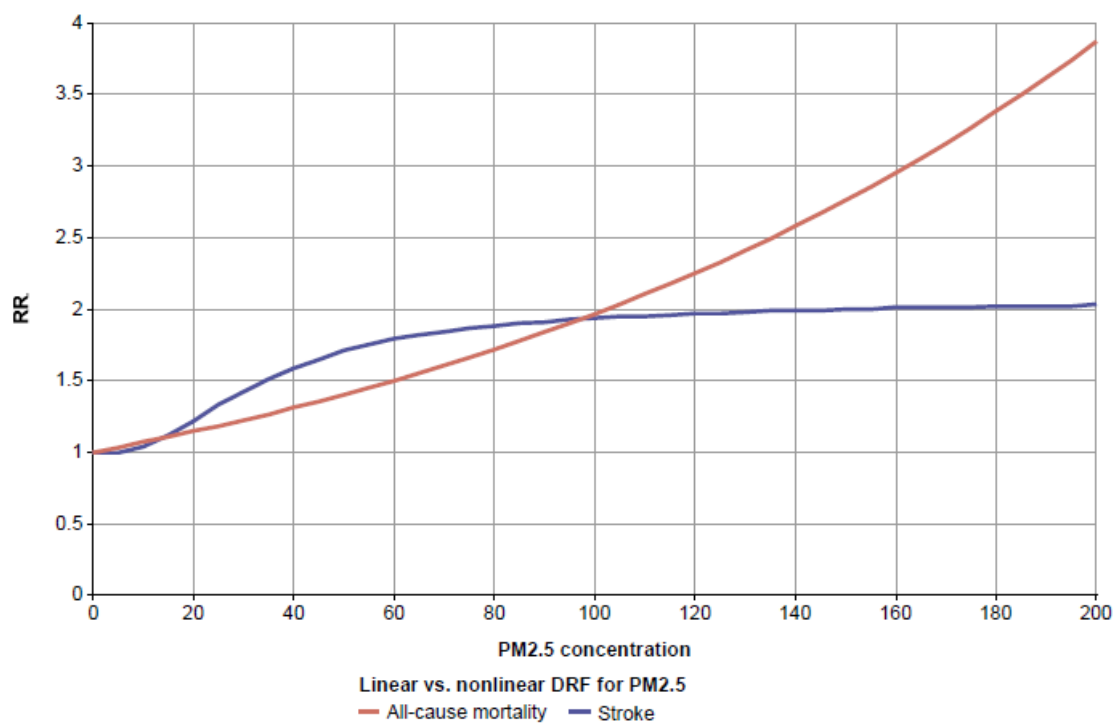


Figure S2: Comparison of linear and nonlinear dose-response function (DRF) for PM2.5 air pollution. Non-linear DRF (Stroke) was obtained from (Burnett et al. 2014).

Results – additional figures and tables

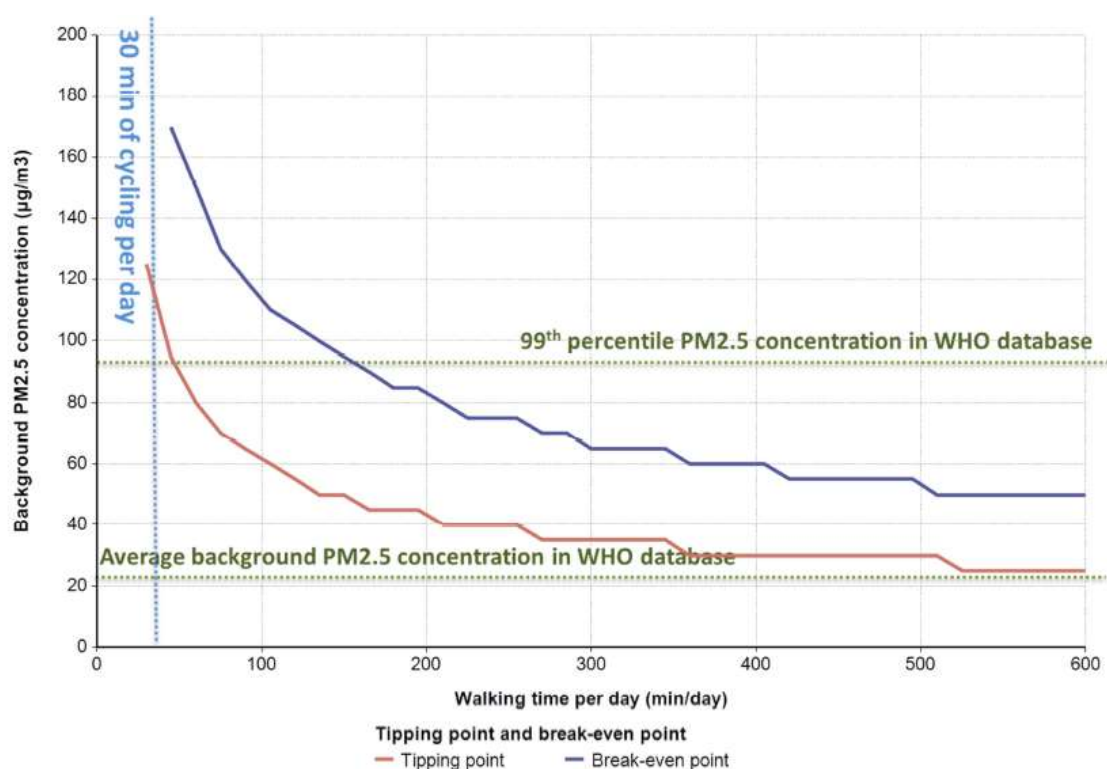


Figure S3: Tipping and break-even points for different levels of walking (brown and blue lines, respectively) (minutes per day, x-axis) and for different background PM2.5 concentrations (y-axis). Green lines represent the average and 99th percentile background PM2.5 concentrations in World Health Organization (WHO) Ambient Air Pollution Database (World Health Organization (WHO) 2014).

Table S1: Tipping and break-even points for cycling in different WHO regions (World Health Organization (WHO) 2014). The average represents the average city in the region and max the city with highest background PM2.5 concentration. PM2.5 concentrations are from WHO (see article for details).

Region	Average city			Most polluted city		
	PM2.5 ($\mu\text{g}/\text{m}^3$)	Tipping point (cycling /day)	Break-event point (cycling /day)	PM2.5 ($\mu\text{g}/\text{m}^3$)	Tipping point (cycling /day)	Break-event point (cycling /day)
Africa	26	8h	-	66	1h30min	5h
Americas	21	12h45min	-	44	3h	11h
Eastern Mediterranean	72	1h15min	4h15min	117	45min	1h45min
Europe	37	4h	15h30min	90	1h	2h45min
South-East Asia	43	3h15min	11h45min	153	30min	1h
Western Pacific	39	3h45min	14h	80	1h	3h30min

Table S2: Tipping and break-even points for walking in different WHO regions (World Health Organization (WHO) 2014). The average represents the average city in the region and max the city with highest background PM2.5 concentration. PM2.5 concentrations are from WHO (see article for details).

Region	Average city			Most polluted city		
	PM2.5 ($\mu\text{g}/\text{m}^3$)	Tipping point (cycling /day)	Break-event point (cycling /day)	PM2.5 ($\mu\text{g}/\text{m}^3$)	Tipping point (cycling /day)	Break-event point (cycling /day)
Africa	26	-	-	66	6h15min	-
Americas	21	-	-	44	14h	-
Eastern Mediterranean	72	5h30min	-	117	2h15min	7h45min
Europe	37	-	-	90	3h30min	13h15min
South-East Asia	43	14h45min	-	153	1h30min	4h45min
Western Pacific	39	-	-	80	4h30min	-

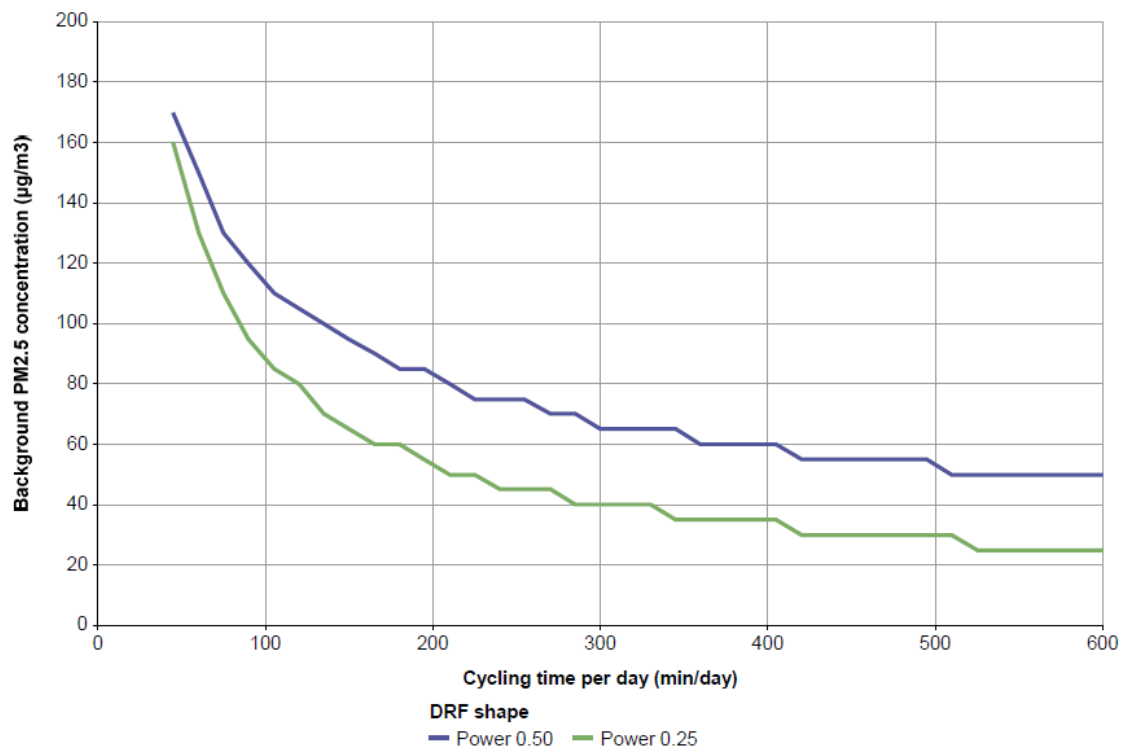


Figure S4: Break-even point for different DRFs for cycling (see Figure S1). Blue line represent the main analysis and green line break-even point “power 0.25” DRF for cycling. With the log-linear DRF (power 1.00) the break-even point was never reached.

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Anexo 3 – Manuscrito “Land-use, transport, and population health: understanding a complex system“

Artigo original aceito para publicação no periódico The Lancet

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Abstract

The effects of land-use and transport modal choice on population health are not well described. Using a health impact assessment framework, we estimated the population health effects arising from alternative land-use and transport policy initiatives across six cities. Land-use changes were modelled to reflect a compact city in which land-use density, diversity, and distances to public transport were enhanced, thereby providing opportunities for a shift from private motor vehicles to walking, cycling, and public transport. The compact city model resulted in health gains for all cities across diabetes, cardiovascular disease, and respiratory disease. However, for moderate to highly motorised cities, such as Melbourne and Boston, the compact city model lead to an increase in road trauma for cyclists and pedestrians. The findings suggest that government policies need to actively pursue land-use elements (particularly a focus towards compact cities) that support a shift away from private motor vehicles and towards walking, cycling and public transport. These policies

must also ensure provision of safe walking and cycling infrastructure along with carbon-free public transport. The findings highlight opportunities for policymakers to influence the overall health of growing cities.

Introduction

Cities around the world are dealing with the consequences of changing population demographics and policies that have failed to effectively manage the relationship between land use, mobility, and population health. In 2007, 51% of the world's population lived in cities, and it is estimated that this will increase to 70% by 2050.¹ These projections are reflected in population growth estimates that the world's population will increase by 66% over the next 40 years, from 7 billion people in 2013 to 10.5 billion people in 2053.² Urban growth and the pressure it places on urban infrastructure is now a major international challenge. By 2050, Australia's four largest cities will have a combined population similar in magnitude to Australia's current total population,³ while the United States, China, and India will see increases in their larger cities of 33%, 38%, and 96%, respectively.⁴

Associated with continued population growth are ever-increasing demands on transport systems. Governments are increasingly emphasising the need to integrate transport and land-use planning,⁵ acknowledging that land-use decisions significantly influence transport options and travel choices. Sprawling residential-only development patterns that dominate most suburban areas in North America, Australia, and New Zealand limit the ability of people to walk or cycle for their daily travel requirements.⁶ In these countries, low density housing developments render public transport development costs prohibitive, which produces a reliance on private motorised transport and increased exposure to the risks associated with traffic speed, traffic volume, vehicle emissions, and physical inactivity.⁷ Alongside economic growth, private car use is dramatically increasing in many middle-income countries such as Brazil,⁸ China, and India.⁹ The resultant declines in physical activity, increased air pollution, and the heightened risk of motor vehicle crashes combine to produce increased rates of chronic disease and injury.¹⁰

For policymakers, town-planners, and transport planners with the power to influence the health of rapidly expanding cities and their increasingly motorised populations, minimising exposure to health risks while maintaining or enhancing the mobility of city residents needs to be a priority. Recent innovations in transportation

have generated an expectation of a transportation revolution. With internet connectivity, automated vehicles, and advanced software, a future is envisaged where road deaths, serious injury, and of the current transport system such as congestion are eliminated. Like an engineering fix for global warming, this vision is seductive and will eventually play some part in solving current transportation challenges. However, serious obstacles, including software viruses, security risks, and fall-back options in the case of major connected system failures, mean that technology solutions will be achieved, but only over the ensuing decades. These solutions will not address the broader health consequences associated with land-use, the transport system, and rapid motorisation, such as increased rates of cardiovascular disease, diabetes,¹¹ and respiratory disease^{12, 13} as well as escalating rates of road traffic injury.¹⁴

Globally, deaths from road traffic injury have increased by 46% over the 20 years to 2012, making it now the eighth leading cause of death.¹⁵ The United Nations General Assembly resolution on global road safety acknowledges the emerging challenges associated with reducing road injury,¹⁶ as do initiatives such as Sustainable Safety¹⁷ and Vision Zero.¹⁸ These efforts are consistent with the United Nations Post-2015 Sustainable Development Agenda, which emphasises the risks associated with global trends towards urbanisation and disaster risk reduction and mitigation. However, despite the focus of these efforts, they have rarely acknowledged the impact of land-use issues such as urban sprawl on travel mode choice or travel distance, and the consequent effects on population health.

The effects of land-use and transport modal choice on population health are not well described. In part, this is because they occur against a backdrop of complex, interacting, and dynamic environmental, technological, and population conditions that evolve over years. This paper investigates, for the first time, land-use policy choices that influence a city's transport modal choice and subsequent population health, and thereby identifies processes that could lead to healthier and more sustainable urban environments.

A model of land-use, transport mode choice, and population health

To assess the relationship between land-use, transport, and population health, we selected the key elements presented in the preceding paper in this series (highlighted in blue in figure 1 below) for which information and relationships have

been demonstrated.¹⁹ We also conducted a systematic search of the literature to identify measures of effect for the key elements identified in the preceding paper. Having obtained estimates of the relationship between land-use and transport modal choice, we applied a health impact assessment framework²⁰ to produce a model for which estimates of population health outcome were derived (see figure 1).

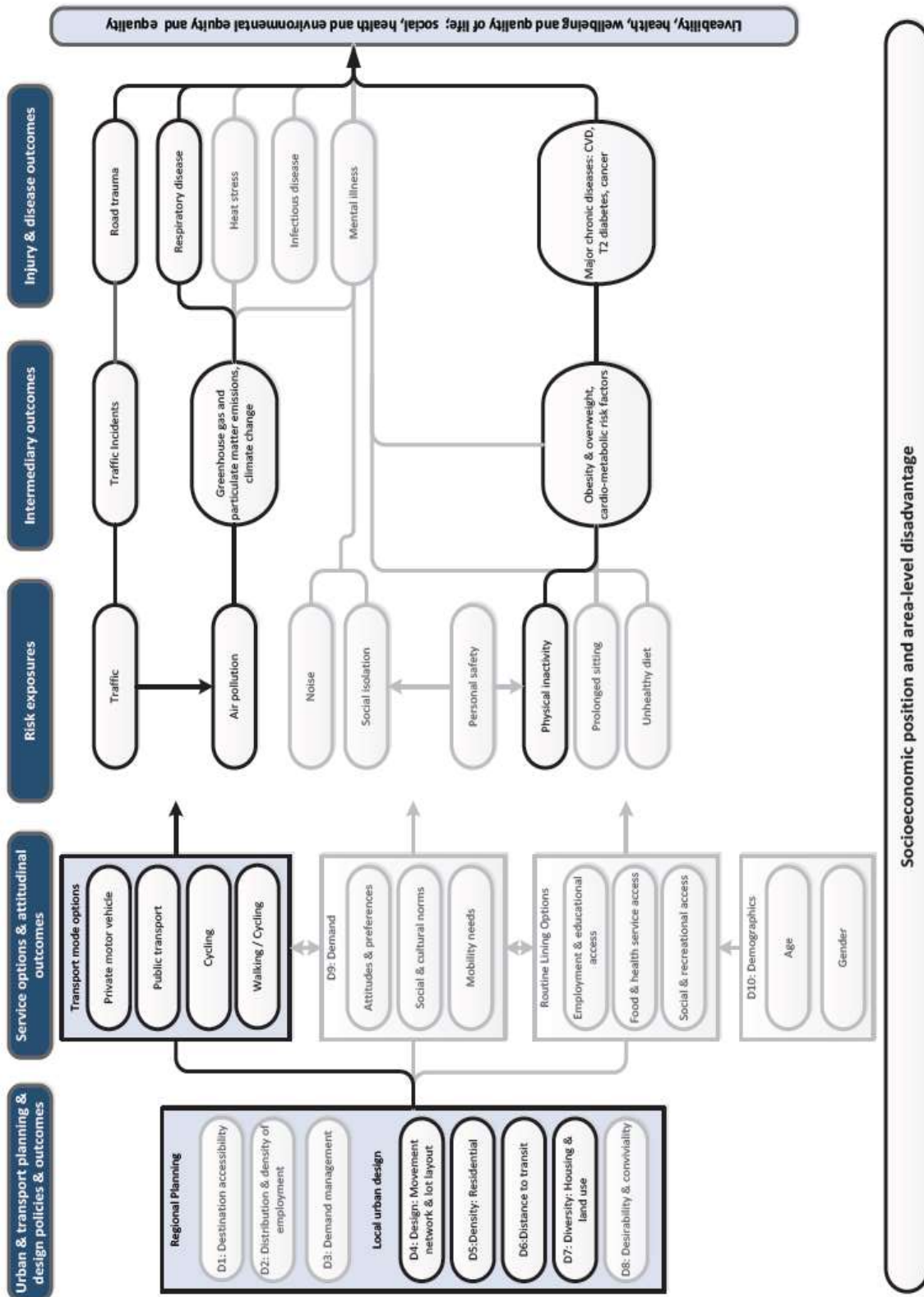


Figure 1: Land-use, transport mode choice, and population health model.

To model the effect of land-use on transport modal choice and population health, we took characteristics from six cities. We selected the cities based on a combination of their country's stage of development, level of motorisation, geographic disparity, and the availability of reliable transport and health data. These cities were: Melbourne, Australia (a high-income and highly motorised city); Boston, United States of America (a high-income and moderately motorised city); London, United Kingdom, (a high-income and moderately motorised city); Copenhagen, Denmark (a high-income and moderately motorised city); São Paulo, Brazil (an upper-middle income and moderately motorised city); and Delhi, India, (a lower- to middle-income and rapidly motorising city).²¹ We applied weighted average elasticities between land-use (density, diversity, and distance) and transport mode choice to each city. These elasticities were derived from work undertaken by Ewing and Cervero.¹⁹ The elasticities ranged from 0.02 to 0.29 per unit change in the relationship between each of the four land-use elements (see figure 2) and the respective transport mode choice.

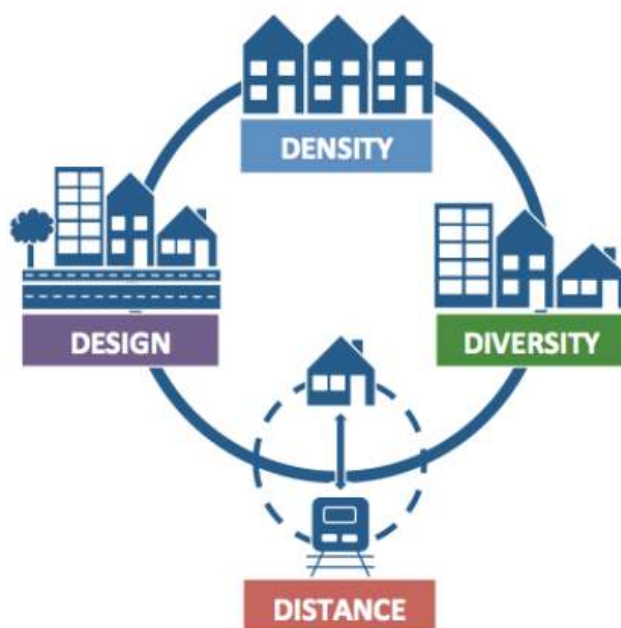


Figure 2: 4 Ds of Design – density, diversity, distance, and design.

The land-use element density encompasses population density, residential unit and or intersection density; diversity relates to the number of separate land-users; design refers to the layout of the land, including the streets, building setbacks and intersection connectivity; while distance refers to the average distance to public transport (see figure 2). The elasticities applied to the four land-use elements in our

model were derived from meta-analytic approaches that included studies with small samples and uncontrolled confounding factors. It is therefore important to consider an element of uncertainty associated with these estimates.¹⁹

We assessed the influence of land-use and transport mode choice on population health outcomes from road trauma (deaths and serious injury; ICD-AM V00-V89), cardiovascular disease (ICD-AM I00-I99), diabetes (ICD-AM E10-E14), and respiratory disease (ICD-AM J30-J98) for each city. For comparative purposes, road trauma and chronic disease health outcomes (cardiovascular disease, diabetes, and respiratory disease) were reported as disability-adjusted life years (DALYs), which are a combination of the sum of the years of potential life lost due to premature mortality and years of productive life lost due to disability.²²

The key determinants of population health associated with transport mode choice that we identified in the literature and applied within the model were:

- risk of death or injury per kilometres travelled by mode²³⁻²⁵
- level of physical inactivity (measured by metabolic equivalents (METs)^{26,27}) associated with the mode choice²⁸⁻³¹ and its effect on cardiovascular disease and type 2 diabetes
- exposure to fine particulate matter (PM10 and PM2.5) associated with emissions from transport.³²

Baseline population, transport mode share, road trauma, levels of physical inactivity, and air quality data were input for each city using the most recent available data.

Modelled changes in road trauma

Travel-mode, road deaths, and serious injury data were available from recent travel surveys and government agencies in Melbourne,^{33,34} Delhi,³⁵ São Paulo,³⁶ London,³⁷ Boston,³⁸ and Copenhagen.^{39,40} This data included distance travelled per mode per day and road fatalities and injuries by mode per year (injury data for Delhi was adjusted to account for historical under-reporting⁴¹). To estimate differences in road trauma as a result of changing mode share, we applied an approach that combined the probability of a crash between different road users given the changing proportions of transport modes within the transport system.^{23,24,42,43} We based estimates of chronic disease burden associated with road trauma on country-level

data (Global Burden of Disease data, 2013)⁴⁴ converted to city-specific DALY estimates scaled to city population size.

Modelled changes in chronic disease

Levels of physical inactivity and vehicle emissions were modelled for each city. Physical inactivity was estimated by calculating changes in the average estimated kilometres travelled per person, per mode, per day. We then applied consistent average METS per hour associated with each of the forms of travel across cities.²⁶ Average time spent in each travel mode was calculated through a combination of average speed by mode and daily kilometres travelled for each city.

The effect of increased physical activity (in METS per week) on cardiovascular disease and diabetes was estimated using linear associations established in the literature of 0.25 and 0.20 per 1000 kcal per week, respectively,⁴⁵⁻⁵⁰ with a benefit threshold restricted to activity in excess of 2.5 METS per hour.⁵¹ We considered this method to be appropriate for the small variations in overall physical activity that we modelled. However, it should be noted that associations between non-vigorous physical activity and disease risk has previously been shown to be non-linear in meta-analysis of studies that incorporate greater proportional changes.⁵² As well, the modelling of physical activity did not take into account demographic differences (eg, age profiles or gender) in the likelihood of modal shift between passive and active transport modes, the effects of exercise compensation,^{53,54} or differences in average speeds or METS associated with various demographic groups. Although these differences have been explored elsewhere,⁵⁵ we considered the levels of uncertainty associated with the estimates to be too great to be reliable at anything other than population-levels.

To estimate total vehicle emissions in each city, we obtained the most recently available city-specific particulate emissions (PM10 and PM2.5) data and estimates of the proportion of particulate matter generated by motor vehicles through combustion and suspended road dust in Melbourne, Delhi, São Paulo, and London.⁵⁶⁻⁶⁴ Data on the proportion of PM10 produced by vehicles for Boston and Copenhagen were unavailable so estimates of 30% were used, which approximated the median of the remaining cities. To reflect the clean fuel technology bus fleets in Delhi⁶⁴ and the urban bus renewal programme in São Paulo,⁶⁵ additional vehicle kilometres travelled

(VKT) by bus was assumed to be undertaken in fleets powered by compressed natural gas, which emits negligible additional fine particle emissions.⁶⁶

We modelled DALYs attributable to respiratory disease and cardiovascular disease that were associated with coarse (smaller than PM10) and fine (smaller than PM2.5) particulate emissions. Changes in particulate emissions associated with vehicles were assumed to alter proportionately with kilometres travelled. The effect of PM2.5 reduction on long-term cardiovascular disease risk and the effect of PM10 reduction on respiratory disease risk were then estimated using associations gathered from a systematic search of the literature. The search identified an approximate 20% increase in cardiovascular disease mortality risk per 10 ug/m³ increase in PM2.5,⁶⁷⁻⁷¹ and an approximate 2.5% increase in respiratory disease risk associated with a 10 ug/m³ increase in PM10⁷²⁻⁷⁷ (although estimates for this effect vary widely between studies). We assumed that air pollution affected mortality and incidence to the same degree,⁷⁸ that levels of PM10 and PM2.5 were closely correlated,^{79, 80} and that their effects on cardiovascular disease were not additive. Particulate emissions from private motorised transport modes per person and per kilometres travelled^{81, 82} were assumed to be equivalent.

City comparisons by land-use, transport, and population health

Baseline population health outcomes – road trauma (road deaths and serious injury), cardiovascular disease, diabetes, and respiratory disease – were estimated for each city. The proportion of VKT by travel mode and the risk of road death and serious injury per VKT for each city are reported in figure 3 and tables 1a and 1b, respectively.

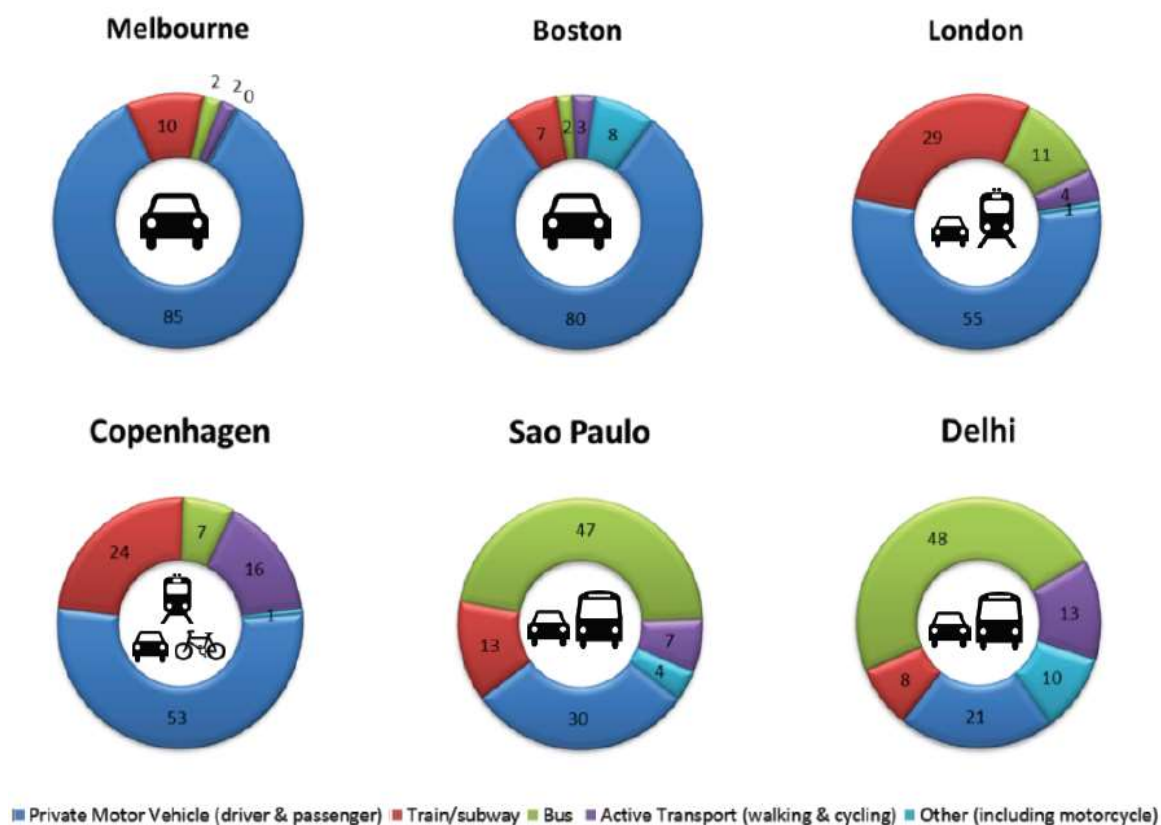


Figure 3: Vehicle kilometres travelled (VKT) by mode in each city at baseline with dominant transport modes (>15% of total VKT) highlighted.

There are considerable differences between cities for the proportion of kilometres travelled using private motor vehicles compared with public transport and active modes of transport such as cycling and walking. The differences in VKT by travel mode reflect, in part, cities with significant population size but low population densities. As a consequence, these cities have typically invested in road infrastructure. These development patterns are conducive to private motorised transport (such as in Melbourne and Boston). Despite the contrast in transport modal choice within and between cities, it is important to highlight the considerable differences between cities in relation to the risk of death or injury given the same transport modes. For example, the risk of death if travelling as a driver in a private motorised vehicle in Delhi is 3.3 times greater than the risk in Melbourne or London, while the risk of death if travelling as a bicyclist in São Paulo is 25 times the risk in Copenhagen (see tables 1a and 1b).

Baseline DALYs for chronic disease (cardiovascular disease, type 2 diabetes, and respiratory disease) and road trauma (road deaths and serious injury) are summarised in tables 2a and 2b. The rates of cardiovascular disease, type 2 diabetes, respiratory disease, and road trauma vary widely across cities, reflecting observations in the recently released global burden of disease study 2013.⁴⁴ For instance, there are four- to five-fold differences in DALYs for cardiovascular disease, type 2 diabetes, and road trauma between the high-income city of Melbourne and the lower- to middle-income city of Delhi. Estimated differences in respiratory disease between cities demonstrate smaller disparities, but the estimates for Delhi are almost twice those of Copenhagen.

Table 1a: Risk of road death and injury per 100 million km travelled by transport mode for

Melbourne, São Paulo, and Delhi

Transport Mode	Melbourne		São Paulo		Delhi	
	Deaths per 100 million km	Injuries per 100 million km	Deaths per 100 million km	Injuries per 100 million km	Deaths per 100 million km	Injuries per 100 million km
Vehicle Driver	0.2	7.3	1.7	38.1	0.4	2.5
Vehicle Passenger	0.2	7.1	1.9	106.7	0.4	2.5
Train/Tram	0.1	0.2	0.0	0.1	1.5	8.7
Bus	0.1	0.7	0.0	7.1	0.2	1.4
Walking	7.6	108.6	16.6	216.6	20.9	125.3
Bicycle	1.4	79.8	25.8	472.7	4.3	25.8
Other (Including motorcycle)	16.5	495.1	23.6	826.5	9.1	54.3

Table 1b: Risk of road death and injury per 100 million km travelled by transport mode for

London, Boston, and Copenhagen

Transport Mode	London			Boston			Copenhagen		
	Deaths per 100 million km	Injuries per 100 million km	Deaths per 100 million km	Deaths per 100 million km	Injuries per 100 million km	Deaths per 100 million km	Deaths per 100 million km	Injuries per 100 million km	
Vehicle Driver	0.2	3.5	0.9	0.3	2.2	0.3	0.3	3.7	
Vehicle Passenger	0.2	3.5	0.5	0.3	1.7	0.3	0.3	3.5	
Train/Subway	0.0	0.2	0.0	0.1	0.1	0.1	0.1	0.6	
Bus	0.1	2.5	0.0	0.2	0.2	0.3	0.3	0.7	
Walking	5.9	64.8	2.7	12.0	12.0	3.2	3.2	50.0	
Bicycle	4.4	140.8	2.5	23.0	23.0	0.6	0.6	26.6	
Other (Including motorcycle)	13.1	229.0	0.1	3.5	3.5	3.4	3.4	171.0	

Table 2a: Disability adjusted life years (DALYs) lost related to cardiovascular disease, diabetes, respiratory disease, and road trauma for Melbourne, São Paulo, and Delhi

Population Health Outcomes	Melbourne		São Paulo		Delhi	
	DALYs lost per 100 000 population	City total	DALYs lost per 100 000 population	City total	DALYs lost per 100 000 population	City total
Cardiovascular Disease	3277	136 622	4961	558 286	13 770	230 6920
Type 2 Diabetes	606	25 265	1116	125 589	2996	501 927
Respiratory Disease	1642	68 457	1623	182 644	3927	657 900
Road Trauma	536	22 346	1447	162 838	2892	484 504

Table 2b: Disability-adjusted life years (DALYs) lost related to cardiovascular disease, diabetes, respiratory disease, and road trauma for London, Boston, and Copenhagen

Population Health Outcomes	London		Boston		Copenhagen	
	DALYs lost per 100 000 population	City total	DALYs lost per 100 000 population	City total	DALYs lost per 100 000 population	City total
Cardiovascular Disease	4579	374 251	5092	236 310	4315	24 261
Type 2 Diabetes	368	30 077	868	40 282	976	5488
Respiratory Disease	2191	179 075	2126	98 663	2268	12 752
Road Trauma	411	33 592	635	29 469	454	2553

The disparity observed in cardiovascular disease between Delhi and the remaining cities may reflect the presence of risk factors that contribute to

cardiovascular disease beyond those associated with the transport system, particularly socio-economic constraints, diet, exercise, tobacco use, and potentially, a genetic predisposition to cardiovascular disease later in life.⁸³

Opportunities for cities to enhance population health

Using the land-use and transport mode choice model illustrated in figure 1, we modelled an opportunity to enhance population health in the selected cities. In what we refer to as the compact cities model, we provided an alternative to each city's land-use. The compact cities model changed each city's land-use by increasing land-use density by 30%, increasing diversity by 30%, and decreasing average distance to public transport by 30%. We also modelled a transport policy initiative that supported a 10% modal shift away from private motor vehicle driver and passenger VKTs (excluding motorcycles) to either cycling (6.6%) or walking (3.3%). This modal shift reflects transport policies currently implemented in a number of European cities that impose barriers to private motor vehicle use.⁸⁴ It is important to note that a 30% increase in land-use density in a city such as Delhi, which already has an estimated population density approaching 20,000 persons per square kilometre,⁸⁵ may seem impractical. However, the compact cities model emphasises the need to enhance the proximity of employment, education, and place of residence in cities such as Delhi.

Figure 4 reports the estimated change in kilometres travelled per day by private vehicles, public transport, walking, and cycling (active transport) under the compact cities model. Table 3 outlines the change in travel-related METS and transport-related particulate emissions under the same model. Given the imposed land-use changes and the mode-shift away from private motor vehicles, it is not surprising that an increase in public transport travel (trains/trams and buses) and walking and cycling is observed in each city.

The largest proportional change in walking and cycling is seen in Melbourne, Boston, and London. But much of the improvement in walking and cycling in these cities comes

from building upon the very low baseline proportion of the city population travelling by these modes. This means that the overall proportion of kilometres travelled by walking and cycling remains low (<10%), even after land use changes are applied. Nonetheless, as a consequence of the increase in walking and cycling, measureable increases in estimated travel-related physical activity (as measured by METS per week) across these cities is observed.

Changes in transport-related particulate emissions due to modal shifts away from private vehicles and towards low-emission public transport were observed across all cities. Although estimated emissions reduced most notably in the highly

Panel 1. Variation in city plans. In the maps highlighted below, Melbourne and Boston, with populations of approximately 4.5 million residents each, demonstrate the most 'grid-like' road networks designed around the predominant use of motorized transport. By contrast, older cities such as London and Sao Paulo (8 and 12 million residents, respectively) have medium levels of motorization combined with a dense, 'spaghetti' road network whilst Copenhagen and Delhi (with 0.6 million and 17 million residents, respectively) have sparse road networks reflecting low levels of infrastructure dedicated to motorized transport.



motorised cities of Melbourne (12%), Boston (12%), London (10%), and Copenhagen (11%), they also reduced (to a lesser extent) in Delhi (3%) and São Paulo (5%), where VKT transfer from private to public transport was proportionately lower.

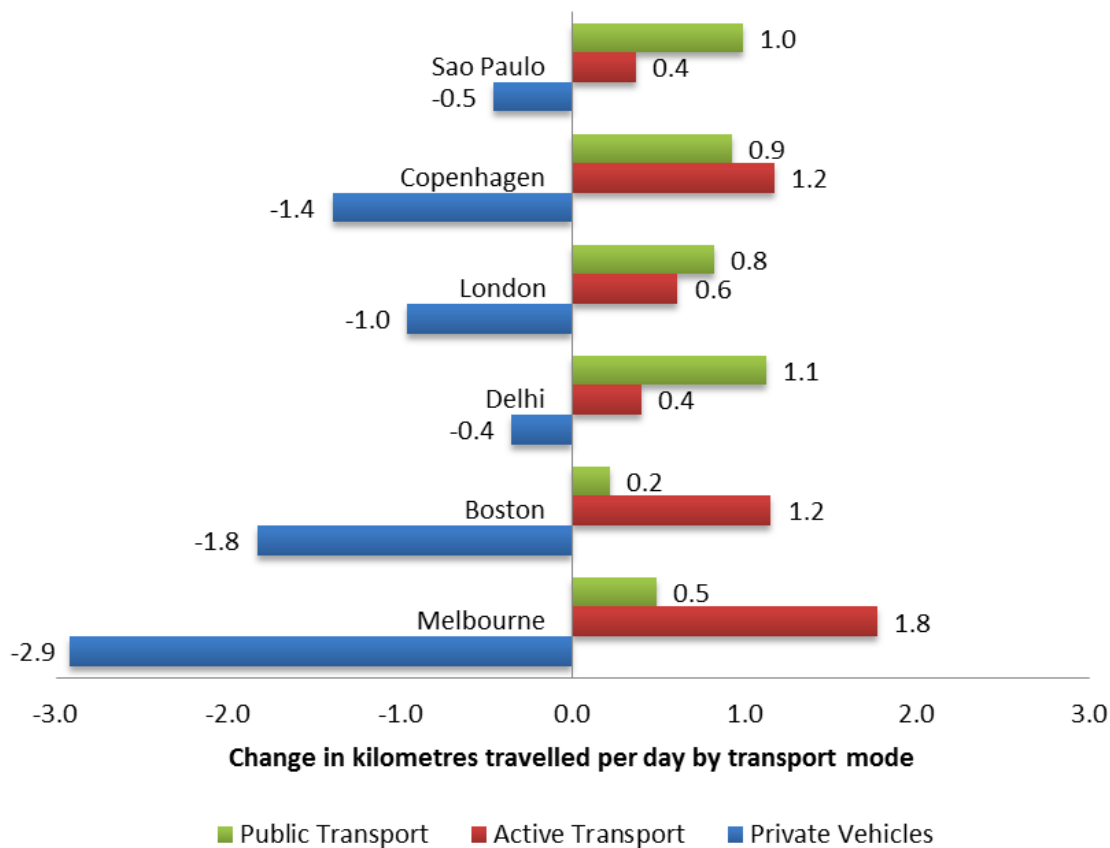


Figure 4: Estimated change in total kilometres travelled per day by mode of transport under the compact cities model for each city.

Table 4 reports the estimated health gains produced by the compact cities model. Health gains were observed across all cities for cardiovascular disease, respiratory disease, and type 2 diabetes. In addition to the reductions in estimated emissions described above, these gains were associated with enhancements to land-use that brought about a modal shift toward walking and cycling that resulted in positive transport-related energy expenditure (as measured by METS) across all cities. The greatest gains in transport-related physical activity were in the highly motorised cities of Melbourne (72%) and Boston (56%), where baseline active transport levels were low. Transport-related energy expenditure was also observed, albeit to a lesser extent, in London (39%), Copenhagen (29%), São Paulo (24%), and Delhi (19%).

Under the proposed compact cities model, road trauma (DALYs per 100 000 people) was estimated to increase in five of the six cities (see table 4). Road deaths and serious injuries were estimated to increase in Melbourne, Boston, London, and to a lesser extent, São Paulo and Copenhagen. Delhi was the only city expected to observe a reduction in road trauma, but this was a marginal change given the confidence intervals for these estimates (see figure 5). These changes in road trauma were a direct consequence of the modal shift from private vehicles to walking and cycling. Despite the application of a safety in numbers⁸⁶ effect, increases in estimated road trauma in each city would be expected to be borne by vulnerable road users in the form of cyclists and pedestrians. This highlights that while safety in numbers may reduce per kilometre risk, it should not be relied upon as a strategy to reduce absolute road trauma.^{87, 88}

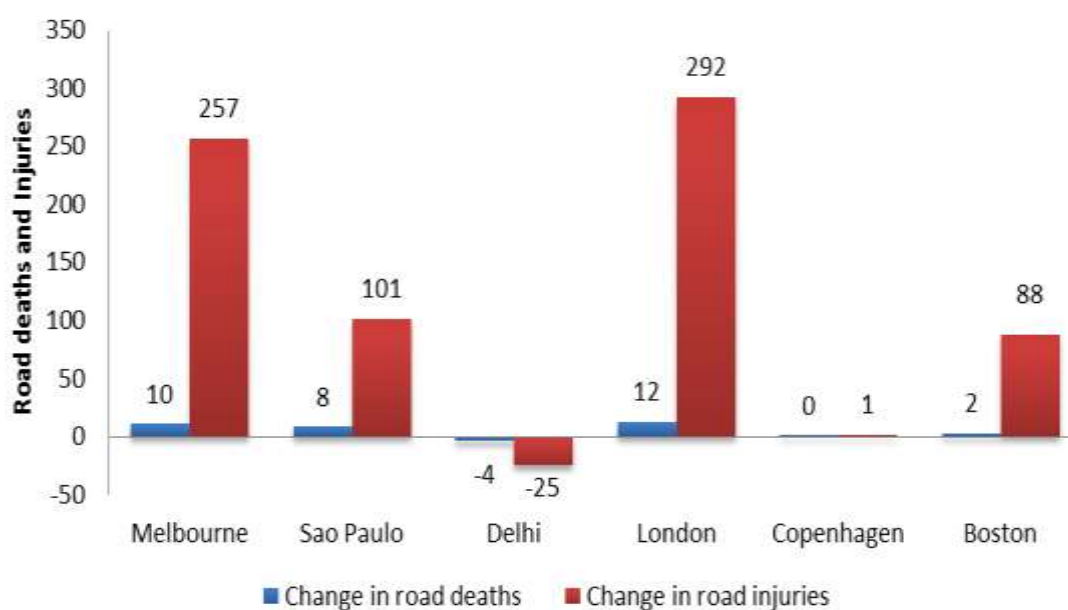


Figure 5: Estimated change in road deaths and official injuries under the compact cities model for each city.

It is important to note that the road trauma findings reported here are limited to trauma associated with motor vehicle crashes. With the exception of São Paulo, the analysis does not include an estimation of the risk associated with bicycle-only incidents. The inclusion of bicycle-only crashes would be likely to add to the burden of road trauma associated with increases in the observed bicycle and pedestrian deaths and injuries. There is also evidence that rates of road deaths and serious

injury alter as a function of long-term economic growth (see panel 1) or short-term economic cycles.⁸⁹ Consequently, elements of a city's economy could attenuate (or amplify) the population health outcomes observed in each city. We have not adjusted the estimates of road trauma for the potential economic fluctuations in the respective cities.

Table 3: Changes in physical inactivity and particulate emissions associated with the compact cities model application in each city

Physical Inactivity	City					
	Melbourne	Boston	London	Copenhagen	Delhi	São Paulo
Change in travel-related METS per week	72.1% (38.9%, 119.5%)	55.7% (26.8%, 99.0%)	39.1% (10.4%, 78.6%)	28.9% (-2.2%, 69.5%)	18.5% (-6.7%, 54.4%)	24.1% (-4.3%, 65.2%)
Particulate Matter						
Change in transport-related particulate emissions	-12.4% (-17.3%, -6.8%)	-11.8% (-16.3%, -6.9%)	-10.1% (-14.3%, 5.4%)	-10.9% (-15.3%, -5.8%)	-3.2% (-4.9%, -1.4%)	-4.9% (-6.8%, -2.8%)

Note: Figures in parentheses are 95% confidence bounds. Other vehicles including powered two- and three-wheelers were not modelled within the scenarios as the proportion of travel within this mode was assumed to remain stable. All transport mode changes refer to change in vehicle kilometres travelled from baseline.

While modal shift toward active transport options resulted in increased road trauma, a considerable proportion of the DALYs gained across the chronic diseases in the compact cities model was contributed to by policies that encouraged walking and cycling uptake rather than land-use changes alone. This was particularly evident in the highly motorised cities of Melbourne, Boston, and London. This underscores the importance of providing additional transport policy, pricing, or regulatory incentives⁹⁰ to encourage active transport if reductions in chronic disease are to be realised. In cities with high baseline levels of walking and cycling, such as Copenhagen and Delhi, most benefit was gained from land-use changes that produced higher rates of walking and cycling rather than promotion of active transport alone.

Applying the compact cities model involved coordination and linkage of multiple studies and effects across a wide variety of disciplines, each with their own inherent sources of error. We acknowledge these uncertainties and undertook Monte Carlo simulation using Analytica 4.4 software⁹¹ across each of the city-specific models. The simulation provided confidence interval boundaries for the estimated

DALYs associated with population health outcomes as well as identifying which factors of the model were most influential in contributing to chronic disease and road trauma outcomes. To reflect the uncertainty associated with both the effect of land-use changes on transport mode choice and the effect of transport mode choice on the risk of road death or injury, we allowed estimates associated with these variables to vary according to normal distributions with standard deviations equal to 20% of the mean.⁹² For example, the effect of land-use density change on VKT was allowed to vary according to a normal distribution, as was the effect of VKT change on the risk of exposure to death or injury per kilometre.

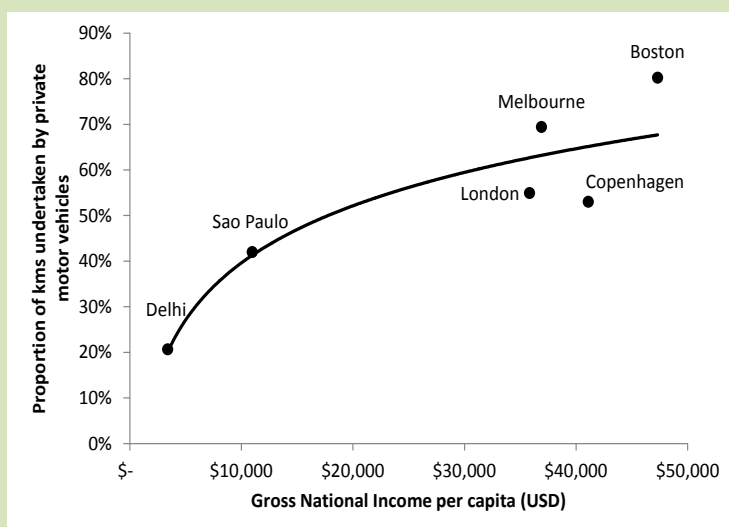
Table 4: Disability adjusted life years (DALYs) gained per 100 000 population under the Compact cities model for each city

Change in population health outcomes	City					
	Melbourne	Boston	London	Copenhagen	Delhi	São Paulo
Cardiovascular Disease (ICD-AM 100-199)	622 (1071:312)	765 (1386:355)	582 (1053:244)	337 (832:4)	565 (1117:169)	363 (915:14)
Type 2 Diabetes (ICD-AM E10-E14)	86 (159:40)	94 (189:41)	27 (61:7)	53 (146:-4)	28 (91:-10)	55 (155:-9)
Respiratory Disease (ICD-AM J30-J98)	2 (4:1)	3 (5:-1)	8 (14:4)	2 (4:1)	22 (42:8)	3 (5:1)
Road Trauma (ICD-AM V00-V89)	-34 (-7:-64)	-42 (-8:-79)	-41 (-19:-64)	-1 (20:-22)	2 (51:-48)	-4 (62:-71)
Total	679 (1181:330)	820 (1521:363)	581 (1084:216)	393 (967:5)	620 (1233:167)	420 (1029:12)

Note: Negative numbers indicate healthy years lost (DALYs lost). Figures represent 50th percentile estimates. Figures in parentheses are 95% confidence bounds. Aggregated individual estimates may not equal the total due to rounding and Monte Carlo estimation.

Other variables that were allowed to vary within the model due to acknowledged real-world uncertainty⁷² and were likely to have skewed distributions were the proportion of active transport transferred from vehicles distributed between cycling and walking; total kilometres travelled per year (a negatively skewed log-normal distribution)⁵¹; METS associated with transport modes⁹³; average speed by mode

Panel 2. The proportion of private motorized transport in cities demonstrates a relationship to gross domestic product per person. For cities with a high GDP, private motorized transport is only off-set by investment in public transport and/or active transport infrastructure (as in London and Copenhagen). In creating a future transport system that enhances both mobility and health, cities such as Delhi and Sao Paulo have the opportunity to invest in public and active transport and thereby reduce the reliance on private motorized transport and hence avoid the consequent mobility and associated negative health consequences associated with highly motorized cities.



in each city; and total particulate matter for each city. The relationship between levels of physical inactivity and chronic disease and the relationship between exposure to particulate matter and chronic disease reflected a normal distribution as described above. Nonetheless, the breadth of findings for many effects of land-use on transport mode choice, or transport mode choice on the key outcomes (road trauma and chronic disease) is likely to vary beyond the conservative estimates made here. The model and underlying assumptions can be viewed in the Webappendix.

Understanding the complexity of land-use and transport as it relates to health

Many countries concerned by the costs associated with the mounting burden of lifestyle-related chronic disease⁹⁴ have put in place plans and public policy initiatives that encourage greater levels of physical activity.⁹⁵⁻⁹⁷ Although the extent to which these plans are successfully disseminated, enacted, and monitored varies,⁹⁸⁻¹⁰² the findings we report here suggest that if governments are going to influence the overall health of growing cities, their policies need to actively pursue land-use elements that encourage a modal shift toward walking, cycling, and clean public

transport. From rapidly motorising to highly motorised cities, enhancements to urban design (such as increases in land-use density and diversity and a decrease in average distance to public transport along with a modal shift of motorised trips to walking and cycling) are needed immediately to limit the rising burden of chronic disease associated with transportation systems.

Infrastructure investment and carless cities

Despite the health gains in chronic disease associated with the compact cities model, the modal shift towards fewer private motor vehicles and increased walking and cycling resulted in an estimated increase in road trauma for all cities except Delhi. Given this, we estimated the extent of separated cycling and walking infrastructure that would be required to off-set the observed increase for each city (see figure 6).

Extent of separation between motor vehicles and active transport users (pedestrians and cyclists)

	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Melbourne	34	31	27	23	19	15	11	6	2	-3	-8	-14	-20	-26	-33	-41	-49	-59	-71	-88	-141
Boston	42	37	31	25	18	12	5	-2	-10	-18	-26	-35	-44	-55	-66	-78	-92	-108	-128	-155	-240
Delhi	-2	-15	-29	-43	-57	-73	-88	-105	-122	-140	-159	-180	-201	-225	-250	-279	-310	-347	-393	-455	-653
London	41	36	30	25	19	14	8	1	-5	-12	-20	-27	-36	-45	-54	-65	-77	-91	-109	-133	-208
Copenhagen	1	-4	-10	-16	-23	-29	-36	-43	-51	-59	-67	-76	-85	-96	-107	-119	-133	-149	-168	-196	-281
Sao Paulo	5	-3	-11	-19	-28	-37	-47	-57	-67	-78	-89	-101	-114	-128	-143	-160	-179	-201	-228	-266	-384

Estimated Disability Adjusted Life Years (DALYs) attributed to road trauma for each city

Figure 6: Estimated effect of separation of active transport vehicle kilometres travelled from motorised traffic required to produce changes in road trauma DALYs for each city under the compact cities model (positive numbers represent estimated increases in road trauma).

As demonstrated in figure 6, the more highly motorised cities of Melbourne, Boston, and London will need to make the largest investments in separated

pedestrian and cycling infrastructure (equivalent to approximately 40%, 30%, and 35% of total pedestrian and cycling VKT, respectively) to off-set the likely increase in road deaths and serious injuries associated with the compact city model. In contrast, Delhi, Copenhagen, and São Paulo are estimated to require minimal additional infrastructure to see no net increase, or even a reduction, in road trauma. This reflects the high proportion of walking and cycling in Copenhagen and Delhi (16% and 13%, respectively) and, to a lesser extent, São Paulo (7%). This also reflects the comparatively low level of increased risk associated with the greater number of vulnerable road users (pedestrians and cyclists) across the respective cities, in part, because of the significant proportion of VKTs undertaken using public transport (56%, 31% and 60%, respectively). This is not to say that further reductions in road trauma from current levels could not be made in these cities by changes to infrastructure alone. Further, these figures do not suggest that increased pedestrian and cyclist deaths would not occur, simply that increases in pedestrian and cyclist deaths would be matched by reductions across other modes (eg, drivers and passengers).

In summary, a modal shift in which there is a reduced reliance on the private motor vehicle and an increased prevalence of walking and cycling (and public transport use) will lead to considerable health benefits in relation to chronic disease. However, the introduction of additional vulnerable road users in the form of cyclists and pedestrians within a highly motorised transport system and without the inclusion of adequate infrastructure is likely to increase road trauma, as demonstrated in our compact cities modelling of Melbourne, São Paulo, London, and Boston. Conversely, additional cyclists and pedestrians may lead to decreased road trauma in cities with lower-levels of motorisation (eg, Delhi) or cities with high levels of walking and cycling and associated infrastructure (eg, Copenhagen). Policies that support walking and cycling within a safe urban environment are paramount to achieving population health, particularly in achieving reductions in chronic disease along with reduced road trauma.



Figure 7: Extensive infrastructure in cities such as Helsinki (pictured) is being delivered to support greater levels of safe cycling.

New urban mobility in which transport policies promote walking, cycling, and public transport while reducing subsidises for private motor vehicle use are being supported by cities across many high-income countries.¹⁰³ Cities such as Helsinki in Finland and Zurich in Switzerland have seen significant modal shifts from private motor vehicle use to walking, cycling, and public transport. For example, 52% of Zurich's daily VKTs are now undertaken either by walking or cycling, 19% on public transport, and only 29% using a private motor vehicle. Zurich has achieved this by limiting car parking, prioritising trams on road space, and deliberately creating congestion with traffic signals providing access to streets to only a few cars at a time.⁸⁴

Cities embracing the new urban mobility are setting ambitious targets to achieve safe and sustainable transport over the ensuing years and are building infrastructure of the quality previously built for the motor vehicle. For example, Helsinki, which is not typical of other European cities because it was designed during a period of considerable motorisation, has embraced sustainable mobility and is transforming its car-dependent suburbs into denser and more walkable mixed-use precincts that are linked to the city centre by rapid and frequent public transport.¹⁰⁴ Figure 7 illustrates the extensive infrastructure being delivered for cycling that

supports their proactive transport policy to achieve a cycling mode share of 15% of VKTs by 2020.¹⁰⁵ Cities that are embracing new urban mobility are doing so in the knowledge that it delivers benefits in terms of reduced congestion, greater opportunities for multimodal travel, and greater efficiency. This paper highlights the considerable health gains that residents of these cities will obtain by adopting low motorised mobility options.

Many countries concerned by costs associated with the mounting burden of lifestyle-related chronic disease⁹⁴ have put in place plans and public policy initiatives that encourage greater levels of physical activity.⁹⁵⁻⁹⁷ Although the extent to which these plans are successfully disseminated, enacted, and monitored varies,⁹⁸⁻¹⁰² the findings reported here suggest that government policies need to actively pursue land-use elements (particularly a focus towards compact cities) that support and even encourage a modal shift away from private motor vehicles towards walking, cycling, and public transport (new urban mobility). This is required if transport and city planners are to positively influence the overall health of growing cities.

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Anexo 4 – Capítulo “Atividade física: andando de lado (2009-2013)”

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Introdução

A atividade física é um importante determinante de saúde geral, tanto na prevenção de doenças (Lee *et al.*, 2012) como na promoção da saúde (World Health Organization - WHO, 2010) e na melhoria das condições de vida dos indivíduos (Woodcock *et al.*, 2009; Rydin *et al.*, 2012). Dessa forma, o declínio histórico dos níveis de atividade física (Hallal *et al.*, 2012) - relacionado à urbanização, à mecanização das atividades laborais e domésticas e ao uso do transporte motorizado (Brownson, Boehmer e Luke, 2005; Katzmarzyk e Mason, 2009; Costa, Garcia e Nahas, 2012) - tem se tornado um grande problema mundial de saúde pública.

A proporção de pessoas inativas, ou seja, que não realizam os níveis recomendados de atividade física (WHO, 2010), é superior a 30% na maioria dos países de média e alta renda (Hallal *et al.*, 2012). A inatividade física é um dos principais fatores de risco para morte e incapacidade em todo o mundo, respondendo por aproximadamente 9% de mortes prematuras por todas as causas (no Brasil, por 13%) (Lee *et al.*, 2012) e por mais de 69 milhões de anos de vida perdidos ajustados por incapacidade (DALY – *disability adjusted life years*) a cada ano (Lim *et al.*, 2012).

Adicionalmente, o comportamento sedentário - usualmente definido como tempo sentado em atividades com baixo gasto energético, como assistir televisão ou trabalhar no computador (Owen, 2012) - está associado ao risco aumentado para mortalidade por todas as causas (Proper *et al.*, 2011) e começa a ser entendido

como um fator de risco à saúde independente do nível de atividade física moderada a vigorosa (Owen, 2012).

No Brasil, dados recentes (2006 a 2009) apontam para uma estagnação em níveis desfavoráveis na prevalência de atividade física no tempo livre, de inatividade física e de comportamento sedentário, além de um cenário incerto quanto ao aumento da atividade física de deslocamento (Hallal *et al.*, 2011). Mais ainda, identificaram-se iniquidades nestes indicadores segundo idade, sexo e escolaridade, quase sempre desfavoráveis aos grupos sociais mais vulneráveis (crianças e idosos, mulheres e indivíduos menos escolarizados) (Florindo *et al.*, 2009; Hallal *et al.*, 2011; Knuth *et al.*, 2011). Diante deste cenário, fica evidente a baixa efetividade dos crescentes esforços de promoção de atividade física no país (Brasil, 2011, 2013).

O monitoramento contínuo dos indicadores de prática de atividade física e de comportamento sedentário segue sendo a primeira etapa de ação para a definição de políticas públicas que buscam a promoção da atividade física (Hallal *et al.*, 2012). Tal área teve grandes avanços no Brasil em anos recentes, em especial a partir da consolidação do Sistema de Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico (Vigitel) (Ministério da Saúde, 2012). O objetivo do presente estudo foi analisar a variação temporal dos níveis de atividade física no tempo livre e no deslocamento, de inatividade física e de comportamento sedentário em adultos das capitais brasileiras e do Distrito Federal entre 2009 e 2013.

Métodos

Foram utilizados dados do Vigitel, inquérito realizado anualmente desde 2006 nas 26 capitais brasileiras e no Distrito Federal. O Vigitel é um estudo transversal de base populacional com adultos (18 anos ou mais) residentes em domicílios servidos por linha telefônica fixa. Em cada cidade, o procedimento de amostragem é realizado em dois estágios: (I) sorteio das linhas telefônicas a partir do cadastro eletrônico de linhas residenciais fixas; (II) identificação das linhas residenciais ativas e sorteio aleatório do indivíduo a ser entrevistado em cada domicílio. No mínimo 2000 entrevistas são realizadas em cada cidade de modo a assegurar erro máximo de dois pontos percentuais e grau de confiança de 95% nas estimativas (total de cerca de 54 mil indivíduos por ano) (Ministério da Saúde, 2012).

Neste capítulo foram utilizados quatro indicadores: (I) ativo no tempo livre (prática semanal de pelo menos 150 minutos de atividade física moderada ou de 75 minutos de atividade física vigorosa no tempo livre¹⁰) (Ainsworth *et al.*, 2000; WHO, 2010); (II) ativo no deslocamento para o trabalho ou para a escola (deslocamento habitual de pelo menos 30 minutos para o trabalho ou escola/curso utilizando bicicleta ou caminhada, considerando os trajetos de ida e volta); (III) fisicamente inativo (ausência de qualquer atividade física no tempo livre nos últimos três meses, de esforços físicos intensos no trabalho, de deslocamento para o trabalho ou curso/escola caminhando ou de bicicleta e de realização de limpeza pesada de sua casa); (IV) tempo assistindo televisão de três ou mais horas diárias (marcador de comportamento sedentário). As variáveis sociodemográficas utilizadas foram sexo, faixa etária (18-24, 25-34, 35-44, 45-54, 55-64, ≥65 anos), e escolaridade (0-8, 9-11 e ≥12 anos de estudo).

Na análise dos dados, foram considerados os fatores de ponderação do Vigitel, levando em consideração a probabilidade desigual que indivíduos residindo em domicílios com maior número de telefone ou menor número de moradores tiveram em participar da amostra, além de igualar a composição sociodemográfica da amostra do inquérito à da população-alvo (identificada com base no censo demográfico) para cada ano de realização do inquérito. Estes fatores de ponderação foram calculados com base no método rake (Battaglia, Frankel e Link, 2008).

A prevalência dos indicadores selecionados foi apresentada segundo sexo, faixa etária e escolaridade da população de estudo para o ano de 2013. Posteriormente, analisou-se a tendência temporal (2009 a 2013) da prevalência de cada indicador segundo sexo. Modelos de regressão linear foram utilizados para identificação de variação significativa na evolução de cada indicador, considerando como variável dependente a prevalência do indicador e como variável independente o ano do inquérito. Foram consideradas significantes as evoluções cujos coeficientes da regressão para a variável 'ano de inquérito' eram estatisticamente diferentes de zero para um p-valor inferior a 0,05. O Vigitel foi aprovado pelo Comitê Nacional de Ética em Pesquisa.

¹⁰Atividade com duração inferior a 10 minutos não foi considerada para efeito do cálculo da soma diária de minutos despendidos pelo indivíduo com exercícios físicos. Caminhada, caminhada em esteira, musculação, hidroginástica, ginástica em geral, natação, artes marciais, ciclismo e voleibol foram classificados como práticas de intensidade moderada; corrida, corrida em esteira, ginástica aeróbica, futebol, basquetebol e tênis foram classificados como práticas de intensidade vigorosa.

Resultados

Enquanto pouco mais de um terço da população estudada é ativa no tempo livre (33,8%), cerca de um oitavo referiu se deslocar de forma ativa por pelo menos 30 minutos para a escola ou trabalho (12,1%). Por outro lado, um em cada quatro entrevistados refere assistir televisão por ao menos três horas diariamente (28,6%), enquanto um a cada seis apresenta-se como fisicamente inativo (16,2%). A proporção de ativos no tempo livre foi maior em homens do que em mulheres, sem que nenhum dos demais indicadores tenha variado de modo marcante entre os sexos (Tabela 1).

De modo geral, a proporção de ativos no tempo livre declina progressivamente com o incremento da idade, ao passo que a prevalência de atividade física por ao menos 30 minutos no deslocamento e de inatividade física se altera de forma expressiva somente a partir dos 55 anos (diminuição de ativos no deslocamento e aumento de inativos). Já o hábito de assistir TV por períodos prolongados atingiu seu nível máximo nas faixas extremas de idade (Tabela 1).

A escolaridade mostrou-se positivamente associada à proporção de ativos no tempo livre e negativamente associada à atividade física por ao menos 30 minutos no deslocamento e ao hábito de assistir TV por três ou mais horas ao dia (Tabela 1).

Tabela 1 - Proporção de indivíduos fisicamente ativos no tempo livre e no deslocamento, fisicamente inativos e que assistem televisão por três horas ou mais por dia segundo sexo, idade e escolaridade. Vigitel, 2013.

	Ativos no tempo livre		Ativos no deslocamento		Inatividade física		TV (≥ 3 horas/dia)	
	%	IC 95%	%	IC 95%	%	IC 95%	%	IC 95%
Sexo								
Masculino	41,2	39,9 - 42,5	12,2	11,2 - 13,2	16,8	15,8 - 17,8	28,1	26,8 - 29,3
Feminino	27,4	26,5 - 28,3	11,9	11,2 - 12,7	15,7	15,0 - 16,5	29,0	28,0 - 30,0
Idade (anos)								
18 a 24	49,7	47,4 - 52,0	13,8	12,1 - 15,5	13,7	12,2 - 15,2	29,5	27,3 - 31,6
25 a 34	39,3	37,4 - 41,2	12,6	11,3 - 14,0	11,6	10,3 - 12,8	27,9	26,1 - 29,7
35 a 44	29,6	27,9 - 31,3	15,0	13,5 - 16,6	12,4	11,2 - 13,7	26,3	24,6 - 28,0
45 a 54	27,3	25,7 - 29,0	13,5	12,1 - 14,8	13,7	12,3 - 15,1	26,5	24,6 - 28,3
55 a 64	26,6	24,9 - 28,4	9,4	8,1 - 10,8	20,2	18,3 - 22,1	30,7	28,6 - 32,8
65 e mais	22,3	20,7 - 24,0	3,0	2,4 - 3,6	38,4	36,3 - 40,5	34,3	32,4 - 36,3
Escolaridade (anos)								
0 a 8	22,0	20,8 - 23,3	12,0	10,8 - 13,1	20,3	19,1 - 21,5	31,4	29,9 - 32,9
9 a 11	37,2	35,9 - 38,5	13,0	12,1 - 14,0	12,9	12,1 - 13,8	30,6	29,4 - 31,8
12 e mais	45,4	43,8 - 47,0	10,8	9,7 - 11,9	15,3	14,2 - 16,4	21,6	20,4 - 22,9
Total	33,8	33,0 - 34,6	12,1	11,5 - 12,7	16,2	15,6 - 16,9	28,6	27,8 - 29,4

Vigitel: Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico; IC95%: Intervalo de Confiança de 95%.

Entre 2009 e 2013, a proporção de ativos no tempo livre aumentou em 2,2 pontos percentuais (pp) para os homens ($p = 0,02$) e 5,3 pp para as mulheres ($p = 0,01$), ao mesmo tempo em que a proporção de ativos no deslocamento diminuiu 5,4 pp nos homens ($p = 0,01$) e 4,6 pp nas mulheres ($p = 0,05$) (Figura 1).

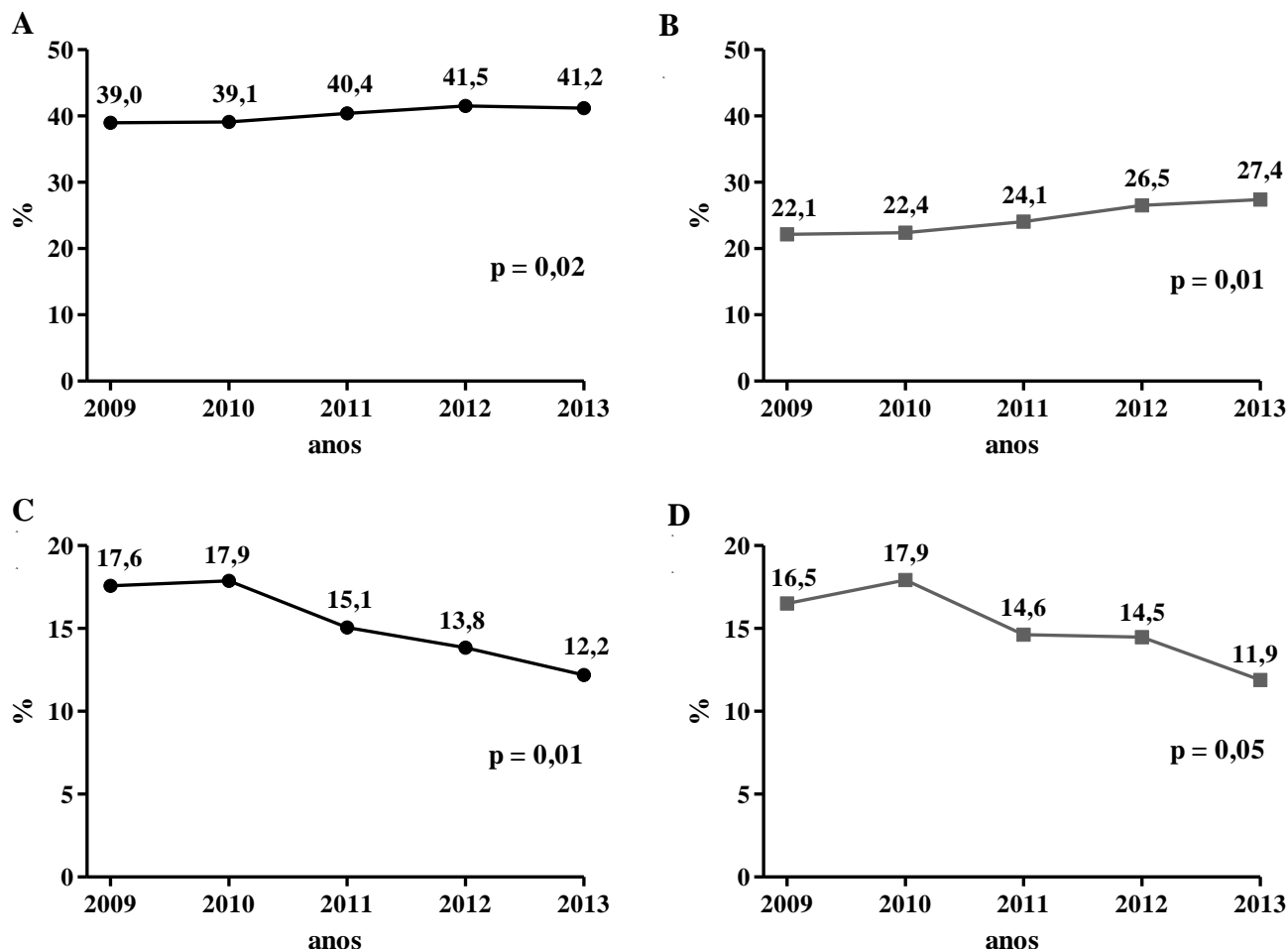


Figura 1 - Tendência temporal da proporção de indivíduos ativos no tempo livre (A - homens; B - mulheres) e da proporção de indivíduos ativos no deslocamento para o trabalho ou para a escola (C - homens; D - mulheres). Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico (Vigitel), 2009 a 2013.

Nesse mesmo período, foi observada estagnação da prevalência de inatividade física e do comportamento sedentário em ambos os sexos (Figura 2).

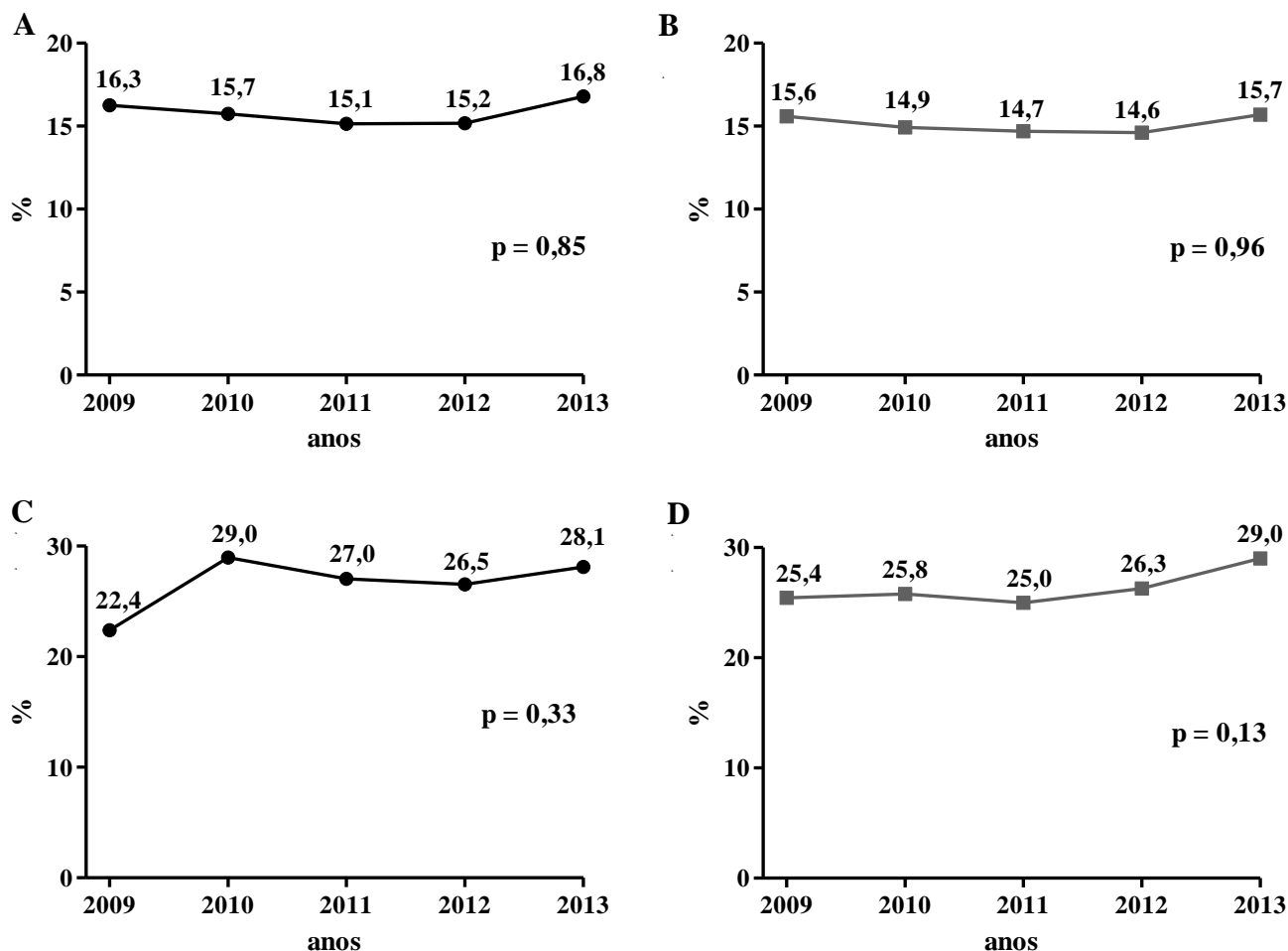


Figura 2 - Tendência temporal da proporção de indivíduos inativos (A - homens; B - mulheres) e da proporção de indivíduos que assistem três ou mais horas diárias de televisão (C - homens; D - mulheres). Vigilância de Fatores de Risco e Proteção para Doenças Crônicas por Inquérito Telefônico (Vigitel), 2009 a 2013.

Discussão

A análise de inquéritos realizados com mais de 250 mil adultos residindo nas capitais e no Distrito Federal possibilitou traçar um quadro dos níveis de atividade física e sedentarismo no Brasil. Os resultados deste capítulo apontam para um cenário preocupante na realidade brasileira, com tendência de manutenção em patamares desfavoráveis das prevalências de prática de atividade física no tempo livre, de inatividade física e de comportamento sedentário, e evolução indesejada das prevalências de atividade física de deslocamento. Além disso, em todos os indicadores, persistem desigualdades segundo sexo, idade e escolaridade para o ano de 2013.

Os resultados aqui apresentados devem ser interpretados considerando algumas limitações. A amostra do Vigitel é representativa apenas das capitais brasileiras e do Distrito Federal e somente indivíduos que residem em domicílios com telefonia fixa podem ser selecionados para participar do estudo. Vale ressaltar, entretanto, que os pesos pós-estratificação empregados na análise são um modo efetivo de corrigir esse viés (Segri *et al.*, 2010). Além disso, informações autorreferidas, como aquelas obtidas pelo Vigitel, não correspondem ao método mais adequado para estudos na área da atividade física. Todavia, a análise da validade e da reprodutibilidade dos indicadores do Vigitel tem atestado favoravelmente quanto à qualidade dos dados (Monteiro *et al.*, 2008). Por fim, é importante atentar para o curto período da série temporal, o que pode ter dificultado a detecção de variações sutis nos indicadores.

É necessário considerar diferenças na construção dos indicadores ao compararmos nossos resultados com outras estimativas nacionais - como as de Knuth *et al.* (2011) e os relatórios anuais do Vigitel - sobretudo com relação à proporção de ativos no tempo livre. Em contraposição à recomendação anterior, as novas recomendações internacionais (WHO, 2010) para este indicador não estipulam um número mínimo de dias na semana para a prática da atividade física, considerando apenas a prática semanal equivalente a 150 minutos de atividade física moderada. Ressalta-se ainda que a alteração na estratégia de ponderação da amostra do Vigitel (método rake) com base nos dados do censo demográfico mais recente (2010) produziu estimativas diferentes das encontradas nos relatórios do Vigitel anteriores a 2012.

Distribuição populacional e tendência temporal

As mulheres, os mais velhos e os menos escolarizados foram menos ativos no tempo livre, mesmo padrão observado para o conjunto da população brasileira (Knuth *et al.*, 2011). Além disso, somente três em cada dez adultos das capitais brasileiras e do Distrito Federal relataram ser ativos no tempo livre em 2013. O aumento na proporção de ativos no tempo livre entre 2009 e 2013 para ambos os sexos está de acordo com a previsão de aumento do gasto energético com atividade física no tempo livre no Brasil de 2008 a 2030 (Ng e Popkin, 2012) e com a tendência mundial de aumento nos níveis de atividade no tempo livre entre adultos (Knuth e Hallal, 2009). A tendência de aumento é positiva e é possível que ela seja

mais antiga, se considerarmos que a prevalência de adultos residentes nas Regiões Nordeste e Sudeste que acumularam 30 minutos de exercício físico ou esporte em pelo menos um dia da semana – indicador menos rigoroso que o nosso – foi de apenas 13% em 1997, sendo 18,2% em homens e 8,2% em mulheres (Monteiro et al., 2003). Entretanto, este aumento nos níveis de atividade física no tempo livre não tem sido suficiente para compensar o declínio no gasto energético em atividades ocupacionais e no deslocamento (Katzmarzyk e Mason, 2009; Costa, Garcia e Nahas, 2012).

Os motivos para essa tendência positiva ainda não podem ser apontados com clareza, mas algumas hipóteses a serem destacadas são o aumento do reforço social positivo em relação à prática de atividade física no tempo livre, a existência de um efeito compensatório por conta da redução da prática em outros domínios (Knuth e Hallal, 2009) e investimentos em políticas e ambientes físicos que facilitem a adoção deste comportamento (Brasil, 2011, 2013).

Os mais velhos e os mais escolarizados foram menos ativos no deslocamento, mesmo padrão encontrado na população em geral (Knuth *et al.*, 2011). Além disso, a proporção de ativos no deslocamento, que já era baixa em comparação com outros países (Hallal *et al.*, 2012), reduziu 5,4 pp para homens ($p = 0,01$) e 4,6 pp ($p = 0,05$) para mulheres entre 2009 e 2013, em contraposição ao aumento observado no período anterior, entre 2006 e 2009, quando foram considerados apenas os deslocamentos ativos para o trabalho (Hallal *et al.*, 2011). Esta diferença entre os dois períodos (2006-2009 e 2009-2013) precisa ser analisada com cautela, tendo em vista a inclusão da escola como novo motivo de deslocamento na construção deste indicador e a alteração na estratégia de ponderação da amostra do Vigitel, possível apenas a partir da divulgação dos resultados do censo demográfico de 2010. Nosso achado é similar ao encontrado em anos anteriores nas poucas regiões metropolitanas brasileiras com séries históricas sobre deslocamento ativo. A proporção de viagens realizadas a pé ou de bicicleta vem diminuindo em São Paulo (1987: 36%; 1997: 34%; 2007: 33%), Belo Horizonte (1995: 42,2%; 2002: 33,5%) (Corporación Andina de Fomento, 2011) e Campinas (2003: 35,8%; 2011: 27,4%) (Secretaria dos Transportes Metropolitanos, 2012).

Muito embora faltem evidências sobre os determinantes da prática de deslocamento ativo, sobretudo em países de baixa e média renda (Bauman *et al.*, 2012), é possível que a crescente motorização dos deslocamentos no Brasil nos

últimos anos tenha tido papel importante nesta tendência de redução (Costa, Garcia e Nahas, 2012). Soma-se a isto o processo de urbanização desordenada, tornando menos atrativo o deslocamento ativo, com a diminuição do acesso a áreas verdes, de espaços de interação social, de calçadas pavimentadas e de ruas iluminadas, além do aumento da violência e da percepção de insegurança por parte da população (Katzmarzyk e Mason, 2009; Bauman *et al.*, 2012). Mudanças no planejamento urbano e na qualidade do sistema de transporte parecem ser elementos centrais para o aumento dos níveis de deslocamento ativo (Katzmarzyk e Mason, 2009; Haines *et al.*, 2012; Pratt *et al.*, 2012), inclusive em cidades de países em desenvolvimento (Cervero *et al.*, 2009; Woodcock *et al.*, 2009).

Em 2013, 16% dos adultos das capitais brasileiras e do Distrito Federal referiram ser fisicamente inativos nos quatro domínios de atividade física, semelhante ao encontrado para toda a população brasileira (20%) (Knuth *et al.*, 2011). Na maioria dos países de média e alta renda, a prevalência de inatividade física é cerca de 30% (Hallal *et al.*, 2012). Essa maior prevalência pode ser explicada pela diferença na construção do indicador, que considera como inativos todos os indivíduos que não alcançam os níveis recomendados de atividade física (WHO, 2010). As maiores prevalências puderam ser observadas entre os mais velhos, também similar à população total (Knuth *et al.*, 2011). A maior proporção de inativos entre os menos escolarizados deve ser interpretada com cautela, pois a relação entre escolaridade e inatividade física está confundida pela idade - indivíduos menos escolarizados tendem a ser mais velhos (dados não apresentados).

A tendência de estagnação na prevalência de inatividade física contrapõe-se à tendência de aumento na proporção de ativos no tempo livre. É importante destacar que os fatores responsáveis por fazer com que o indivíduo inativo pratique alguma atividade física são diferentes daqueles responsáveis por aumentar a duração da atividade física entre os que já a praticam em baixos volumes (Glanz e Bishop, 2010). Ao se considerar as evidências de que os maiores benefícios à saúde advêm de se sair da condição de inativo (Powell, Paluch e Blair, 2011), a estagnação da prevalência de inatividade física pode ter importante impacto negativo futuro à saúde da população.

Um quarto dos adultos relatou assistir três ou mais horas de televisão por dia. Na população brasileira, esta proporção foi de 35,7% (Knuth *et al.*, 2011). Maiores

prevalências deste indicador foram observadas nas faixas etárias extremas, como na população total (Knuth *et al.*, 2011), e nos indivíduos com até 11 anos de estudo. A tendência de estagnação deste indicador em níveis elevados é particularmente preocupante, tendo em vista o crescimento da participação de outros comportamentos sedentários no tempo livre (p.e., uso de computador e videogame) e no ambiente de trabalho. Deve-se destacar que o tempo de televisão tem limitações como indicador único de comportamento sedentário (Clemes *et al.*, 2012) e que, portanto, é possível que um aumento mais expressivo do tempo total em atividades sedentárias tenha ocorrido neste período.

Intervenções para a promoção de atividade física e redução do sedentarismo

É preciso haver saúde em todas as políticas (Krech e Buckett, 2010): o desenvolvimento de políticas públicas intersetoriais para promoção de atividade física e redução do tempo sedentário torna-se imprescindível, tendo em vista que as esferas com maior potencial para a melhoria destes indicadores estão fora do setor saúde, como nos setores de transporte e comunicação (Pratt *et al.*, 2012). Ao mesmo tempo, é necessário considerar também o impacto de políticas públicas de outros setores, como transporte e planejamento urbano, sobre os indicadores de saúde relacionados à atividade física e sedentarismo. Além disso, a promoção de atividade física no Brasil prescinde da construção de mais evidências sobre a efetividade das intervenções (Hoehner *et al.*, 2013) e da priorização de programas e políticas com evidências de adequação e custo-efetividade em países em desenvolvimento, como, por exemplo, o fomento à atividade física escolar (Hoehner *et al.*, 2013) e a ampliação de programas de abertura das vias públicas para o lazer ativo (Montes *et al.*, 2012).

Por fim, é necessário repensar o foco das ações de promoção, a partir de uma visão ampliada de saúde, que leve em conta não apenas a utilidade da atividade física ou seu caráter preventivo, mas também a relação da atividade física com os modos de viver e com a integração das pessoas com seu meio ambiente, na perspectiva do desenvolvimento humano sustentável (Das e Horton, 2012; Haines *et al.*, 2012; Barreto, 2013), o que implicaria uma discussão ampliada sobre os modelos sociais e produtivos sob os quais está estruturada a sociedade brasileira.

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- LIM, S. S. et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. **The Lancet**, v. 380, n. 9859, p. 2224-2260, 2012.
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SEGRI, N. J. et al. Health survey: comparison of interviewees according to ownership of a residential telephone line. **Revista de Saúde Pública**, v. 44, n. 3, p. 503-12, 2010.

WOODCOCK, J. et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. **The Lancet**, v. 374, n. 9705, p. 1930-43, 2009.

WORLD HEALTH ORGANIZATION. **Global Recommendations on Physical Activity for Health.** Geneva: World Health Organization, 2010.



Thiago Hérick de Sá

Eu trabalho em saúde pública porque espero ajudar a entender como o meio afeta a saúde humana e, a partir deste entendimento, como atuar na defesa do direito humano à saúde. Minha motivação para fazer isso está relacionada com minha história pessoal e se fortalece com as ações de voluntariado desenvolvidas no Hospital das Clínicas (2005 a 2007), no Centro para Promoção do Envelhecimento Saudável (2007 a 2009) e na especialização em Fisiologia do Exercício e Treinamento Resistido na Saúde, Doença e Envelhecimento (Faculdade de Medicina-USP, 2005 a 2006). Desde então, tenho agregado à minha formação de Bacharel em Esporte (EEFE-USP, 1999 a 2002) conhecimentos sobre educação profissional e promoção da atividade física via sistema único de saúde, tema do meu mestrado em Nutrição em Saúde Pública (Faculdade de Saúde-USP, 2009 a 2011). No momento, meu desafio é compreender melhor a relação entre o transporte e a saúde, bem como as ameaças que a desigualdade social no contexto dos deslocamentos representam para a saúde e para o bem-estar. Portanto, pretendo aprimorar-me na intersecção entre transporte, saúde pública, equidade em saúde e sustentabilidade ambiental, com foco nas atividades cotidianas. É com este objetivo que desenvolvo meu doutorado em Nutrição em Saúde Pública, também pela Faculdade de Saúde-USP (2012 -), em colaboração com outros centros de pesquisa. Sou, desde 2012, professor colaborador na disciplina "Introdução à Revisão Sistemática e Meta-análise" do Programa de Mestrado/Doutorado em Ciências da Saúde da Faculdade de Medicina do ABC (FMABC) e pesquisador do Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde (NUPENS-USP). Email: thiagodesa@usp.br **(Texto informado pelo autor)**

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Sexo	Masculino

Formação acadêmica/titulação

2012

Doutorado em andamento em Nutrição em Saúde Pública.

Faculdade de Saúde Pública da Universidade de São Paulo.

Título: Como estamos indo? Estudo do deslocamento ativo no Brasil,

Orientador: 👤 Carlos Augusto Monteiro.

Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo.

Palavras-chave: urban health; public health practice; physical activity promotion; obesity; motor activity; epidemiology.

Grande área: Ciências da Saúde / Área: Saúde Coletiva.
Grande Área: Ciências da Saúde / Área: Educação Física.

2009 - 2011

Mestrado em Nutrição em Saúde Pública.

Faculdade de Saúde Pública da Universidade de São Paulo.

Título: Construção e avaliação de um programa educativo para a promoção de atividade física junto a Equipes de Saúde da Família., Ano de Obtenção: 2011.

Orientador:  Alex Antonio Florindo.

Palavras-chave: Teoria Educacional de Paulo Freire; Estratégia de Saúde da Família; atenção básica à saúde; educação física; educação em saúde.

2005 - 2006

Especialização em Treinamento Resistido no Envelhecimento. (Carga Horária: 400h).

Faculdade de Medicina da Universidade de São Paulo.

Título: Relação entre Insuficiência Cardíaca e Treinamento Resistido em Idosos.

1999 - 2002

Graduação em Bacharel em Esporte.

Escola de Educação Física e Esporte da Universidade de São Paulo.

Título: Critérios para Seleção e Continuidade do Patrocínio Esportivo.

Orientador: Maria Tereza da Silveira Bohme.

Formação Complementar

2013 - 2013

Workshop de Capacitação em Publicação Científica. (Carga horária: 16h).

Pró-Reitoria de Pesquisa da Universidade de São Paulo (SP).

2013 - 2013

Introduction to causal inference methods. (Carga horária: 20h).

Universidade Federal de Pelotas.

2012 - 2012

4th Int. Course on Epidemiological Methods. (Carga horária: 80h).

International Epidemiological Association.

2012 - 2012

Inglês Acadêmico. (Carga horária: 45h).

Faculdade de Filosofia, Letras e Ciências Humanas - USP.

2011 - 2011

Revisão Sistemática e Meta-análise. (Carga horária: 30h).

Faculdade de Saúde Pública da Universidade de São Paulo.

2009 - 2009

EndNote Web. (Carga horária: 3h).

Faculdade de Saúde Pública da Universidade de São Paulo.

2008 - 2008

Curso Básico de Técnica para Instrução de Rafting. (Carga horária: 42h).

Canoar Rafting.

2000 - 2000

Nutrição na Atividade Física. (Carga horária: 12h).

Faculdade de Ciências Farmacêuticas da Universidade de São Paulo.



Carlos Augusto Monteiro

Bolsista de Produtividade em Pesquisa do CNPq - Nível 1A - CA SN - Saúde Coletiva e Nutrição

A formação acadêmica do Professor Monteiro inclui graduação em Medicina, Residência e Mestrado em Medicina Preventiva, Doutorado em Saúde Pública, todos cursados na USP, e pós-doutorado no Instituto de Nutrição Humana da Columbia University. Sua carreira de pesquisador e orientador (já formou 12 mestres e 17 doutores) foi feita no Depto.de Nutrição da Faculdade de Saúde Pública da Universidade de São Paulo (USP), onde é Professor Titular desde 1989. Entre 1990 e 1992, trabalhou na Unidade de Nutrição da OMS em Genebra e foi professor visitante das universidades de Bonn e de Genebra. É coordenador científico do Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde da USP (NUPENS/USP) desde 1992. De dezenas de projetos de pesquisa realizados na área da Nutrição em Saúde Pública, resultaram vários livros e monografias e mais de 150 publicações indexadas com mais de 5 mil citações no JCR (H=36) e mais de 20 mil no Google Scholar Citations (H=72). É bolsista de produtividade científica do CNPq desde 1981 e pesquisador nível IA desde 1989. São destaques de sua produção científica voltada para o Brasil artigos sobre inquéritos populacionais em saúde e nutrição infantil realizados em São Paulo nas décadas de 70, 80 e 90, cujos resultados foram essenciais para redefinir o enfoque e o conteúdo dos programas nutricionais nas unidades básicas de saúde de São Paulo e, posteriormente, de todo o país; projeto temático interdisciplinar FAPESP de resgate e interpretação das tendências temporais das condições de saúde e nutrição da população brasileira na segunda metade do século XX, do qual resultou livro ganhador do prêmio Jabuti de melhor livro do ano na categoria Ciências Naturais e Medicina; análises das Pesquisas de Orçamentos Familiares do IBGE, que trouxeram nova e crítica visão para o problema da segurança alimentar no país; projeto de desenvolvimento e validação de sistema nacional de monitoramento de fatores de risco para doenças crônicas baseado em entrevistas telefônicas, ganhador do Prêmio de Incentivo em Ciência e Tecnologia para o SUS de 2005 e inspirador do sistema VIGITEL implantado desde 2006 pelo Ministério da Saúde nas 26 capitais de estados brasileiros e Distrito Federal e estudos sobre padrões de alimentação e saúde no Brasil, que orientaram a elaboração do Guia Alimentar para a População Brasileira 2014. Como parte de sua produção científica de impacto internacional (publicada em revistas como Lancet, BMJ, WHO Bull, PLoS Medicine, Am J Pub Health, A J Cl Nut, Eur J Cl Nut, Int J Obes, Obesity Reviews, Trans R Soc Trop Med Hyg, Ann Hum Biol, entre outras) destacam-se estudos publicados no final dos anos 80 sobre determinantes da tendência secular do aleitamento materno e da mortalidade infantil em países em desenvolvimento; contribuições metodológicas para a criação de novos indicadores para a avaliação antropométrica do estado nutricional de populações publicadas entre 1991 e 1997; e 3 dezenas de artigos sobre o fenômeno da transição alimentar e nutricional nos países em desenvolvimento publicados entre 1995 e 2014 e que já receberam mais de 3 mil citações computadas pelo JCR. Foi co-chairman do comitê sobre transição nutricional da International Union for Nutritional Sciences (IUNS). É Editor Científico da Revista de Saúde Pública e membro do Conselho Editorial da Public Health Nutrition. Integra, ainda, o comitê NUGAG (Nutrition Guidance

Expert Advisory Group) de experts em Nutrição da OMS e a recém criada WHO Ending Child Obesity Commission e fez parte de duas forças-tarefa da Organização Panamericana de Saude (OPAS) para eliminação das gorduras trans e para redução do consumo de sódio nas Américas. Em 2010, foi o terceiro brasileiro a ganhar o prêmio Abraham Horwitz de Liderança Científica em Saúde nas Américas outorgado pela OPAS todos os anos ao pesquisador latinoamericano que mais se destacou no campo. É membro da Academia Brasileira de Ciências desde 2007. **(Texto informado pelo autor)**

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Formação acadêmica/titulação

1978 - 1979

Doutorado em Saúde Pública (Conceito CAPES 6).
Universidade de São Paulo, USP, Brasil.
Título: O peso ao nascer no município de São Paulo: impacto sobre os níveis de mortalidade na infância., Ano de obtenção: 1979.
Orientador: Yaro Ribeiro Gandra.
Palavras-chave: Infância; Mortalidade.
Grande área: Ciências da Saúde / Área: Nutrição / Subárea: Análise Nutricional de População.
Setores de atividade: Nutrição e Alimentação.

1975 - 1977

Mestrado em Medicina (Medicina Preventiva) (Conceito CAPES 7).
Universidade de São Paulo, USP, Brasil.
Título: A EPIDEMIOLOGIA DA DESNUTRICAÇÃO PROTEICO-CALÓRICA EM NÚCLEOS RURAIS DO VALE DO RIBEIRA, Ano de Obtenção: 1977.
Orientador: YARO RIBEIRO GANDRA.
Grande área: Ciências da Saúde / Área: Saúde Coletiva / Subárea: Medicina Preventiva.

1976 - 1976

Especialização em Saúde Pública.
Universidade de São Paulo, USP, Brasil.

1967 - 1972

Graduação em Medicina.
Universidade de São Paulo, USP, Brasil.

Pós-doutorado e Livre-docência

1982

Livre-docência.

Universidade de São Paulo, USP, Brasil.

Título: AVALIAÇÃO DO ESTADO NUTRICIONAL NA IDADE PRÉ-ESCOLAR EM ÁREAS DE BAIXA RENDA DO ESTADO DE SÃO PAULO, Ano de obtenção: 1982.

Palavras-chave: Estado Nutricional; Baixa Renda; Pre-Escolares.

Grande área: Ciências da Saúde / Área: Nutrição / Subárea: Análise Nutricional de População.

Setores de atividade: Saúde Humana.

1979 - 1981

Pós-Doutorado.

Columbia University, COLUMBIA, Estados Unidos.

Grande área: Ciências da Saúde / Área: Nutrição / Subárea: Análise Nutricional de População.