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The relationship between bicycle commuting and perceived stress: a cross-sectional study

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ABSTRACT

Introduction Active commuting — walking and bicycling for travel to and/or from work or educational addresses — may facilitate daily, routine physical activity. Several studies have investigated the relationship between active commuting and commuting stress; however, there are no studies examining the relationship between solely bicycle commuting and perceived stress, or studies that account for environmental determinants of bicycle commuting and stress. The current study evaluated the relationship between bicycle commuting, among working or studying adults in a dense urban setting, and perceived stress.

Methods A cross-sectional study was performed with 788 adults who regularly travelled to work or study locations (excluding those who only commuted on foot) in Barcelona, Spain. Participants responded to a comprehensive telephone survey concerning their travel behaviour from June 2011 through to May 2012. Participants were categorised as either bicycle commuters or non-bicycle commuters, and (based on the Perceived Stress Scale, PSS-4) as either stressed or non-stressed. Multivariate Poisson regression with robust variance models of stress status based on exposures with bicycle commuting were estimated and adjusted for potential confounders.

Results Bicycle commuters had significantly lower risk of being stressed than non-bicycle commuters (Relative Risk; RR (95% CI)=0.73 (0.60 to 0.89), p=0.001). Bicycle commuters who bicycled 4 days per week (RR (95% CI)=0.42 (0.24 to 0.73), p=0.002) and those who bicycled 5 or more days per week (RR (95% CI)=0.57 (0.42 to 0.77), p<0.001) had lower risk of being stressed than those who bicycled less than 4 days. This relationship remained statistically significant after adjusting for individual and environmental confounders and when using different cut-offs of perceived stress.

Conclusions Stress reduction may be an important consequence of routine bicycle use and should be considered by decision makers as another potential benefit of its promotion.

Strengths and limitations of this study

- ► The study had high internal validity, with a good representation of bicycle commuters.
- ► The study was conducted in Barcelona (a dense, Mediterranean/Southern European city), adding evidence on these issues in a different context than the current literature.
- ► The Transportation, Air Pollution and Physical ActivitieS (TAPAS) Travel Survey sample is representative of Barcelona's population, taking into account home-neighbourhood deprivation, and home and work-neighbourhood population density.
- ► The study used a cross-sectional design, which is not well suited to assess the direction of causation.
- ► Using questionnaire data, we could have misclassification error (information bias) of bicycle commuting and physical activity due to the data being self-reported.

INTRODUCTION

Walking and bicycling for transport are increasingly being promoted due to their potential for increasing physical activity (PA) levels in the general population.[1–3] Active commuting — walking and bicycling for travel to and/or from work or educational addresses — has been associated with multiple health benefits, from reductions of cardiovascular risk,[4 5] lowering of body weight,[2 5] improvement of fitness, reduction of diabetes risk,[3] and increasing levels of physical and mental well-being.[6 7] Specifically, bicycle commuting has been inversely associated with all-cause mortality among both men and women in all age groups,[8] and it seems likely to improve the health-related quality of life in previously untrained healthy adults.[9] Active commuting has been shown to have other societal benefits, such as helping reduce air pollution, greenhouse gas emissions and noise, and improving social interaction.[10]

Perceived stress is a global and comprehensive stress construct that refers to the interaction between the individual and the environment in the presence of a stressor.[11] The perception of an event as being stressful can result in a range of physiological, behavioural and psychological changes, and can lead to cardiovascular disease, increased

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negative affect, lowered self-esteem and lowered feelings of control. Hence, it is possible that mental health outcomes such as anxiety disorders and depression can be manifestations of chronic, perceived stress.[12] Furthermore, others have suggested gender differences in stress-related variables. Women seem to be more likely to have daily stress, being more physiologically reactive to social rejection challenges[13] and be more impacted by life events.[14]

Some literature recognises commuting as a potential source of stress[15]; however, active commuters have been shown to have higher levels of satisfaction, lower stress, higher relaxation and a heightened sense of freedom compared with car drivers.[16–18] Recent qualitative research has suggested that commuting can be perceived as a relaxing or transitional time between home and work life, which can also be about enjoying pleasant landscape, nature and wildlife.[19] Emerging literature has highlighted the relevance of a positive natural and built environment to increase bicycle commuting and to improve mental health outcomes. Bicycle lane connectivity, bikeability, separation of bicycling from other traffic, high population density, short trip distance, proximity of a cycle path, green space and also walkability have been suggested as determinants of bicycling.[20–24] Green space has also been associated with better self-perceived general health and better mental health.[25 26]

Several studies have examined the relationship between active commuting and commuting stress (stress directly related with the act of commuting),[17 18 27 28] but none of them have studied the relationship between solely bicycle commuting and perceived stress (global and comprehensive stress construct) in adults, nor taking into account environmental determinants. Moreover, most studies of active commuting and its beneficial effects on mental health have been conducted in North America, where the urban design tends to be less dense than many parts of the world, or Northwest Europe.[6 7 17 28–30] Consequently, a need exists to understand the relationship between bicycle commuting and perceived stress, particularly in dense, Mediterranean/Southern European urban environments.

The current study aimed to evaluate the relationship between bicycle commuting and perceived stress among the working or studying adult population of a dense, Mediterranean/Southern European urban setting.

MATERIALS AND METHODS

Study population

This cross-sectional study was based on participants from the Transportation, Air Pollution and Physical ActivitieS (TAPAS) Travel Survey. TAPAS is a relatively large study aimed at investigating the risks and benefits of active commuting. Participant recruitment was conducted by trained interviewers on the streets of Barcelona city between June 2011 and May 2012. To ensure adequate geographical coverage, a total of 40 random points (four random points within each of the ten city districts across Barcelona) were sampled. Adult bicycle commuters and non-bicycle commuters were asked in the street to answer a few screening questions, and those who fulfilled the inclusion criteria (being older than 18 years of age; living in Barcelona city since 2006 or earlier; working or going to school in Barcelona city; being healthy enough to ride a bicycle for 20 min; having a commute distance greater than a 10 min walk; and using at least one mode of transport other than walking to commute) were invited to respond to a telephone survey. Bicycle commuters were oversampled to ensure enough bicycle commuters in the study. Those solely commuting on foot were excluded as the main interest was in the contrast between motorised modes (private and public transportation) and the bicycle. Of the 18 469 participants approached across the 40 sampling random points, 6701 agreed to answer screening questions. Of these, 1508 met the inclusion criteria, and 871 participants completed the survey. After survey responses were checked by the research team, 815 still fulfilled the inclusion criteria and 789 had geocodable home address. After excluding one PA outlier (total of all walking, moderate and vigorous time variables >960 min/day), 788 participants remained. Further details on the recruitment are given elsewhere.[31]

The study protocol was approved by the Clinical Research Ethical Committee of the Parc de Salut Mar (CEIC-Parc de Salut Mar), and written informed consent was obtained from all participants.

Bicycle commuting

The TAPAS Travel Survey assessed the regular use of transport modes,[32] including bicycles.[33] Participants who indicated using a bicycle (private or from a public bicycle-sharing system) to go to work or school at least once the week prior to survey administration were classified as ‘bicycle commuters’. Participants who did not commute by bicycle in the week prior to survey administration were classified as ‘non-bicycle commuters’.

As part of the sensitivity analyses, commuting behaviour was further classified according to bicycle commuting levels and bicycle commuting propensity.[24] Classification of bicycle commuting levels was based on the days of bicycle commuting in the week prior to survey administration: ‘low-level’ being 3 days or fewer, ‘medium-level’ for 4 days and ‘high-level’ for 5 or more days. This measure could be interpreted as a proxy of bicycle commuting frequency. Bicycle commuting propensity classification took into account both frequency and willingness to commute by bicycle: the ‘bicycle commuters’ were further classified as ‘frequent’ (4 or more days) or ‘infrequent’ (3 or less days), and the ‘non-bicycle commuters’ were classified as ‘willing’ or ‘unwilling’. The ‘willing’ group were those ‘non-bicycle commuters’ who indicated bicycling as ‘never or nearly never’ their general transport mode, but who also indicated that they would consider bicycle commuting in Barcelona (by answering positively to ‘considering costs, travelling time, comfort and safety, how ready would you be to use the bicycle/*Bicing* (public bicycle-sharing system) for your trip to work or education centre?'). The 'unwilling' group were those 'non-bicycle commuters' who indicated 'never or nearly never' bicycling for travel and indicated that they would not consider bicycle commuting in Barcelona by answering negatively to the above question. More details of the bicycle commuting propensity classification are given elsewhere.[24] This measure was included in the analysis to assess the effect on perceived stress by being willing to commute by bicycle.

Perceived stress

The last four questions of the TAPAS Travel Survey were the short version of the Perceived Stress Scale (PSS-4),[11] which is a well-validated psychological instrument to measure the degree to which situations in one's life over the past month are appraised as stressful. The instrument contains four statements, which measure how unpredictable, uncontrollable and overloaded respondents feel that their lives are (online supplementary table S1). The higher the score on the PSS-4 (from 0 to 16), the greater the respondent perceives that their demands exceed their ability to cope. There are no cut-off scores. Instead, an individual's score is compared with a normative value.[34] In the TAPAS Travel Survey, the 5-point Likert scale was modified to a 4-point Likert scale, removing the midpoint option for consistency with other questions in the survey (using a 4-point Likert scale). The sample did not have high levels of perceived stress (online supplementary table S2); therefore, for an easier interpretation, participants with a PSS-4 score higher than 3 (median of the total sample) were classified as 'stressed', and those equal or lower than 3 were classified as 'non-stressed'. The sensitivity of our results to this choice was examined further in sensitivity analyses by classifying the respondents with PSS-4 scores in the 75th percentile (P75) and above (a score higher than 4) and in the 90th percentile (P90) and above (a score of 6 and above) as stressed and all others as non-stressed.

Other explanatory measures

Individual determinants of bicycle commuting and perceived stress such as PA levels,[35] sociodemographic variables and work or school addresses were also derived from the TAPAS Travel Survey to be used as potential confounders. In addition, the MEDEA Index (Mortalidad en áreas pequeñas Españolas y Desigualdades socioEconómicas y Ambientales, in Spanish; Environmental and socioEconomic Inequalities in Mortality in small Spanish areas, translated to English) was used as an area deprivation indicator assigned to each participant's address. MEDEA measures deprivation at the census tract level based on five domains, namely percentage of manual workers, temporary workers, total population with low education, young population with low education and unemployment.[36]

Environmental determinants of bicycle commuting and perceived stress within a 400 m buffer surrounding home and work/study addresses, and a route-by-area surrounding predicted commute routes, were calculated to be used as potential confounders too. The number of public bicycle stations within a 400 m buffer surrounding home and work/study addresses was calculated based on information from the Ajuntament de Barcelona – Informació de Base i Cartografia (Barcelona City Council – Basic information and mapping). Greenness was calculated as the interquartile range of the mean of Normalised Difference Vegetation Index via satellite imagery (LANDSAT 4 and 5, NASA). The mean NO_2 levels were estimated using a land-use regression model developed for a previous project.[37] Noise was calculated as the proportion of street length above a 55 dB(A) threshold.[38] A bikeability index was calculated taking into account five factors shown to influence bicycling: bicycle facility availability, bicycle facility quality, street connectivity, topography and land use.[39] Commute distance did not use buffers and it was calculated in kilometres following the street network of the shortest route from home address to work address. Further details of the environmental determinants calculation are given elsewhere.[24]

Statistical analyses

Descriptive univariate analyses were done for all study variables. Descriptive bivariate analyses were done using χ^2 and Mann-Whitney U tests to assess the relationship between determinants and bicycle commuting variables (bicycle commuting status, bicycle commuting levels and bicycle commuting propensity), and using Poisson regression with robust variance models to assess the relationship between determinants and perceived stress. A generalised additive model was used to test linearity between perceived stress and total physical activity (total PA), moderate-to-vigorous physical activity (MVPA), vigorous physical activity (VPA) and age.[40] As there was no statistical evidence to reject linearity between perceived stress and total PA (p=0.382), MVPA (p=0.503), VPA (p=0.163) and age (p=0.228), these variables were included as continuous variables in the models assuming a linear relationship. Multivariate Poisson regression with robust variance models were used to assess the relationship between bicycle commuting and perceived stress. Four regression models were done: (1) unadjusted; (2) adjusted by individual determinants that showed a p value <0.05 in the model; (3) adjusted by the individual determinants of model 2, as well as those found to be statistically significant within previous literature; and (4) adjusted by the individual determinants of model 3 and environmental determinants that showed a p value <0.05 in the bivariate analyses. All multivariate regression models were conducted with a complete case analysis. Possible mediation by different levels of PA between bicycle commuting and perceived stress, and any interaction between gender and bicycle commuting, were also tested with Poisson regression with robust variance models. The first descriptive statistical analyses (univariate, χ^2 and Mann-Whitney U tests) were conducted in Stata SE V.12, while Poisson regression with robust variance models were conducted in Stata SE V.14.

RESULTS

The included sample had an equal distribution of genders and the median age (P25–P75) was 36 (29–43) years (table 1). The majority of participants were non-stressed (having a PSS-4 score of 3 or lower), were Spanish, had completed university studies or equivalent-level education, were living with their family or partner, with at least two employed people and were not with children (64.34%). Among those living with children, ~8% had children younger than 3 years of age. The sample had positive self-perception of health (with only <1% of participants self-perceiving bad or very bad health), healthy weight (body mass index of 18.5–24.9; 71.12%) and generally no chronic disease (92.26%). The majority of participants considered that they could release stress when riding a bicycle and that they enjoyed their trip more if they used a bicycle. Compared with non-bicycle commuters, bicycle commuters were statistically significantly (p<0.05) more likely to be non-stressed; younger (35 years); men; have higher levels of PA; possess a university or equivalent-level education; live alone and/or with flat mates; live with one or less employed people; live with no children; and have better self-perception of health, and healthy weight, but more chronic diseases. Bicycle commuters had shorter commutes compared with non-bicycle commuters, and we observed a gradient between commute distance and bicycle commuting levels; shorter distances were travelled for those who bicycle commuted more frequently. This tendency was also seen with bicycle commuting propensity; shorter distances were travelled for those more willing to bicycle commute (online supplementary table S3). Bicycle commuters also had more public bicycle stations around the home and work/study addresses, less greenness around the home address, and higher levels of bikeability at home, work/study address and on the commute route compared with non-bicycle commuters (table 1). These environmental determinants stayed statistically significant for bicycle commuting propensity, but not between bicycle commuting levels (online supplementary table S3).

Participants more likely to be stressed (p<0.05) were typically women, non-Spanish, living with one or less people employed and had a chronic disease (table 2). For environmental determinants, participants who had more public bicycle stations around their work/study area and higher levels of bikeability in the work/study address area, as well as on the commute route, were less likely to be stressed (p<0.05). There was no statistically significant relationship between commute distance, greenness, NO_2 and noise, and perceived stress. The possible mediation of PA was not further explored as there was no statistically significant relationship between levels of PA (total PA, MVPA and VPA) and perceived stress for the three different classifications of perceived stress (P50, P75, P90) (RR, Relative Risk; RR (95% CI): 1.00 (0.99 to 1.00), all p>0.10) (table 2, online supplementary table S4).

Multivariate Poisson regression with robust variance analyses showed a statistically significant inverse relationship between bicycle commuting and perceived stress. Considering the total sample, bicycle commuters had a lower risk of being stressed compared with non-bicycle commuters (model 1: RR (95% CI)=0.73 (0.60 to 0.89), p=0.001). This relationship remained statistically significant in the adjusted models (model 2: RR (95% CI)=0.75 (0.62 to 0.91), p=0.003; model 3: RR (95% CI)=0.77 (0.63 to 0.94), p=0.009; model 4: RR (95% CI)=0.80 (0.66 to 0.99), p=0.036) (table 3) and when using perceived stress cut-offs of either P75 or P90 (online supplementary table S5). Regarding bicycle commuting levels in the total sample, those who bicycle commuted 4 days per week (considered 'medium-level' of bicycle commuters) and those who bicycled 5 or more days per week ('high-level') had lower risk of being stressed than non-bicycle commuters ('Medium-level'—model 1: RR (95% CI)=0.46 (0.28 to 0.78), p=0.004; 'High-level' — model 1: RR (95% CI)=0.63 (0.49 to 0.81), p<0.001). These relationships remained statistically significant in the adjusted models ('Medium-level' — model 2: RR (95% CI)=0.45 (0.27 to 0.74), p=0.002; model 3: RR (95% CI)=0.45 (0.27 to 0.75), p=0.002; model 4: RR (95% CI)=0.48 (0.29 to 0.80), p=0.005; 'High-level'—model 2: RR (95% CI)=0.66 (0.51 to 0.85), p=0.001; model 3: RR (95% CI)=0.68 (0.52 to 0.88), p=0.003; model 4: RR (95% CI)=0.71 (0.54 to 0.92), p=0.010) (table 3) and in the majority of perceived stress sensitivity analyses (using cut-offs of P75 and P90), with the exception of the unadjusted and fully adjusted models (models 1 and 4) for 'medium-level' bicycle commuters using P90 as a perceived stress cut-off ('Medium-level' — model 1: RR (95% CI)=0.15 (0.02 to 1.05), p=0.056; model 4: RR (95% CI)=0.15 (0.02 to 1.04), p=0.054) (online supplementary table S5). Regarding bicycle commuting propensity in the total sample, 'frequent' bicycle commuters had lower risk of being stressed than 'unwilling' non-bicycle commuters (model 1: RR (95% CI)=0.53 (0.41 to 0.67), p<0.001). This relationship remained statistically significant in the adjusted models (model 2: RR (95% CI)=0.55 (0.43 to 0.70), p<0.001; model 3: RR (95% CI)=0.56 (0.43 to 0.72), p<0.001; model 4: RR (95% CI)=0.58 (0.45 to 0.76), p<0.001) (table 3) and when using perceived stress cut-offs of either P75 or P90 (online supplementary table S5). Also, 'willing' non-bicycle commuters had lower risk of being stressed than 'unwilling' non-bicycle commuters (model 1: RR (95% CI)=0.72 (0.56 to 0.94), p=0.014). This relationship remained statistically significant in the adjusted models (model 2: RR (95% CI)=0.75 (0.58 to 0.97), p=0.029; model 3: RR (95% CI)=0.74 (0.57 to 0.96), p=0.022; model 4: RR (95% CI)=0.75 (0.58 to 0.97), p=0.031) (table 3), but not when using perceived

Table 1 Descriptive analyses of participant perceived stress and its determinants as a total sample and according to bicycle commuting status

			Bicycle commuting status				
	Total sample (788)		Non-bicycle commuters (390)		Bicycle commuters (398)		
Variables	n	%	n	%	n	%	p Value*
Outcome							
Stressed (median) (yes)	280	35.53	162	41.97	118	30.33	0.001
Individual determinants							
Age (median; P25–P75)	36	29–43	37	30–45	35	29–41	0.025
Total PA – min/week (median; P25–P75)	424.99	269.99–700.00	374.99	209.99–624.99	484.98	329.99–734.99	<0.001
MVPA – min/week (median; P25–P75)	197.49	72.50–374.99	90.00	0–240.00	299.99	159.99–464.99	<0.001
VPA – min/week (median; P25–P75)	72.50	0–180.00	35.00	0–134.99	105.00	0–225.00	<0.001
Gender (woman)	410	52.03	234	60.00	176	44.22	<0.001
Country of birth (non-Spanish)	97	12.31	41	10.51	56	14.11	0.125
Working status (student)	104	13.20	347	87.19	51	12.81	0.748
Education level (university studies completed or equivalent-level education)	551	69.92	247	63.33	304	76.38	<0.001
Living with family/partner	635	80.58	327	83.85	308	77.58	0.026
Employed people in household (2–5)	510	64.72	261	67.27	249	62.88	0.198
MEDEA Index							0.355
First tertile (least deprived)	263	33.38	130	33.33	133	33.42	
Second tertile	263	33.38	122	31.28	141	35.43	
Third tertile (most deprived)	262	33.25	138	35.38	124	31.16	
Children in household (yes)	279	35.41	151	38.82	128	32.24	0.054
Children <3 years in household (yes)	64	8.12	36	9.25	28	7.07	0.264
Self-perceived health (very good/excellent)	323	40.99	140	35.90	183	45.98	0.004
BMI (overweight/obese)	212	26.9	124	31.96	88	22.11	0.002
Chronic disease (yes)	61	7.74	25	6.41	36	9.05	0.166
Stress releasing (agreement)	658	83.50	302	79.47	356	90.59	<0.001
Bicycle trip enjoyment (agreement)	629	79.82	249	65.35	380	96.20	<0.001
Environmental determinants							
Commute distance, estimated (km) (mean; SD)	3.85	2.05	4.38	2.25	3.35	1.70	<0.001
Public bicycle stations (mean; SD)							
Home, count in 400 m buffer	4.25	2.54	3.75	2.51	4.75	2.47	<0.001

Continued

Table 1 Continued

Variables	Total sample (788)		Bicycle commuting status: Non-bicycle commuters (390)		Bicycle commuters (398)		p Value*
	n	%	n	%	n	%	
Work/study, count in 400 m buffer	4.92	3.11	4.50	3.13	5.33	3.04	<0.001
Greenness, NDVI (mean; SD)							
Home, average in 400 m buffer	0.79	1.07	0.91	1.08	0.68	1.06	<0.001
Work/study, average in 400 m buffer	0.62	0.96	0.70	1.07	0.55	0.83	0.086
Commute route, average in RBA	0.97	0.96	1.07	1.06	0.87	0.85	0.062
NO_2 (µg m^{-3})(mean; SD)							
Home, concentration in 400 m buffer	76.20	17.52	75.16	17.12	77.21	17.87	0.058
Work/study, concentration in 400 m buffer	78.43	22.51	78.56	23.92	78.31	21.10	0.843
Commute route, concentration in RBA	84.40	16.97	84.24	16.82	84.55	17.13	0.987
Noise, >55 dB (mean; SD)							
Home, proportion in 400 m buffer	78.63	11.40	78.77	10.99	78.50	11.79	0.823
Work/study, proportion in 400 m buffer	79.59	14.66	79.09	14.86	80.07	14.46	0.369
Commute route, proportion in RBA	77.40	9.04	77.51	8.58	77.30	9.48	0.924
Bikeability (mean; SD)							
Home, weighted average in 400 m buffer	6.20	1.41	5.93	1.45	6.46	1.31	<0.001
Work/study, weighted average in 400 m buffer	6.56	1.39	6.31	1.54	6.79	1.17	<0.001
Commute route, weighted average in RBA	6.70	1.12	6.45	1.20	6.94	0.98	<0.001

Data are n and %, unless otherwise noted. There are missing data in perceived stress (13; 1.65%), total PA (5; 0.63%), country of birth (1; 0.13%), living with family/partner (1; 0.13%), employed people in household (4; 0.51), children in household (2; 0.25%), children <3 years old in household (3; 0.38%), BMI (2; 0.25%), stress releasing (15; 1.90%), bicycle trip enjoyment (12; 1.52%), commute distance (20; 2.54%), greenness (20; 2.54%), NO_2 (20; 2.54%) . * χ^2test, except for age, total PA, MVPA, VPA and all the environmental determinants (Mann Whitney U test).
BMI, body mass index; MEDEA, Mortalidad en áreas pequeñas Españolas y Desigualdades socioEconómicas y Ambientales, in Spanish (Environmental and socioEconomic Inequalities in Mortality in small Spanish areas, translated to English); MVPA, moderate-to-vigorous physical activity; NDVI, Normalised Difference Vegetation Index; PA, physical activity; RBA, route by area; total PA, total physical activity; VPA, vigorous physical activity.

stress cut-offs of either P75 or P90 (online supplementary table S5).

When considering bicycle commuting levels within the bicycle commuters only sample, 'medium-level' and 'high-level' bicycle commuters had lower risk of being stressed than 'low-level' bicycle commuters ('Medium-level' — model 1: RR (95% CI)=0.42 (0.24 to 0.73), p=0.002; 'High-level' — model 1: RR (95% CI)=0.57 (0.42 to 0.77), p<0.001). These relationships remained statistically significant in the adjusted models (('Medium-level' — model 2: RR (95% CI)=0.39 (0.23 to 0.67), p=0.001; model 3: RR (95% CI)=0.39 (0.23 to 0.65), p<0.001; model 4:

Table 2 Bivariate analyses of the relationship between participant determinants and perceived stress

Variable	Perceived stress (median) RR (95% CI)	p Value
Individual determinants		
Age	1.00 (0.99 to 1.01)	0.502
Total PA – min/week	1.00 (0.99 to 1.00)	0.669
MVPA – min/week	1.00 (0.99 to 1.00)	0.114
VPA – min/week	1.00 (0.99 to 1.00)	0.658
Gender (woman)	1.55 (1.27 to 1.89)	<0.001
Country of birth (non-Spanish)	1.34 (1.05 to 1.70)	0.017
Working status (student)	1.22 (0.95 to 1.56)	0.115
Education level (university studies completed or equivalent-level education)	0.92 (0.75 to 1.12)	0.387
Living with family/partner	0.91 (0.73 to 1.15)	0.439
Employed people in household (2–5)$^{-5}$	0.74 (0.62 to 0.90)	0.002
MEDEA Index		
First tertile (least deprived)	1.00	
Second tertile	1.08 (0.85 to 1.37)	0.537
Third tertile (most deprived)	1.18 (0.94 to 1.48)	0.162
Children in household (yes)	0.90 (0.74 to 1.11)	0.330
Children <3 years in household (yes)	0.87 (0.60 to 1.27)	0.475
Self-perceived health (very good/excellent)	0.87 (0.71 to 1.06)	0.157
BMI (overweight/obese)	0.95 (0.77 to 1.18)	0.669
Chronic disease (yes)	1.38 (1.04 to 1.83)	0.024
Stress releasing (agreement)	0.87 (0.68 to 1.11)	0.273
Bicycle trip enjoyment (agreement)	0.91 (0.72 to 1.14)	0.425
Environmental determinants		
Commute distance, estimated (km)	1.02 (0.97 to 1.06)	0.508
Public bicycle stations		
Home, count in 400 m buffer	0.99 (0.95 to 1.02)	0.503
Work/study, count in 400 m buffer	0.96 (0.93 to 0.99)	0.024
Greenness, NDVI		
Home, average in 400 m buffer	0.94 (0.85 to 1.05)	0.258
Work/study, average in 400 m buffer	1.06 (0.96 to 1.16)	0.241
Commute route, average in RBA	0.99 (0.89 to 1.09)	0.838

Continued

Table 2 Continued

Variable	Perceived stress (median) RR (95% CI)	p Value
NO_2 (μg m^{-3})		
Home, concentration in 400 m buffer	1.00 (0.99 to 1.01)	0.827
Work/study, concentration in 400 m buffer	1.00 (0.99 to 1.00)	0.100
Commute route, concentration in RBA	1.00 (0.99 to 1.00)	0.518
Noise, >55 dB		
Home, proportion in 400 m buffer	1.00 (0.98 to 1.00)	0.363
Work/study, proportion in 400 m buffer	1.01 (0.99 to 1.01)	0.125
Commute route, proportion in RBA	1.00 (0.98 to 1.01)	0.405
Bikeability		
Home, weighted average in 400 m buffer	1.00 (0.94 to 1.07)	0.931
Work/study, weighted average in 400 m buffer	0.92 (0.86 to 0.98)	0.009
Commute route, weighted average in RBA	0.91 (0.84 to 0.98)	0.018

Complete case analysis excluding missing data of the variables of final models (table 3; n=771). The variables that still present missing data and are not included in the final models are total PA (5; 0.63%), living with family/partner (1; 0.13%), children in household (2; 0.25%), children <3 years old in household (3; 0.38%), BMI (2; 0.25%); stress releasing (15; 1.90%), bicycle trip enjoyment (12; 1.52%), commute distance (20; 2.54%), greenness (20; 2.54%), NO_2(20; 2.54%).BMI, body mass index; MEDEA, Mortalidad en áreas pequeñas Españolas y Desigualdades socioEconómicas y Ambientales, in Spanish (Environmental and socioEconomic Inequalities in Mortality in small Spanish areas, translated to English); MVPA, moderate-to-vigorous physical activity; NDVI, Normalised Difference Vegetation Index; RBA, route by area; RR, Relative Risk; total PA, total physical activity; VPA, vigorous physical activity.

RR (95% CI)=0.38 (0.23 to 0.65), p<0.001; ‘High-level’ — model 2: RR (95% CI)=0.59 (0.44 to 0.80), p=0.001; model 3: RR (95% CI)=0.59 (0.44 to 0.80), p=0.001; model 4: RR (95% CI)=0.59 (0.44 to 0.80), p=0.001) (table 3) and when using perceived stress cut-offs of either P75 or P90 (online supplementary table S5). Regarding bicycle commuting propensity, ‘frequent’ bicycle commuters had lower risk of being stressed than ‘infrequent’ bicycle commuters (model 1: RR (95% CI)=0.54 (0.40 to 0.72), p<0.001). This relationship remained statistically significant in the adjusted models (model 2: RR (95% CI)=0.55 (0.41 to 0.73), p<0.001; model 3: RR (95% CI)=0.54 (0.41 to 0.72), p<0.001; model 4: RR (95% CI)=0.54 (0.41 to 0.72), p<0.001) (table 3) and when using perceived stress

Table 3 Multivariate models assessing the relationship between bicycle commuting and participant perceived stress (median)

Variable	Perceived stress (median) Model 1* RR (95% CI)	p Value	Model 2† RR (95% CI)	p Value	Model 3‡ RR (95% CI)	p Value	Model 4§ RR (95% CI)	p Value
All sample (771)								
Bicycle commuting status								
Non-bicycle commuters	1.00		1.00		1.00		1.00	
Bicycle commuters	0.73 (0.60 to 0.89)	0.001	0.75 (0.62 to 0.91)	0.003	0.77 (0.63 to 0.94)	0.009	0.80 (0.66 to 0.99)	0.036
Bicycle commuting levels								
Non-bicycle commuters	1.00		1.00		1.00		1.00	
Low-level bicycle commuters	1.10 (0.87 to 1.39)	0.436	1.11 (0.88 to 1.40)	0.369	1.13 (0.89 to 1.44)	0.297	1.17 (0.92 to 1.48)	0.205
Medium-level bicycle commuters	0.46 (0.28 to 0.78)	0.004	0.45 (0.27 to 0.74)	0.002	0.45 (0.27 to 0.75)	0.002	0.48 (0.29 to 0.80)	0.005
High-level bicycle commuters	0.63 (0.49 to 0.81)	<0.001	0.66 (0.51 to 0.85)	0.001	0.68 (0.52 to 0.88)	0.003	0.71 (0.54 to 0.92)	0.010
Bicycle commuting propensity								
Unwilling non-bicycle commuters	1.00		1.00		1.00		1.00	
Willing non-bicycle commuters	0.72 (0.56 to 0.94)	0.014	0.75 (0.58 to 0.97)	0.029	0.74 (0.57 to 0.96)	0.022	0.75 (0.58 to 0.97)	0.031
Infrequent bicycle commuters	0.98 (0.76 to 1.25)	0.847	1.00 (0.78 to 1.27)	0.980	1.01 (0.79 to 1.30)	0.940	1.04 (0.81 to 1.34)	0.739
Frequent bicycle commuters	0.53 (0.41 to 0.67)	<0.001	0.55 (0.43 to 0.70)	<0.001	0.56 (0.43 to 0.72)	<0.001	0.58 (0.45 to 0.76)	<0.001
Bicycle commuters sample (387)								
Bicycle commuting levels								
Low-level bicycle commuters	1.00		1.00		1.00		1.00	
Medium-level bicycle commuters	0.42 (0.24 to 0.73)	0.002	0.39 (0.23 to 0.67)	0.001	0.39 (0.23 to 0.65)	<0.001	0.38 (0.23 to 0.65)	<0.001
High-level bicycle commuters	0.57 (0.42 to 0.77)	<0.001	0.59 (0.44 to 0.80)	0.001	0.59 (0.44 to 0.80)	0.001	0.59 (0.44 to 0.80)	0.001
Bicycle commuting propensity								
Infrequent bicycle commuters	1.00		1.00		1.00		1.00	
Frequent bicycle commuters	0.54 (0.40 to 0.72)	<0.001	0.55 (0.41 to 0.73)	<0.001	0.54 (0.41 to 0.72)	<0.001	0.54 (0.41 to 0.72)	<0.001
Non-bicycle commuters sample (384)								
Bicycle commuting propensity								
Unwilling non-bicycle commuters	1.00		1.00		1.00		1.00	
Willing non-bicycle commuters	0.72 (0.56 to 0.94)	0.015	0.73 (0.57 to 0.95)	0.020	0.72 (0.56 to 0.93)	0.013	0.74 (0.57 to 0.95)	0.020

*Unadjusted.
†Adjusted by gender, country of birth, employed people in household, chronic disease.
‡Adjusted by age, gender, country of birth, employed people in household, chronic disease, self-perceived health, moderate-to-vigorous physical activity.
§Adjusted by age, gender, country of birth, employed people in household, chronic disease, self-perceived health, moderate-to-vigorous physical activity, public bicycle stations at work/study, bikeability at work/study, bikeability at commute route.
RR, Relative Risk.

cut-offs of either P75 or P90 (online supplementary table S5).

Considering bicycle commuting propensity within the non-bicycle commuters only sample, 'willing' non-bicycle commuters had lower risk of being stressed than 'unwilling' non-bicycle commuters (model 1: RR (95% CI)=0.72 (0.56 to 0.94), p=0.015). This relationship remained statistically significant in the adjusted models (model 2: RR (95% CI)=0.73 (0.57 to 0.95), p=0.020; model 3: RR (95% CI)=0.72 (0.56 to 0.93), p=0.013; model 4: RR (95% CI)=0.74 (0.57 to 0.95), p=0.020) (table 3), but not when using perceived stress cut-offs of either P75 or P90 (online supplementary table S5).

In the fully adjusted models (model 4), we found no statistically significant interactions between gender and being a bicycle commuter (p=0.165), between gender and bicycle commuting levels (p=0.226, p=0.266, p=0.431) or between gender and bicycle commuting propensity (p=0.982, p=0.197, p=0.277) (results not shown).

DISCUSSION

Summary of results

We evaluated relationships between bicycle commuting and perceived stress while adjusting for several confounders in a representative sample of adults in Barcelona, Spain. We found statistically significant inverse relationships between several measures of bicycle commuting and perceived stress. Bicycle commuters who bicycled 4 or more days per week had lower risk of being stressed compared with those who bicycled less or did not bicycle commute at all. This relationship remained statistically significant in all sensitivity analyses and after controlling for individual and environmental confounders.

Comparison with previous studies

To our knowledge, this study is the first to assess whether a relationship exists between solely bicycle commuting and perceived stress. A few studies have focused on the relationship between active commuting (as a combination of both walking and bicycling) and mental health,[6 7 29] but the relationship is still unclear. One study found a positive association of active commuting with well-being in adults,[6] and another with better mental health in only men.[29] Meanwhile, Humphreys and colleagues[7] found a positive relationship between time spent actively commuting and levels of physical well-being, but not with mental well-being. The relationship between PA and mental health has been studied more. It has been suggested that PA can reduce stress and anxiety on a daily basis while improving positive self-perception and mood,[41–43] and it has been associated with lower depressive symptomatology and greater emotional well-being.[44] These findings suggest that the PA gained during bicycle commuting[31] may act as a mediator in the relationship between bicycle commuting and perceived stress. Our results are consistent with the general idea that active commuting is associated with better mental health, but in our case PA did not act as a mediator in this relationship. Our sample was composed of young, healthy and active participants with relatively low PSS-4 levels of perceived stress, which might have led to an underestimation of the relationship between PA and perceived stress.

Qualitative research has suggested that choice of travel mode may affect well-being.[19] The quantity of public bicycle (*Bicing*) stations and the amount of greenness have been related to bicycle commuting propensity,[24] which could imply that commuting by bicycle provides people with more opportunities to 'enjoy' or 'experience' greenness than commuting in public transport or a car. At the same time, the availability of green space close to one's home has been shown to be related to better self-perceived general health and better mental health.[25 26 45] Therefore, it seems that perceptual and environmental factors related to bicycle commuting could affect perceived stress, in the way that the more pleasant an environment to bicycle commuting is, the lower the perceived stress we will get. This general idea is consistent with our results, which show an inverse relationship between perceived stress and bicycle-friendly environments (public bicycle stations and bikeability levels) in work/study address area and the commute route. Importantly, the relationship between bicycle commuting and perceived stress was unchanged after controlling for environmental confounders. Our results also showed that general attitude might have a role in this relationship, as we have seen that non-bicycle commuters willing to start bicycle commuting, compared with those unwilling, had lower risk of being stressed. This becomes unclear, however, as the relationship approaches statistical non-significance in sensitivity analyses.

Limitations and strengths

Our study has some limitations. First, our study used a cross-sectional design, which is not well suited to assess the direction of causation, and we cannot exclude reverse causality or residual confounding. It has been suggested that stressed people can engage in unhealthy behaviours, such as poor dietary practices or a lack of PA.[46] This reasoning could be applied to a behaviour like bicycle commuting, where those individuals who are more stressed would bicycle less. Second, our measurement method may be prone to information bias. With the questionnaire data we could have random misclassification error of bicycle commuting and PA due to the data being self-reported. Therefore, the risk estimate and also the potential mediation by PA could be an underestimation.[47] The TAPAS Travel Survey only measured levels of PA without differentiating between travel PA (being most accurate for commute studies) and other types of PA (work, recreational). Furthermore, the modification of the 5-point PSS-4 Likert scale into a 4-point Likert scale could incorrectly estimate the perceived stress.

This study has several strengths, too. The study has high internal validity, with a good representation of bicycle commuters. Related to participants' characteristics (sociodemographics), the TAPAS Travel Survey sample is representative of Barcelona's population. It was compared with data from the Catalan government's Barcelona Active Population Survey (Statistics and information service, Catalan government 2011), and no statistically significant differences between participants' neighbourhood deprivation index and home and work population density in both surveys were found.[24 31] Finally, our study in a southern European city has added evidence on these issues in a different context from the current literature.

Future research

Our findings underscored the need for future research. There is a need to obtain a clear understanding of the relationship between bicycle commuting and perceived stress in longitudinal studies. The role of PA in this relationship seems unclear, and it is likely that other factors could affect the relationship between these two variables, especially those related to environmental determinants and personal attitudes. Further work related to determinants and mediators of bicycle commuting and perceived stress is needed.

CONCLUSIONS

We found that healthy, adult bicycle commuters had lower risk of being stressed than commuters of other transport modes. Also, bicycle commuters who bicycled 4 or more days per week had a lower risk of being stressed than those who bicycled less than that. Environmental determinants such as the number of public bicycle stations and bikeability, and also personal attitudes, seem to have an influence on this relationship. Further research is needed in order to disentangle the relationship between bicycle commuting and perceived stress, and its determinants (individual and environmental) and potential mediators. Our findings suggest that decision makers may promote bicycle commuting as a daily routine to reduce stress levels and improve public health and well-being.

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