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# Cross-sectional association between active commuting and perceived commuting stress in Austrian adults: Results from the HOTway study

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ABSTRACT

*Objective:* Little is known about the acute psychological stress responses caused by commuting. Evidence for the benefits of active commuting (e.g., walking, cycling) is usually based on studies without measurements in free-living environments and without consideration of daily variations in stress. This study investigated the association between commuting mode (active, passive) and perceived commuting stress, assessed on multiple days immediately after commuting.

*Methods:* Adults participating in the cross-sectional 'Healthy On The way' (HOTway) study between 2016 and 2017 in Graz, Austria, were included. Participants completed an online survey and responded to statements about perceived stress (demands, tension) on three days before commuting (baseline stress) and after arrival (commuting stress), respectively. Active commuting was defined as cycling and/or walking (passive: car, motorbike, public transport).

*Results:* Of 188 participants (93 women, mean age: 28.0 ± 10.0 years) included, 124 were active and 64 were passive commuters. Active commuting was associated with less perceived commuting stress compared to passive commuting ($b_i = -2.95$, 95% CI: $-4.97$ to $-0.92$, $p = .005$), even after controlling for subjective well-being, physical activity, commuting time and other confounding variables.

*Conclusion:* Active commuting is related to a small reduction in perceived commuting stress. The results of this study support the promotion of active commuting for population (mental) health but future studies on the causal mechanisms and the role of active commuting in the recovery from previous stressors are needed.

## 1. Introduction

Physical activity (PA) plays a key role in promoting and maintaining health (Lee et al., 2012). Extensive research has shown that higher levels of moderate-to-vigorous physical activity are linked to lower risks for cardiovascular disease and dementia, and improvements in quality of life and mental well-being (Physical Activity Guidelines Advisory Committee, 2018; Lee et al., 2012). Current guidelines for the adult population recommend at least 150 min of moderate-intensity, or 75 min of vigorous-intensity aerobic PA (or an equivalent combination) together with muscle-strengthening activities on two or more days per week (US Department of Health and Human Services, 2018). In addition, evidence for the health benefits of short-term and lower-intensity activities is increasing, indicating that some activity is better than none (US Department of Health and Human Services, 2018).

Walking and cycling are activities of everyday life and are among the best investments to increase PA in the population. They are effective in terms of providing significant health benefits and can often be integrated into the daily routine. For instance, many daily journeys (e.g., to the supermarket) are short and can be covered by walking and cycling (GAPA, 2012; World Health Organization, 2002). Walking and cycling can also be used for daily commuting (e.g., to work or university), which was shown to be helpful in meeting recommended levels of PA (Sahlqvist, Song, & Ogilvie, 2012). Such 'active commuting' does not only provide various environmental benefits such as reducing noise and greenhouse gas emissions (Nazelle et al., 2011), but is also beneficial for ones' physical health. For instance, it was estimated that walking around 1.9 km in 22 min twice per day, on five days per week, is already

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associated with a reduction in all-cause mortality (Shephard, 2008). Moreover, active commuting is related to lower risks for major non-communicable diseases such as cardiovascular disease and diabetes (Dinu, Pagliai, Macchi, & Sofi, 2019). Previous research also demonstrated a positive link to mental health. For example, perceived stress in the past month was lower in bicycle compared to motorized commuters (Avila-Palencia et al., 2017). Based on longitudinal data from the British Household Panel Survey, greater well-being was observed in walking and bicycle commuters compared to car commuters (Martin, Goryakin, & Suhrcke, 2014).

Several studies recognized commuting itself as a potential source of psychological stress (Antoun, Edwards, Sweeting, & Ding, 2017). Psychological stress, which occurs when environmental demands are perceived to tax or exceed the adaptive capacity of the person (Cohen, Kessler, & Gordon, 1995), is central in the downstream development of disease (Cohen, Janicki-Deverts, & Miller, 2007). In fact, considering commuting as a source of psychological stress is relevant because it is well-known that daily stressors can threaten our health (Cohen, Edmondson, & Kronish, 2015; McEwen, 2007).

Morris & Hirsch (2016) showed that driving at peak times was associated with fatigue and stress, potentially because of greater unpredictability due to congestion (Wener & Evans, 2011) and the behaviour of other drivers (Rasmussen, Knapp, & Garner, 2000). Also, public transport may be perceived as more emotionally taxing than commuting by car, for instance due to the demands associated with interchanges, such as waiting times and delays when changing between different bus routes (Wardman, Hine, & Stradling, 2001). When perceived stress of commuting is measured immediately after arrival, car commuters reported less commuting stress than train commuters (Wener & Evans, 2011), whereas bicycle commuters reported less commuting stress than car commuters (Brutus, Javadian, & Panaccio, 2017). One study (Friman, Olsson, Ståhl, Ettema, & Gärling, 2017) did not report any differences between different types of commuters with respect to the dimension 'relaxation-stress' (although differences were observed for 'enthusiasm-boredom'). However, altogether, a recent review on the relationship between commuting and well-being showed that active commuting (walking, cycling) seems to be associated with relatively lower levels of perceived commuting stress compared to more physically passive commuting modes, such as using the car or public transport (Chatterjee et al., 2019).

Despite this evidence, several limitations must be acknowledged. First, much of the evidence is based on data from large surveys without measurements in the free-living environment (LaJeunesse & Rodríguez, 2012; Morris & Hirsch, 2016). This rather unspecific approach reduces the external validity of the results and does not provide insight into the acute psychological stress responses during commuting, for instance due to recall problems (Friman et al., 2017). Secondly, of those studies in which perceived commuting stress was measured immediately upon arrival at work (Brutus et al., 2017; Friman et al., 2017; Wener & Evans, 2011), only one study (Friman et al., 2017) performed baseline measurements (e.g., moods before commuting). The lack of an appropriate baseline increases the susceptibility to other influences such as previous work stress (Beattie & Griffin, 2014) and sleep quality (Blaxton, Bergeman, Whitehead, Braun, & Payne, 2017). Also, positive and negative moods experienced early in the morning can influence the perception of subsequent, potentially stressful, events (Rothbard & Wilk, 2011). Finally, the measurement of commuting stress at a single time point (Brutus et al., 2017; Wener & Evans, 2011) disregards the strong intra-individual variation in daily stress levels and may increase measurement error (Hutcheon, Chiolero, & Hanley, 2010; Sliwinski, Almeida, Smyth, & Stawski, 2009). Only few assessed commuting stress over multiple days (Friman et al., 2017).

Therefore, the aim of this study was to investigate the cross-sectional association between commuting mode (active, passive) and perceived commuting stress in a sample of Austrian adults. Commuting stress was measured on up to three days at arrival, including baseline measurements of stress before commuting. We hypothesized that active commuters (walking, cycling) perceive less commuting stress than passive commuters (car, motorbike, public transport).

## 2. Methods

### 2.1. Study design and participants

This cross-sectional observational study was part of the 'Healthy On The way' (HOTway) study which was designed to assess the association between the commuting mode and several environmental and psychological factors in residents of Graz, Austria. Study centre was the Institute of Human Movement Science, Sport and Health of the University of Graz. Recruitment of participants and data collection was performed between October 2016 and July 2017. All participants received information about the study procedures and provided informed consent. The HOTway study received ethical approval by the local research ethics committee (GZ. 39/1/63 ex 2016/179).

A convenience sample of adults was recruited using the following eligibility criteria: i) aged ≥18 years; ii) employed and/or studying (e.g., at the university); iii) German-speaking; iv) having a persistent residential address and place of work for at least two months in (the surrounding area of) Graz; and v) using the same commuting mode on at least four days per week.

Study materials included a city map, paper-pencil questionnaires for perceived baseline and commuting stress as well as a link to an once-only online survey. Before (i.e., after waking up) and after (i.e., at arrival) commuting on three days, participants were asked to respond to statements about perceived stress. The three days could be chosen by each participant, but Monday, Wednesday and Friday were recommended. The route of commuting was recorded on the city map and information regarding sociodemographic background, commuting mode, PA and mental health were collected by the online survey. For the reporting of this study, we followed the 'Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)' recommendations (Vandenbroucke et al., 2014).

### 2.2. Measurements

#### 2.2.1. Commuting stress and baseline stress

Since no commuting specific stress questionnaire was available in the German language, seven statements, adopted from the validated Perceived Stress Questionnaire (Fliege, Rose, Arck, Levenstein, & Klapp, 2001; Levenstein et al., 1993) and the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983; Klein et al., 2016), were used to obtain information about baseline stress and commuting stress. The statements refer to the dimensions 'tension' (internal stress response; items 1 to 3) and 'demands' (perception of external stressors; items 4 to 7), which have been used in previous research (Biehl, Boecking, Brueggemann, Grosse, & Mazurek, 2019; Groarke et al., 2017). Although different factor structures have been suggested, the obtained dimensions are usually highly correlated and thus, also the sum score across the obtained dimensions was shown to have good measurement properties (Montero-Marin, Piva; Demarzo, Pereira, Olea, & García-Campayo, 2014; Fliege et al., 2001; Reis, Lehr, Heber, & Ebert, 2019; Rönnlund et al., 2015).

Participants were asked to refer to their current perceptions ('You feel rested') when responding to these statements before commuting (baseline stress) and to refer to the commute ('On your commute, you felt rested') when responding to them after commuting (commuting stress). Reponses were made on a 10-point Likert scale ranging from 'very little' to 'very strong'. For each participant, the sum of all responses, averaged across all days (i.e., up to three days), was calculated (minimum: 0, maximum: 63). The original statements can be found in the Supplementary File (Appendix A).

#### 2.2.2. Commuting mode

A single question within the online survey was used to assess the commuting mode (walking, cycling, car, motorbike, public transport) and the average time spent in different modes. Participants who reported only walking and/or cycling were considered as active commuters whereas those reporting any combination of the remaining modes were considered as passive commuters.

#### 2.2.3. Confounding variables

Information on age (years), gender (female/male), education (university degree: yes/no), employment status (student: yes/no), monthly income (<1000, 1000–1800, >1800 €), marital status (relationship: yes/no) as well as height and weight [used to calculate body mass index (BMI; kg/m$^2$)] were obtained. Furthermore, information about commuting time [i.e., "How long (in minutes) does it take you to get to work, on average?] was available.

Information about PA was obtained by the self-administered German version of the International Physical Activity Questionnaire – short form (IPAQ-SF) (Craig et al., 2003). This questionnaire showed acceptable construct validity and reliability (Lee, Macfarlane, Lam, & Stewart, 2011) and is commonly used for assessing PA in European populations (Loyen et al., 2016). The IPAQ-SF assesses moderate PA, vigorous PA and walking performed in the past seven days across all domains (e.g., leisure time, work). Data processing was performed in accordance with the analysis guide (IPAQ Research Committee, 2005) although we also included values of <10 min due to the increasing evidence for the health benefits of shorter bouts of PA (Physical Activity Guidelines Advisory Committee, 2018). The sum of all three items (moderate, vigorous, walking), expressed in average minutes per day (min/day), was calculated.

The self-administered German version of the World Health Organization Well-Being Index (WHO-5) was used to measure subjective well-being (Brähler, Mühlan, Albani, & Schmidt, 2007; World Health Organization, 1998). The WHO-5 consists of five positively phrased questions about the well-being during the past two weeks and was shown to be a valid screening tool for depression (Topp, Østergaard, Søndergaard, & Bech, 2015). Responses were made on a 6-point Likert scale (0: all time, 5: at no time). The answers were summarized for each participant (minimum: 0, maximum: 25).

Overall, the following confounding variables were considered in our models based on previous research (Avila-Palencia et al., 2017; Wener & Evans, 2011): Baseline stress, age, sex, education, employment status, marital status, BMI, well-being, PA and commuting time. As employment status and income were highly correlated ($r < -.50$) and information about income was missing for a substantial proportion of the sample, only employment status was included as a confounding variable.

### 2.3. Sample size

No criterion for a minimum sample size was applied in this study. However, a sample size of approximately 150 participants was targeted which allowed us to detect a moderate effect ($f^2 = .15$) with at least 80% statistical power in the final model, considering exposure, outcome and all confounding variables (Faul, Erdfelder, Lang, & Buchner, 2007).

### 2.4. Statistical analysis

Statistical analyses were performed using SPSS Data Analysis version 26 (IBM Corp, Armonk, NY, USA). Descriptive statistics for all variables were calculated, including mean and standard deviation (SD) for continuous variables with normal distribution, median and interquartile range for continuous variables without normal distribution, and count and percentage for categorical variables. Normal distribution was assessed by Shapiro-Wilk, Q-Q-Plots and Histogram. Skewed variables were log-transformed prior to analysis. Bivariate Pearson correlation coefficients ($r$) were calculated to investigate the association between commuting stress, commuting mode and all confounding variables.

Ordinary least squares regression was used to assess the association between commuting mode and commuting stress. We performed minimally and fully adjusted models based on a complete-case analysis. Differences between active and passive commuters as well as between included and non-included participants were evaluated using independent $t$-test, Mann-Whitney $U$ test or Chi Square test, depending on the distribution of the data. Significance was considered as $p < 0.05$.

Several sensitivity analyses were performed. First, we excluded BMI because it may have been on the causal pathway between PA and mental health (Kandola, Lewis, Osborn, Stubbs, & Hayes, 2020). This was done to reduce overadjustment bias (Schisterman, Cole, & Platt, 2009). Secondly, we excluded employment status due to the moderate overlap with education in our sample. This was done to reduce multi-collinearity. Thirdly, the two dimensions of commuting stress (tension, demands) may be considered separately, depending on the observed factor structure (Fliege, Rose, Arck, Levenstein, & Klapp, 2001). Therefore, we repeated our main analysis for the outcomes 'tension' and 'demands'. Lastly, to evaluate the impact of missing data on the results, multiple imputation was used based on the missing at random (MAR) assumption (i.e., MAR depending on outcome and covariates). Using a fully conditional specification method [Markov Chain Monte Carlo (MCMC)], 50 imputed datasets were created to account for the uncertainty about the missing values. Our imputation model included outcome, exposure and all confounding variables of the fully adjusted model. In addition, a model was calculated in which employment status was replaced by income. In order to reduce the risk of misspecification because of missingness in many variables for the same individual (Seaman & White, 2013), we imputed missing values for all participants who did not change their mode during the measurement period and (partially) completed the online survey. After repeating the analysis, the results were combined using Rubin's rules (Rubin, 1987).

## 3. Results

### 3.1. Participants and descriptive data

Of 253 who consented to participate in the study, data on baseline and commuting stress were available for 247 participants (232 provided all three days and 15 provided two days). Of those, 213 (84.2%) answered the online survey and provided information on commuting mode and confounding variables. However, 12 participants were excluded because they changed their commuting mode throughout the measurement period (based on participants' records on the paper-pencil questionnaires). For further 13 participants information about commuting mode was missing because of reporting an implausible combination of modes (with respect to the total commuting time) in the online survey. Therefore, the final sample of the present analysis consisted of 188 participants (74.3%; overall, missing data ranged from 2.3% for baseline and commuting stress to 39.5% for income).

Of the final sample, two participants were removed from all analyses including the IPAQ-SF [one had an implausible high value (daily PA > 960 min) and one did not report on minutes of PA per day]. Finally, one participant reported 120 min for the commuting time (one-way). This extreme value was replaced by 60 min, the maximum value observed in the remaining sample.

The sample included 124 active and 64 passive commuters (Table 1). Participants were between 18 and 64 years old ($M = 28.0 \pm 10.0$). Active and passive commuters showed similar levels of baseline stress ($M_{active} = 16.9 \pm 8.0$, $M_{passive} = 16.9 \pm 8.0$, $p = .988$) but active commuters reported less commuting stress ($M_{active} = 13.9 \pm 7.1$, $M_{passive} = 17.3 \pm 9.2$, $p = .007$, Fig. 1). The results for the comparison between included ($n = 186$) and non-included ($n = 27$) participants with respect to the confounding variables of the main model are shown in Supplementary Table S1. Compared to included participants, non-included

**Table 1**
Sample characteristics of the 188 Austrian commuters.

| Characteristic | Total ($N$ = 188) | Active commuters ($n$ = 124) | Passive commuters ($n$ = 64) | $p$ |
|---|---|---|---|---|
| Age (years) | 28.0 ± 10.0 | 25.4 ± 6.5 | 33.1 ± 13.3 | <.001 |
| Sex (female) | 93 (49.5) | 61 (49.2) | 32 (50.0) | .917 |
| Education (university) | 78 (41.5) | 51 (41.1) | 27 (42.2) | .889 |
| Employment status (student) | 81 (43.1) | 68 (54.8) | 13 (20.3) | <.001 |
| Monthly income[a] | | | | <.001 |
| <1000 € | 80 (42.6) | 62 (50.0) | 18 (28.1) | |
| 1000–1800 € | 44 (23.4) | 27 (21.8) | 17 (26.6) | |
| >1800 € | 29 (15.4) | 10 (8.1) | 19 (29.7) | |
| Marital status (relationship) | 92 (48.9) | 56 (45.2) | 36 (56.3) | .150 |
| BMI (kg/m$^2$) | 22.7 ± 2.5 | 22.3 ± 2.3 | 23.4 ± 2.7 | .002 |
| Well-being (WHO-5, sum score) | 15.1 ± 4.0 | 15.0 ± 4.0 | 15.3 ± 4.1 | .689 |
| PA (IPAQ-SF, min/day) | 111.4 (66.3–162.5)[b] | 114.3 (74.8–167.9)[b] | 105.0 (43.2–150.5) | .103 |
| Commuting time (min) | 15.0 (10.0–20.0) | 11.0 (8.3–18.0) | 20.0 (15.0–25.0) | <.001 |

*Note.* BMI = body mass index, IPAQ-SF = International Physical Activity Questionnaire – short form, M = mean, min = minutes, PA = physical activity, $Q_{1/3}$ = quartile 1 or 3, SD = standard deviation, WHO-5 = World Health Organization (Five) Well-being Index. Values are shown as $M \pm SD$, Median ($Q_1$–$Q_3$) or $n$ (%) depending on the distribution of the variable. Active commuters: walking, cycling; passive commuters: car, motorbike, public transport. PA and commuting time were log-transformed prior to significance testing.

[a] A total of 35 participants selected 'no answer' (25 active and 10 passive commuters).

[b] Values from two participants (active commuters) were removed.

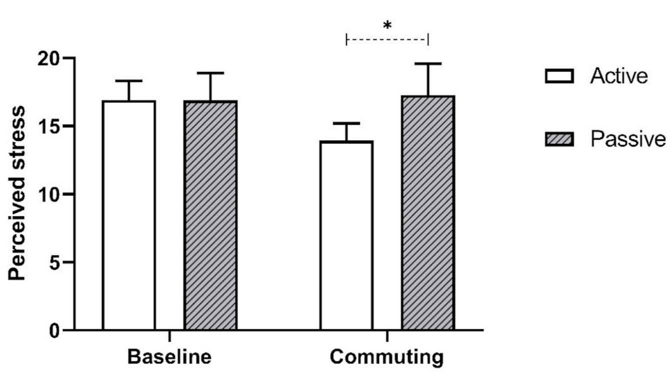


**Fig. 1.** Perceived baseline and commuting stress for the 188 Austrian commuters (active commuters: $n$ = 124, passive commuters: $n$ = 64). Mean values for perceived stress, derived from up to three days of commuting, are shown together with 95% confidence intervals (CI). Active commuters: walking, cycling. Passive commuters: car, motorbike, public transport. Asterisks (*) indicate significant differences ($p$ < .05).

participants reported greater commuting time. Bivariate inter-correlations among all variables included in the main model are shown in Supplementary Table S2.

### 3.2. Commuting mode and commuting stress

In both minimally and fully adjusted models, active commuting was negatively associated with commuting stress (Supplementary Table S3). Baseline stress was positively associated with commuting stress. The fully adjusted model revealed a decrease of 3 points [$b_i = -2.95$, 95% confidence interval (CI): −4.97 to −0.92] in commuting stress for active compared to passive commuters (minimally adjusted model: $b_i = -3.55$, 95% CI: −5.34 to −1.76). Excluding BMI or employment status had no considerable influence on the coefficients in the model (Supplementary Table S4). Likewise, similar results were obtained when considering the two dimensions of commuting stress (tension, demands) as separate outcomes (Supplementary Table S5). The combined results from multiple imputed datasets did not change the main results concerning the association between commuting mode and commuting stress (Supplementary Table S6 and S7).

## 4. Discussion

The present study investigated the association between commuting mode (active, passive) and psychological commuting stress in a sample of Austrian adults. Commuting stress was measured on up to three days at arrival. As hypothesized the results showed that active commuting (walking, cycling) was associated with lower perceived commuting stress compared to passive commuting (car, motorbike, public transport). The results were also robust to several sensitivity analyses. Overall, our results support the promotion of active commuting for population (mental) health even though we only observed a small effect of active commuting.

In contrast to previous research on commuting stress (Brutus et al., 2017; LaJeunesse & Rodríguez, 2012; Morris & Hirsch, 2016; Wener & Evans, 2011), we performed field-based measurements of commuting stress on multiple days and considered daily differences in stress before commuting. Using this methodology, our results are in line with those from previous studies. For instance, Avila-Palencia et al. (2017) showed that bicycle commuters had lower risks of being stressed than non-bicycle commuters. Employees in Montreal who cycled to work reported less commuting stress than those who commuted by car (Brutus et al., 2017). Also, Gatersleben & Uzzell (2007) observed lower levels of commuting stress for active compared to passive commuters among British university employees. A recent review concluded that commuters who walk or cycle are generally more satisfied with their commute compared to car and public transport commuters (Chatterjee et al., 2019).

The observed differences in commuting stress in the current study are consistent with research showing that PA can have acute psychological effects. For example, exercise sessions in moderate intensity of around 20 min (e.g., cycling, yoga, resistance training) can reduce state anxiety in healthy adults (Asmundson et al., 2013) while similar bouts of exercise can increase mood and decrease rumination in psychiatric patients (Brand et al., 2018). Commuting can also provide an opportunity for relaxation and detachment and thereby, may help to recover from previous (work) stress (Gatersleben & Uzzell, 2007; van Hooff, 2015). However, the role of active commuting in the recovery from previous stressful experiences needs to be explored in future studies.

When commuting by car or public transport several factors, such as unexpected delays, congestion and the behaviour of other travellers, can be stressful for the individuum (Morris & Hirsch, 2016; Rüger, Pfaff, Weishaar, & Wiernik, 2017). For instance, exposure to congestion resulted in acute increases in systolic and diastolic blood pressure in a recent study in Lebanon drivers (Bou Samra et al., 2017). While demands can also occur during active commuting, for example when cycling close to traffic (Caviedes & Figliozzi, 2018), passive commuting may be associated with somewhat higher levels of demanding events. Moreover, passive commuting may reduce the extent to which a person can exercise behavioural control (e.g., due to congestion) or predict outcomes of the commute (e.g., time of arrival) (Evans, Wener, & Phillips, 2002; Sposato, Röderer, & Cervinka, 2012; Wener & Evans, 2011). Although the potential discrepancy in demanding events, perceived control and predictability may help in explaining the differences in commuting stress between active and passive commuters, the causal mechanisms remain unclear from this cross-sectional investigation. For instance, also several other factors such as weather or greenness along the commute may shape the relationship between commuting mode and stress. In summary, this study showed a positive, yet weak, association between active commuting and psychological commuting stress.

### 4.1. Strengths and limitations

This study has several strengths: i) commuting stress was measured on three days in the free-living environment to reduce measurement error and increase external validity; ii) commuting stress was measured immediately at arrival which allows a better assessment of acute psychological stress responses; and iii) baseline measurements of perceived stress, namely before commuting, were obtained to control for stressful events before commuting.

However, a convenience sample of participants was included which increases selection bias and limits the generalizability of the results. Secondly, we were unable to control for the exact time when participants reported on baseline and commuting stress. For instance, it is possible that some participants responded to the statements not immediately after arrival at work but somewhat later. Furthermore, the design of the study was cross-sectional which makes conclusions about causality impossible. One may also consider a bi-directional relationship between commuting mode and commuting stress (i.e., the stress caused by a specific commute potentially affects the choice of the mode). This study compared two types of commuters, which does not allow to draw conclusions about commuting stress for different sub-types such as electric bike or motorbike commuters, and may lack in addressing all relevant variables involved in the relationship between commuting mode and commuting stress (e.g., job satisfaction, weather). For example, it was shown that temperature, precipitation and wind can affect the emotional state of active commuters (Böcker, Dijst, & Faber, 2016). Likewise, we did not control for PA prior commuting (e.g., exercise sessions early in the morning), the (relative) intensity of PA involved during active commuting (e.g., brisk walking in relation to aerobic capacity or age) or whether a person was a driver or co-driver. Finally, one may argue to consider public transport as a form of active commuting due to the active parts of the journey (Rissel, Curac, Greenaway, & Bauman, 2012). However, differences in physical activity energy expenditure (PAEE) illustrate a distinction between them. Walking [4.6 metabolic equivalents (METs)] and cycling (6.4 METs) for commuting require more energy than car (1.3 METs) and bus use (1.7 METs) (Costa et al., 2015). Considering walking and cycling as the primarily active modes is also in line with previous studies (Celis-Morales et al., 2017).

### 4.2. Future studies

Future studies should use devices (e.g., accelerometers) to measure the level of PA involved during active commuting. This can help to identify aspects of the dose-response relationship between active commuting and commuting stress such as the optimum 'dose' (e.g., duration, intensity) (Shephard, 2008). Future studies may consider a more sophisticated approach by measuring perceived stress also when commuting home after work, by including environmental aspects such greenness and congestion as well as by implementing longitudinal and experimental studies to better understand the causal mechanism between commuting and stress and the potential of active commuting to facilitate coping with previous stressors. Lastly, we observed a small difference in commuting stress between active and passive commuters. Because we are unaware about clinically relevant differences in daily commuting stress, future studies should also investigate the long-term consequences of different commuting modes, including associations with other (mental) health outcomes.

## 5. Conclusion

Walking and cycling are everyday activities and important for health promotion in the population. The results of this study expand the evidence for the mental health benefits of active commuting and showed that active commuters perceive less commuting stress than passive commuters. Although the results support the promotion of active commuting, we only observed a small effect. More longitudinal and experimental studies are needed to identify the underlying causal mechanism.

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## Author contributions

Matteo C. Sattler: Conceptualization, Methodology, Investigation, Project administration, Formal analysis, Validation, Visualization, Writing - Original Draft. Tanja Färber: Software, Data Curation, Writing – Review and Editing. Katharina Traußnig: Software, Data Curation, Writing – Review and Editing. Gottfried Köberl: Conceptualization, Investigation, Software, Writing – Review and Editing. Christoph Paier: Software, Data Curation, Validation, Writing – Review and Editing. Pavel Dietz: Conceptualization, Methodology, Investigation, Writing – Review and Editing. Mireille N. M. van Poppel: Conceptualization, Methodology, Resources, Investigation, Project administration, Supervision, Writing – Review and Editing.

## Data availability

The dataset used and/or analyzed during this current study is available from the corresponding author on reasonable request.

## Declaration of competing interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mhpa.2020.100356.

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