Modelling the Effect of Health Indicators on Commute Mode Choice:  
a cross-sectional study in southern Sweden

Kristoffer Mattisson\textsuperscript{a}, Ahmed O. Idris\textsuperscript{b}* , Ellen Cromley\textsuperscript{a,c}, Carita Håkansson\textsuperscript{a}, Per-Olof Östergren\textsuperscript{d}, Kristina Jakobsson\textsuperscript{a}

\textsuperscript{a} Department of Occupational and Environmental Medicine, Lund University, 221 85 Lund, Sweden.
\textsuperscript{b} School of Engineering, University of British Columbia, EME 4242 - 3333 University Way, Kelowna, BC V1V 1V7, Canada.
\textsuperscript{c} Department of Community Medicine and Health Care, University of Connecticut School of Medicine, 263 Farmington Avenue, MC 6325, Farmington, CT 06030-6325, USA.
\textsuperscript{d} Social Medicine and Global Health, Lund University, Jan Waldenstroms gata 35, 205 02 Malmö, Sweden.

*Corresponding author: ahmed.idris@ubc.ca

Email Addresses:
Kristoffer Mattisson kristoffer.mattisson@med.lu.se
Ahmed O. Idris ahmed.idris@ubc.ca
Ellen Cromley ellen.cromley@med.lu.se
Carita Håkansson carita.hakansson@med.lu.se
Per-Olof Östergren per-olof.ostergren@med.lu.se
Kristina Jakobsson kristina.jakobsson@med.lu.se

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Abstract
The impact of commuting on the environment and health depends on the mode of travel that is used. Little is known about how health is associated with mode choice among commuters. We investigated associations between health and commuting mode choice using population-based public health questionnaire data collected from 7,574 commuters in southern Sweden in 2012, integrated with register data on residential and workplace location, information on transportation networks, and other spatial data. Discrete Multinomial Logit (MNL) models were used to study the relationship between health indicators (everyday stress, vitality, long-term illness, walking difficulties, and body mass index) and commuting mode (car, active transportation, and public transit). Along with the health indicators, the models included conventional mode choice indicators such as socio-demographic attributes, commuting characteristics, and spatial variables. Everyday stress, obesity, and difficulty walking were associated with mode choice, as were most of the conventional indicators. Understanding the relationship between health and mode choice in commuting can help decision-makers develop more efficient interventions aiming at making car commuters switch to more environmentally friendly modes such as active transportation and public transit.

Keywords
Commuting, Health, Mode choice, Obesity, Stress, Difficulty Walking
1. Introduction

The continuous growth of local labor markets generates economic wealth through a more accessible and flexible workforce. However, work commute (i.e. travel between home and workplace) has become a serious concern as commuting distances/durations are increasing in many parts of the world (1-5). This increased travel has substantial health, environmental, and economic consequences through emission of air pollutants, noise, and stress experienced by commuters, and demands on transportation infrastructure.

The work commute makes up an important part of everyday travel (6). The impact of commuting on health, the environment, and the economy depends on the mode of travel that is used (7). Cars can potentially have a large impact on health and the environment through emission of greenhouse gases, air pollutants and noise (8, 9). Public transportation options (e.g. buses, trains, etc.) are, from an environmental perspective, preferred due to their relatively lower carbon footprint per passenger in comparison to the car option (10). Public transportation also consumes less land through using relatively smaller parts of the street in comparison to cars (11). The most environmentally friendly option is the active commuting (e.g. walking, cycling, etc.). Active commuting does not emit air pollutants and requires small land area inside the already crowded cities. As such, it has low impact on residents’ health and the environment. Active commuting is also considered the healthiest mode of travel as it is associated with higher physical activity, which in turn is associated with reduced overweight and increased protection against cardiovascular diseases (12-14).

In order to design transportation planning policies that promote sustainable and healthy transportation alternatives (e.g. active transportation and public transit), the determinants of commute mode choice need to be well understood (15). A recent review on the interventions designed to reduce car use showed that only 12 out of 77 studies were judged to be methodologically strong and only six of these 12 interventions actually reduced car use (16). This finding highlights that there are a number of unknown factors, such as commuters’ health status, that need to be considered in order to design efficient mode shift interventions.

Transportation mode choice has been extensively studied over the years (6, 17-19). Socio-demographic information, commuting characteristics, spatial indicators, and socio-psychological attributes have all been studied and found to be important for transportation mode choice (20). However, little has been reported on how the health status of commuters can influence their mode choice. Better knowledge about the relationship between health and mode choice would help transportation planners and policy makers develop policies for sustainable and healthy transportation alternatives.

The purpose of this study is to investigate the relationship between health and commuting mode choice in the county of Scania, Sweden as a case study. We aim to examine the contribution of commuters’ health status to their mode choice, in addition to more conventional explanatory variables such as socio-demographic information, commuting characteristics, and geographical context. Given that little is known about how commuters’ health status contributes to their mode choice, this study will help transportation planners and policy makers design better mode shift interventions, not only in Scania and Sweden, but elsewhere as well.

2. Indicators of Mode Choice - A Literature Review

Research has shown that commute mode choice decisions are complex and involve many different factors (21-23). In a recent study, De Witte, et al. (20) investigated the determinants...
of transportation mode choice in an attempt to develop a framework for analyzing passengers’ choices. The investigation showed that typical determinants of mode choice are concerned with socioeconomic and demographic attributes, travel characteristics, spatial variables, and socio-psychological indicators. Factors that set the environment for the decision were divided into three different types: socioeconomic and demographic indicators, travel characteristics, and spatial indicators. Subjective factors that decide how the decision-maker will react in relation to factors that set the environment were called socio-psychological indicators.

Socioeconomic and demographic indicators capture individual situations and social interactions such as age, gender, income, and education. Household responsibility, compensation in the form of income, and the spatial distribution of job locations have all been considered in explaining gender differences in commuting mode choice (21, 24). Males make higher use of cars in some communities (4, 21, 25). Other research has suggested that cars are more useful to women, due to the greater responsibility for domestic work and children, as cars facilitate transporting children, grocery shopping, and completing other errands on the way to and from work (26).

The educational level of commuters affects their attitudes concerning travel behavior and the environment. Commuters with higher levels of education have been found to use more public transit (21, 25). Higher income makes it possible for commuters to choose a mode of travel independent of the economic cost and has been found to have a positive relationship with car use and a negative relationship with public transportation (27-29).

Another aspect of the socio-economic indicators that has been studied in the literature is the employment characteristics of the commuter, such as occupational status and work conditions (e.g. part-time, full-time, etc.). Part-time workers have been found to use more transit and car, and less active commuting (30). The same study also concluded that the timing of the commute is important for mode choice.

Family situation is another aspect that has been found to be important. Studies have found that the larger the family is, the more the car is used as a mode of travel (31). Having children living at home also increases the use of the car (21).

Travel characteristics describe the factors related to the trip itself such as travel duration, distance, cost, etc. Duration is considered to be one of the most important indicators of mode choice as the commuter wants to be able to travel quickly between home and work (32). Distance is related to mode choice in a similar way as duration; that is, faster modes are more preferred for longer distances. However, distance does not consider the effect of congestion. That is why it is commonly used as a determinant of mode choice for non-motorized modes or in congestion-free networks.

Spatial indicators describe the geographical context of where activities take place and include population density, land use diversity (i.e. mix), and availability of parking among others. The relationship between the geographical context of the commute and the choice of commuting mode cannot be overstated (22). Research has shown that population density is a key determinant of mode choice, creating a context more suitable for public transit and active transportation (e.g. walking and cycling) (33). Further, proximity to public transit stops/stations has been found to increase transit utilization (21). A distance of 400 m is often used as a suitable transit access threshold (34).
The socio-psychological indicators affect how the possibilities based on the other indicators are evaluated in making the mode choice. Socio-psychological factors are usually latent and include variables such as perception, experience, habits, and lifestyle (8).

2.1 Health indicators
The association between health and mode choice of commuting has only been studied to a limited extent. In one of the few studies, Carse, et al. (35) investigated the associations between mental health, physical health, Body Mass Index (BMI), and mode choice. Mental health was measured using the mental health summary score of SF-8 called MCS-8. Physical health was measured by the physical summary score of SF-8 called PCS-8 and the BMI (categorized in normal, overweight, and obese). SF-8 is an eight question health survey form including questions on general health, physical functioning, and limitation during the last 4 weeks and can be classified into one mental score and one physical score. An association was found between overweight, obesity, and higher use of car, in a separate model which included only health indicators. After adjustment for conventional indictors including socio-economic, spatial indicators, and commuting characteristics, the statistical significance in the association between BMI and car disappeared.

Very little research on the association between mental aspects of health and mode choice in commuting has been conducted. Acute stress has been suggested to have an impact on general decision-making (36, 37). The effect of chronic stress on decision-making has been even less analyzed than acute stress (38). Information about the commute mode as stressful has been found to be associated with mode choice (39). People travelling by car who were given information about the health benefits and reduced stress of using park-and-ride (i.e. park the car and connect to public transportation near city centers) showed reduced use of car.

More research has been conducted on how physical aspects of health rather than mental aspects influence mode choice, even though the literature cannot be considered large (40). Schmöcker, et al. (40) found that age and disability influence mode choice for shopping trips. People with disabilities preferred not to use public transportation. This was also found in an older study where disabled people did not prefer to use buses (41). The study showed that the use of bus, being driven, and walking were negatively associated with having walking difficulty, while using para-transit or taxi was positivity associated with walking difficulties.

3. Case Study
3.1 Study area
The study area, Scania, the southernmost county in Sweden, has witnessed a large increase in the use of bus and train and there are plans for large investments in public transportation, thus creating a potential for continued increase in commuting duration for inhabitants in the area, as shown in Figure 1. Scania has a population of 1.2 million and a polycentric regional structure (42). The population and workplaces are concentrated along the west coast. The largest city in the area is Malmö with 320,000 inhabitants. Malmö is connected to the Danish capital Copenhagen (2 million inhabitants in its metropolitan region) by a bridge supporting road and rail traffic. Thus, Scania is the gateway between Sweden and Europe and commuters need to share space with goods shipments.
Transportation infrastructure is well developed but there is a need for investments in both railways and roads due to capacity issues in the southwest of the county and quality issues in northeast (43). Improvements to the present bus and train services have been identified as needed as well as increased capacity on the railways and introduction of trams and high capacity regional buses. Accessibility by bike is considered as an important component in the regional development and the cycling infrastructure is well-developed both within and between cities (44). The three largest cities, Malmö, Lund, and Helsingborg which together comprise 44% of the population, are considered to be some of the most biking-friendly cities in Sweden (44).

3.2 Study sample, questionnaire, and data
Population-based public health surveys are regularly performed in Scania every fourth years. The study sample was selected from participants in the 2012 survey (45). A questionnaire was sent out to 56,600 individuals and was answered by 28,029 (response rate 49.5%). The sample selection procedure of the survey was geographical stratification based on the 33 municipalities in Scania. Strata were created based on gender distribution within each municipality to maintain the ratio of males to females. Large municipalities such as Malmö, Lund, Helsingborg, and Kristianstad had more strata than the rest of the 29 municipalities based on their sizes.

The questionnaire contained more than 130 questions about background, family composition, commuting, and health. For all participants in this study, residential addresses were obtained and linked to the questionnaire responses, resulting in a study population of 19,300. The workplace locations for these individuals were linked to the database using data on employment location obtained from Statistics Sweden resulting in 11,087 participants who had both residential and workplace coordinates as of January 1st, 2013. Information about income was also obtained from Statistics Sweden and joined to the individual records.
Residence in urban or rural area was also determined for each individual commuter based on spatial spread of urban areas from Statistics Sweden. Spatial locations of transit lines/routes and stops/stations were obtained from Region Skåne.

To study commuters travel behaviour, the following inclusion criteria were applied: respondents had to be between 18-65 years old, work 15-60 hours/week, have answered the question about commuting mode and be both living and working inside Scania. This yielded a final study sample of 7,574 with residential and workplace location inside Scania, as shown in Figure 2. Ethical approval to connect the data from Statistics Sweden to the survey data was granted by the regional ethical review board (Dnr 2014/418).

Figure 2. Distribution of residential and workplace locations of the 7,574 study

3.3 Outcome measure and indicators of mode choice
Mode choice was self-reported in the questionnaire based on responses to the question “How do you usually go to work?” 1) walking 2) cycling 3) car 4) bus 5) train 6) other. These responses were reclassified into active transportation, car, and public transit - Active transportation included those commuters who answered walking or cycling (or both), car commuters included those answering only car or car and walking or cycling, and public transit included all commuters answering bus or train. Commuters reporting other modes were excluded from the analysis.

Health was measured using five different indicators. Stress was included in the model based on the self-reported question “Do you feel stressed in your everyday life?” with three response alternatives 1) Yes, in general 2) Yes, sometimes 3) No (almost never). This variable was dichotomized into stressed (1) and not stressed (2-3). This was included as an indicator of “stressed often”.

Vitality was measured with the vitality-scale of SF36. The scale consisted of four items asking about energy level with answers on a 6-point scale. The answers of the four questions
were summed up and participants with a sum of 16 or more were coded as having “Low vitality”. For a more detailed description of the coding see (46).

Long-standing illness was measured with the question “Do you have a long-standing health condition, discomfort after accident, disability or other long term health condition?” Followed by the question “Does this condition lower your work performance or obstruct you in your daily activities?” Three alternatives were presented and commuters who were moderately or highly affected were classified as having a long-standing illness.

Having a problem walking was addressed with the question “Are you, due to your current health condition, limited in any of the following activities?” Followed by the attendant question “Can you take a shorter walk (about 5min) in moderate pace?” with the alternatives yes or no.

Body mass index was calculated based on self-reported weight and height. Commuters with a BMI $\geq 30$ were classified as obese (47).

Socioeconomic variables (e.g. age, gender, occupation, educational level, and family composition) were captured using the questionnaire and register (income) data.

Level-of-service attributes were generated for car, transit, walk, and cycle using the Google Directions API for all trips given respondents’ residential and work addresses. In order to calculate the commuting duration and distance, a real-time update of the traffic situation was used and the date of the calculation was set as 8:00 am on November 28th, 2012. This time and date reflect the peak hour on the day the data was collected.

Spatial indicators were prepared using ArcMap GIS software. Proximity to bus stops and train stations was calculated by creating a buffer of 400m around each stop/station, as shown in Figure 3. Residential and work locations were then overlaid on top of the buffer in order to decide which commuters lived and/or worked inside the 400m buffer area.
Figure 3. Buffer areas of 400m around all transit stops/stations in Scania

3.4 Descriptive analysis
Car was the dominant mode of commuting (61%), followed by active transportation (20%), and public transit (19%), as shown in Table 1. Both active transportation and public transit commuters lived and worked in urban areas and had access to transit stops/stations both close to home and close to work to a larger extent than car commuters. Car commuters, on the other hand, more commonly lived in their own, single-family detached houses. Active and public transportation modes were less common among men. The proportion of commuters with a high level of education was highest for public transit, followed by active transportation, with car last. Proportionally, more car commuters had a high income (35%) compared to public transit and active commuters (both 28%). Active commuters had the lowest levels of obesity, problems walking (share with public transit), and long-standing illness. Public transit commuters had the highest proportion of commuters with low vitality and being stressed often. Active commuters had the shortest distance to walk to work. Car commuters had the longest duration to work using transit whereas public transit users had the longest duration to work using car.
Table 1. Descriptive statistics

<table>
<thead>
<tr>
<th>Mode choice (%)</th>
<th>Active Transportation (N=1,509)</th>
<th>Public Transit (N=1,410)</th>
<th>Car (N=4,655)</th>
<th>Average (N=7,574)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode choice (%)</td>
<td>20</td>
<td>19</td>
<td>61</td>
<td></td>
</tr>
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</table>

Spatial indicators and commuting characteristics

<table>
<thead>
<tr>
<th>Trip distance by walking (Mean km)</th>
<th>4</th>
<th>24</th>
<th>17</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip duration by transit (Mean min)</td>
<td>20</td>
<td>49</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>Trip duration by car (Mean min)</td>
<td>7</td>
<td>24</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Live in urban area (%)</td>
<td>95</td>
<td>93</td>
<td>81</td>
<td>86</td>
</tr>
<tr>
<td>Working in urban area (%)</td>
<td>91</td>
<td>95</td>
<td>84</td>
<td>87</td>
</tr>
<tr>
<td>Transit within 400m from home (%)</td>
<td>84</td>
<td>81</td>
<td>65</td>
<td>72</td>
</tr>
<tr>
<td>Transit within 400m from work (%)</td>
<td>87</td>
<td>94</td>
<td>79</td>
<td>84</td>
</tr>
<tr>
<td>Living in own house (%)</td>
<td>48</td>
<td>53</td>
<td>74</td>
<td>65</td>
</tr>
</tbody>
</table>

Sociodemographic indicators (%)

<table>
<thead>
<tr>
<th>Age</th>
<th>18-34</th>
<th>35-44</th>
<th>45-54</th>
<th>55-65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>19</td>
<td>27</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Education more than 12 years</td>
<td>59</td>
<td>67</td>
<td>48</td>
<td>54</td>
</tr>
<tr>
<td>High income (more than 600000 SEK/year)</td>
<td>27</td>
<td>28</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>Manual worker</td>
<td>41</td>
<td>29</td>
<td>42</td>
<td>39</td>
</tr>
<tr>
<td>Working part-time</td>
<td>14</td>
<td>15</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Inconvenient work hours (night work, shift, duty)</td>
<td>21</td>
<td>18</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Cohabiting</td>
<td>72</td>
<td>75</td>
<td>80</td>
<td>77</td>
</tr>
<tr>
<td>Having children under 12 living at home</td>
<td>24</td>
<td>30</td>
<td>33</td>
<td>31</td>
</tr>
</tbody>
</table>

Health indicators (%)

| Being Obese (BMI ≥ 30) | 9 | 12 | 15 | 13 |
| Problem to walk quickly for five min | 18 | 18 | 21 | 20 |
| Long-standing illness | 14 | 15 | 17 | 16 |
| Low vitality (SF36-vitality scale) | 16 | 19 | 17 | 17 |
| Often everyday stress | 16 | 21 | 18 | 18 |

4. Mode Choice Modelling

Discrete Multinomial Logit (MNL) models were developed based on the principle of Random Utility Maximization (RUM) originated at microeconomics (17, 19). According to the RUM principle, commuters are assumed to be rational decision-makers who select the mode of travel that maximizes their utility which is divided into a systematic and a random component as follows:

\[ U_{ij} = V_{ij} + \epsilon_{ij} \]

The systematic (i.e. observable) component of utility \( V_{ij} \) is a linear additive function of a vector of explanatory variables multiplied by a vector of parameters (i.e. weights). The random component \( \epsilon_{ij} \) captures uncertainty.

Variables here added to the utility functions in order to explain the utility for each mode. All variables where added as mode specific and car was used as the reference. Some variables
such as access to transit stops/stations, duration/distance were included only in single utility functions. Three mode choice models were developed; the first one included spatial indicators and commuting characteristics; the second one also included socioeconomic indicators; the third model included all variables from the second model in addition to health indicators. By constructing models in three steps it is possible to see if the additional variables are adding any explanatory power. Probability of mode selection can be calculated for each mode using the following formula:

\[ U_{ij} = \frac{e^{V_{ij}}}{\sum_k e^{V_{ik}}} \]

The developed models accounted for various indicators to predict commuters’ mode choice among a set of transportation options, namely, active transportation, car, and public transit. Biogeme 2.0 software was used to estimate the models (48).

5. Results and Discussion

The final model was built in three steps, first with only spatial indicators and commuting characteristics, then also socio-demographic indicators, and finally also health indicators, as shown in Table 2. The specification of the final model was derived based on the accommodation of variables with proper signs and statistical significance. The critical value (1.96) of the t-statistic with a 95% confidence limit was considered as the threshold value of considering variables in the model. However, some parameters with t-statistics values lower than 1.96 were retained in the model because the corresponding variables provide considerable insight into the decision-making process.

The explanatory level of the model increased in all steps, showing that all these different types of indicators (especially health indicators) are important to explain mode choice. The rho-squared value of the final model, which is an estimate of the goodness of fit, is 0.342 and thereby explaining 34.2% of the variance in the final model including all indicators.

Spatial indicators and commuting characteristics all turned out statistically significant for each of the three models with increasing complexity of covariates. The signs of the indicators were mostly in the expected direction. Increased walking distance lowered the probability of active commuting as well as increased duration of public transit lowered the probability of using public transit. Commuters want to be able to travel fast between home and work (32). The sizes of the estimates for distance and duration stayed in the same magnitude when including sociodemographic and health indicators. Living and working in urban areas both separately increased the probability of using both active and public modes, with living in urban areas especially increasing the probability of active commuting. This is in accordance with prior research (22). Commuters with access to a transit stops/stations had a higher probability of using public transit. The estimate for access to transit at work was twice as high for transit close to home, indicating the importance of having transit at the trip destinations. Living in one’s own house was associated with having a lower probability of using both active transportation and public transit, with similar estimates in all three models. Living in one’s own house would probably mean having access to a parking space next to the residence.
### Table 2. Results from three multinomial logit models with increasing complexity

<table>
<thead>
<tr>
<th>Variable name</th>
<th>V&lt;sub&gt;active&lt;/sub&gt;</th>
<th>Model 1</th>
<th>V&lt;sub&gt;transit&lt;/sub&gt;</th>
<th>Model 1</th>
<th>V&lt;sub&gt;active&lt;/sub&gt;</th>
<th>Model 2</th>
<th>V&lt;sub&gt;transit&lt;/sub&gt;</th>
<th>Model 2</th>
<th>V&lt;sub&gt;active&lt;/sub&gt;</th>
<th>Model 3</th>
<th>V&lt;sub&gt;transit&lt;/sub&gt;</th>
<th>Model 3</th>
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<td><strong>Spatial indicators and commuting characteristics</strong></td>
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<tr>
<td>Distance walking (km)</td>
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<td>-28.20*</td>
<td>-</td>
<td>-</td>
<td>-0.26</td>
<td>-28.45*</td>
<td>-</td>
<td>-</td>
<td>-0.27</td>
<td>-28.00*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Duration transit (min)</td>
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<td>-0.03</td>
<td>-13.64*</td>
<td>-</td>
<td>-0.28</td>
<td>-25.00*</td>
<td>-0.57</td>
<td>-5.34*</td>
<td>-0.32</td>
<td>-2.38*</td>
<td>-0.55</td>
<td>-4.98*</td>
</tr>
<tr>
<td>Live in urban area</td>
<td>0.73</td>
<td>5.10*</td>
<td>0.44</td>
<td>3.37*</td>
<td>0.69</td>
<td>4.73*</td>
<td>0.46</td>
<td>3.49*</td>
<td>0.67</td>
<td>4.45*</td>
<td>0.46</td>
<td>3.33*</td>
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<tr>
<td>Working in urban area</td>
<td>0.47</td>
<td>4.04*</td>
<td>0.40</td>
<td>2.73*</td>
<td>0.37</td>
<td>3.12*</td>
<td>0.39</td>
<td>2.58*</td>
<td>0.40</td>
<td>3.27*</td>
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<td>2.72*</td>
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<tr>
<td>Transit within 400m from home</td>
<td>-</td>
<td>-</td>
<td>0.28</td>
<td>3.15*</td>
<td>-</td>
<td>-</td>
<td>0.26</td>
<td>2.90*</td>
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<td>2.89*</td>
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<td>0.73</td>
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<td>-</td>
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<td>4.21*</td>
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<td>-</td>
<td>0.56</td>
<td>3.93*</td>
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<td></td>
</tr>
<tr>
<td>Age 35-44</td>
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<td>-3.00*</td>
<td>-0.58</td>
<td>-5.42*</td>
<td>-0.32</td>
<td>-2.38*</td>
<td>-0.55</td>
<td>-4.98*</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Age 45-54</td>
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<td>-2.50*</td>
<td>-0.57</td>
<td>-5.34*</td>
<td>-0.27</td>
<td>-2.34*</td>
<td>-0.55</td>
<td>-4.98*</td>
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<tr>
<td>Age 55-65</td>
<td>-0.13</td>
<td>-1.15</td>
<td>-0.49</td>
<td>-4.49*</td>
<td>-0.13</td>
<td>-1.10</td>
<td>-0.49</td>
<td>-4.25*</td>
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<tr>
<td>Male</td>
<td>-0.27</td>
<td>-3.75*</td>
<td>-0.46</td>
<td>-6.31*</td>
<td>-0.27</td>
<td>-3.56*</td>
<td>-0.45</td>
<td>-5.98*</td>
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<tr>
<td>Education more than 12 years</td>
<td>0.55</td>
<td>6.76*</td>
<td>0.49</td>
<td>6.09*</td>
<td>0.53</td>
<td>6.26*</td>
<td>0.48</td>
<td>5.66*</td>
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<tr>
<td>High income</td>
<td>-0.13</td>
<td>-1.50</td>
<td>-0.23</td>
<td>-2.82*</td>
<td>-0.13</td>
<td>-1.55</td>
<td>-0.23</td>
<td>-2.82*</td>
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<tr>
<td>Manual worker</td>
<td>-0.11</td>
<td>-1.34</td>
<td>-0.17</td>
<td>-1.89</td>
<td>-0.14</td>
<td>-1.63</td>
<td>-0.17</td>
<td>-1.87</td>
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<tr>
<td>Working part time</td>
<td>-0.13</td>
<td>-1.29</td>
<td>0.15</td>
<td>1.53</td>
<td>-0.10</td>
<td>-1.88</td>
<td>0.21</td>
<td>2.01*</td>
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<tr>
<td>Inconvenient work hours</td>
<td>0.07</td>
<td>0.77</td>
<td>-0.21</td>
<td>-2.33*</td>
<td>0.07</td>
<td>0.74</td>
<td>-0.24</td>
<td>-2.62*</td>
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<tr>
<td>Cohabiting</td>
<td>0.19</td>
<td>2.13*</td>
<td>0.17</td>
<td>1.82</td>
<td>0.18</td>
<td>1.95</td>
<td>0.18</td>
<td>1.96</td>
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<tr>
<td>Having children under 12 living at home</td>
<td>-0.24</td>
<td>-2.45*</td>
<td>0.17</td>
<td>-1.88</td>
<td>-0.28</td>
<td>-2.79*</td>
<td>-0.17</td>
<td>-1.81</td>
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<tr>
<td><strong>Health indicators</strong></td>
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<td>Being Obese (BMI &gt;30)</td>
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<tr>
<td>Problem to walk quickly for five min</td>
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<td>Long term illness</td>
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<td>Low vitality (SF36)</td>
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<td>Stress often</td>
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<tr>
<td><strong>Number of observations</strong></td>
<td>N=7,430</td>
<td></td>
<td>N=7,285</td>
<td></td>
<td>N=6,903</td>
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<tr>
<td>P²</td>
<td>0.313</td>
<td></td>
<td>0.332</td>
<td></td>
<td>0.342</td>
<td></td>
<td></td>
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<tr>
<td>Adjusted P²</td>
<td>0.311</td>
<td></td>
<td>0.328</td>
<td></td>
<td>0.336</td>
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</table>

Note: Duration for car was also added in the models: Model 1: Esti -0.084 and t-test of -18.13, Model 2 Esti -0.081 and t-test of -16.93, Model 3 Esti -0.084 and t-test of -16.83

* Bold text indicate statistically significant values at the 95% level (p<0.05).
The expected directions of association between socioeconomic indicators and commuting mode were found in most analyses. Being male reduced the probability of using both active transportation and public transit, similar results have been found in prior studies (4, 21, 25). Having a higher level of education increased the use of both active transportation and public transit, which is also in accordance with prior studies (21, 25), and also previously seen in a Scanian population (46). Family composition was associated with mode choice and cohabiting with someone increased the utility for both active transportation and public transit. This could be due to competition with the other family members for use of the car (49). Having children under the age of 12 living at home, on the other hand, had a negative impact on the utility for both active transportation and transit. This could be explained by an increased need for a car in order to drive children to school and/or to participate in other activities in connection to the commute. Commuters with a high income were less likely to commute actively or by public transit, which could be explained by a greater possibility to choose the car because cost would not be a limiting factor. Occupational class, part-time work, and working during inconvenient work hours were not associated with the choice of active commuting, but being a manual worker and working during inconvenient work hours had a negative impact on the probability of choosing public transit. Car and active transportation are both more flexible modes than public transit and these findings are therefore plausible.

The health indicators contributed to the explanatory degree of the model through increasing the rho-square value. Having difficulty walking quickly for five minutes was negatively associated with both active and public transportation. For active commuters the result was as expected as difficulty walking would make it harder to use this mode. The same goes for public transportation as this type of mode almost always would include some active transportation to and from the transit stop/station. These results were supported by prior studies that found negative association with the use of public transportation for travel among physically disabled people (40, 41). Being obese was negatively associated with active commuting. Obesity was also studied by Carse, et al. (35) who found a significantly higher use of car for commuting trips for obese persons in comparison to active commuters, but only in their domain-specific model and not when they included socio-economic and commuting characteristics. The causal direction of this association is not clear as a prior review study found protective effect against obesity when cycling, although the evidence for this was described as inconclusive (13). The effort for obese commuters to use active commuting is probably higher and could explain why they rely more on car and public transportation. Long-term illness and low vitality were not statistically associated with mode choice for neither active nor public transportation. Stress was negatively associated with active commuting. As very few studies have been conducted on the causal relationship between chronic stress and decision-making, the expected direction of the association between stress and mode choice was not known beforehand. Car is often considered to be the quickest alternative and could therefore intuitively be expected to have a positive association with being a stressed commuter from a mode choice perspective. In other words, one could argue that a stressed commuter is more likely to choose the car (the fastest option) as a mode of transportation to avoid the burden of travel. Associations between commuting and stress, with the hypothesis that car commuting causes stress, have been studied and car was found to be the most stressful mode of commuting (50-53).
5.1 Strengths and limitations

The study sample consisted of a large number of participants in a public health survey answered by residents in southern Sweden. The purpose of the questionnaire was to map public health in the county and not only commuting, thereby avoiding response bias. The study sample seems to be representative for the region when comparing mode share with a travel survey for the same area as the study area (54). Also the socio-economic variables correspond well by comparing the study sample with the travel survey. The questionnaire data along with additional register data on income, residential, and workplace location enabled the inclusion of sociodemographic indicators, spatial indicators, commuting characteristics along with health indicators. Comparatively few studies included all these different dimensions of mode choice (55). Excluding any of these dimensions could give results that are biased due to missing indictors. Even so, there are some indicators that have been found important in prior studies that was not possible to adjust for. No information about car ownership was available which is often found significant in mode choice models (20). No information about commuting habits (present and prior used commute mode) and perception of the commute was available. Commuting habit especially is another indicator that often has been found to be statistically significant in models of mode choice when included (20).

A relationship in both directions could be expected for many of the health outcomes included in this study, for instance stress and obesity. While for other health outcomes, such as having difficulty walking, mode choice is more likely to be the effect (e.g. effect of disability on mode choice). More studies with the aim of investigating the association between mode choice and health, with the assumption that mode choice would affect health rather than health would affect mode choice, have been conducted (46, 56, 57). There could be feedback mechanism between health status and mode choice with health status and mode choice as both a cause and an effect. Understanding how this works and how to intervene would be valuable knowledge. In order to study this causality in more details, a longitudinal study would be needed.

6. Conclusions

It has been proven difficult to encourage people to shift mode from car to more environmentally friendly modes such as active and public transportation. Understanding indicators that are associated with mode choice is therefore important in order to make commuters opt for more environmentally friendly modes. The results of this study showed that health indicators measuring physical aspects of health such as having difficulty walking and being obese, were negatively associated with the use of active and public transportation. Weaker associations were found for indictors measuring mental aspects of health, although being stressed was negatively associated with the use of active commuting. This suggests that mental health is not as strongly connected to mode choice as physical aspects of health.

The health status among commuters can vary among different groups and spatially, and it is important to consider this heterogeneity when designing interventions to encourage commuters to shift from car to active and public transportation. The effect of one type of intervention might be very different for different groups or in different areas due to health status. One example of such interventions would be to identify areas with a high proportion of commuters with difficulty walking (e.g. hospitals, seniors’ residences, etc.) and improve accessibility to transit stations by minimizing access distance and providing disability services in these areas. Another intervention would be introducing park-and-ride facilities to attract commuters with walk problems to choose transit instead of car. Improved walkability with
better possibilities to walk and cycle would make it easier for commuters with difficulty walking to use these modes of transportation.

Conventional indicators of mode choice including, age, gender, education, family composition, occupation, duration, and other spatial indicators were found to be important in mode choice among commuters in the study population. From a policy perspective, living and working in urban areas was found to have a strong positive association with the use of both active and public transportation, strengthening the importance of density in order to make commuters use more environmentally friendly modes. The same goes for access to transit stops/stations, especially close to work. Increased access to stops/stations could help commuters make the switch to public transportation.

The results of this study contribute to the very limited number of studies including both mental and physical aspects of health in relation to mode choice among commuters. As only few studies have been made to study the associations between health and mode choice, especially mental aspects of health, more studies need to be conducted to strengthen the results in this research. In order to understand the causal relationship between health and commuting mode, longitudinal studies are needed.

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Competing interests
The authors declare that they have no competing interests.

Ethical approval
Ethical approval (Dnr 2014/418) was granted by the regional ethical review board in Lund to connect the data from SCB to the survey data and to conduct the study.

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Authors contribution
KM compiled the data from different sources and prepared it for analysis. KM and AI, designed the study, developed the models, conducted the analyses, interpreted the results, and drafted the manuscript. EC, POÖ, CH and KJ contributed to the study design, selection of covariates, and interpretation of the results. All authors critically reviewed the manuscript and gave comments.
References


