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Variations in active transport behavior among different neighborhoods and across adult lifestages

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Abstract

Objective—Built environment characteristics are closely related to transport behavior, but observed variations could be due to residents own choice of neighborhood called residential self-selection. The aim of this study was to investigate differences in neighborhood walkability and residential self-selection across life stages in relation to active transport behavior.

Methods—The IPEN walkability index, which consists of four built environment characteristics, was used to define 16 high and low walkable neighborhoods in Aarhus, Denmark (250.000 inhabitants). Transport behavior was assessed using the IPAQ questionnaire. Life stages were categorized in three groups according to age and parental status. A factor analysis was conducted to investigate patterns of self-selection. Multivariable logistic regression analyses were carried out to evaluate the association between walkability and transport behavior i.e. walking, cycling and motorized transport adjusted for residential self-selection and life stages.

Results—A total of 642 adults aged 20–65 years completed the questionnaire. The highest rated self-selection preference across all groups was a safe and secure neighborhood followed by getting around easily on foot and by bicycle. Three self-selection factors were detected, and varied across the life stages. In the multivariable models high neighborhood walkability was associated with less motorized transport (OR 0.33 95%CI 0.18–0.58), more walking (OR 1.65 95%CI 1.03–2.65) and cycling (OR 1.50 95% CI 1.01–2.23). Self-selection and life stage were also associated with transport behavior, and attenuated the association with walkability.

Conclusion—This study supports the hypothesis that some variation in transport behavior can be explained by life stages and self-selection, but the association between living in a more walkable neighborhood and active transport is still significant after adjusting for these factors. Life stage significantly moderated the association between neighborhood walkability and cycling for transport, and household income significantly moderated the association between neighborhood walkability and walking for transport. Getting around easily by bicycle and on foot was the highest rated self-selection factor second only to perceived neighborhood safety.

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Keywords

Built environment; active transport; self-selection; life-stage; adults; neighborhood Preferences

1. Introduction

There are several benefits of increasing non-motorized transport modes. Walking and cycling for transport i.e. active transport can enhance public health and additionally decrease CO_2 emissions, ease traffic congestion and contribute to more liveable cities (Gehl, 2010; Hallal et al., 2012; Hamer and Chida, 2008; Saunders et al., 2013; Woodcock et al., 2009). The decision to walk or cycle for transport is rooted in a complex interplay of factors at the individual, social, environmental and political level (Burbidge and Goulias, 2009). The built environment is one of the most important factors, and growing evidence supports the association between certain urban form characteristics and active transport (Ewing and Cervero, 2010; Pucher et al., 2010). Previous research has shown consistent positive associations between active transport and residential density, land-use-mix and street connectivity, among others (Ewing and Cervero, 2010; Saelens and Handy, 2008). These characteristics have furthermore been evaluated as a composite, the so-called walkability index, developed in the Neighborhood Quality of Life Study (NQLS) (Frank et al., 2010; Sallis et al., 2009). The index has later been replicated in various settings in the International Physical Activity and the Environment Network (IPEN) (Kerr et al., 2013), and has shown a consistently positive relationship with walking for transport and cycling for transport (Frank et al., 2006; Owen et al., 2010; Sallis et al., 2009; Van Dyck et al., 2012). By and large, the objective walkability index differentiates the denser, more developed city centers from the more sprawled, less developed suburbs. It does not capture the fine scale microenvironment qualities such as greenery, sidewalks, streetscapes, cycle lanes and safe crossings (Moudon and Lee, 2003).

Even though built environment and urban form characteristics are important for transport behavior within a city, uncertainty exists regarding whether observed differences across urban forms could be due to underlying preferences for transport activity and residential choices (Eid et al., 2008). The self-selection bias has frequently been mentioned as one of the most fundamental biases in establishing causation between the built environment and urban form (Cao et al., 2009; Ding and Gebel, 2012; Handy et al., 2006). It generally results from two sources: attitudes and socio-demographic traits (Cao et al., 2009). The self-selection mechanism can be observed when people with a positive attitude for an active lifestyle choose to live in neighborhood with those opportunities e.g. close proximity to recreational venues or vice versa. Besides this intentional self-selection bias, socio-demographic factors can also influence the choice of neighborhood. The segregation of a population in more alike groups defined by ethnic, economic and social characteristics is widely accepted (Riggs, 2014). Additionally, the life stage itself can have great impact on the transport behavior and therefore also on the relation to the built environment (Villanueva et al., 2013). Within the health and place based research there has been a focus on four main groups: children, adolescents, adults and older adults (Papas et al., 2007). Adults are often categorized as one common group, even though a variety of fundamental life events occur from early, across middle to late adulthood, e.g. from education to paid employment; from single to married: from non-parent to parent (Scheiner and Holz-Rau, 2013). These events can often trigger changes in neighborhood preference and residential relocation (Boone-Heinonen et al., 2010; Scheiner and Holz-Rau, 2013).

Research to date states that self-selection attenuates, but not eliminates, the relationship between the built environment and physical activity (Cao et al., 2009; Handy et al., 2006; McCormack and Shiell, 2011). In a Belgian study it was found that walkability characteristics were strongly associated with neighborhood selection, independent of age group, education and gender. Surprisingly, people living in objectively measured low-walkable areas stated walkability characteristics as an important factor for their residential choice (Van Dyck et al., 2011b). Living in less dense neighborhoods (suburbs) in a European context is therefore not per se synonymous with living in an environment hostile to active transport. Conditions for walking and cycling can still be good given lower traffic loads and high quality walking and bicycle infrastructure. The same study also found a negative relationship between residential density and neighborhood satisfaction, which could rely on poorer aesthetics, more pollution, lower overall safety and more crime in the most dense high walkable neighborhoods (Van Dyck et al., 2011a). Frank et al. found differences between neighborhood preferences and actual residential neighborhoods, and stated that living in a high walkable neighborhood was not related to walking if people had no preference for living in a walkable neighborhood (Frank et al., 2007).

Regarding self-selection from a life stage perspective, Villanueva et al. investigated the correlation between walking and walkability for three groups of adults (18–65 years) and one group of older adults (+65 years) living in different walkable neighborhoods, and found no life stage related difference between the groups. Thus, adults living in high walkable neighborhoods were more likely to walk independent of life stage (Villanueva et al., 2013). This study did however not report differences in self-selection across the four groups.

Research on transport behavior from a life stage perspective, referred to as a mobility biography approach, is fragmentary at best (Scheiner and Holz-Rau, 2013), and research into life stage groups including built environment and self-selection is almost absent. It has been recommended to take a more detailed life stage perspective into account when examining the association between built environment and physical activity (Papas et al., 2007), and within transportation research it is seen as a promising emerging approach (Scheiner, 2007).

The aim of this study was to investigate differences in walkability and residential self-selection across life stages, and in continuation hereof how this was related to active transport behavior. It involves analyses of the associations between neighborhood characteristics and preferences at different adult life stages, and how these associations are related to active transport behavior.

2. Material and methods

This study followed the International Physical Activity and the Environment Network (IPEN) study design (Kerr et al., 2013) and contributes data as one of the 12 countries participating in the cross national IPEN analyses. It is a cross sectional study which was designed to maximize the variation within the sample by selecting participants based on objectively measured walkability and household income of the neighborhoods.

2.1 Walkability index and neighborhood selection

In Denmark the smallest administrative unit, called statistical districts, was used to delineate neighborhoods, and the study site, the city of Aarhus, consisted of 87 districts. For every district a walkability index score was calculated as a function of four variables: a) net residential density (ratio of residential units to the land area devoted to residential use), b) land use mix (diversity of the following land use types: residential, retail, commercial, entertainment and civic institutions), c) intersection density (ratio of intersections, at least 3-way, to area of district), and d) the retail floor-area-ratio (ratio of retail building footprint to the area of the land devoted to retail). The walkability index is described in more detail elsewhere (Frank et al., 2010). In short, the walkability index (Wi) for the districts was calculated using a summed score of normalized values (z-scores) of the four variables, with intersection density counting double:

$$\text{Wi}=2\times z_{\text{intersection density}}+z_{\text{net residential density}}+z_{\text{retail floor area ratio}}+z_{\text{land use mix}}$$

Additionally, the median household income of the districts was derived from municipality records. Based on the median split of walkability and household income, four types of districts were categorized: high walkability-high income, high walkability-low income, low walkability-high income and low walkability-low income. Four districts from each quadrant were selected aiming at maximizing the variation of the walkability index and household income while ensuring geographic separation of districts (Figure 1). The districts have an average size of 3 km^2, but vary in size as they were intended to have a more or less equal number of inhabitants. A photo codebook illustrating the built environment of the different districts is available as electronic supplementary material.

2.2 Study sample

From each of the 16 selected districts 115 persons between 20–65 years were randomly sampled, which gave a total sample of 1840 persons. The aim was to assess 150 respondents in every quadrant with an equal distribution between districts, age groups and gender, which corresponded with the IPEN protocol and gave reasonable power in independent national analyses. All potential respondents received an invitation letter to participate in the internet-based questionnaire, and non-responders were reminded by a second letter and in some districts also by telephone. Respondents could request a paper version of the questionnaire which was sent to them by mail.

2.3 Self-reported measures of transport behavior

Transport behavior was assessed using the International Physical Activity Questionnaire, in its long form (IPAQ-long), and dichotomized in *user* or *non-user* for three transport modes during the last week (walking, cycling and motorized transport including public transport). The questions were formulated as: "On how many days during the last 7 days did you [walk] for at least 10 minutes at a time to go from place to place?" All but zero days were categorized as *user*.

2.4 Life stage, self-selection and other survey measures

While recognizing the complexity of the life stage theory, a simple distinction was used in this study. The following three life stage groups were defined: 1) *young adults* without children (20–35 years); 2) *midlife adults* without children (35–65 years); and 3) *parents* with children below 18 years living at home, regardless of age (20–65 years). Instead of simply dividing the sample in three even groups defined by age, the parent group was added as an age independent group, because previous research has emphasized having children as a major life event triggering changes in neighborhood preferences and residential relocation (Geist and McManus, 2008; Scheiner and Holz-Rau, 2013). The 12-item self-selection battery of questions asked for reasons for moving to the current neighborhood, e.g. closeness to job or education, affordability, quality of schools and ease of walking. The wording of the question was: "How important were the following reasons as to why you moved to your current neighborhood?", and the response options were on a 5-point Likert-type scale (1 = *not important at all* to 5 = *very important*). The battery was based on previous research (Frank et al., 2007; Sallis et al., 2009), and adapted to the Danish setting by adding a specific cycling question.

Household income was based on self-report, and dichotomized to below the median household income if less than 300.000 DDK per year (52.000 USD/40.000 EUR; equivalent to the median household income for the municipality) and above the median household income. Nativity was based on municipality records and dichotomized in native Danes or not. Distance to work or education was based on self-report and categorized in: up to 5 km, more than 5 km, or no workplace or education. Threshold was selected based on The Danish National Travel Survey showing that 87% of cycling trips were within 5 km.

2.5 Statistics

The association between the three transport behaviors (each as a binary variable) and the independent variables was evaluated using multilevel statistical models. To account for the clustering of behavior in the 16 statistical districts, a two-level structure of respondents (Level 1) nested in districts (Level 2) was applied. Univariable multilevel regression analyses were used to compare demographic and transport behavior variables across the three life stage groups.

The 12-item self-selection battery of questions was combined into latent variables using factor analysis with principal component factoring and oblique rotation to allow for correlation between factors. Based on these analyses new latent variables (i.e. factors) were created with scoring coefficients for the 12 variables for each defined factor.

Multilevel multivariable logistic regressions were applied to: 1) evaluate the association between use of different transport modes (walking, cycling and motorized transport) and neighborhood walkability; 2) observe whether adding life stage and self-selection variables changed the association (possible mediation or confounding); and 3) investigate, using interaction analyses, whether the association with transport behavior was different between life stages, education level, distance to work or household income. Likelihood-ratio tests were performed to determine if the inclusion of interactions significantly improved the predictive value of the models (Cervero, 2002). To interpret the variation between the 16 districts an intra-class correlation coefficient (ICC) was calculated as $ICC=\frac{\sigma_2^2}{\sigma_1^2+\sigma_2^2}$, where σ_2^2 is the variance between districts (second-level variance) and σ_1^2 is the variance between individuals approximated as $\sigma_1^2=\frac{\pi^2}{3}$ (Goldstein et al., 2002). Statistical analyses were carried out using STATA (v. 11).

4. Results

From the eligible sample of 1840 persons, 642 respondents completed the questionnaire giving a response rate of 34.9%. Across the 16 districts the response rate varied from 19.1% to 45.2%. Using data from municipal records we were able to compare age, gender, nativity and employment status between the respondents and the eligible sample. The respondents were more likely to be living in high walkable districts (53.4% vs. 50.0%), be female (56.2% vs. 49.5%), native Danes (92.4% vs. 83.9%), and older (average age 39.0 years vs. 37.8 years). Furthermore, there was an overrepresentation of respondents working (58.9% vs. 54.1%) and studying (26.2% vs. 21.1%), compared to respondents receiving welfare payments (14.9% vs. 24.8%).

4.1 Demographics and life stages

Categorizing the respondent by life stage resulted in 38.6% young adults, 25.7% parents, and 35.7% midlife adults (Table 1). Naturally, there were age differences between the life stage groups, and there was a majority of women within the young adult group. The young adults differed from the other two groups by more often living in an apartment; living in a more walkable district; having no cars in the household; and having a low household income. They were also less often users of motorized transport and more often users of cycling for transport. Parents were more often living with a partner than the respondents in the two other groups. Despite the differences between groups regarding active transport behavior, the proportion of respondents engaging in any active transport within the last week was still relatively high for all groups and varied between 54.2%–73.8% for cycling, and 75.8%–85.9% for walking.

4.2 Self-selection & life stages

Across life stage groups the most important self-selecting criteria was the feeling of a safe neighborhood (mean score: 3.8), followed by getting around easily by bicycle (mean score: 3.6), and getting around easily on foot (mean score 3.5) and short distances to green areas (mean score: 3.5). The least important self-selection criterion was easy access to a highway (mean score: 1.8). The variations between life stage groups for the 12 self-selection criteria are illustrated in Figure 2. Four self-selection scores were significantly different between all three groups. Social support, quality of schools, distance to recreation facilities and access to highways were most important for the parents, less important for the midlife adults and least important for the young adults. The young adults rated affordability significantly higher and access to green areas lower than the other two groups, while the midlife adults rated distance to place of work or education lower than the other two. Finally, the young adults rated “easy to get around by bicycle” significantly higher, and “easy to get around on foot” lower compared to the midlife adults, and they rated a safe neighborhood significantly lower compared to the parents. There were no significant differences between the life stage groups in distance to shops and access to public transport.

The results from the factor analysis of the self-selection items resulted in three factors accounting for 63.6% of the variance (Table 2). The first factor was mostly defined by four items: getting around easily on foot and by bicycle and short distance to shops and public transport. This factor was interpreted as *destination accessibility.* The second factor distinguished itself by scoring high on quality of schools, social support, short distance to recreational facilities, access to highway, and feeling of safety in the neighborhood. This factor was named *public service*. Finally, the third factor was characterized by affordability and short distance to work or place of education, and was interpreted as *affordable.* Based on this, three new variables were created with a mean score of zero and a standard deviation of one. Between life stage groups there were no significant differences in scores for the new *destination accessibility* factor variable, but the *public service* factor variable was significantly different between all three groups with highest average score for the parents and lowest score for the young adults. The *affordable* factor variable was significantly lower for the midlife adults compared with the other two groups and highest for the young adults.

4.3 Neighborhood walkability and transport behavior

The multilevel logistic regression analyses of the *unadjusted* association between neighborhood walkability and transport behavior resulted in significant odds ratios for all three transport modes (Table 3). Living in high walkable neighborhoods was associated with more respondents walking for transport (OR 2.44 95%CI 1.63–3.64), cycling for transport (OR 2.11 95%CI 1.52–2.92), and using motorized transport less (OR 0.24 95%CI 0.14–0.40). The *adjusted* models show attenuated but still significant associations between neighborhood walkability and motorized transport, walking and cycling for transport.

The odds ratio for using motorized transport at least once the last week was significantly higher for respondents living in a low walkable neighborhood; being unemployed; or having more than 5 km to place of work or education. Cycling was significantly more likely for respondents living in high walkable neighborhoods; being young adult; having a higher score in the *affordable* self-selection composite factor; having less than 5 km to place of work or education; and having a tertiary education. Finally, walking was significantly more prevalent for respondents in high walkable neighborhoods; being unemployed; having a higher score in *destination accessibility* self-selection composite factor; or having a lower score on the *public service* self-selection composite factor. Additionally, there was a tendency towards a lower proportion of motorized transport for non-native Danish respondents and for respondents with low household income. There were no significant gender differences, but a tendency towards women cycling and walking for transport more often was visible.

The variation between the 16 neighborhoods in the variance component models with no explanatory variables, which could be ascribed to factors on the neighborhood level and expressed as the intra-class correlation coefficient (ICC), was 14.9%, 3.4% and 5.9% for motorized transport, cycling and walking respectively. In the bivariate model with walkability as only dependent variable, the ICC diminished to 2% for motorized transport and was less than 1% for the cycling and walking. Finally, in the adjusted model, the ICC for all three transport modes was less than 1%.

4.4 Interaction analyses

The interaction analyses testing for moderators of the association between neighborhood walkability and the three transport modes were conducted for the different life stages, household income, education level and distance to work. Two of the twelve models were overall significant, while there was no significant moderation in the other models.

For transport related cycling the association with neighborhood walkability was moderated by life stages (Figure 3). The young adults were most likely to cycle and the midlife adults less likely to cycle, almost independent of walkability. Only for the parent group cycling was dependent of neighborhood walkability. Parents living in a high walkable neighborhood had a higher odds ratio for cycling (OR 1.31 95%CI 0.55–3.16), while parents living in a low walkable neighborhood had significantly lower odds ratio (OR 0.40 95%CI 0.19–0.84), with the young adults living in a low walkable neighborhood as reference group.

The second significant moderating factor was income, which moderated the relationship between walking for transport and neighborhood walkability (Figure 4). For respondents with an above median income walking was dependent on walkability. Living in a high walkable neighborhood with an above median income was associate with more walking for transport, compared to living in a low walkable neighborhood with an above median income (OR 3.00 95%CI 1.74–5.17). For respondents with a below median income neighborhood walkability was not associated with walkability. There were no difference between living in a high walkable neighborhood (OR 1.84 95%CI 0.94–3.60) or a low walkable neighborhood (OR 1.68 95% CI 0.82–1.68) for respondents with a below median income.

5. Discussion

This study supported the notion that the walkability index was associated with active transport modes even in a Danish context with high prevalences of cycling for transport. Adjusted for all relevant confounding factors, the odds ratio for motorized transport was significantly lower, and odds ratios for walking and cycling were significantly higher, in the high walkable neighborhoods.

5.1 Young adults and active transport

Studying the three life stages revealed that there was an overrepresentation of young adults without children living in high walkable areas. This group more often lived in apartments, without access to motorized transport and fell more often in the below median income category. This was also reflected in the neighborhood selection questionnaire in which the young adults rated affordability higher than parents and midlife adults. Interestingly, the young adults also rated bikeability (easy to get around by bicycle) higher than the other two groups, and higher than walkability (easy to get around by foot). The young adult group also had a much higher proportion of weekly cyclists, and looking at the interaction analysis, cycling was almost independent of neighborhood walkability for this group (Figure 3).

This gives reason to argue that cycling for transport in Aarhus to some extent, but not exclusively, is a youth culture related to the demographic or life stage circumstances (Boone-Heinonen et al., 2010; Scheiner and Holz-Rau, 2013). Aarhus is a major city with second-most studentships in Denmark. The high cost of car ownership in Denmark and a well-developed cycling infrastructure make cycling the most obvious choice for this group. In Aarhus, and other Danish cities, a sufficient cycling infrastructure is still present in the less dense suburbs. As cycling has a larger transport range due to travel speed compared to walking, living in a low walkable neighborhood is a manageable barrier for young adults. In the multivariable model four variables were significantly associated with cycling for transport. Besides living in a high walkable neighborhood and being part of the young adult life stage group, having a place of work or education less than 5 km from home, and holding a tertiary education, were associated with higher odds ratios for cycling. The importance of a bikeable city was illustrated with "easy to get around by bicycle" being the second highest ranked self-selection factor after perceived neighborhood safety.

5.2 Life stages, self-selection and transport behavior

The analysis of the 12-item neighborhood self-selection battery supported the hypothesis that life stage was an important discriminating factor. The largest differences were seen for the rating of the importance of the quality of schools, social capital, short distances to recreation facilities and short distance to highway access, which were most important for the parent group. The factor analysis substantiated this finding by grouping these issues into one self-selection factor, named *public service*, which was higher for the parent group. The second self-selection factor was called *destination accessibility*, and did not differ between the three life stage groups, suggesting that the attraction of a walkable neighborhood is independent of life stage. In the multivariable model these two self-selection factor variables were significantly associated with walking, and they substantially attenuated the association with neighborhood walkability. The third factor was called *affordable*, which was lower for the midlife adults, and associated with more cycling for transport.

For all three transportation modes the association with neighborhood walkability was attenuated in the multivariable models, but remained significant. The interaction analyses furthermore revealed life stage as a moderating factor in the association between cycling and neighborhood walkability. Independent of neighborhood walkability, the young adults cycled the most and the midlife adults the least, while the parent group living in a high walkable neighborhood had a significantly higher odds ratio for cycling than their counterparts living in the low walkable neighborhoods. As found in a previous study (Villanueva et al., 2013), this was not the case for walking for transport, as no moderating effect was found. Contrary to walking, cycling might not be independently associated with neighborhood walkability, but is moderated by life stage factors.

Household income was the other significant moderator of the association between neighborhood walkability and walking. The result suggests that the association between neighborhood walkability and walking is dependent on household income as there were no differences in walking for respondents with a below median income, regardless of neighborhood walkability. On the contrary, the effect of neighborhood walkability was convincing for respondents with an above median income, with an odds ratio of 3.00 for walking. Previous studies have reported mixed results regarding the moderating effect of household income or socioeconomic status (SES) (Van Dyck et al., 2010). The Australian IPEN study found a stronger relationship in areas of high SES (Owen et al., 2007), which is in accordance with the result from this study. This moderating effect was however not found in the Belgian or American IPEN studies (Sallis et al., 2009; Van Dyck et al., 2010). One explanation for the moderating effect could be variation in the quality of the physical characteristics between the high walkable areas in spite of a similar walkability index score (Van Dyck et al., 2010). Another explanation could be related to individual characteristics, residents with a high SES might respond better to increased possibilities for physical activity in their neighborhood.

5.3 Variations between neighborhoods

The cluster structure of the data in 16 neighborhoods gave us the opportunity to analyze variation between and within neighborhoods. A large intra-cluster correlation coefficient (ICC) would indicate that differences on neighborhood level are responsible for much of the unexplained variation in transport behavior. The variance component models indicated a large variation on the neighborhood level for motorized transport, and a considerable but lesser difference for walking and cycling. In the unadjusted model only including neighborhood walkability the results indicated less variation between the high walkable neighborhoods and between the low walkable neighborhoods, respectively. This clear attenuation and elimination of the ICC in the adjusted models implies that the discrimination of neighborhoods by the walkability index and its included variables accounts for almost all neighborhood level variation. The walkability index is therefore supported.

5.4 Perspectives and limitations

The research on built environment and physical activity has recently been accused of being an overly deterministic approach, without taking the complex interplay between relevant factors into consideration (Riggs, 2014). Much of the research in the field of public health uses a socio-ecological model, but only focuses one-directionally on different levels of possible determinants. The depth of the socio-ecological model however offers a more dualistic theoretical understanding of the relationship (Kremers et al., 2006). This study contributes to a more nuanced understanding, and found very different underlying moderating mechanisms between three life stage groups of adults. To our knowledge, research combining life stage, self-selection, built environment and active transport is very scarce (Scheiner and Holz-Rau, 2013).

The implications of this study for urban planning are first of all the importance of long term planning for active transport and especially transport cycling, which is the case in Denmark (Pucher and Buehler, 2008). A total of 80.1% and 62.5% of respondents in this Danish sample reported any transport related walking or cycling respectively. This is a considerably higher proportion than in other similar studies within the IPEN network where the proportion for walking has been reported to be between 52.4% and 74.9%, and for cycling between 6.6% and 43.4% (Van Dyck et al., 2012). Even in the less dense low walkable neighborhoods in Denmark the proportion of cycling was higher (53.2%) than in any of the other countries included in the IPEN study. The well-developed cycling infrastructure and longstanding cycling culture can probably take the credit for the high bikeability even in the suburbs (Carstensen and Ebert, 2012; Pucher and Buehler, 2008). Furthermore, planning and AT-research should give higher priority to a “mobility biography” approach taking travel demands, neighborhoods preferences and economic capabilities into consideration. Urban form characteristics and demographic segregation are closely connected, but controlling for demographic variables (age, gender and income) might not fully take this interdependence into account. Research evidence should be seen in its context, and it becomes more and more evident, that the relationship between the built environment and active transport is not deterministic in nature (Riggs, 2014).

There are several limitations in this study. Statistical districts were selected to increase variation in the sample, and are therefore not directly representative for the population of Aarhus. Despite random sampling and sending targeted reminders to increase the representativeness of the respondents, there was still an underrepresentation of certain groups (men, younger, unemployed and non-native Danish). Data were mostly self-reported, which could lead to traditional recall or overestimation biases. We have no reasons to believe these biases to be different for respondents in different neighborhoods, or in different life stages. Measuring self-selection is not without complications, and the answers could be a reflection of the actual current neighborhood characteristic rather than preferences. Transport behavior was dichotomized and it does not include the duration or trip frequency of the transport mode. Therefore, we have not distinguished between respondents solely reliable on one transport mode and those only using this option weekly but less often. This study has taken a neighborhood scale approach, which naturally is followed by some limitations. The statistical districts might not be regarded as a neighborhood by the residents, and living near the border between two or more neighborhoods was not taken into consideration. The IPEN walkability index was used to differentiate neighborhoods by urban form characteristics, but other similar methods could have been used as well (Manaugh and El-Geneidy, 2011). Such methods could be designed to better capture cycling infrastructure, and take the longer transport distance by bicycle into account (Madsen et al., 2014). The separation of respondents in three life stage groups can also be discussed, and other group distinctions could have been made based on employment status, marital status, or education level. Finally, the study is cross-sectional and can therefore not draw conclusions on causality.

6. Conclusion

This study supports the hypothesis that some variation in transport behavior can be explained by life stages and self-selection, but the association between living in a more walkable neighborhood and active transport is still significant after adjusting for these factors. Our findings support the overall validity of the walkability index, as walking and cycling were more often reported and motorized transport less often reported in the high walkable neighborhoods, also after adjustment for other factors. Young adults without children more often lived in high walkable neighborhoods, had poorer access to cars, and had other neighborhood preferences than the midlife adults. A walkable neighborhood in the city of Aarhus seemed to matter most for the parent group and for respondents with an above median income, while the young and less affluent used active transport more, independent of walkability. Getting around easily by bicycle and on foot was the second and third highest rated self-selection variable, only surpassed by perceived neighborhood safety.

The inclusion of self-selection preferences in combination with life stages gives a more nuanced understanding of the relationship between the built environment and AT, and sheds more light on the questions of what works, for whom, under which circumstances. The relationship between the built environment and transport behavior is complex and more research on mediating and moderating mechanisms is still needed in both cross sectional, experimental and longitudinal studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- European based research with high level of active transport
- Self selection preferences across three adult life stage are presented
- Associations between neighborhood walkability and transport modes
- Higher level of active transport in high walkable neighborhoods after adjusting
- Young adults and respondents with lower income was less affected by walkability

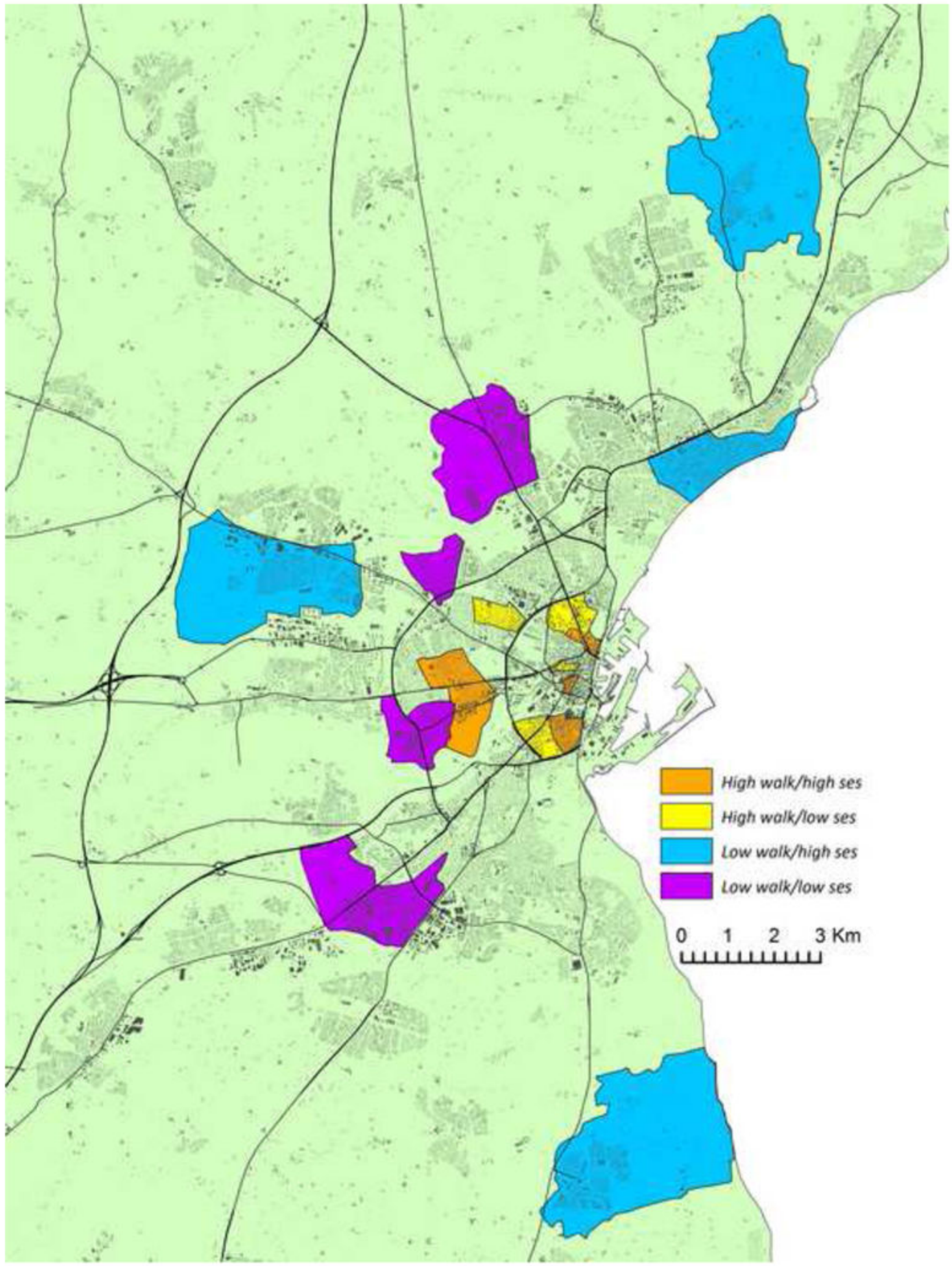

Figure 1.
The city of Aarhus and the selected areas based on objective walkability and household income. The inner ring road encircles the city center, the harbor and 60.000 residents. The second ring road surrounds the rest of the city and connects many of the surrounding suburbs.

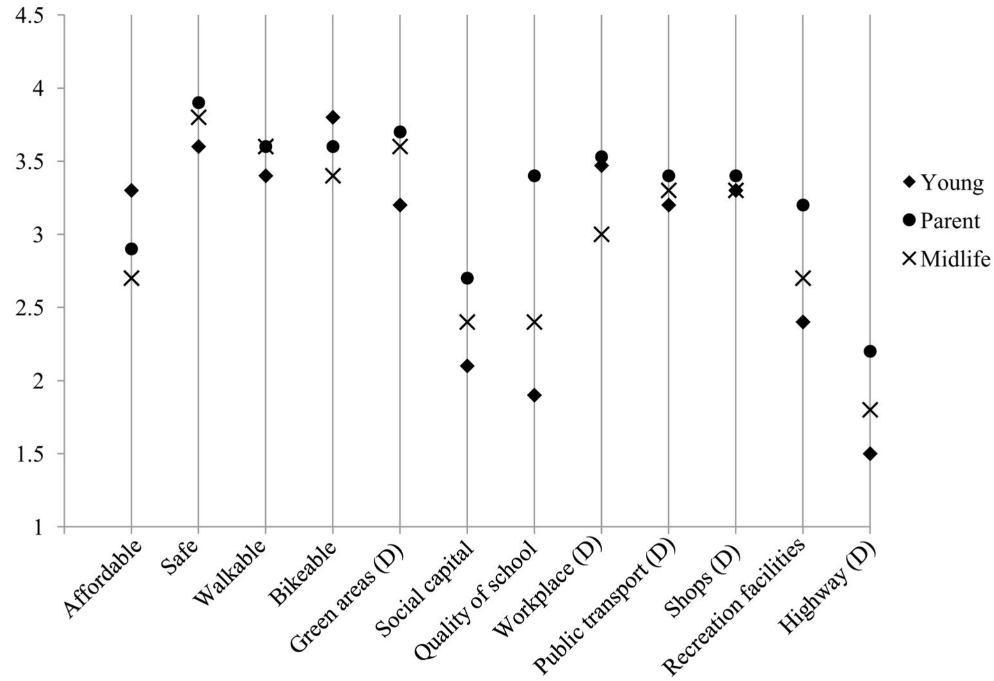

Figure 2.
Mean score of self-selection preference by life stage and adjusted for gender and cluster effect. (D=distance)

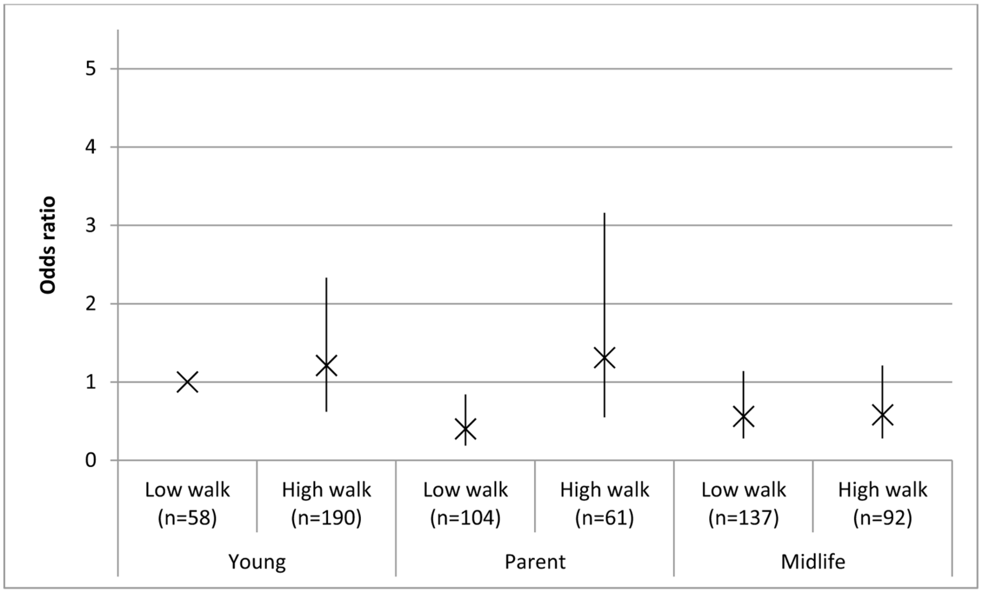

Figure 3.
Odds ratio for having used cycling for transport the last week based on interaction between life stage and walkability. Adjusted for gender, nativity, education, income and distance to place of work or education.

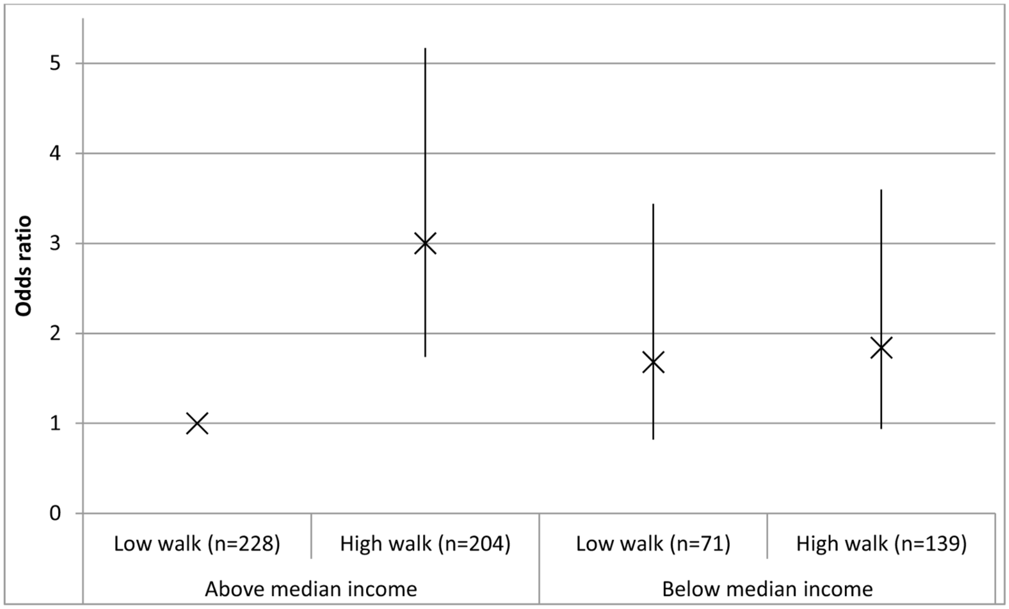

Figure 4.
Odds ratio for having used walking for transport the last week. Based on interaction between income and walkability and adjusted for gender, nativity, education, life stage and distance to place of work or education.

Table 1

Distribution of individual, geographic and transport behavior factors by life stages.

	Life stage		
	Young adult =<35 years No children (n=248)	**Parent with children <18 years (n=165)**	**Midlife adult >35 years No children (n=229)**
Age, years (sd)	25.1[c] (3.5)	40.2[b] (8.7)	53.1[a] (7.9)
Females, %	61.3[a]	57.0[a,b]	50.2[b]
Living in an apartment, %	87.5[a]	32.1[b]	42.9[b]
Married and cohabiting, %	49.8[b]	88.5[a]	65.1[b]
Living in walkable neighborhood, %	76.6[a]	37.0[b]	40.2[b]
Below median household income, %	58.1[a]	13.9[b]	18.8[b]
Household with no cars, %	67.9[a]	13.9[b]	21.6[b]
User of motorized transport, %	70.2[b]	88.5[a]	86.9[a]
User of cycling for transport, %	73.8[a]	57.0[b]	54.2[b]
User of walking for transport; %	85.9[a]	75.8[a]	76.9[a]

[a]Significant different from b and c at 5%-level;

[b]Significant different from a and c at 5%-level;

[c]Significant different from a and b at 5%-level;

[a,b,c]Based on regression models adjusted for cluster of statistic districts.

Table 2

Results of factor analysis after promax oblique rotation[a)]

Self-selection variable	**Factor 1**	**Factor 2**	**Factor 3**
Affordability	−0.178	−0.035	**0.943**
Neighborhood feels safe and secure	0.238	**0.560**	0.102
Easy to get around by foot	**0.902**	−0.016	−0.137
Easy to get around by bike	**0.661**	0.043	0.112
Easy access to open areas (ex. green spaces, parks)	0.281	0.368	0.073
Strong social support	0.007	**0.722**	−0.022
High quality of schools	−0.175	**0.839**	0.024
Short distance to work or education	0.351	−0.066	**0.501**
Short distance to public transport	**0.625**	0.086	0.044
Short distance to shops	**0.859**	−0.107	−0.113
Short distance to recreational facilities	0.193	**0.714**	−0.166
Access to highway	−0.227	**0.616**	0.032
Eigenvalue	3.185	2.967	1.484
Cumulative proportion[b)]	0.265	0.513	0.636
Suggested interpretation	Urban	Suburban	Affordable

[a)] Loadings, eigenvalues, cumulative proportion of the total variance and a suggested interpretation are given for three factors. Only variables with loadings above 0.5 or below −0.5 were used in interpretation (displayed in bold).

[b)] The cumulative proportion is the cumulative proportion of the total variance in data. Since the variables are standardized to a variance of 1, the total eigenvalue=12 (number of variables).

Table 3

Multivariable logistic regression models of the associations between walkability and motorized transport, cycling and walking.

	Frequent user of motorized transport		Frequent user of cycling for transport		Frequent user of walking for transport	
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
	Unadjusted	***Adjusted***	***Unadjusted***	***Adjusted***	***Unadjusted***	***Adjusted***
Walkability						
High vs. low	0.24*** (0.14–0.40)	0.33*** (0.18–0.58)	2.11*** (1.52–2.92)	1.50* (1.01–2.23)	2.44*** (1.63–3.64)	1.65* (1.03–2.65)
Life stage						
Young adult		1.0 (ref.)		1.0 (ref.)		1.0 (ref.)
Parent		1.33 (0.67–2.65)		0.53* (0.31–0.91)		0.76 (0.40–1.44)
Midlife adult		1.18 (0.66–2.11)		0.56* (0.35–0.90)		0.70 (0.39–1.26)
Self-selection						
Destination accessibility		1.25 (0.96–1.62)		1.06 (0.86–1.31)		1.54*** (1.20–1.98)
Public service		1.19 (0.90–1.58)		1.12 (0.90–1.38)		0.69* (0.54–0.90)
Affordable		0.79 (0.62–1.01)		1.22 (1.01–1.47)*		1.02 (0.81–1.28)
Distance to work or education						
<5 km		1.0 (ref)		1.0 (ref)		1.0 (ref)
>5 km		3.78*** (2.06–6.94)		0.49*** (0.32–0.74)		1.33 (0.81–2.19)
Unemployed		1.93* (1.02–3.62)		0.72 (0.44–1.19)		1.90* (1.00–3.60)
Demographic						
Gender		1.02 (0.65–1.61)		1.19 (0.84–1.68)		1.29 (0.85–1.96)
Nativity		0.53 (0.24–1.17)		0.89 (0.47–1.66)		0.90 (0.43–1.87)
Tertiary education		1.03 (0.66–1.62)		1.49 (1.04–2.15)*		1.28 (0.83–1.96)
Below median household income		0.78 (0.48–1.28)		0.99 (0.65–1.52)		1.00 (0.59–1.68)
ICC[a)]	2.0%	<1%	<1%	<1%	<1%	<1%

[a)] ICC in the variance components models were 14.9%, 3.4% and 5.9% for motorized transport, cycling and walking, respectively.

* $p<0.05$;

** p<0.01;

*** p<0,001

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