

Effects of Climbing Choice, Demographic, and Climate on Walking Behavior

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Abstract

Walking is a public health recommendation to increase physical activity. Although walking for transport is associated with health benefits, it is frequently avoided when a mechanized alternative is available and when the weather or individuals' available resources are unfavorable. The present quasi-experimental study used chosen walking speed to estimate the use of resources by pedestrians and investigated 730 pedestrians' behavior when approaching a choice point between a short stair and a ramp at an exit from a university campus toward the local train station on six separate days. Results revealed that individuals who climbed the stairs walked faster than those who chose the ramp. In addition, females and those who were overweight walked slower than their comparator groups. Temperature was associated with walking behavior; as temperature increased, the walking speed of pedestrians decreased. Moreover, the purpose of walking is an important determinant of walking speed. Minimization of time to arrive at the train station as quickly as possible is a plausible alternative explanation for the effects of resource allocation on walking speed.

Keywords: choice point, pedestrians, temperature, walking speed

Introduction

Current public health approaches targeting inactivity focus on the accumulation of physical activity during daily life.^{1,2} Walking is a popular physical activity that has low risk of injury and is freely available to most of the population.^{3,4} In the Health Survey for England 2016, men and women reported spending more time per day on walking than on any other physical activity outside of work.⁵ Furthermore, regular walking has been found to reduce cardiovascular risk factors and have beneficial effects on an individual's general health and vitality.^{6,7} Evidence associates walking for transport with reductions in cardiovascular disease.⁸ Although walking for transport is strongly associated with better health outcomes,⁹⁻¹² many individuals do not perform this activity as part of their daily life when a mechanized alternative is available. For example, Goodman estimated that only 11% of people in England and Wales walk for transport, 18% take public transport, and 3% ride a bike; most people surveyed chose private motorized transport for their journey.¹³ Similarly, the National Travel Survey of England 2016 reported that 64% of commuters use cars

or vans to travel from home to work and vice versa; only 11% and 7% chose to walk and take the surface rail, respectively.¹⁴ Walking for transport, which would benefit health, is frequently avoided.

Speed is a parameter of the intensity of walking behavior. Public health guidelines recommend that adults should accumulate 30 minutes or more of daily moderate-intensity physical activity,^{15,16} this intensity is equivalent to brisk walking for 3 - 4 m.h⁻¹ or 1.34 - 1.79 m.s⁻¹. However, studies from Canada and Australia report that the duration of walking for transport in the adult population is only 23.3 minutes per day and that only 3 - 4 out of 10 adults meet public health guidelines.^{17,18} In addition, females appear to be more likely to engage in walking for transport than males,^{14,18,19} differences in ethnicity seem to contribute to this variation. Another study showed that the mean global positioning system (GPS)-tracked pace of normal walking by males (1.17 ± 0.25 m.s⁻¹) is slower than that of females (1.44 ± 0.13 m.s⁻¹).²⁰ This intensity is able to meet the current physical activity recommendations because the mean GPS-tracked walking pace is 1.52 ± 0.20 m.s⁻¹, which exceeds

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the minimum pace required for moderate-intensity physical activity.

When the cost of active transport is high, e.g., the cost of climbing stairs is three times the cost of level walking,²¹ only 7.5% choose to take the route that is more physically demanding.²² Avoidance of stairs when a mechanized alternative is available occurs very frequently. Demographic subgroups with reduced resources for climbing, e.g., women, overweight pedestrians, and those carrying large bags, are more likely to avoid stairs by choosing the escalator.²² In modern cities, sloped ramps are an alternative to stairs that allow equal access for wheelchair users who cannot negotiate a staircase. Data from two separate sites where a sloped ramp is the alternative revealed that ramps are more frequently chosen than stairs.²² Ascent using a ramp allows a more gradual use of resources for the climb than a staircase. Demographic groups that are more likely to avoid stairs by taking the escalator, such as women, overweight pedestrians, and those carrying large bags, are also more likely to choose the ramp to ascend than their comparator groups.²²

Weather conditions and seasonality deter the physical activity behavior of all populations.²³⁻²⁵ Studies specific to young children and older adults suggest that low and high temperatures represent a barrier to physical activity.^{26,27} Previous studies reported that temperature and humidity have a direct impact on walking speed,^{28,29} rate of walking,³⁰ and walking duration.²⁹ In addition, climatic conditions are relevant to the different effects of temperature and humidity on sex. Females, for example, tend to reduce their walking duration more than males when the daily temperature is high.²⁹

The present quasi-experimental study investigated the behavior of pedestrians approaching a choice point between stairs and a ramp at an exit of a university campus toward the local train station. A short flight of stairs on the direct route to the station was the alternative to a slope that allowed avoidance of stair climbing. Previous observations revealed that most pedestrians choose the ramp [65.2% (95% CI = 63.0, 67.3), n = 2,529].²² The current study used chosen walking speed to estimate the use of resources by pedestrians and hypothesized that a faster speed would require more resources. It was predicted that the resource chosen would reflect the resources available. If avoidance of the stairs is related to available resources, then those choosing the ramp would walk slower upon approaching the choice point. Additionally, it was predicted that demographic subgroups with reduced resources would walk slower than their comparators. Finally, it was predicted that higher temperatures would cause individuals to decrease their walking speed.

Method

On the route to the University station, pedestrians crossed a distance of 10.2 meter on level ground 20 meter before they reached a short staircase (1.02 meter high, number of steps = 7). The direct route over the staircase to the station, 42.6 meter, was shorter than the more circuitous route via ramp, 46.1 meter. Figure 1 depicts pedestrians' route that leads to the train station and beyond it. The black arrow is direct route over the staircase. The red arrow is circuitous route. The pink arrow parallel to the brown arrow is the sidewalk that leads to the entrance of the station. The brown arrow is the road beyond the train station.

Participants were individuals who are going to or past the train station from the university square at the University of Birmingham, the United Kingdom. Data of 730 male and female pedestrians' walking speed crossing level ground (see figure 1, the yellow arrow) were collected during six separate days between 02:00 pm - 04:00 pm. Observations were made in July 17th July - October 13, 2016. Only pedestrians walking alone were timed to control for potential effects of social interaction on the speed of walking and subsequent choice.



Figure 1. Pedestrians' Route Leading to the Train Station and Beyond It

The walking speed to estimate the use of resources by pedestrians was recorded covertly using a stopwatch when the participant crossed the distance between the two short staircases. The speed was timed from when the leading foot was placed on the top of the first staircase until one of the feet was placed on the first step of the second staircase. The pedestrians' choice behaviour whether they subsequently climbed the staircase or chose the ramp was coded by the observer. In addition, weight status was coded from appearance using separate silhouettes for men and women to determine whether the pedestrian was overweight (body mass index / BMI > 25). As previous observations revealed that few pedestrians carry large bags, the presence of any bag, as well as the pedestrian's sex, was coded. Double coding revealed excellent Kappa values for weight status ($\kappa = 0.79$), presence of bags ($\kappa = 1.00$), and sex ($\kappa = 1.00$). Weather data every hour, starting from 12:00 and lasting until 18:00 on each day of measurement, were obtained from the Winterbourne, University of Birmingham weather station. During the data collection period, the ranges of temperature and humidity were 10 - 32°C and 41% - 91%, respectively.

Seven participants were excluded from the analysis due to incomplete data. There was strong negative correlation between temperature and humidity ($r = -0.874$, p -value < 0.001); as the temperature increased, humidity decreased. To counter the multi-collinearity between these two variables, the temperature was used to predict humidity in the data set, and the residuals saved for inclusion in the analysis. The net outcome was a measure of humidity that could not be explained by temperature. Multiple regression analysis were used to investigate the influence of the six independent variables on the participants' walking speed.

Results

The average walking speed was 1.075 m.s⁻¹ (SE = 0.004). The average temperature was 19.7°C (SE = 0.26; range 10 - 32°C), and the average humidity was 59.6% (SE = 0.25; range 41% - 91%). In the present observations, 64.8% of the pedestrians chose the slope, consistent with previous findings.²² The sample was composed of 49.3% female, 16.2% overweight pedestrians, and 41.8% pedestrians carrying bags.

Table 1 contains standardized coefficients and summarizes the results of multiple regression analyses for walking speed (m.s⁻¹). Choice, sex, weight status, temperature, and humidity significantly affected walking speed, and the regression equation obtained, $F_{7,713} = 21.91$ (p -value < 0.001), accounted for 16.9% of the variance found. The data did not reveal any effect of the presence of a bag or any interaction between the presence of a bag and choice on walking speed.

Pedestrians who chose the stairs walked faster than those who avoided them (stairs: $M = 1.105$ m.s⁻¹, 95% CI = 1.089, 1.120 vs. slope: $M = 1.063$ m.s⁻¹, 95% CI = 1.053, 1.074). The data confirm that males walked faster than females (males: $M = 1.109$ m.s⁻¹, 95% CI = 1.097, 1.120 vs. females: $M = 1.041$ m.s⁻¹, 95% CI = 1.029, 1.054) and that healthy weight individuals walked faster than those who were overweight (healthy weight: $M = 1.090$ m.s⁻¹, 95% CI = 1.081, 1.099 vs. overweight: $M = 1.000$ m.s⁻¹, 95% CI = 0.981, 1.020). In addition, individuals slowed their walking speed at higher temperatures. Paradoxically, pedestrians walked faster at higher humidity. Carrying a bag did not significantly slow the speed of walking (with bag: $M = 1.066$, 95% CI = 1.053, 1.079 vs. no bag: $M = 1.082$, 95% CI = 1.070, 1.094).

Discussion

This study aimed to investigate the walking behavior

Table 1. Standardized Coefficients for the Effects on Speed of Walking (m.s⁻¹)

Variable	p-value	Standardized Coefficient	95% CI
Choice (stair > slope)	0.036	-0.074*	-0.143, -0.005
Sex (M > F)	0.000	-0.247***	-0.316, -0.178
Healthy weight > overweight	0.000	-0.236***	-0.303, -0.168
Bag / no bag	0.112	-0.056	-0.126, 0.013
Bag by choice interaction	0.178	-0.046	-0.499, 0.093
Temperature, mean centered	0.007	-0.093**	-0.161, -0.025
Humidity residual, mean centered	0.004	0.101**	0.032, 0.169
Adjusted R ²		0.169	
F _(7, 713)	0.000	21.91***	

Notes: M: Male, F: Female, *p-value < 0.05, **p-value < 0.01, ***p-value < 0.001, CI: Confidence Interval

of pedestrians approaching a choice point between stairs and a ramp toward the local station in a university setting. In summary, the speed of walking was related to the choice of pedestrians when leaving the university campus. Individuals who chose the stairs en route to the station walked faster than those who avoided them. In addition, women and overweight individuals walked slower than their comparator groups. Consistent with Klenk, *et al.*,²⁹ increasing temperature was associated with reducing walking speeds.

Public health guidelines recommend a walking speed of 3 - 4 m.h⁻¹ or 1.34 - 1.79 m.s⁻¹ for most healthy adults. In the present study, the average walking speed was 1.075 m.s⁻¹, which is lower than the recommendation. This finding agrees with previous reports showing that walking for transport does not meet public health recommendations. Given that the preferred walking speed that minimizes the energy cost of the activity is approximately 1.3 m.s⁻¹, this result is surprising.³¹ This contradiction may be related to the walking site. To reach the flat section of ground over which individuals were timed, pedestrians must climb a height of about 4 meter from the university main square. Thus, pedestrians may have slowed their walking speed prior to reaching the measurement site.

When approaching the choice point, pedestrians had to choose whether to take the stairs or avoid them. The study found that individuals who avoided the stairs walked slower than those who climbed them. In addition, women and overweight persons walked slower than their comparator groups. Taking the stairs requires more energy than walking on a level surface. Teh and Aziz,³² estimated that the energy expenditure for climbing stairs is 9.6 times that of the resting state. Demographic groups with reduced resources may slow their pace to preserve resources, similar to how they are more likely to avoid the stairs when an alternative method of ascent is available.^{22,33} The effects of demographics may also reflect differences in available resources to complete individuals' journey, consistent with differences in method of ascent. An alternative explanation for why some pedestrians choose the stairs is time minimization. The distance of the pathway from the staircase to the station is shorter than the circuitous route via the ramp. Pedestrians in a hurry to catch the train may choose the shorter route to arrive at the station. Time pressure for a specific journey is a reasonable alternative explanation for the observed difference in speed based on choice.³⁴ One aspect not addressed in this study, however, is pedestrians' perception of the stairs as they approached the choice point. The apparent steepness of stairs in one's consciousness may affect the behavioral choice of pedestrians in a public access setting.³⁵ Interviewing pedestrians about their perceived steepness of the stairs and auditing the pedes-

trians' choice behavior at this site may clarify this issue.

Physical environment attributes, such as temperature and humidity, may reduce walking speeds and durations as they increase.^{29,36} Consistent with previous studies, as temperature increased, individuals slowed their walking speed. The need to minimize the cost of mobility in a hot and humid environment reduces the speed of walking, as resources, e.g., the supply of oxygenated blood, are required to cool the skin and support muscle exercise.³⁷ In contrast to previous study, however, pedestrians walked faster at higher humidity, a paradoxical finding inconsistent with the underlying physiology. Despite the relatively large sample size, only six separate days of monitoring were employed. Thus, between-day differences in both climate variables may have been confounded with within-day differences. Computing residuals to separate the two variables may be insufficient to distinguish between- and within-day effects. The increase in speed with increasing humidity is physiologically implausible and likely to reflect limitations in the data set.

Conclusion

Proffitt,³⁵ argued that three factors influence individuals' choice of walking speed, namely, the purpose of walking, anticipated duration, and anticipated energetic cost. In this study, the purpose of persons walking toward the observation location is to arrive at the train station as quickly as possible. Some individuals who walked faster and then climbed the stairs may have been affected by time pressure due to the train schedule. These persons increased their walking pace to minimize the time required to reach their destination. In conclusion, pedestrians' choice of walking speed on the route to the university train station may be related to time minimization rather than resource considerations. In this instance, chosen walking speed may not solely reflect available resources.

Abbreviations

BMI: Body Mass Index; GPS: Global Positioning System

Ethics Approval and Consent to Participate

Not Applicable

Competing Interest

Author declares that there are no significant competing financial, professional, or personal interests that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' Contribution

Febriani Fajar Ekawati and Frank Francis Eves were involved in the design of the study, the data analysis, and discussed the final results and contributed to the manuscript. Febriani Fajar Ekawati prepared and revised the manuscript.

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