Preventive Medicine Reports 2 (2015) 529–532

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Choosing between stairs and escalators in China: The impact of location, height and pedestrian volume

John Zacharias *, Boshen Tang

College of Architecture and Landscape, Peking University, Beijing 100080, China

ARTICLE INFO

Available online 10 June 2015

Keywords:
Physical activity
Stair climbing
Environmental factors
Voluntary activity
China
Comparative study

ABSTRACT

Objective. This research examines whether Beijing residents are more or less likely than Montréal residents to avoid stair climbing, by replicating a study in Montréal, Canada that measured the impacts of distance between stairs and escalator, height between floors and pedestrian volume on stair climbing rate.

Method. 15 stairways, 14 up-escalators and 13 down-escalators were selected in 13 publicly accessible settings in Beijing. Distance between the bottom or top of nearest stair and escalator combinations varied from 2.1 m to 114.1 m with height between floors varying from 3.3 m to 21.7 m. Simultaneous counts were conducted on stair and escalator pairs, for a total of 37,081 counted individuals.

Results. In the ascent model, pedestrian volume accounted for 16.3% of variance in stair climbing, 16.4% when height was added and 45.1% when distance was added. In the descent model, 40.9% of variance was explained by pedestrian volume, 41.5% when height was added and 45.5% when distance was added.

Conclusion. Separating stairs and escalator is effective in increasing stair climbing in Beijing, accounting for 29% of the variance in stair climbing, compared with 43% in Montreal. As in the Montreal case, distance has less effect on stair use rate when descending. Overall, 25.4% of Beijingers opted for stairs when ascending compared with 20.3% of Montrealers, and for descending 32.8% and 31.1% respectively.

Environmental interventions to promote stair use

Motivational interventions to promote stair use are relatively effective. A review of 26 intervention studies in stair use in 2012 reported increases in physical activity varying from 2.3% to 4.8% from baseline (Reynolds et al., 2014). The conclusion in this review is that motivational interventions were effective, with maintenance above baseline in some of the studies beyond the period of intervention. However, a review of the findings of the effectiveness of environmental modifications on stair climbing rates found there were insufficient such studies to draw conclusions (Soler et al., 2010). Two studies did report on stair use following non-structural design interventions – new carpet, artwork, new paint and music – reporting 4.4% increase (Boutelle et al., 2001) and 8.6% increase (Kerr et al., 2004). Before and after studies of major environmental modification are exceedingly rare. Sun et al. (2014) report increased rates of ascent involving stairs when the bus that used to carry passengers upward decreased its service level.

Other possible environmental interventions include decreasing the height of the stair run, widening the stairway and separating the stairway from the mechanical alternative. In a review of studies, it was reported that less height between levels was associated with higher levels of use (Dolan et al., 2006), but these studies did not include height as an independent variable. Height was a significant deterrent to stair climbing and descending in a study of 13 stairways and 12 pairs of escalators in a public setting (Zacharias and Ling, 2014), while lower buildings in a worksite also had higher rates of stair climbing (Olander and Eves, 2011). Greater distance between stairway and escalator accounted for higher use of the stairway (Zacharias and Ling, 2014) while proximity to the stairway over the elevator alternative increased stairway use (Olander and Eves, 2011).

Architects often favor wider stairways to give prominence to a particular ascent into a building or public place, one of the most famous being the Spanish Steps in Rome. It is not known, however, whether stair width alone encourages use. Greater visibility of the stairway option is associated with higher rates of use (Eves et al., 2009) but visibility does not require width. A modeling study suggests greater stairway width may promote greater use by commuters under time pressure (Eves et al., 2008). Devoting more space to the stairway may give it more importance and can create the opportunity to make the ascent and descent more interesting, but controlled studies have yet to reveal they are effective measures.

Finally, location of the stairway as a factor in choice when a mechanical alternative is available has been reported in two studies. In a 10-site study of stairs and elevators (Nicoll, 2007), higher rate of use of the stairs could be explained by the stairway's position with respect to the

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* Corresponding author. Tel.: +86 18801197232.
E-mail address: johnzacharias@pku.edu.cn (J. Zacharias).

http://dx.doi.org/10.1016/j.pmedr.2015.06.005

centrally positioned, most frequented corridors of the buildings. To evaluate the possibility that stair location might motivate stair climbing and descending, a study was conducted of existing stair and escalator combinations with varying distances between nearest choices, and varying travel heights (Zacharias and Ling, 2014). Pedestrian volume was retained as a control variable. It was found that distance between the stair and escalator choices and height in the ascending model accounted for 71% of the variance in stair climbing and 21% in stair descending. Pedestrian volume had marginal impact on stair use.

This last study was conducted in Montréal, Canada, and is replicated here using similar sets of stairs and escalators in Beijing, China.

Physical activity and stair climbing in Mainland China

There are suggestions in the literature that China's population, under the combined forces of urbanization and rising incomes, is following the trajectory to more sedentary lifestyles of the West. In 1996 in Tianjin, China, 60% of participants did not engage in leisure time physical activity but 91% of males and 96% of females walked or bicycled to work (Hu et al., 2002). The dramatic decline in bicycling since 1986 – for example, Beijing's bicycle commuting share dropped from 62.7% in 1986 to 13.2% in 2012 (BTRC) – has not been replaced by leisure-time or occupation-related physical activity. Only 13.2% of Chinese men and 8.4% of women declared that they engaged in any leisure-time exercise in 2006 (Ng et al., 2009). The decline in occupation-related physical activity, in particular, has been dramatic compared with declines in other domains such as leisure-related physical activity or transportation (Monda et al., 2007). Overall, the rates of voluntary leisure-related and incidental physical activity are lower in China than those measured in the West. The question is whether this tendency for voluntary physical activity extends to stair choice.

We know little about stair climbing behavior in China. Response to stair climbing prompts in Hong Kong was much lower than those recorded in the UK, for example (Eves and Masters, 2006). High temperature and humidity reduced the rates further. Stair climbing may be different in the Mainland compared with Hong Kong, given many other differences in public behavior, but these differences, including differences in stair climbing and escalator riding, remain largely unexplored.

Overall, active transportation declined in China from 1997, when the question was first included in the China Health and Nutrition Survey. In that survey, active transportation declined from 46–51% in 1997 to 28–33% in 2006 (Ng et al., 2009, 2014). This survey does not account for the higher rates of stair-climbing and escalator use in mass public transport. Climbing a flight of stairs costs about double the energy for the same time spent walking at typical walking pace (Campbell et al., 2002).

The literature suggests that sedentariness in China follows urbanization as it did in the West. However, there are also reasons and evidence why environment may prevail over widely exhibited behaviors in a particular population. With regard to differences across cultural contexts, do separation of stairway and escalator to the same destination, height of the stairway climb and overall pedestrian volume have the same effects on stair climbing?

Methods

To replicate the conditions of the Montréal study, an exhaustive search of locations in central Beijing was undertaken, since the great majority of shopping centers do not provide open stairways. As a consequence, the locations included 3 stair-escalator sets just outside several major electronics markets (6, 7, 8 in Table 1) and 2 sets in a metro station (9, 10). All other locations were inside shopping centers. Variations in height between floors and distance between stair-escalator combinations were a requirement for the sites. The mechanical alternative was visible in all cases from the foot or top of the stairway with a barrier-free passage between them. Pedestrian volume was included as a control variable since perceived congestion on the mechanical alternative and resulting slower ascent might induce stair climbing or descending.

Visible congestion and delay at the foot of the escalator did not occur in the observation study, as might be expected in shopping environments. Although counts were conducted in 2 metro station stair-escalator combinations, the associated counts could not be said to generate a wait at the foot of the escalator. This is an important condition because of the observed major positive effect of delay on stair choice.

As in the previous study, 5-minute counts were conducted simultaneously or in immediate succession, between 10 a.m. and 5 p.m., with counts conducted to represent variable overall pedestrian flow at each location in the middle of the day. Counts at individual locations were conducted simultaneously, with two and three successive counts conducted at locations 11 and 12, respectively. The researchers also used the same recording devices and software.

The independent variables of total pedestrian volume, height between floors and distance from the stairway to the nearest escalator were entered successively in a linear regression, to observe the relative contributions to variance in both the ascent and descent models. Height

Table 1
Descriptive data on stair and escalator systems in 13 centers.

Location[a]	Height (m)	No. stairs	Escalators up/down	Mean stairs up volume (95% CI)	Stair % up	Mean stairs down volume (95% CI)	Stair % down	Mean escalator up volume (95% CI)	Mean escalator down volume (95% CI)	Distance to up escalator (m)	Distance to down escalator (m)
1	4.55	1	1/1	6.8 (3.7)	41.7	5.7 (4.2)	31.9	10.0 (7.8)	12.2 (11.0)	45.5	2.1
2	4.38	1	1/1	1.8 (7.3)	8.4	3.2 (2.4)	16.9	19.0 (8.5)	15.6 (5.8)	21.0	28.0
3	5.25	1	1/1	44.8 (22.6)	47.0	76.7 (36.3)	50.3	50.7 (32.9)	75.5 (24.0)	88.9	114.1
4	21.7	1	1/1	0.1 (0.3)	0.2	0.3 (0.5)	0.4	67.0 (33.0)	69.7 (51.1)	4.2	2.1
5	4.38	1	1/1	12.4 (7.0)	19.8	7.5 (5.4)	6.1	50.3 (20.1)	115.1 (51.3)	17.5	46.2
6	8.23	1	1/1	33.0 (8.7)	47.2	28.3 (9.1)	54.1	36.9 (11.8)	24.0 (7.5)	60.9	14.7
7	8.23	1	1/1	29.0 (8.1)	46.4	28.4 (8.8)	38.0	33.6 (10.2)	46.4 (7.8)	42.7	12.6
8	7.53	1	1/1	11.5 (3.5)	29.5	12.9 (4.9)	37.5	27.5 (7.2)	21.5 (5.1)	49.0	8.4
9	9.28	1	1/1	1.0 (1.5)	10.0	24.3 (15.5)	42.7	9.3 (4.5)	32.6 (17.4)	8.4	34.3
10	9.28	1	1/1	11.6 (6.9)	9.3	2.9 (1.5)	35.4	112.8 (52.4)	5.3 (5.0)	8.4	34.3
11	6.13	1	2/1	3.7 (2.2)	1.7	6.0 (3.9)	15.7	70.8 (47.6)	31.9 (17.7)	44.1/20.3[b]	23.8
12	4.20	3	1/1	4.7 (3.4)	2.2	1.8 (1.8)	2.6	22.3 (11.1)	9.0 (5.1)	6.3	22.4
				101.0 (4.9)	48.2	24.6 (10.4)	35.1			58.8	32.9
				15.4 (4.5)	7.4	34.8 (13.2)	49.6			52.5	33.6
13	3.32	1	1/1	5.8 (3.4)	11.9	3.8 (3.3)	10.0	27.0 (16.8)	6.7 (7.2)	2.1	2.1

[a] 1—Shopin Shopping Center; 2—Beichen Shopping Center; 3—New Gate Shopping Center; 4—Haidian Huangzhuang B outside New Gate; 5—Haidian Huangzhuang A2; 6—Zhongguancun pedestrian bridge at IT Shopping Center NW; 7—Zhongguancun SW; 8—Zhongguancun SE; 9—Zhuxinzhuang metro entrance B1; 10—Zhuxinzhuang B2; 11—Xidan Shopping Center; 12—77th Street Shopping Center; 13—77th Street Shopping Center South.

[b] 52%/48% of escalator up flow.

was transformed by taking its reciprocal, while the natural logarithm of distance was used to reduce the effects of disparity.

Results

The mean ascent volume was 46.4 persons per 5-minute block while mean descending volume was 48.5, 11.1% and 19.5% respectively higher than in the previous study (Table 1). Stair climbing as a percentage of the total ascending volume was 25.4, with 32.8 descending, 25% higher and 5% respectively than the values in the previous study. The Beijing cases had much greater distances between the foot of the stair and its paired escalator, averaging 32.0 m in Beijing compared with 17.4 m in Montréal. Similarly, mean distance between the top of the stair and its corresponding escalator in Beijing, 27.4 m, can be compared with 15.5 m in Montréal. Distances between choices were greater and so were the heights between floors. Mean height between floors in Beijing was 7.6 m compared with 4.2 in Montréal. Overall, greater height reduced stairway use while greater distance to the escalator increased it.

The data were entered in a hierarchical linear regression to understand the impacts of each of the three independent variables, presented in Table 2. The Poisson model, normally appropriate for count data, had to be rejected because variances did not match means. Pedestrian volume data were entered first, followed by height and finally distance. In the ascending model, 16.7% of the variance is explained by pedestrian volume, while height alone accounts for 2.0%. Distance between choices raises the explained variance in the model to 50.9%. In the descending model, pedestrian volume accounts for 40.9% of stair choice, 42.0% when height is added. Distance between choices raises the total explained variance in the model to 45.8%. The interaction between pedestrian volume and distance indicates that overall pedestrian volume has less impact as the distance between ascent and descent alternatives increases.

Conclusion and discussion

Distance between stairway and escalator had similar major, positive effect on stair climbing in Beijing as observed in the Montréal case. Height also had a dampening effect on stair climbing, although an increase in height results in less than proportional declines in numbers in both cases. The greater tendency to take the stairs to descend when pedestrian volume increases, compared with ascending, is also replicated, reflecting the much lower expenditure of energy required to descend. The Beijing case exhibits higher rates of stair use than in Montréal, which can be explained in part by the much greater distances between the manual and mechanical options, and the higher pedestrian volumes. The stairs also offer a faster descent when there is higher passenger volume on the escalator, and when pedestrians are stationary.

It is not known whether separating a single, long stairway into two or more shorter stairways affects the likelihood of stair climbing, although it seems a good candidate for evaluation. A smaller number of stairs between floors were associated with more stair climbing in one study (Titze et al., 2001). Most building codes require landings at 12 or 13 stairs but greater separation between successive stairways might inspire a different evaluation of the more modest first stairway, based on the limited evidence.

The substantial effect of environment, in this case distance between options, on the decision to ascend stairs rather than use the nearest escalator has immediate implications for the planned public environment. Separating the manual from the mechanical means for changing levels clearly confers different meanings on these devices in the eyes of the users. Given these results, it seems reasonable to consider other environmental variables that have not received adequate treatment, such as the width of the stairway. The limited results on the design aesthetics and lighting of stairways also merit further exploration.

With concern about rising sedentariness in China, the design of the public environment would appear to offer some opportunities to increase physical activity in everyday experience. The multiple-level city

Table 2
Hierarchical linear regression for distance between nearest options, pedestrian volume, and height between floors as predictors of stairway choice.

			Change in		
Regression variable	Regression coefficient	Standardized error of estimate	Standardized β	R^2	F-value
Model I: ascending					
Pedestrian volume	.145**		.407		
		13.363		.163	70.742**
Pedestrian volume	.152**		.428		
Height (h^{-1})	13.655		.063		
		13.353		.001	36.182**
Pedestrian volume	.142**		.398		
Height (h^{-1})	10.863		.050		
Distance (LN)	7.112**		.531		
		10.873		.287	97.020**
Pedestrian volume × distance (LN)	1.901		.051		
Height (h^{-1})	−202.821**		−.334		
		38.719		−.342	22.897**
Model II: descending					
Pedestrian volume	.306**		.641		
		17.444		.409	249.394**
Pedestrian volume	.312**		.654		
Height (h^{-1})	29.553**		.088		
		17.356		.006	128.307**
Pedestrian volume	.264**		.554		
Height	18.177*		.054		
Distance (LN)	5.017**		.259		
		16.507		.060	107.474**
Pedestrian volume × distance (LN)	4.161*		.103		
Height (h^{-1})	−108.000**		−.154		
		35.719		−.040	93.277**

* $p < .05$.
** $p < .01$.

is increasingly the norm as underground development, metro rail and multi-story shopping environments become commonplace. The placement, dimensions and perhaps other attributes of the means to go between levels offer ways to increase daily physical activity.

Conflict of interest statement

The authors declare having no conflict of interest in the present study.

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