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Short Communication

Associations of self-reported stair climbing with all-cause and cardiovascular mortality: The Harvard Alumni Health Study

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ABSTRACT

To evaluate the association between numbers of floors climbed (per week) and all-cause and cardiovascular (CVD) mortality in men. A prospective study was conducted in 8874 men (Median [interquartile range] age: 65 years [60–71.6 years]) from the Harvard Alumni Health Study. Participants reported the number of floors habitually climbed, physical activity in their leisure time, other health related behaviours and any physician diagnosed disease in 1988. Men were followed for mortality through December 2008. Multivariate Cox hazard models to examine the association between weekly number of floors climbed and all-cause and CVD mortality adjusted for participation in total physical activity and other confounders.

During a median follow-up of 12.4 years, 4063 men died (1195 from CVD). After adjusting for confounders (age, walking, sports/recreation, body mass index, alcohol intake, and smoking, diagnoses of hypertension or diabetes or high cholesterol) number of stairs habitually climbed was inversely associated with all-cause mortality (p trend < 0.001). Compared with the group who climbed < 10 floors/week, the hazard ratio (HR) for the ≥35 floors/week group was 0.84 95% confidence interval (CI) (0.78–0.91). In contrast, we found no evidence for an association between stair climbing and CVD mortality risk (p trend = 0.38), in the ≥35 floors/week group: HR = 0.94 95%CI (0.81–1.09). In this cohort of older men, stair climbing was associated with a lower risk of mortality from any causes. Further insights may be gained from future observational studies utilizing emerging pattern recognition of stair climbing from objective measurements of physical activity.

1. Introduction

Insufficient physical activity is a risk factor for major non-communicable diseases such as coronary heart disease, type 2 diabetes, and breast and colon cancers (Autenrieth et al., 2011; Lee et al., 2012; Wen et al., 2011), and is responsible for 9% of premature mortality, or > 5.3 million deaths globally each year (Lee et al., 2012). Physical activity undertaken by adults in different contexts or domains can be accumulated to attain the recommended minimum for aerobic activity of 150 min of moderate intensity or 75 min of vigorous intensity physical activity, or an equivalent combination, each week (Australia Goverment, 2014; U.S. Deparment of Health and Human Services, 2018; World Health Organization, 2010).

Regular stair climbing has the potential to provide opportunities for engaging in moderate-to-vigorous intensity physical activity (MVPA) and achieving numerous health benefits. In a landmark study of Morris and colleagues (Morris et al., 1953), bus conductors who regularly climbed the stairs on London double deck buses had a lower risk of coronary heart disease compared with the sedentary bus drivers. In analyses conducted in middle-aged Harvard alumni men followed from 1977 through 1992 (deaths = 4231), stair climbing (> 20 floors per week) was associated with a reduced risk of death compared with less active participants (< 20 floors) (Paffenbarger and Lee, 1998). In a similar way, Lee and Paffenbarger (Lee and Paffenbarger, 2000) reported that men who climbed at least 10 flights (5 floors) per day (compared with those climbing < 3 flights per day) had 18% lower risk

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Table 1
Baseline characteristics of participants of the Harvard Alumni Health Study, Boston, (USA).

	Total floors per week				
	< 10	10–19	20–34	≥35	Total
	(n = 2557)	(n = 1890)	(n = 1527)	(n = 2900)	(n = 8874)
Age, years	67 (62–74)	64 (60–71)	64 (60–70)	64 (60–70)	65 (60–71)
Cigarette habit					
Current smokers (%)	8.6	9.1	7.5	7.7	8.2
Alcohol intake					
Never (%)	31.7	26.2	23.4	23.8	26.5
1–3 drinks/wk (%)	18.2	19.7	18.8	18.8	18.8
4–6 drinks/wk (%)	11.7	13.6	13.4	13.9	13.2
≥7 drinks/wk (%)	38.4	40.4	44.4	43.5	41.5
BMI, kg/m^2	24.4 (22.9–26.5)	24.6 (22.9–26.6)	24.4 (22.9–26.4)	24.4 (22.7–26.1)	24.4 (22.8–26.3)
Physician diagnosed hypertension Yes (%)	29.1	28.6	26.6	25.6	27.4
Physician diagnosed diabetes Yes (%)	5.5	4.6	4.5	3.7	4.6
Physician diagnosed high cholesterol Yes (%)	19.1	19.4	19.5	17.5	18.7
Blocks walked	6 (2 – 12)	6 (2–12)	7 (4–12)	11 (4–20)	8 (3–15)
Physical activity (MET-hr/wk in sports/recreation)	12 (0 – 32)	13 (0–29)	13 (0–29)	14 (0–32)	13 (0 – 31)

Continuous variables (age, BMI, blocks walked and physical activity) are shown as median and interquartile range (IQR); BMI: Body Mass Index (kg/m^2); MI: Myocardial Infarction; METs: Metabolic equivalents.

of all-cause mortality after adjusting for other components of physical activity (walking, and participation in light, moderate, and vigorous activities). However, all these previous epidemiological studies have potential methodological limitations. For example, in the analysis performed by Paffenbarger and Lee (1998), authors did not exclude participants with chronic diseases at baseline, which may have influenced the results by reverse causation. Another limitation of the existing literature is the lack of information on disease specific mortality in relation to stair climbing.

Despite these gaps of knowledge, recent studies have given new momentum to the potential use of stair climbing for population health. Panczak et al. (2013) found an inverse association between the floor of residence and mortality risk (all cause and due to cardiovascular (CVD) reasons) in analyses based on 1.5 million people. In addition, a recent systematic review concluded that the majority of interventions to increase stair climbing in public settings resulted in significant positive changes (Jennings et al., 2017). Although the experimental evidence of the health effects of stair climbing is scarce, some studies conducted in young adults have showed beneficial changes on traditional CVD risk factors (Boreham et al., 2005; Kennedy et al., 2007).

The current study aimed to evaluate the associations of stair climbing with all-cause mortality and CVD mortality among men recruited in the Harvard Alumni Health Study, using a long follow-up period (up to 20 years).

2. Methods

The Harvard Alumni Health Study is a prospective cohort study of men who matriculated as undergraduates at Harvard University between 1916 and 1950 (Lee, 2009). Beginning in either 1962 or 1966, surviving alumni were mailed questionnaires periodically, that requested information about physician-diagnosed diseases and health related behaviours, including physical activity.

For the purpose of the present analysis, we investigated the 12,805 men who returned questionnaires in 1988. We excluded 3487 men with a history of CVD or cancer and 444 men with missing physical activity data, leaving 8874 participants in the present study. The Harvard T.H. Chan School of Public Health IRB approved this study.

In 1988 (baseline for the present analyses), participants were mailed questionnaires and self-reported their walking, stair climbing, and sports or recreational activities during the past year, as well as the frequency and duration of each of these activities. The reliability and validity of this physical activity questionnaire has been extensively investigated (Lee, 2009).

The main exposure variable was the weekly (wk) number of floors climbed (1 floor = 2 flights of stairs). To assess the association of stair climbing with mortality, independent of other physical activities, we adjusted for the number of blocks habitually walked and participation in sports or recreational activities. The energy expended on sports and recreational activities was estimated by multiplying its metabolic equivalent (MET) score (Ainsworth et al., 2000) by hours per week of participation and summing across all activities.

In the 1988 questionnaires, men also reported information on date of birth, weight, height (converted to body mass index, BMI, kilograms divided by height (Lee et al., 2012) in meters), smoking, alcohol intake and physician-diagnosed hypertension, diabetes and high cholesterol.

Men were followed through 2008 for mortality. Deaths through 1998 were identified using information on mortality from the Harvard University alumni office and obtaining death certificates obtained from the state health departments. Diagnoses recorded on death certificates were coded according to the International Classification of Diseases (ICD) 7th revision, with CVD deaths identified as codes 330 to 334 and 410 to 446. Deaths after 1998 were ascertained from the National Death Index and coded according to ICD 9th revision, with CVD deaths identified as codes 053 to 075.

Cox proportional hazards regression models estimated the associations of weekly number of floors climbed using four categories based on cut-points previously used (Lee and Paffenbarger, 2000) (0–9 floors/wk; 10–19 floors/wk; 20–34 floors/wk; ≥35 floors/wk) and determined a priori to categorize participants into approximate quartiles with the hazard ratio (HR) and 95% confidence interval (95% CI) of all-cause and CVD mortality. We checked the proportional hazards assumption using *Schoenfeld* residuals and the proportionality assumption was not violated. Three models were run: Model 1 adjusted for age, number of blocks walked, and energy expended on sports/recreation. Model 2 included all Model 1 covariates plus smoking, and alcohol intake. Model 3 included all Model 2 covariates plus BMI, and diagnoses of hypertension, diabetes, or high cholesterol. All analyses were performed with the statistical package STATA 14 (StataCorp, College Station, TX).

Table 2
Hazard ratios (HR) and 95% confidence intervals (CI) of all-cause and CVD mortality by stair climbing (floors per week), the Harvard Alumni Health Study, Boston, USA.

Outcomes	Events/N	< 10 floors/wk	10–19 floors/wk	20–34 floors/wk	≥35 floors/wk	p for trend
		(n = 2557)	(n = 1890)	(n = 1527)	(n = 2900)	
All-cause						
Model 1	4063/8874	1358	859	649	1197	< 0.001
HR (95%CI)		1	0.91 (0.83–0.99)	0.87 (0.79–0.95)	0.82 (0.76–0.89)	
Model 2	4020/8802	1336	851	646	1187	< 0.001
HR (95%CI)		1	0.92 (0.84–1.00)	0.88 (0.80–0.97)	0.83 (0.77–0.90)	
Model 3	3965/8704	1317	834	637	1177	< 0.001
HR (95%CI)		1	0.92 (0.84–1.00)	0.87 (0.79–0.96)	0.84 (0.78–0.91)	
CVD	1195/8874	397	241	191	366	0.164
Model 1		1	0.94 (0.80–1.11)	0.93 (0.78–1.10)	0.90 (0.78–1.04)	
HR (95%CI)						
Model 2	1178/8802	391	237	189	361	0.177
HR (95%CI)		1	0.93 (0.79–1.10)	0.92 (0.77–1.10)	0.90 (0.78–1.04)	
Model 3	1160/8704	385	231	184	360	0.376
HR (95%CI)		1	0.94 (0.79–1.11)	0.90 (0.76–1.08)	0.94 (0.81–1.09)	

HR: hazard ratio; CI: confidence interval: N: sample size.
Model 1: adjusted for age, number of blocks walked, and MET-hr/wk from sports/recreation.
Model 2: Model 1 plus smoking and alcohol intake.
Model 3: Model 2 plus BMI, diagnoses of hypertension or diabetes or high cholesterol.

3. Results

Baseline characteristics of the men (median age [interquartile range] = 65 years [60–71 years]) categorized by number of floors per week are shown in Table 1. As reported, participants distributed in each group of stairs climbing had similar characteristics in relation to: age, smoking, alcohol intake, BMI, and levels of leisure time physical activity. However, the prevalence of hypertension and diabetes reported at baseline by participants was lower with each increase in the number of floors climbed. During a median of 12.35 years of follow-up, 4063 men died (1195 from CVD).

As shown in Table 2, compared with men who reported climbing fewer than 10 floors/wk, higher amounts of stair climbing were significantly associated with lower risk for all-cause mortality, (Model 1): [HR (95% CI) = 0.91 (0.83–0.99)], [HR (95% CI) = 0.87 (0.79–0.95)], and [HR (95% CI) = 0.82 (0.76–0.89)] for 10–19 floors/wk, 20–34 floors/wk, and ≥35 floors/wk, respectively. This inverse relation persisted after additionally adjusting for smoking and alcohol intake (Model 2: ≥35 floors/wk, [HR (95% CI) = 0.83 (0.77–0.90)]), as well as after additionally adjusting for BMI, hypertension, diabetes, high cholesterol (Model 3): [HR (95% CI) = 0.84 (0.78–0.91)] for ≥35 floors/wk.

Compared with men who reported climbing fewer than 10 floors/wk (Table 2), a larger number of stairs climbed was not significantly associated with a lower risk for CVD mortality in any of the models. For example, (Model 1): [HR (95% CI) = 0.94 (0.79–1.11)], [HR (95% CI) = 0.90 (0.76–1.08)], and [HR (95% CI) = 0.94 (0.81–1.09)] for 10–19 floors/wk, 20–34 floors/wk, and ≥35 floors/wk, respectively.

4. Discussion

This is one of the very few studies examining the association between stair climbing and mortality. Overall, our data support previous epidemiological studies whereby habitual stair climbing was associated with health outcomes, specifically reducing all-cause mortality risk. As noted in Table 2, there was an inverse dose-response relation between stairs climbed and all-cause mortality risk. Despite the notable differences among studies in the analytical methods used, our findings are in broad agreement with two previous epidemiological studies of stair climbing and all-cause mortality (Lee and Paffenbarger, 2000; Paffenbarger and Lee, 1998), yet both used a shorter follow-up compared with the present study. Moreover, our findings are congruent with a recent epidemiological study where residents living in higher floors had a lower mortality rate compared with those living in lower floors. According to Panczak et al. (2013), the inverse gradients of mortality associated with the floor of residence might be explained by residual socioeconomic stratification that can be mediated by behavioural (higher physical activity due to stair climbing) and environmental exposures (for example, lower levels of airborne pollutants in upper floors).

The absence of statistically significant associations between stair climbing and CVD mortality based exclusively on the p values must be interpreted cautiously (Greenland et al., 2016). The interpretation of scientific findings into significant and non-significant results based on the use of p values ≤0.05 is however discouraged in modern epidemiological studies (Greenland et al., 2016). The effect sizes and the upper confidence intervals (close to the unit) found in our study for stair climbing and CVD mortality, are suggestive of an inverse relation with cardiovascular mortality. In analyses based on 1.5 million people (number of CVD deaths = 47,356) (Panczak et al., 2013) and compared with residency in the eighth or higher floor, living in the ground floor was associated with a higher hazard rate of CVD (fully adjusted model: [HR (95% CI) = 1.35 (1.22–1.49)]). Whether the lower CVD risk observed in residents living in higher floors (compared with those living in ground floor) (Panczak et al., 2013) could be accounted for a higher use of stairs is a possibility.

Two short-term stair climbing interventions showed favourable changes in some traditional cardiovascular risk factors. In a randomized controlled trial in which young sedentary women (mean age (SD): 18.8 years (0.7)), were assigned to 8 weeks of a progressive stair climbing program or a control group, the stair climbing group (n = 8) had a 17% increase in the maximal oxygen consumption ($VO2_{max}$) and a 8% reduction in low-density lipoprotein cholesterol (LDL-c) after the intervention (all $p < 0.05$) (Boreham et al., 2005). However, it should be noted that in the stair climbing group some cardiovascular risk factors remained unaltered after the intervention (ex. total-cholesterol, high-density cholesterol, triglycerides and homocysteine). In another randomized controlled trial of 8 weeks of duration conducted among middle-aged men and women (mean (SD) age, 42.3 years (9.0)), the stair climbing group showed a 9% increase in $VO2_{max}$. Nevertheless, some CVD risk factors (blood pressure, blood lipids and body composition) showed no statistically significant changes after the intervention (Kennedy et al., 2007).

Compared with previous analyses of the Harvard Alumni cohort study (Lee and Paffenbarger, 2000; Paffenbarger and Lee, 1998), the present study has several important strengths: a larger number of deaths, a longer follow-up period (up to 20 years) and the examination of CVD mortality, in addition to all-cause mortality. Several limitations need to be discussed. Number of stairs climbed was self-reported rather than objectively measured. This measurement error (misclassification), however, may have occurred randomly across all participants. Although we did not account for change in stair climbing changes in participants during the follow-up, our assumption is that most participants maintained their stair climbing habits during the follow up period. Another threat to the internal validity of any observational study is confounding. We included several covariates in the statistical models (for example, BMI, diagnoses of hypertension or diabetes). While we tried to account for reverse causation by excluding participants with major chronic disease in this observational study, we cannot discard the possibility that fewer stairs climbed may reflect early signs of frailty. Finally, participants in the present study were predominantly white men, with a high level of education and socioeconomic status. Future epidemiological studies should recruit participants with diverse personal characteristics (sex, socioeconomic status or ethnic background).

5. Conclusions

In this cohort of older US-men, a higher number of floors climbed were associated in a dose-response manner with lower mortality from all causes. Since most of the buildings are today equipped with elevators and it is unlikely that individuals will climb many floors, the lower range of stair climbing may be more relevant to today's world. We found that the lower end of the stair climbing spectrum (10–19 floors of climbing per week) was associated with a lower mortality risk versus the referent group. This finding highlights that minor changes in physical activity levels, such as stair climbing, in inactive populations may provide health benefits in the population. Future well-designed observational studies (incorporating pattern recognition from objective measurements of stair climbing and overall physical activity (Skotte et al., 2014)) will provide further light on the health enhancing potential of stair climbing.

Declaration of Competing Interest

ES has received grants of PAL Technologies, Scotland. JPRL, MM, HDS and IML do not have any potential conflicts of interest to disclose.

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