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MAXIMAL ISOMETRIC KNEE EXTENSION STRENGTH AND STAIR-MOUNTING ABILITY IN 75- AND 80-YEAR-OLD MEN AND WOMEN

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ABSTRACT. The objective was to study whether the ability to mount different step heights depends on knee extension strength, and if this dependence varies according to age or sex among elderly persons. Altogether, 198 independently living 75-year-old women, 98 75-year-old men, 117 80-year-old women and 45 80-year-old men participated in the study. Maximal isometric knee extension strength was measured in a sitting position using a custom-built dynamometer chair. Results were standardized for body mass and height. In the stair-mounting test 10 cm high boxes were combined to form steps with heights of 10 to 50 cm. Older subjects, especially the women, exhibited poorer results in both tests. However, when groups based on maximum step height were analysed separately for strength, three-way analysis of variance revealed no sex effects. Although the number of men in the analysis was quite small, it was concluded that the strength requirements for mounting a certain step height were similar for both sexes. Owing to their sex-related lower average strength, old women may be at greater risk than old men of becoming impaired in certain motor tasks.

Key words: aging, functional capacity, mobility, muscle force.

INTRODUCTION

Among elderly people, poorer lower extremity muscle strength and power have been found to be among the factors associated with difficulties in everyday mobility (2, 3, 4, 6, 10, 13, 14). Such difficulties are particularly common in older women (12). The association between strength and functional ability probably contains a threshold level. Below the strength threshold, muscle strength is wholly or in part insufficient for the task. Above the threshold strength is sufficient to perform the activity. The strength threshold depends on the task performed and the muscles involved in the taks. In old age, decreasing strength may bring people close to functional thresholds, even for basic motor tasks such as standing up, walking about or mounting stairs (16).

The purpose was to study whether men and women aged 75 and 80 years would need to be able to produce equal amounts of maximal isometric knee extension strength in order to manage mounting equally high steps. We also tried to determine the minimum amounts of strength required for mounting different step heights, so-called strength thresholds.

MATERIALS AND METHODS

The study was part of larger gerontological research programme known as the Evergreen Project. The data were collected during autumn 1989 and winter 1990. The study consisted of in-home interviews and laboratory examinations. All the registered permanent residents of the city of Jyväskylä born in 1910 ($n = 291$) and 1914 ($n = 388$) formed the target group. Of these people, 46 refused to participate at all, 12 died before the study began and 4 could not be reached. In addition, 57 80-year-old persons and 55 75-year-olds agreed to participate solely in the interview which preceded the laboratory tests. In 12 cases proxy interview was necessary. Eventually, of the 80-year-old cohort, 198 (69% of the population) and of the 75-year-old residents 295 (77% of the population) participated in the laboratory tests. Informed consent was obtained in all cases. Ethical issues confirmed the guide-lines of the Academy of Finland.

The strength measurements were preceded by a 30-minute medical examination. The physician did a medical history interview, auscultation of heart and lungs, and examination of the musculoskeletal system. The physician also determined contraindications for hand grip, elbow flexion, knee extension, and trunk flexion and extension strength tests. Altogether 44 subjects had health problems that prevented them from taking part in all the strength tests. The most common reasons for exclusion were musculoskeletal problems (endoprothesis, painful arthritis, $n = 20$), cardiovascular disease (unstable angina, recent myocardiac infarction, systolic blood pressure over 200 mmHg at rest, $n = 13$), poor cooperation (poor hearing, fear of testing, impaired cognitive capacity, refusal, $n = 9$) and other reasons ($n = 2$). The knee extension strength test was performed by 45 80-year-old men and 117 80-year-old women and by 98 75-year-old men and 189 75-year-old women.

Maximal isometric knee extension strength was measured on the side of the dominant hand with the knee flexed 60° from full extension. The subject was seated in an adjustable dynamometer chair constructed at the Department of Health Sciences (9, 15). The ankle was attached by belts to a strain-gauge system. The subject was allowed two or three practice trials. The measurer checked that the subject understood and was able to perform the task in an acceptable manner. Three formal measurements were performed and recorded with 1-minute rest periods between the trials. The best trial was accepted as the result.

The strength test results were standardized by dividing the results by body mass × body height and expressed as Newtons/kilogrammeter (N/kgm). In the stair-mounting test a heavier person performs a greater amount of work and needs to exhibit more force than a lighter person. A taller person has an advantage because of more advantageous joint angles. The same standardization procedure has been described by Buchner et al. (5). Body mass and height were measured in the laboratory using conventional scales.

As expected, the men and the younger people exhibited greater strength than the women and the older people both in absolute (sex: $F = 199.0$, $p < 0.001$, age: $F = 39.9$, $p < 0.001$) and adjusted scores (sex: $F = 55.7$, $p < 0.001$, age: $F = 25.5$, $p < 0.001$).

The stair-mounting test was carried out using five 10-cm-high boxes, which were combined to form steps with heights of 10, 20, 30, 40 and 50 cm. The test was started with the lowest step. The subject was asked to step up and down each step once and was allowed to choose on which leg to step up. The highest step managed without support from the hand rail was recorded as the result (1).

Cross-tabulation was used to study stair-mounting capacity in different study groups. Two-way analysis of variance was used to analyse the effects of age and sex on knee extension strength in the whole study population. Three-way analysis of variance was used to study the effects of stair-mounting height, age and sex on maximal isometric knee extension strength. One-way analysis of variance followed by Least Significant Difference procedure (LSD) was use to analyse the strength differences between different riser heights. If a p-value less than 5% was found, differences were accepted as significant. The analyses were carried out using the SPSSX program.

RESULTS

In the stair-mounting test the results of the women were evenly distributed. Twenty-nine percent of the 75-year-old women and 20% of the 80-year-olds could ascend the 50-cm step. However, among the men a ceiling effect occurred, since the majority of men in both age groups managed the 50-cm step and might have been able to ascend higher steps (Table I).

Those able to climb the higher steps exhibited greater strength than those who were only able to manage the lower steps, with the exception of the small group ($n = 14$) of 10-cm mounters (see Fig. 1).

Table I. *The percentage distribution of maximal stai mounting height in 75 and 80-year-old men and wome*

Step height	Men 75 ($n = 98$) %	Men 80 ($n = 45$) %	Women 75 ($n = 189$) %	Women 8 ($n = 117$) %
0 cm	6	9	7	5
10 cm	2	0	5	3
20 cm	1	0	10	13
30 cm	10	11	24	31
40 cm	5	20	25	28
50 cm	76	60	29	20

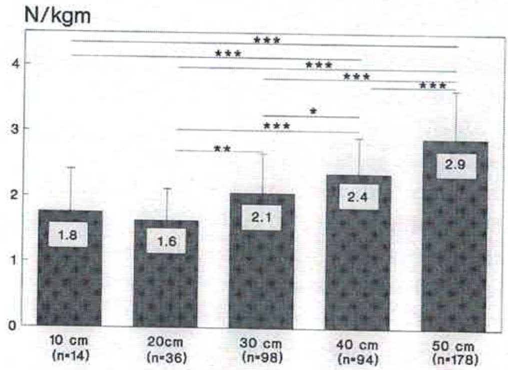

Fig. 1. Maximal body mass and height-adjusted knee extension strength according to maximal stair-mounting height in the 75- and 80-year-old men and women (Mean, SD, LSD-test procedure). $^{***}p < 0.001$ $^{**}p < 0.01$.

To eliminate the ceiling effect the 50-cm mounters were omitted from the analysis. In addition, as there were no 80-year-old men whose maximal step height was 10 or 20 cm, these heights were also excluded. Table II shows the effects of age, sex and stair-mounting height on knee extension strength adjusted

Table II. *Maximal isometric body mass and height-adjusted knee extension strength in groups by age, sex and stair mounting height (mean, SD, three-way analysis of variance)*

	30 cm	40 cm
75-year-old men (N/kgm)	2.5 (0.7)	2.3 (0.8)
80-year-old men (N/kgm)	1.7 (0.5)	2.2 (0.4)
75-year-old women (N/kgm)	2.1 (0.6)	2.5 (0.5)
80-year-old women (N/kgm)	2.0 (0.6)	2.2 (0.6)

Main effects: Age: $F = 8.0$ ($p < 0.01$), Sex: $F = 0.2$ ($p > 0.05$), Step height: $F = 14.2$ ($p < 0.001$).
Two-way and three-way interactions were not significant ($p > 0.05$).

to body size in the 30- and 40-cm mounters. The step height managed was the most powerful source of variation in knee extension strength. Age also was significantly associated with strength: the older participants had lower strength scores. Sex showed no effect on strength.

The cumulative percentage distributions of the body mass and height-adjusted knee extension strength test results of the groups with maximum stair-mounting heights from 20 to 50 cm is illustrated in Fig. 2. The curves were S-shaped and clearly distinct from each other and show some evidence for the existence of threshold phenomena. Practically nobody with a maximal isometric knee extension strength of less than 1.75 N/kgm could ascend the 50-cm high step. At the other end, 60% of the 50-cm group exhibited more than 2.74 N/kgm, whereas none in the 20-cm group reached that strength level. In the 40-cm group only 17% exhibited less than 1.75 N/kgm and only 2% more than 3.24 N/kgm. Nevertheless, strength thresholds could not be determined as precise numerical values, since there was considerable overlapping of the knee extension force distributions of those with different maximum stair-mounting heights.

DISCUSSION

This paper contains new information about the strength requirements for mounting stairs in elderly men and women. The lack of a significant sex effect on strength in groups constituted by maximal stair-mounting height suggests that the body size-adjusted strength requirements for mounting stairs are similar for both sexes. Consequently, in women their 30–40% lower average strength might be one of the factors explaining the greater risk of becoming restricted in mobility as compared to men. Relative knee extension strength was positively associated with stair-mounting ability in both sexes, as has also been observed in a number of previous studies (e.g. 2, 3, 6, 10, 11, 13). Had the strength values been studied in absolute terms, the results would have been different. Some earlier studies have failed to establish an association between absolute strength test results and climbing ability (7).

Our analyses were performed on those persons with a maximum stair-mounting height of 30 or 40 cm in order to eliminate the ceiling effect. The number of men in the 30-cm and 40-cm groups was relatively

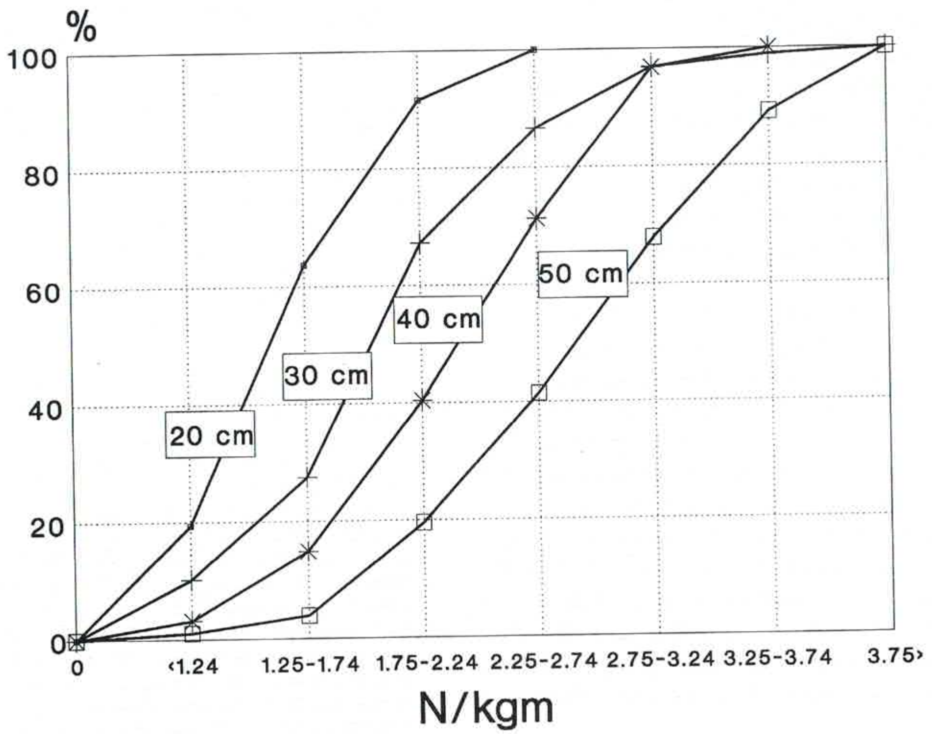

Fig. 2. Cumulative percentage distributions of body mass and height-adjusted maximal knee extension force in groups according to maximum stair-mounting height.

small. Since the majority of men were able to mount the 50-cm high step, those with a maximum step height less than that were, in fact, restricted in mobility. The lack of statistically significant sex effects may have resulted from this relatively small number of men, and should be confirmed in later studies.

The association between maximal muscle strength and functional performance has been suggested to be curved in shape and include a threshold (5). Below the threshold, strength would not be sufficient to perform the designated task. Above the threshold, strength would be sufficient and the curve flat. In the present study some evidence for the existence of strength thresholds was observed. The S-shape of the cumulative percentage distributions of knee extension strength evident in all groups suggests that below a certain strength level the task is practically impossible to perform. At the other end of the curve the flat part suggests that above a certain level an increase in strength does not increase the probability for successful performance in that particular task. Consequently, two "critical levels" seem to exist: "the minimum level required" and "the safe level".

One earlier study among healthy 65 to 89-year-old men and women failed to designate a strength threshold for stair-mounting (14). The failure to identify a threshold was explained by suggesting that the subjects were too strong, mobile and physically active to enable such a threshold to be identified among them. In the current study the subjects represented an independently living ordinary population. Moreover, this population may not have been impaired enough for a single threshold to be detected.

The considerable variation and overlapping of the relative knee extension strength test results of the groups with different maximum riser heights is a likely consequence of other factors affecting climbing ability. Some of the variation may result from the robustness of the criteria for an acceptable performance (able/not able). Here no information about the quality of the stair-mounting performance, such as ease or speed of movement, was recorded. In addition to age, sex, body weight, height and muscle strength, factors such as hip flexibility (11) and balance (8) affect performance in stair-mounting tests. An illustrative example of this is that stepping up on a stool is in many cases avoided by old people due to feelings of dizziness.

In Finland, according to a law which came into force in 1983 the maximum step height in public buildings must not exceed 16 cm. In homes the corresponding maximum height is 18 cm. However, older buildings may have higher steps, and trains and buses may have steps up to 40 cm high from the platform. Information about the strength requirements for various daily tasks and the proportion of older people meeting these requirements is important in terms for making environmental adjustments, such as the design of furniture, vehicles and flats as well as in planning and implementing prevention and rehabilitation programmes. Moreover, older women in particular would be a fruitful target group for strength training interventions.

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