TITLE: Shoe-fit is correlated with exercise tolerance in community-dwelling elderly people.

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Short Title: Shoe-fit and exercise tolerance

ABSTRACT

Purpose: Maintenance of physical activity significantly affects quality of life, and the frequency of physical activity depends upon exercise tolerance. However, there is minimal information on the external factors that contribute to exercise tolerance. The aim of this study was to examine the association between exercise tolerance and shoe-fit in community-dwelling elderly people.

Methods: Subjects were 155 elderly, healthy, community-dwelling Japanese volunteers. Exercise tolerance (Shuttle Walk Test [SWT]), 10-m walking time (10mWT), and Forced expiratory volume in 1 second (FEV1) were measured. Shoe-fit was assessed and participants were divided into 3 groups according to the heel-fit of their shoes (Too Loose, Loose, Fit). Group scores in the above variables were compared. Further, a multivariate logistic regression model using a stepwise method was performed to investigate which shoe-fit factors were independently associated with SWT.

Results: No significant differences in age, gender, Body Mass Index, 10mWT, FEV1, or presence or absence of pain sites were observed between the three groups. The Fit ($p = 0.001$) and Loose ($p = 0.008$) groups had significantly higher SWT score than the Too Loose group. Multivariate logistic regression analysis showed that poor heel-fit was significantly correlated with a low SWT score, even following adjustments for age, gender, 10mWT and FEV1 (Odds Ratio: 0.25, 95%; Confidence Interval: 0.07–0.95, $p = 0.04$).

Conclusions: This study demonstrates that heel-fit is associated with exercise tolerance in community-dwelling elderly people. It is important for elderly people to wear adequate fit shoes in order to enhance physical functions and prevent from declining physical functions.

Key words: shoe-fit, heel, exercise tolerance, shuttle walk test, physical function

INTRODUCTION

The maintenance of physical activity has been linked to a higher quality of life, especially in the elderly. Exercise tolerance plays an important role in increasing physical activity (1) and preventing injuries and complications (2). Further, decreased exercise tolerance is associated with physical frailty (3, 4) and higher mortality (4). Therefore, exercise tolerance is a crucial factor in the maintenance of a healthy life for elderly people.

Evidence suggests that exercise tolerance is associated with numerous physical functions such as walking speed (5), balance (6), and pulmonary function (7). Thus, to enhance exercise tolerance and such various physical functions create a synergy effect for each factors, but such changes would take considerable time (8). Elderly people would likely cease exercising before such improvements would manifest (9). It is consequently necessary to explore additional approaches towards the maintenance of efficient exercise that focus on external contributing factors as well as physical functions.

Shoes are required for many kinds of exercise and have various influences on physical functions. Particularly in the elderly, shoes play an important role in exercise because of age-related changes in foot structure and function. Wearing inadequate shoes increases foot problems (10, 11, 12), instability (13, 14, 15), and fall risk (16, 17) in the elderly. Conversely, adequate shoes may improve gait characteristics (18, 19), walking speed (20), and balance (21). Further, several researchers investigated shoe-fit defined as the length and width difference between the foot and the shoe in the elderly and found that more than half of people wear poor fit shoes (11, 22). Thus, wearing well-fitting shoes may enable rapid increases in physical activity in the elderly; however, few studies have addressed the association between shoe-fit and exercise tolerance.

Therefore, the goal of the present study was to examine the association between exercise tolerance and shoe-fit in community-dwelling elderly people.

METHODS

Participants

Participants were recruited for the study through local press that requested healthy community-dwelling volunteers. A total of 155 Japanese people participated in the study. Initial participation requirements stipulated that subjects be 65 years of age or older; community-dwelling; able to walk without assistance; willing to participate in physical fitness assessments, had normal pulmonary function; and met minimum hearing requirements. An interview was subsequently conducted to exclude participants based on the following exclusion criteria: severe cardiac, pulmonary, or musculoskeletal disorders; comorbidities associated with a greater risk of falls, such as Parkinson’s disease and stroke; and use of psychotropic drugs. Written informed consent was obtained from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Helsinki. The study protocol was approved by the ethical committee of Kyoto University Graduate School of Medicine.

Demographic data

Data on age, body mass index (BMI), gender, and presence or absence of pain sites were obtained. All data were collected in a single session. Information on age, gender and presence or absence of pain sites was directly obtained from the participants and BMI was calculated from measured height and weight using standardized height and weight scales.

10-m walking time test and shuttle walking test

A comfortable 10-m walking time test (10mWT; 23) and a Shuttle Walk Test (SWT; 24) were used to assess physical functions. In the 10mWT, participants walked 15 m at an individually determined comfortable pace. A stopwatch was used to record the time required to reach the 10-m point marked in the middle of the path. The SWT is used to evaluate exercise tolerance. During the SWT, subjects walk back and forth along a 10-m flat course, and progressively increase pace in accordance with audio signals until they are unable to maintain the pace. We performed SWT as the maximum was 50 times of 10 m walking (500 m walking in total). Participants were divided into groups by SWT score: ≤390 or >390. A cutoff of 390 or 400 has been shown to be diagnostically accurate for elderly people (25).

Pulmonary function

All subjects underwent spirometric evaluation. Forced expiratory volume in 1 second (FEV1) was measured by spirometry (Spiro Sift SP-370; Fukuda Denshi Co., Ltd, Tokyo, Japan). Pulmonary function tests were conducted according to the guidelines of the Japanese Respiratory Society. (26)

Evaluation of footwear

A shoe-fit checklist was used to assess the adequacy of subjects' habitual shoes. We told the subjects to wear their most common shoes on the day of the test. The evaluated factors included heel-fit, toe space, width-fit (Width), sole stiffness, the presence or absence of a heel counter (Counter), adjuster type (Adjuster; i.e., lace, Velcro fastening, and zip fastening), and adjusting (Adjusting). We checked their shoes to exclude participants based on the following exclusion criteria: high heels, not covered upper, high-cut shoes, sandals and boots.

Heel-fit was assessed and designated as too loose (Too Loose), loose (Loose) and fit (Fit) at the indicated points. While in a standing position, subjects were asked to raise their heel while the heel region of their shoe was held by the experimenter. The degree of fit between the heel region and the shoe was then assessed. A shoe was considered too loose if it was separated from the inferior of calcaneal bone. A shoe was deemed merely loose if it was separated from the inferior calcaneus at the rear of the insole. A shoe that adhered to the calcaneal region was considered a good fit (Figure 1). Toe space, width, and sole stiffness were assessed with a scale: 1 = loose or soft, 2 = fit, and 3 = tight or hard at the indicated points. Thus, a score of 1 or 3 indicated that a shoe was a poor fit, while a score of 2 indicated a shoe was a good fit. Toe space and width was assessed by palpating the shoe and evaluating the space between the toes and shoe, and between the dorsum of the foot and the shoe. Intra-rater reliability testing of questionnaire responses revealed kappa coefficients consistency over 0.60 (0.75-0.78) for each item, and data ranges suggested the coaches and parents, who had no medical knowledge, could answer with substantial reliability. (27) Sole stiffness was assessed by twisting the shoe. Counters and Adjusters were checked by palpating the shoe. Finally, information on Adjusting was obtained directly from participants by listening “Do you always adjust your adjuster (i.e., lace, Velcro fastening, and zip fastening)?” (Figure 2).

Statistical analyses

The participants were divided into three groups based on heel-fit: Too Loose, Loose, and Fit. Differences between the three groups were assessed using an ANOVA for age, BMI, 10mWT and FEV1; a Kruskal-Wallis test for SWT because SWT score is not normally-distributed; and a chi-square test for gender, and presence or absence of pain sites. The Mann-Whitney test was used for post-hoc analysis of SWT. A multivariate logistic regression model using a stepwise method was performed to examine which measurements of shoe-fit were independently associated with SWT. We assigned SWT as a dependent variable and measurements of shoe-fit as independent variables adjusted by age, gender, BMI, 10mWT, presence or absence of pain cites and FEV1. In addition, a chi-square test was performed to investigate which shoe-fit factors were best associated with exercise tolerance.

A p-value of <0.05 was considered statistically significant for the ANOVA, Kruskal-Wallis test, and the multivariate logistic regression model. A p-value of <0.016 was considered statistically significant for the post-hoc test.

RESULTS

The demographic characteristics of the overall sample and the Too Loose, Loose, and Fit groups are summarized in Table 1. Thirty-one participants were assigned to the Too Loose group, 60 to the Loose group, and 64 to the Fit group. There were no significant differences in age, BMI, 10mWT, FEV1, or presence of pain between the three groups. There was significant difference in gender. Adequate heel-fit was associated with a better SWT score than inadequate heel-fit (Too Loose group = 358.7 ± 68.2 m, Loose group = 401.5 ± 78.6 m, Fit group = 415.9 ± 76.9 m, $p = 0.002$; Table 1). In addition, the Fit group had significantly higher SWT scores than the Too Loose group ($p = 0.001$), and the Loose group had higher SWT scores than the Too Loose group ($p = 0.008$), as indicated by a post-hoc Mann-Whitney test.

The multivariate logistic regression analysis showed that inadequate heel-fit (odds ratio: 0.16, 95% confidence interval: 0.04–0.63, $p = 0.009$) was significantly correlated with a low SWT score, even after adjustments for age, gender, 10mWT, presence or absence of pain cites and FEV1 (Table 2).

The chi-square test showed that a better heel-fit was significantly correlated with better width, better sole stiffness, presence of Counters, presence of Adjusters, and better Adjusting (Table 3, $p < 0.016$).

DISCUSSION

The present study analyzed the relationship between exercise tolerance and shoe fit in community-dwelling elderly individuals. Results showed that heel-fit is associated with exercise tolerance after adjustment for age, gender, foot pain, physical function, and pulmonary function. There is minimal data on the relationship between shoe-fit and physical function, and the present findings indicate that adequate shoe-fit is associated with exercise tolerance.

We considered that heel-fit has been demonstrated to influence walking efficacy in exercise tolerance tests. Adequate shoe-fit is associated with faster walking speed (20, 28) and better gait performance. (28) In our study, there was no significant in 10mWT between three groups. However, three groups' results showed a trend similar to SWT's results. We considered that shoe-fit, particularly heel-fit, is not influence to walking speed, but to walking test walked long distance. Thus, an adequate heel-fit may enhance the efficiency of walking with each cycle, and support elderly people. Further, heel-fit may influence walking to a greater degree over a prolonged period. It follows that well-fitting shoes may improve exercise tolerance in elderly people. In contrast, we can produce a mindset that people who have inadequate fit shoes are walking at a much slower pace and shorter distances. It is unclear that whether adequate shoe-fit enhances exercise tolerance or whether inadequate shoe-fit negatively affects exercise tolerance. However, it is important for elderly people to wear adequate fit shoes in order to enhance physical functions or prevent from declining physical functions and foot problem.

In addition, we demonstrated that heel-fit is associated with Width, sole stiffness, Counter, Adjuster, and Adjusting. Previous reports have suggested that sole stiffness affects balance (29, 13). Adequate shoe-fit also depends on the adhesion of both the calcaneal region of the foot and anterior ankle to the heel-counter and adjuster of shoes. Furthermore, suitable shoe width decreases foot movement within the shoes. Thus, these elements of shoe-fit may influence heel-fit. In this study, toe space did not influence heel-fit. This may have resulted from the fact that the majority of participants wore shoes with appropriate toe space, similar to a previous study. (11) Taken together, results of the present study indicate that external contributing factors, such as shoe-fit, may sufficiently be associated with exercise tolerance.

This study had several limitations. First, because this study used a cross-sectional design, further investigation of certain matters, such as whether wearing suitable shoes for an extended period can improve SWT scores and other physical functions, is needed. Also, because direction of causality is unclear, it is unknown which well-fitting affects exercise tolerance or people who have much exercise tolerance wear well-fitting shoes. Second, a thorough survey of foot complications such as bunion, hammer toe, high/low arch, and neuropathy and shoe type which can affect the exercise tolerance level was not performed. Due to these limitations, the results of the present study should be interpreted with caution.

CONCLUSION

Results of the present study showed a significant relationship between exercise tolerance and heel-fit. This finding indicates that shoe-fit may positively influence physical function.

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Table 1. Comparison of demographic characteristics and measurements between Overall, Too Loose, Loose, and Fit groups.

	Overall (n=155)	Too Loose (n=31)	Loose (n=60)	Fit (n=64)	P value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Age †	73.6 ± 4.4	74.9 ± 4.7	73.4 ± 4.0	73.2 ± 4.6	0.183
BMI †	23.1 ± 2.7	23.4 ± 2.5	23.0 ± 2.2	22.9 ± 3.3	0.714
10m walking time test †	7.4 ± 1.1	7.6 ± 1.3	7.5 ± 0.9	7.2 ± 1.1	0.103
FEV1 †	2.0 ± 0.6	1.7 ± 0.6	2.0 ± 0.6	2.0 ± 0.6	0.052
Shuttle walking test ††	399.0 ± 78.3	358.7 ± 68.2	401.5 ± 78.6	415.9 ± 76.9	0.002
	n (%)	n (%)	n (%)	n (%)	
Female gender, n (%) †††	81 (52.3%)	23 (74.2%)	30 (50.0%)	28 (43.8%)	0.019
Pain, n (%) †††	37 (23.9%)	11 (35.5%)	15 (25.0%)	11 (17.2%)	0.14
Hallux valgus, n (%) †††	36 (23.2%)	8 (25.8%)	16 (26.7%)	12 (18.8%)	0.54
Bunionette, n (%) †††	11 (7.0%)	3 (9.6%)	4 (6.7%)	4 (6.3%)	0.82

Note: BMI=Body Mass Index, FEV1= Forced expiratory volume in 1 second

†ANOVA, ††Kruskal Wallis test, †††$\chi 2$ test

1 **Table 2. Multivariate logistic regression model using a stepwise method to determine the**

2 **SWT association**

	Odds Ratio	95%CI	P value
Heel fitting			0.023
Too Loose	0.16	(0.04 - 0.63)	0.009
Loose	0.94	(0.38 - 2.33)	0.90
Fit	1 [reference]	1 [reference]	-
Toe-space	-	-	not significant
Width	-	-	not significant
Sole-stiffness	-	-	not significant
Counter	-	-	not significant
Adjuster	-	-	not significant
Adjusting	-	-	not significant

Adjusted by age, gender, BMI, 10m walking time, pain and FEV1

Note: BMI=Body Mass Index, FEV1= Forced expiratory volume in 1 second

3

Table 3. Associations between heel-fit and each shoe-fit measurement

	Too Loose (i)	Loose (ii)	Fit (iii)	P value	*Post hoc*
		Proper (percent in each group)			
Toe-space	26 (83.9%)	58 (96.7%)	59 (92.2%)	not significant	-
Width	3 (10.7%)	25 (41.7%)	34 (53.1%)	p<0.001	i < ii , iii
Sole-stiffness	8 (25.8%)	28 (46.7%)	40 (62.5%)	p=0.004	i < iii
Counter	7 (22.6%)	33 (55.0%)	32 (50.0%)	p=0.01	i < ii , iii
Adjuster	13 (41.9%)	50 (83.3%)	52 (81.3%)	p<0.001	i < ii , iii
Adjusting	1 (3.2%)	13 (21.7%)	19 (29.7%)	p=0.013	i < iii

Figure 1

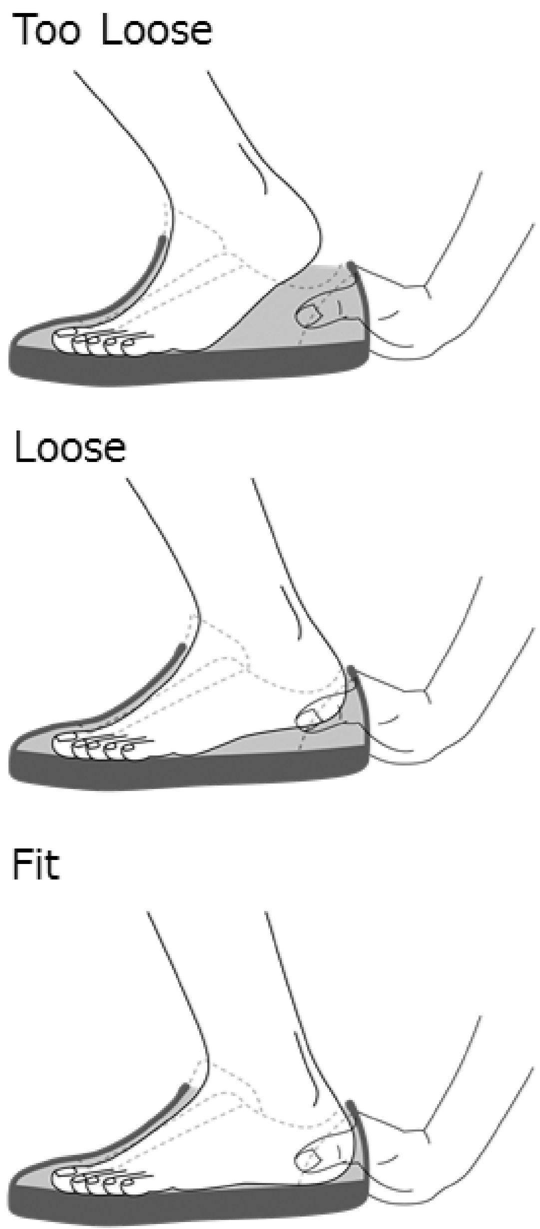

Figure 2