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Original Research

Increasing Physical Activity Might Be More Effective to Improve Foot Structure and Function Than Weight Reduction in Obese Adults

Xiaoguang Zhao, PhD [1], Takehiko Tsujimoto, PhD [2], Bokun Kim, PhD [3,4], Yasutomi Katayama, PhD [5], Kiyoji Tanaka, PhD [6]

[1]*Staff, Research Academy of Grand Health, Faculty of Sport Science, Ningbo University, Zhejiang, China*
[2]*Lecturer, Faculty of Human Sciences, Shimane University, Shimane, Japan*
[3]*Staff, Faculty of Sports Health Care, Inje University, Gimhae, Korea*
[4]*Staff, Faculty of Foundation for Industry-Academy Cooperation, Dong-A University, Pusan, Korea*
[5]*Associate Professor, Faculty of Education, Kogakkan University, Ise, Mie, Japan*
[6]*Professor, Faculty of Health and Sport Sciences, University of Tsukuba, Ibaraki, Japan*

A R T I C L E I N F O

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A B S T R A C T

Obesity is reported to be an important factor affecting foot structure and function. For obese individuals, weight reduction or increasing weight physical activity could be an effective approach to improve foot structure and function. The present study sought to determine the effect of weight reduction and increasing physical activity on foot structure and function in obese Japanese and to investigate which intervention is more beneficial. The participants were divided into the weight reduction group (n = 30; body mass index 29.0 ± 2.5 kg/m^2), with the intervention consisting of dietary modification, and the increasing physical activity group (n = 15; body mass index 28.2 ± 3.1 kg/m^2), with the intervention consisting of walking and jogging. A 3-dimensional foot scanner was used to measure the foot anthropometric data with the participants both sitting and standing. The dorsum height declined and the arch stiffness index increased after the weight reduction intervention, and the truncated foot length decreased and the arch stiffness index increased after the increasing physical activity intervention ($p < .05$). The arch height index showed a downward trend after the weight reduction intervention ($p = .060$) and an upward trend after the increasing physical activity intervention ($p = .069$). Moreover, a greater change was found in the increase of the dorsum height and arch height index and decrease of the truncated foot length in the increasing physical activity group than in the weight reduction group ($p < .05$). These findings suggest that increasing physical activity might be more effective to improve foot structure and function than weight reduction in obese adults.

Foot disorders that weaken foot function have been documented to affect ~24% of those aged >45 years (1) and 42% of those aged >60 years (2). A number of studies have shown that foot structure and function are related to obesity (3–5). It also has been reported that foot structure and function play important roles in balance, gait, and daily physical activities in obese individuals (6), which could decrease their overall health-related quality of life and thus increase the morbidity of obesity (7).

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Address correspondence to: Xiaoguang Zhao, PhD, Research Academy of Grand Health, Faculty of Sport Science, Ningbo University, No. 818 Fenghua Road, Ningbo, Zhejiang 315211, China.

E-mail address: xiaoguangzhao1985@gmail.com (X. Zhao).

The association of obesity with foot function can be explained by the changed foot structure and decreased foot and ankle muscle strength in obese individuals. A previous study showed that the excess body weight results in collapse of the medial longitudinal arch, which can adversely influence the functional capacity of the foot (8). Moreover, it is known that obesity is always accompanied by lowered muscle strength. It has been reported that obesity is associated with ankle instability and poor walking ability (9,10) and that foot and ankle muscle strength is a strong predictor of ankle stability and walking ability (11). Although no direct evidence has been reported to date, indirectly, research has shown that obesity is associated with lowered foot and ankle muscle strength.

For obese individuals, weight reduction or increasing weight physical activity could be an effective approach, not only to decrease the risk of health-related diseases (12,13), but also to affect positively the foot structure and function (14). However, to the best of our

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knowledge, no systematic study of the effect of weight reduction and increasing physical activity on foot function in obese individuals has been performed to date. Therefore, the aims of our study were to determine the effect of weight reduction and increasing physical activity on foot structure and function in obese adults and to investigate which intervention is more effective.

Materials and Methods

The participants were recruited through advertising in local newspapers in Tsukuba City, Ibaraki Prefecture, Japan in May 2015. They were selected for the present study if they had a body mass index (BMI) >25 kg/m^2 in accordance with the Japanese obesity guidelines (15), had no exercise habit (not >150 minutes of moderate to vigorous activity weekly), and had no current or previous foot and ankle disorders or other neuromuscular or musculoskeletal disorders. Initially, 51 volunteers were recruited and divided into 2 groups, with 32 individuals in the weight reduction group and 19 in the increasing physical activity group, relying on their self-selection. A weight reduction program mainly composed of dietary modification and an increasing physical activity program mainly composed of walking and jogging were performed for 12 weeks. However, 2 participants in the weight reduction group and 4 in the increasing physical activity group did not complete the intervention programs for personal reasons, leaving 30 participants in weight reduction group and 15 in the increasing physical activity group. Before the beginning of the intervention programs and tests, all the participants were asked to read and sign a written informed consent form. The human ethics board of the University of Tsukuba approved the present study, which complied with the Declaration of Helsinki.

Foot anthropometric data were measured with the participants both sitting and bipedal standing positions using a 3-dimensional foot scanner (FSN-2100; Dream GP Inc., Osaka, Japan; Fig. 1). Of the many obtained parameters, the arch height index and arch stiffness index are comprehensive indicators for assessing function of the arch and foot. The arch height index is defined as the dorsum height divided by the truncated foot length (Fig. 2), which was developed by Williams and McClay (16). The arch stiffness index is defined as the ratio of the standing and sitting arch height index, which was introduced by Richards et al (17). An arch height index close to 0 represents a lower arch, and an arch stiffness index close to 1 indicates a stiffer arch.

The weight reduction program consisted of dietary modification. The participants met 1 time each week (90 minutes per session) with our work team and were instructed to restrict their energy intake to ~1680 kcal/day for males and 1200 kcal/day for females. The purpose of the dietary modification intervention was to help participants obtain a nutritionally well-balanced daily diet. Our work team has instructed patients in this diet for >20 years. Our experience over many years has shown the weight reduction program to be safe and very effective in reducing weight and helping participants to form healthy dietary habits. More detailed information about the dietary modification intervention has been reported previously by our laboratory (18).

The increasing physical activity program constituted a 90-minute session, 3 times each week for 12 weeks. Each session mainly consisted of a 15-minute warm-up and stretching portion, 60 minutes of brisk walking and jogging, followed by a 15-minute cool-down and stretching session. During the first 4 weeks, the exercise intensity was set at 50% to 60% of maximal heart rate and gradually increased afterward. The participants were exercising at 60% to 70% of their maximal heart rate for the final 4 weeks. On rainy days, indoor exercise was performed using stationary cycling or stair-stepping. Several experienced exercise instructors and principal investigators were responsible for the increasing physical activity program. In addition to the exercise in the physical activity sessions, these participants were also encouraged to perform their preferred type of physical activity at home or workplace as much as possible.

Considering the independence of assumption of statistical analysis, only the right-side anthropometric data were measured for the main analyses. The paired-samples test was used to determine the change in the foot structure and function parameters before and after the weight reduction and increasing physical activity interventions. Next, the change in the differences in the foot structure and function between the weight reduction group and increasing physical activity group were tested using the independent samples test. For data analysis, $p < .05$ was considered to indicate statistical significance. The data were analyzed using the Statistical Package for Social Sciences, version 22.0 (IBM Corp., Armonk, NY).

Fig. 1. The 3-dimensional foot scanner.

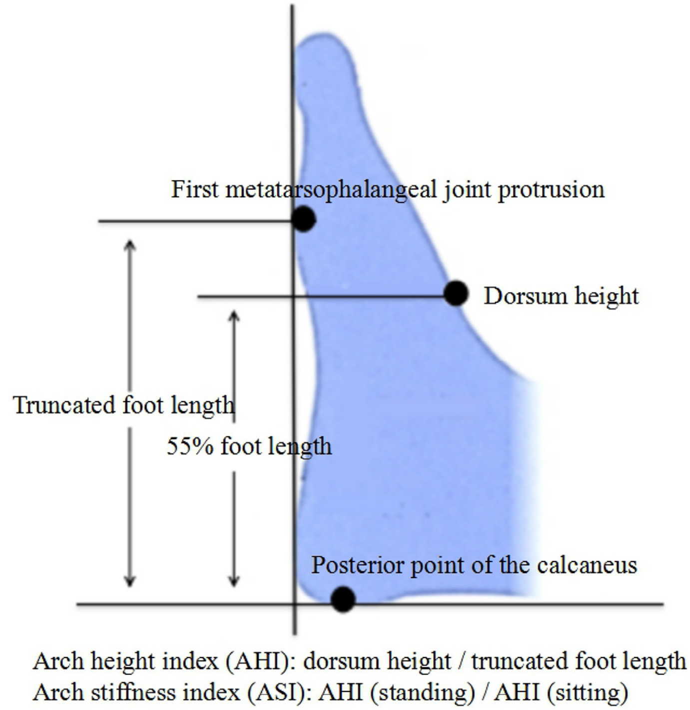

Fig. 2. Diagram showing the arch height index and arch stiffness index.

Results

No significant differences were found in the anthropometric variables, such as age and BMI, between the weight reduction group and increasing physical activity group ($p > .05$) at baseline (Table 1). The

Table 1
Participant characteristics at baseline

Characteristic	WR	IPA	*p* Value
Participants (n)	30	15	NA
Gender			NA
Male	20 (67%)	10 (67%)	
Female	10 (33%)	5 (33%)	
Age (y)	52.1 ± 10.3	54.2 ± 7.1	.44
Height (cm)	165.4 ± 8.2	167.7 ± 9.3	.43
Weight (kg)	79.6 ± 12.3	79.2 ± 10.8	.90
BMI (kg/m^2)	29.0 ± 2.5	28.2 ± 3.1	.40

Abbreviations: BMI, body mass index; IPA, increasing physical activity; WR, weight reduction.