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Effects of weight loss on foot structure and function in obese adults: A pilot randomized controlled trial

Jinsup Song [a,*], Reagan Kane [a], Dana N. Tango [a], Stephanie S. Vander Veur [b], James Furmato [a], Eugene Komaroff [c], Gary D. Foster [b]

[a] Gait Study Center, Temple University School of Podiatric Medicine, 148 N 8th St., 2nd Floor, Philadelphia, PA 19107-2496, United States
[b] Center for Obesity Research and Education, Temple University School of Medicine, 3223 N. Broad Street, Suite 175, Philadelphia, PA 19140, United States
[c] Biostatistical Support Research Center, Temple University, College of Health Professions and Social Work, 1301 Cecil B. Moore Avenue, 939 Ritter Annex, Philadelphia, PA 19122, United States

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ABSTRACT

Objective: To investigate the effects of weight reduction on foot structure, gait, and dynamic plantar loading in obese adults.
Design: In a 3-month randomized-controlled trial, participants were randomized to receive either a weight loss intervention based on portion-controlled meals or a delayed-treatment control.
Participants: 41 adults (32 F, 9 M) with a mean ± SD age of 56.2 ± 4.7 years and a BMI of 35.9 ± 4.2 kg/m^2.
Measurements: Arch Height Index (AHI), Malleolar Valgus Index (MVI), spatial and temporal gait parameters, plantar peak pressure (PP) and weight were measured at baseline, 3, and 6 months.
Results: The intervention group experienced significantly greater weight loss than did the control group (5.9 ± 4.0 kg versus 1.9 ± 3.2 kg, p = 0.001) after 3 months. There were no differences between the groups in anatomical foot structure or gait. However, the treatment group showed a significantly reduced PP than the control group beneath the lateral arch and the metatarsals 4 (all p values < .05) at 3 months. The change in PP correlated significantly with the change in weight at the metatarsal 2 (r = 0.57, p = 0.0219), metatarsal 3 (r = 0.56, p = 0.0064) and the medial arch (r = 0.26, p < 0.0001) at 6 months.
Conclusion: This was the first RCT designed to assess the effects of weight loss on foot structure, gait, and plantar loading in obese adults. Even a modest weight loss significantly reduced the dynamic plantar loading in obese adults. However, weight loss appeared to have no effects on foot structure and gait.

1. Introduction

Over two thirds of Americans are at least overweight and one third is obese [1]. Globally, obesity has nearly doubled since 1980 [2]. In addition to being a major risk factor for heart disease, diabetes, diminished quality of life, and increased mortality, obesity can have a profound impact on mobility [3,4].

Obesity accelerates the progression of knee osteoarthritis in the presence of moderate knee malalignment [5–9]. Based on a systematic review of 25 studies, Butterworth and colleagues noted an association between higher body mass index (BMI) and higher rates of chronic heel pain, non-specific foot pain, and tendonitis [10]. Population-based studies suggest that the prevalence of significant foot pain is about 20% [11,12]. Foot pain was associated with age (50 years or older), gender (female), obesity, and presence of other pain (knee, hip, and lower back pain) [11]. Increased forces and aberrant foot biomechanics may explain the association between obesity and foot pain. A case–controlled study of 80 subjects with chronic heel pain syndrome and 80 age- and gender-matched control subjects found that those with chronic heel pain syndrome were three times more likely to be obese and four times more likely be flatfooted [13].

Studies have shown significant differences in gait and plantar loading between obese and normal weight individuals. A three dimensional gait analysis of obese young Chinese adults revealed that the stride length was significantly shorter and the stance phase and the double support phase of gait were significantly longer in obese (n = 14 with mean age of 35.4 years and BMI of 33.1 kg/m^2) than in normal-weight (n = 14 with mean age of 27.6 years and BMI of 21.3 kg/m^2) group [14]. A number of other

* Corresponding author. Tel.: +1 215 625 5369; fax: +1 215 629 0278.
E-mail address: jsong@temple.edu (J. Song).

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cross-sectional studies showed that plantar pressure was higher in obese subjects compared to non-obese controls, both in standing and walking conditions [15–18].

To date, all published studies examining the relationship between obesity and plantar pressure have been cross sectional and associative. No studies have prospectively examined the effects of weight change on foot structure and function in a randomized controlled trial (RCT). Such data are need to better elucidate the relationship between body weight and lower extremity biomechanics and to inform patients and practitioners whether weight loss can be expected to improve foot structure and function. Therefore, this exploratory RCT was conducted to objectively examine the effects of weight loss on foot structure, temporal and spatial gait parameters, and dynamic plantar loading in obese adults.

2. Subjects and methods

2.1. Participants

Participants were 41 persons (32 women, 9 men) with a mean ± SD age of 56.2 ± 4.7 years and a BMI of 35.9 ± 4.2 kg/m^2 (Table 1). Inclusion criteria were ages 50–75 years, BMI of 30–45 kg/m^2, and body weight of less than 136 kg (due to limitation of optical foot scanner). Participants were excluded if they had any of the followings: diabetes, uncontrolled hypertension (defined as a blood pressure > 180/100 mmHg), uncontrolled dyslipidemia (triglycerides > 500 mg), established cardiovascular disease or an inflammatory condition, participated in another formal weight loss program within past 6 months, history of using weight-loss inducing medications or dietary supplements within 6 months prior to enrollment, weight loss > 5 kg during the last 6 months, history of surgical or device treatment for obesity, history of alcohol or drug abuse, smoker or tobacco users, major mood disorder, unable to ambulate safely without the use of walking aid, or were unable or unwilling to eat pre-packaged meals. Those with history of surgery on the back, hips, knees, ankles, or feet were also excluded. Baseline characteristics of the sample are described in Table 1.

Participant flow for this study is shown in Fig. 1. Participants who appeared, via scripted phone screen, to meet eligibility requirements were scheduled to meet with research staff. The staff described the study's nature and requirements, assessed suitability for participation, and obtained written informed consent. Temple University's Institutional Review Board approved the protocol.

2.2. Design

Participants were randomly assigned, via stratified randomization procedure based on their BMI (30–39 and 40–45), to either a 3-month weight loss intervention or a delayed treatment control as described below. After 3 months, the control group received a weight loss intervention and the intervention group continued the same weight loss intervention. Postural foot structure, gait, and dynamic plantar pressure in gait were assessed on all participants at baseline, at end of 3 months and 6 months. Primary comparison was at 3 months.

2.2.1. Treatment group (N = 21)

An experienced group leader (MPH or RD) provided educational sessions in groups of 8–11 participants. Educational sessions consisted of materials specific to making behavioral changes toward weight loss and weight maintenance. Participants received information on diet, exercise, nutrition and related topics. Participants were prescribed energy intakes of 1200–1500 kcal/d

Table 1
Baseline characteristics and change at 3-months.

Parameters, baseline and change at 3 months	Control		Treatment		*p*-value
	Mean	SE	Mean	SE	
Age (years)	56.25	1.29	56.24	0.80	0.9937
N (female)	20 (15)		21 (17)		0.7186
Race: White/Black/Hispanic	7/12/1		7/13/1		0.9922
Education: HS/College/Grad	8/6/6		8/7/6		0.7664
Body weight (kg)	99.45	3.77	99.67	2.80	0.9632
Δ Body weight (kg)	-1.89	-0.81	-5.93	-0.78	0.001
Body mass index (kg/m^2)	35.77	0.89	36.12	0.99	0.7939
Δ BMI (kg/m^2)	−0.66	−0.29	−2.15	−0.29	0.0008
Malleolar Valgus Index (%)	12.96	1.29	14.95	1.37	0.2982
Δ MVI (%)	0.08	−0.65	−1.16	−0.63	0.0376
Arch Height Index, sitting	0.35	0.01	0.34	0.01	0.3876
Δ AHI sitting	0.00	0.00	−0.01	0.00	0.2928
Arch Height Index, standing	0.32	0.01	0.31	0.01	0.592
Δ AHI standing	0.00	0.00	0.00	0.00	0.6933
Arch height flexibility (mm/kN)	12.62	1.01	11.54	1.02	0.4555
Δ AHF (mm/kN)	1.29	−0.91	−0.62	−0.89	0.1424
Walking speed (m/s)	0.96	0.18	0.96	0.16	0.9276
Δ Speed (m/s)	0.06	−0.02	0.04	−0.02	0.3681
Stride length (m)	1.100	0.120	1.030	0.250	0.2524
Δ Stride length (m)	0.040	−0.019	0.051	−0.018	0.6981
Support base (m)	0.24	0.06	0.23	0.05	0.8606
Δ Support base	0.003	−0.005	−0.019	−0.005	0.0017
Double support time (s)	0.019	0.006	0.011	0.006	0.3418
Δ Double support time	−0.038	−0.015	−0.021	−0.010	0.2672
Stance phase (%, gait cycle)	61.84	0.34	62.65	0.42	0.3985
Δ Percent stance	−1.17	−1.47	1.80	−1.43	0.1558
Cadence (steps/min)	104.14	1.91	106.84	2.36	<0.0001
Δ Cadence (steps/min)	2.80	−1.14	0.07	−1.11	0.1970

Analysis was limited to left foot only. Mean and SE at baseline and the mean change and SE at 3 months from the baseline are shown. Negative numbers indicate a decrease at 3-months. Malleolar Valgus Index (MVI) is a measure of hindfoot valgus alignment in resting stance. Arch Height Index (AHI) is the ratio of arch height at half the foot length and the truncated foot length – distance from the heel to the first metatarsal phalangeal joint. Arch height flexibility (mm/kN) is defined as (arch height in sitting − arch height in standing)/(body weight × 0.4)