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Obese older adults suffer foot pain and foot-related functional limitation

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Publication Details

Mickle, K. J. & Steele, J. R. (2015). Obese older adults suffer foot pain and foot-related functional limitation. *Gait and Posture*, 42 (4), 442-447.

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Obese older adults suffer foot pain and foot-related functional limitation

Abstract

There is evidence to suggest being overweight or obese places adults at greater risk of developing foot complications such as osteoarthritis, tendonitis and plantar fasciitis. However, no research has comprehensively examined the effects of overweight or obesity on the feet of individuals older than 60 years of age. Therefore we investigated whether foot pain, foot structure, and/or foot function is affected by obesity in older adults. Three hundred and twelve Australian men and women, aged over 60 years, completed validated questionnaires to establish the presence of foot pain and health related quality of life. Foot structure (anthropometrics and soft tissue thickness) and foot function (ankle dorsiflexion strength and flexibility, toe flexor strength, plantar pressures and spatiotemporal gait parameters) were also measured. Obese participants (BMI >30) were compared to those who were overweight (BMI = 25-30) and not overweight (BMI <25). Obese participants were found to have a significantly higher prevalence of foot pain and scored significantly lower on the SF-36. Obesity was also associated with foot-related functional limitation whereby ankle dorsiflexion strength, hallux and lesser toe strength, stride/step length and walking speed were significantly reduced in obese participants compared to their leaner counterparts. Therefore, disabling foot pain and altered foot structure and foot function are consequences of obesity for older adults, and impact upon their quality of life. Interventions designed to reduce excess fat mass may relieve loading of the foot structures and, in turn, improve foot pain and quality of life for older obese individuals.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

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Obese older adults suffer foot pain and foot-related functional limitation

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ABSTRACT

There is evidence to suggest being overweight or obese places adults at greater risk of developing foot complications such as osteoarthritis, tendonitis and plantar fasciitis, however, no research has comprehensively examined the effects of overweight or obesity on the feet of individuals older than 60 years of age. Therefore we investigated whether foot pain, foot structure, and/or foot function is affected by obesity in older adults. 312 Australian men and women, aged over 60 years, completed validated questionnaires to establish the presence of foot pain and health related quality of life. Foot structure (anthropometrics and soft tissue thickness) and foot function (ankle dorsiflexion strength and flexibility, toe flexor strength, plantar pressures and spatiotemporal gait parameters) were also measured. Obese participants (BMI >30) were compared to those who were overweight (BMI = 25-30) and not overweight (BMI <25). Obese participants were found to have a significantly higher prevalence of foot pain and scored significantly lower on the SF-36. Obesity was also associated with foot-related functional limitation whereby ankle dorsiflexion strength, hallux and lesser toe strength, stride/step length and walking speed were significantly reduced in obese participants compared to their leaner counterparts. Therefore, disabling foot pain and altered foot structure and foot function are consequences of obesity for older adults, and impact upon their quality of life. Interventions designed to reduce excess fat mass may relieve loading of the foot structures and, in turn, improve foot pain and quality of life for older obese individuals.

Key words: Aging; pain; foot; ultrasound; muscle strength

Abbreviations: BMI: body mass index; CI: confidence interval; MPFDI: Manchester Foot Pain and Disability Index; SF-36: 36-Item Short Form Health Survey

INTRODUCTION

The prevalence of obesity is rising at an alarming rate worldwide. The elderly are no exception with up to 42% of men and women aged over 60 years classified as obese[1, 2]. As the number of elderly people is rapidly increasing and the negative health consequences of obesity are numerous and well documented[3], it is imperative that interventions aimed at combating obesity are developed and implemented. It has been suggested that the difference between the current upward trend in obesity and a downward trend could be as simple as an additional 3-minute walk per day[4]. However, interventions targeted at older individuals, are often confounded by pain or diseases affecting the musculoskeletal system which can be a barrier to older people participating in physical activity[5].

The feet are the base of support of the musculoskeletal system during most physical activities. Although feet that are structurally sound can perform daily tasks with ease, deviations from normal foot structure can compromise foot function and, in turn, cause discomfort and/or pain[6]. Extensive research has confirmed that overweight and obesity negatively affect foot structure and function in children, whereby obese children have been found to have flatter feet and generate significantly higher plantar pressures during walking relative to non-overweight children[7-13]. High plantar pressures, which describe the potential damaging effects of increased load on the plantar tissues[14], have been found to correlate with reduced physical activity and more time spent in sedentary behaviour, possibly due to foot pain and discomfort experienced during weight-bearing activities[15]. Furthermore, high plantar pressures in older people have been found to be associated with a higher incidence of foot pain and a greater risk of falling[16].

Although there is some evidence to suggest being overweight or obese places adults at greater risk of developing foot complications such as osteoarthritis, tendonitis and plantar fasciitis[17], there is only limited research investigating the effects of obesity on the feet of adults[18, 19]. No research has comprehensively examined the effects of overweight or obesity on the feet of older individuals (i.e >60 years).

Given the role of feet as the base of support during weight-bearing activities, it would seem logical that foot pain or alterations to foot structure and function as a result of bearing excessive mass would be associated with gait changes in obese individuals, although this notion remains unexplored. Therefore, the purpose of this study was to determine whether obese older adults report a greater incidence of foot pain and display significant changes in foot structure and function compared to non-overweight older individuals. We hypothesized

that obese older adults would report a greater incidence of foot pain and display significant changes in foot structure and function compared to non-overweight older individuals. Obesity affected foot structure and function resulting in foot pain is a potential deterrent to participate in physical activity, deeming it a major health issue for older people.

METHODS

158 men and 154 women aged 60-90 years were randomly recruited via the electoral roll using methods previously described[20]. Briefly, all participants were independently-living and ambulatory, but were excluded if they had neurological diseases or cognitive impairment. Each participant gave written informed consent before any testing commenced. The University's Human Research Ethics Committee (HE05/169) approved all recruiting and testing procedures.

Each participant's height and mass was measured using a portable stadiometer and electronic scales, respectively, as they stood with their shoes, socks and any heavy outer clothing removed. Body Mass Index (BMI) for each participant was calculated by dividing body mass by height squared (kg/m^2). Participants were classified as obese ($\text{BMI} > 30$), overweight ($25 < \text{BMI} < 30$) or not overweight ($\text{BMI} < 25$) [28] to obtain three groups for comparison.

Foot pain and health status

Foot pain was assessed using the Manchester Foot Pain and Disability Index (MFPDI)[21]. A conservative classification of foot pain was used, whereby participants who marked at least one item as 'on most/every day(s)' were deemed to suffer disabling foot pain[22, 23]. Each participant completed the 36-Item Short Form Health Survey (SF-36)[24]. The answers were numerically coded and combined to give scores for each health concept and a total SF-36 score out of 100, with a lower score indicating poorer health.

Foot structure

Musculoskeletal structure: Foot anthropometrics were measured using a three-dimensional foot scanner (I-Ware, Japan). Seventeen measurements (see Table 2), including lengths, widths, heights, circumferences and angles[25], were obtained and foot anthropometrics (excluding angles) were normalised to foot length to allow later comparisons between feet of different lengths.

Soft tissue thickness: Thickness of the soft tissue and plantar fat pad at the heel, midfoot and

the 1st and 5th metatarsal heads of each foot were measured using a ultrasound system (SonoSite) with a 38 mm broadband linear array transducer (10-5 MHz) to characterize the cushioning properties of the plantar surface[26].

Foot-related function

Strength: Maximum isometric dorsiflexion strength was recorded using a spring balance attached to a metal platform as each participant dorsiflexed their foot at the ankle over three trials[23, 27]. Hallux and lesser toe flexor strength were measured using an emed pressure platform (Novel, Germany) which is described elsewhere[20]. Briefly, participants were instructed to push down on the platform as hard as possible under two conditions: using only their hallux or using all their toes. To counteract the effects of gravity in the standing test, force was normalised to body weight to represent maximum hallux and lesser toe flexor strength (% BW).

Flexibility: Ankle dorsiflexion flexibility was measured using a modified lunge test[23, 27], whereby the minimum angle (i.e. the greatest range) measured by a goniometer was recorded for three trials.

Gait: The spatial and temporal gait characteristics were measured using a GAITRite[®] mat (CIR Systems, Inc; USA). Participants were instructed to “*walk at a comfortable pace, as if you were walking down the street*”. Each participant completed 10-15 walking trials, with walking speed, stride length, step length and width and time spent in the swing, stance, single support and double support phases of the gait cycle averaged across the trials. The plantar pressures generated underneath each participant’s feet while they walked over a pressure platform (emed AT-4, Novel, Germany) were assessed to represent barefoot dynamic foot function. To minimise fatigue and limit participant burden, the 2-step method was used as described elsewhere[16]. The footprints were divided into 10 masks, based around the following anatomical landmarks: heel, midfoot, 1st metatarsal, 2nd metatarsal, 3rd metatarsal, 4th metatarsal, 5th metatarsal, hallux, 2nd toe and toes 3-5. The footprints were analysed to determine total force and area as well as the peak pressure (the highest pressure value recorded by a single sensor) across the total foot and in each of the masked areas. Data were analyzed for each participant’s right foot to ensure the assumption of data independence was met, and averaged across five trials.

Statistical analysis

Chi-square tests were conducted to compare categorical variables (gender, presence of foot pain) among the three participant groups. Analysis of covariance tests were then used to

determine whether there were any significant differences in the SF-36 scores and foot structure and function variables between the three participant groups, with gender entered as a covariate due to the disproportionate percentage of men and women in the participant categories. Bonferroni pairwise comparisons of main effects were used. An alpha of $p \leq 0.05$ was established for all statistical analyses, which were conducted using SPSS software (Version 19).

RESULTS

Obesity prevalence

105 (34%) participants were identified as obese (BMI >30) and 128 (41%) were overweight (25 < BMI < 30)[28]. Seventy-nine individuals (25%) had a BMI less than 25 and were therefore classified as not overweight (Table 1). The distribution of genders differed significantly between the three groups whereby there were a higher proportion of men in the overweight group (63.3%), whereas the non-overweight group had a higher percentage of women (62%).

Foot pain and health status

Obese participants had a significantly higher prevalence of disabling foot pain (40%) than overweight (23.4%) and non-overweight participants (11.4%; Chi-squared test; $p < 0.001$). The proportion of overweight participants reporting disabling foot pain was also significantly higher than the non-overweight participants. In the Physical Health dimension of the SF-36, the obese participants had a significantly lower adjusted mean score (95% CI) [65 (62-69)] compared to the overweight [73 (70-77)] and non-overweight participants [74 (70-78)] ($p = 0.001$). Conversely, the adjusted mean score of the Mental Health dimension of the obese group [75 (72-78)] did not differ from either the overweight [79 (76-81)] or non-overweight group [79 (76-83)] ($p = 0.1$). However, the total SF-36 score was significantly lower in the obese group [71 (68-75)] compared the overweight [77 (74-80)] and non-overweight participants [78 (74-82)] ($p = 0.006$). The overweight and non-overweight participants did not differ significantly on any of the SF-36 scores.

Foot structure

Musculoskeletal structure: Obese participants had significantly longer feet than the overweight participants (adjusted means [95% CI] 259 mm [257-262] vs 255 mm [253-258]). A comparison of the foot dimensions, normalised to foot length, between the three participant

groups is displayed in Table 2, whereby the obese foot differed on eight of the 17 foot dimensions. Although not statically significant ($p=0.07$), navicular height was on average 1.5 mm lower in the obese participants compared to the non-overweight participants.

Soft tissue thickness: The obese group displayed significantly greater tissue thicknesses at all sites except for soft tissue at the 1st metatarsal head (Figure 1) when compared to the non-overweight group. Tissue thickness of the obese group was also significantly greater than the overweight group at the 1st metatarsal fat pad, midfoot, heel soft tissue and heel fat pad. Additionally, the overweight group had thicker soft tissue and fat pad at the 5th metatarsal head and heel when compared to the non-overweight group.

Foot-related Function

Obese participants had significantly reduced flexor strength of the hallux and lesser toes when compared to the overweight and non-overweight participants (Table 3). However, neither ankle dorsiflexion strength nor flexibility differed between any of the participant groups ($p>0.5$; Table 3).

Most spatiotemporal variables characterizing the gait of the obese participants differed from the overweight and non-overweight participants. Stride and step lengths were significantly shorter in the obese participants, resulting in a walking speed that was 11 cm/s slower than their non-overweight and overweight counterparts ($p<0.001$; Table 3). Obese participants also had a greater step width and spent more time in the stance and double support phases and less time in swing and single support phases of the gait cycle than the overweight and non-overweight groups (Table 3). The overweight group, generally did not statistically differ from the non-overweight group in the spatiotemporal gait variables with the exception of support time.

Obese participants generated significantly greater total force across the foot when walking than their overweight and non-overweight counterparts, but this higher force was distributed over a significantly greater contact area. Similarly, the total force and contact area was also significantly greater across the whole foot of the overweight group compared to the non-overweight group.

Consistent with the slower walking speed of the obese group, the total contact time was significantly increased for the obese participants (881 ms) compared to the non-overweight

group (840 ms) and the overweight group (830 ms; $p<0.01$). The obese group generated significantly increased peak pressure at the midfoot compared to both the overweight and non-overweight groups and this pressure was also significantly increased in the overweight group compared to the non-overweight group (Figure 2). The peak pressure was significantly increased in the obese group compared to the non-overweight group at the 1st metatarsal region compared to the overweight group.

DISCUSSION

This study comprehensively highlights the effects of obesity on foot structure and function, as well as the disabling foot pain suffered by community-dwelling older adults. Of concern was the finding that almost two-thirds of the obese participants reported foot pain, with 40% classified as having disabling foot pain. It is possible that foot pain severity was reflected in the SF-36 scores, whereby obese participants had a significantly lower total score, with the physical health dimension being the domain that was limiting their health-related quality of life. Foot pain has been shown to impair balance and functional ability in older people [23, 29] and may deter older individuals from being physically active, in turn, perpetuating the cycle of obesity. In fact “*pain*” has been found to be a constraint on physical activity in older people [30], however specific body regions were not categorized. It is likely that the changes to foot structure and function noted for the obese participants, contributed to their increased incidence of foot pain.

Structurally, the obese older foot was characterized by larger, thicker and broader foot dimensions relative to their leaner counterparts. From a functional perspective, this is the first published study to investigate an association between foot muscle strength and obesity, revealing that obese participants had weaker toe flexor muscles than their overweight and non-overweight counterparts. This muscle weakness, however, was not evident at the ankle, as there were no significant differences in ankle dorsiflexion strength among the three participant groups. Intrinsic foot muscles such as the abductor hallucis, flexor hallucis brevis and flexor digitorum brevis make specific contributions to supporting the MLA [31] and have been found to be reduced in individuals with a lowered arch [32]. This reduced muscle strength may contribute to the increased foot pain evident in the obese participants, possibly due to an inability of the weaker foot muscles to maintain structural integrity of their feet.

As expected, the heavier individuals generated more force when walking compared to their leaner counterparts. However, these higher forces were distributed across a greater foot-

ground contact area, due to the flatter, larger feet of the obese participants. This increased contact area, however, was not sufficient to compensate for the higher forces such that the peak plantar pressures were significantly elevated in the midfoot region of the obese and overweight participants. This finding is consistent with that which is typically displayed by overweight and obese children and adults during gait[10, 13, 18]. In addition to the elevated midfoot plantar pressures, obese participants in this cohort of older people displayed increased pressure under medial forefoot compared to their non-overweight counterparts. A significant relationship between high plantar pressures and foot pain has been previously established in older people[16]. It would appear that the increase in mechanical load associated with the need to continually bear excessive mass, as evidenced by the higher plantar pressures, could contribute to excess stress/strain to the musculoskeletal structures of the foot.

In agreement with previous research[33], obese participants in the current study spent 2.4% longer in the stance phase, 5% longer in double support and 2% less time in single support than non-obese adults. The increase in the proportion of time spent in double support may represent a coping mechanism whereby obese individuals are trying to avoid over-loading their painful feet by distributing the load across both feet simultaneously. These alterations to the gait of older obese adults suggest that the ability of older individuals to perform common activities of daily-living is inhibited by their excess mass and the confounded by the presence of foot pain.

This is a cross-sectional study and any cause-and-effect relationships should be interpreted with caution. As the proportion of the participants who have been obese throughout most of their lifespan is unknown, we cannot determine whether the structural and functional changes to the foot are acute or developed over an extended period of time. We also don't know if there is a reverse causation effect, i.e. that foot pain and/or problems is reducing or limiting mobility and physical activity to the point where people are becoming overweight and obese. Current evidence suggests that intentional weight-loss provides benefits in controlling cardiovascular risk factors and reducing medications for weight-related health conditions[3]. One study reported that substantial weight loss following gastric bypass surgery resulted in an 83% improvement in foot complaints[34]. Similarly, McGoey et al.[35] found that the proportion of morbidly obese people suffering from foot pain was reduced from 21% to 1% following weight loss surgery. Therefore, reducing body mass might also lead to a reduction in foot pain in overweight and obese adults, although if foot pain is inhibiting ambulation, non-weight bearing exercise should be recommended to aid with weight loss. It is

additionally acknowledged that multiple statistical tests have been done without formal correction of the p-value.

CONCLUSIONS

Our study demonstrates that foot pain, foot structure, and foot function are compromised by excess mass in older adults. These changes to foot pain, structure and function resulted in functional limitations and a reduction in health-related quality of life, particularly in older adults classified as obese. Further research is recommended to determine whether interventions designed to reduce excess fat mass may relieve loading of the foot structures and, in turn, improve foot pain and quality of life for older adults.

Conflict of interest statement: There are no known relationships which could cause a conflict of interest between anyone involved in conducting this research.

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Tables:**Table 1:** Descriptive Characteristics of the Non-Overweight, Overweight and Obese Participant Groups.

Variable	Non-overweight	Overweight	Obese
	(n = 79)	(n = 128)	(n = 105)
	mean ± SD	mean ± SD	mean ± SD
Women (n [%])	49 [62]	47 [36.7] ^a	58 [55.2]
Age (years)	72.2 ± 7.1	71.4 ± 6.2	71.4 ± 6.8
Height (m)	1.65 ± 0.1	1.67 ± 0.1	1.66 ± 0.1
Weight (kg)	62.4 ± 8.7	77.2 ± 9.7	91.9 ± 15.2
BMI (kg.m ⁻²)	22.8 ± 1.6	27.5 ± 1.4	33.8 ± 4.1

^a significant difference compared to non-overweight group; $p < 0.05$

^b significant difference compared to overweight group; $p < 0.05$

Table 2: Mean, Adjusted (\pm SE) Foot Anthropometrics (Normalised to Foot Length Where Appropriate) of the Three Participant Groups.

Variable	Non-overweight	Overweight	Obese
Foot length (mm)	258.1 \pm 1.6	255.3 \pm 1.2	259.3 \pm 1.4 ^b
Ball girth	0.94 \pm 0.01	0.96 \pm 0.01 ^a	0.97 \pm 0.01 ^a
Instep circumference	0.92 \pm 0.01	0.95 \pm 0.01	0.97 \pm 0.01
Ball width	0.39 \pm 0.01	0.4 \pm 0.01 ^a	0.4 \pm 0.01 ^{a,b}
Ball height	0.15 \pm 0.01	0.16 \pm 0.01 ^a	0.17 \pm 0.01 ^{a,b}
Heel width	0.25 \pm 0.01	0.26 \pm 0.01 ^a	0.27 \pm 0.01 ^{a,b}
Navicular height	0.17 \pm 0.01	0.17 \pm 0.01	0.17 \pm 0.01
1 st toe height	0.09 \pm 0.01	0.09 \pm 0.01	0.10 \pm 0.01 ^{a,b}
5 th toe height	0.07 \pm 0.01	0.07 \pm 0.01	0.08 \pm 0.01 ^a
Instep height	0.26 \pm 0.01	0.27 \pm 0.01	0.27 \pm 0.01
Instep length	0.73 \pm 0.01	0.73 \pm 0.01	0.73 \pm 0.01
Fibular instep length	0.63 \pm 0.01	0.63 \pm 0.01	0.63 \pm 0.01
Lateral malleolus height	0.29 \pm 0.01	0.29 \pm 0.01	0.29 \pm 0.01
Medial malleolus height	0.33 \pm 0.01	0.33 \pm 0.01	0.31 \pm 0.01 ^{a,b}
1 st toe angle ($^{\circ}$)	12.2 \pm 1.0	11.8 \pm 0.8	11.3 \pm 0.9
5 th toe angle ($^{\circ}$)	13.0 \pm 0.7	10.6 \pm 0.6 ^a	12.1 \pm 0.6
Heel bone angle ($^{\circ}$)	4.0 \pm 0.6	3.4 \pm 0.5	3.1 \pm 0.5

^a significant difference compared to non-overweight group; $p < 0.05$

^b significant difference compared to overweight group; $p < 0.05$

Table 3: Foot Function and Gait Characteristics of the Non-Overweight, Overweight and Obese Participant Groups.

Variable	Non-overweight (n = 79)	Overweight (n = 128)	Obese (n = 105)
Foot function	mean (95% CI)^c	mean (95% CI)^c	mean (95% CI)^c
Hallux flexor strength (% BW)	15.2 (13.5 – 16.9)	14.2 (12.9 – 15.6)	11.6 (10.2 – 13.1) ^{a,b}
Lesser toe flexor strength (% BW)	11.0 (10.0 – 12.1)	10.7 (9.9 – 11.5)	8.6 (7.7 – 9.5) ^{a,b}
Ankle dorsiflexion strength (kg)	9.7 (8.9 – 10.5)	10.3 (9.6 – 10.9)	10.2 (9.5 – 10.9)
Ankle dorsiflexion flexibility (°)	48.9 (47.2 – 50.6)	49.6 (48.2 – 50.9)	49.9 (48.4 – 51.3)
Walking speed (m.s ⁻¹)	1.04 (1.0 – 1.08)	1.04 (1.01 – 1.07)	0.93 (0.9 – 0.96) ^{a,b}
Stride length (m)	1.21 (1.18 – 1.24)	1.19 (1.16 – 1.22)	1.10 (1.07 – 1.13) ^{a,b}
Step length (cm)	60.5 (58.8 – 62.2)	59.6 (58.3 – 61.0)	55.0 (53.6 – 56.5) ^{a,b}
Step width (cm)	9.0 (8.3 – 9.6)	9.6 (9.1 – 10.1)	11.8 (11.2 – 12.3) ^{a,b}
Stance time (% GC)	60.7 (60.3 – 61.1)	61.3 (60.9 – 61.6)	63.1 (62.8 – 63.5) ^{a,b}
Swing time (% GC)	39.3 (38.9 – 39.7)	38.8 (38.4 – 39.1)	36.9 (36.5 – 37.2) ^{a,b}
Double support time (% GC)	21.5 (20.7 – 22.2)	22.8 (22.2 – 23.5) ^a	26.5 (25.8 – 27.1) ^{a,b}
Single support time (% GC)	39.3 (38.9 – 39.7)	38.6 (38.3 – 38.9) ^a	36.8 (36.4 – 37.1) ^{a,b}

BMI = body mass index; BW = body weight; GC = gait cycle; Data collected in 2006 in New South Wales, Australia.

^a significant difference compared to non-overweight group; $p < 0.05$

^b significant difference compared to overweight group; $p < 0.05$

^c adjusted for gender

Figures:

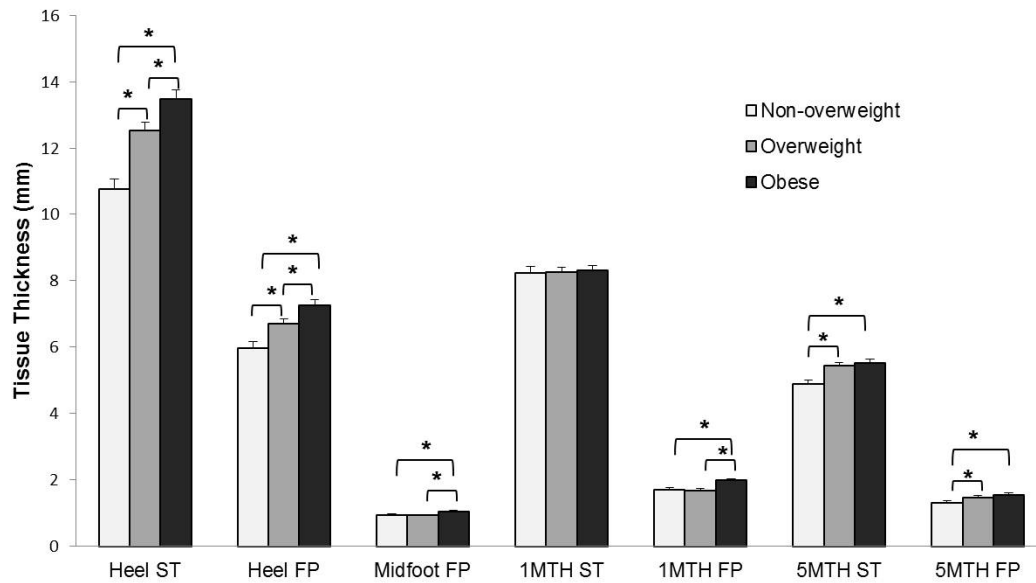


Figure 1: Mean (\pm SEM) total soft tissue (ST) and fat pad (FP) thickness (mm) at the heel, midfoot, 1st metatarsal head (1MTH) and 5th metatarsal head (5MTH) of the non-overweight, overweight and obese participant groups. Means have been adjusted to gender. * indicates a significant difference between groups ($p < 0.05$).

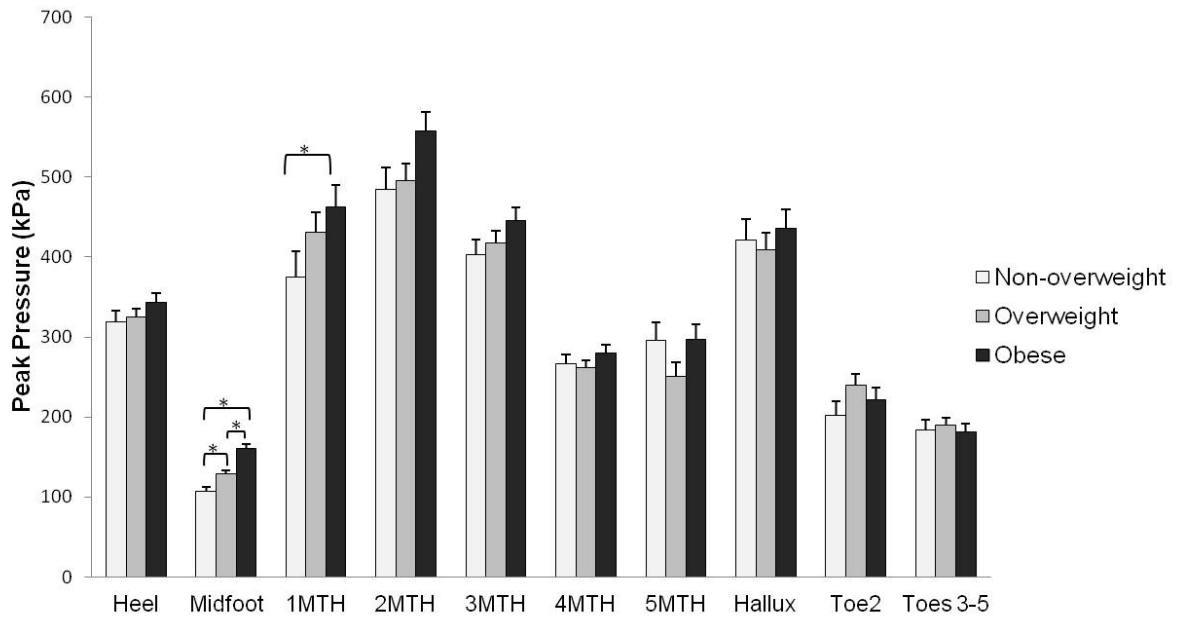


Figure 2: Mean (\pm SEM) peak pressure at the 10 foot regions of the non-overweight, overweight and obese participant groups. Means have been adjusted to gender. * indicates a significant difference between groups ($p < 0.05$).