Foot Anthropometric Dimensions of Occupational Wheelbarrow Pushers in Enugu, Nigeria

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Summary

BACKGROUND

This study explored the impact of occupational wheelbarrow pushing on foot anthropometric dimensions and plantar indices among occupational wheelbarrow pushers (OWBPs) at selected markets in Enugu.

MATERIALS AND METHODS

This ex-post-facto survey involved 407 participants (204 of OWBPs and 203 non-OWBPs). The foot anthropometric characteristics were measured using a measuring tape, vernier callipers, A4 plain white paper, and endorsing ink. The body weight and height were measured using standardized procedures. Data were summarized in mean, standard deviation, frequency count, and percents. An independent T-test was used to test the stated hypotheses at the significance level of 0.05.

RESULT

The OWBPs had higher values (P<0.001) for foot length, foot width, ball of the foot circumference, ankle height, heel width, dorsal arch height, midfoot width, forefoot width, and rearfoot width, but lower (P<0.001) plantar arch height than non-OWBPs. The Staheli index showed that only 11 right feet and 14 left feet of OWBPs had pes planus while 7 right feet and 10 left feet of the non-OWBPs had pes planus.

CONCLUSION

The findings of this study indicate that there were significant differences between the right and left foot anthropometric measurements of OWBPs. Even though the foot anthropometric indices are greater in OWBPs than the non-OWBPs, the majority of both groups had normal feet. The also results suggest that occupational wheelbarrow pushing increases most foot anthropometric dimensions except plantar arch height. Occupational wheelbarrow pushers have larger feet than non-occupational wheelbarrow pushers and are also prone to developing pes planus.

***Keywords**: Foot Anthropometric indices, Occupation, Wheel-Barrow Pushers*

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Introduction

The foot is one of the most important shock-absorbing structures, in the human body, during various weight-bearing activities [1]. The morphology of the human foot is greatly influenced by the combined effects of heredity and lifestyle which determine the size and shape of the foot, thereby making them unique data to establish human identity [2]. Indeed, anthropometric data, such as the size and shape of the foot, are useful for forensics, physical anthropology, and ergonomic design of the workplaces [3]. Thus, appropriate foot dimensions may improve wellbeing, health, comfort, and safety, especially for footwear design [4]. Furthermore, a change in any of the foot dimensions may serve as warning signs of structural and functional defects of the foot in a given population [4].

Occupations [5, 6], environments, socio-economic developments [7], ethnicity, and cultures [8], have been found to influence the foot dimensions of individuals. Occupations requiring long-standing periods affect foot dimensions [5]. Specifically, it has been noted that the foot girth of soldiers, participating in a 56km night march while carrying a rifle and water bottle, increases by as high as 9 mm in 49 per cent [9]. Long-term mechanical stress acting on the lower limbs, particularly during high demand activities, may cause injuries and hazards to the limbs [10]. Other factors that may influence the foot structure are age, sex, and weight [11].

To make it relatively easy and reliable to classify foot arch, there are many indices to quantify the arch such as the arch index, arch length index, Staheli's index, Chippaux-Smirak index, the arch or footprint angle, the footprint index, the truncated arch index, the modified arch index and the Brucken index [12]. In this study, the Staheli index was utilized. This index establishes a relationship between the central and posterior regions of the footprint.

A few studies have reported on the effect of occupations on foot anthropometry [5, 7, 11]. However, none on occupational wheelbarrow pushing is available for reference. Also, studies have correlated flat foot with obesity, footwear, gender, stature, and ethnicity [13, 14], but none has done so with wheelbarrow pushing. It is therefore important to fill out this knowledge gap. This study explored the impact of occupational wheelbarrow pushing on foot anthropometric dimensions and plantar indices among occupational wheelbarrow pushers (OWBPs) at selected markets in Enugu, Nigeria.

Materials and Methods

This ex-post-facto study utilized a non-probability consecutive sampling technique. A sample of 204 OWBPs at Ogbete Main market (60), Kenyatta market (54), Newmarket (34), Mayor market (32) and Gariki market (24), and 203 Non-OWBPs participated in this study. The OWBPs had worked for at least 1 year, had no history of congenital lower limb deformities, surgical operation on foot and lower extremity, or recent foot injuries. The Non-OWBP were healthy individuals who were not involved in activities requiring long-standing and weight-bearing. The participants consented to be part of the study after understanding what the study entailed.

Procedures employed in this study were approved by the Ethical Review Committee of the Nnamdi Azikiwe University Teaching Hospital, Nnewi. The purpose and procedures for the study were explained to the participants, and their informed consent was obtained. The participants were screened for the inclusion and exclusion criteria before data collection. The participants' ages, gender, marital status and number of years in the occupation, days of work per week, and the number of hours per day were collected using a self-developed questionnaire.

Foot anthropometric characteristics were measured by asking the participants to take off their footwear. The measurements were taken on a flat surface with the participants standing on both feet. The participants were asked to step each foot smeared with endorsing ink on the sole, and steps on the A4 white paper for the footprint. From the footprints, the following foot anthropometric dimensions were measured:

Foot length was measured in centimetres from the heel to the tip of the longest toe with a measuring tape.

Foot width was measured at right angles to its long axis or on the diagonal between the 1st and 5th metatarsophalangeal joints (maximum breadth of the foot) from the footprint trace with a ruler in centimetres.

Ankle height was measured in millimetres from the middle of the foot at the top (instep) to the sole, the distance is taken with a Vernier calliper.

Heel width was measured in millimetres behind the projections of the "ankle bone" (lateral and medial malleoli) using a Vernier calliper.

Ball of the foot circumference was measured in centimetres using a tape measure passing over the medial and lateral 'balls' of the foot (metatarsophalangeal joints).

Heel-Ankle circumference was measured with the tape passing under the tip of the heel and over the instep junction of the foot and the leg.

Ankle height was measured from the floor to the level of the minimum circumference of the lower leg, the vertical distance is taken with a Vernier calliper in millimetres.

Ankle circumference was measured above the "ankle bones" (lateral and medial malleoli) with a measuring tape in centimetres.

Forefoot width was measured as the widest horizontal distance of the forefoot, from the medial aspect of the first metatarsal head to the most lateral aspect of the fifth metatarsal head [15] with a Vernier calliper in millimetres.

Midfoot width was measured at 50% of the foot length, at which point the width of the foot is taken with Vernier calliper in millimetres.

Rearfoot width was measured behind the projections of the “ankle bone” (lateral and medial malleoli) with a Vernier calliper in millimetres.

Dorsal arch height was determined by measuring the vertical height from the supporting surface to the dorsum of the foot at 50% of the total foot length, measured with a Vernier calliper in millimetres.

Plantar arch height was measured in millimetres with Vernier callipers as the distance from the standing surface of the inferior medial border of the navicular tuberosity [16].

Bodyweight was measured in kilograms using a weighing scale. The participants were asked to remove their footwear and heavy outer garments or objects from their bodies. The participant stood on the footpad with the weight evenly distributed on both feet. The weight was taken by bending over the scale and the reading was recorded.

Height was measured in centimetres using a stadiometer. Participants were asked to remove shoes, heavy outer garments, stands with his back to the height rule, the back of the head, back, buttocks, calves, and heels touch the upright rule and feet together. The top of the external ear canal was levelled with the inferior margin of the cheekbone as the participant faced straight on. The headpiece of the stadiometer was lowered so that the hair (if present) is pressed flat. The value was obtained and recorded.

Based on these measures obtained, we calculated some other variables like body mass index (BMI) and Staheli index. The Staheli index was calculated as follows: a line is drawn tangent to the medial forefoot edge and a heel region. The mean point of this line is calculated. From this mean point, a perpendicular line is drawn crossing the footprint; the same procedure is repeated at the heel tangency. Measurements are obtained at the width of the central region of the foot (A) and the heel region (B) in millimetres. The arch index is obtained by dividing A by B [17, 18].

The index compared the width of the heel to the width of the middle of the foot in standing. A lower index value means a higher arch. The plantar arch values for children (5-9 years) range from 0.61 to 0.67, with plantar arch indexes greater than 1.15 being regarded as flat feet. Vijayakumar *et al* in 2016 [19] established that the Staheli plantar arch index for adults (25-40 years) ranges from 0.5 to 0.7, with flat feet ranging from 0.7 and above.

Data analysis

Data collected were analyzed using SPSS version 20.0 for Windows. Data were summarized using descriptive statistics of mean, standard deviation, frequency, and proportion. The statistical comparisons of the foot anthropometric dimensions between the OWBPs and Non-OWBPs were done using independent T-Tests at the significance level of 0.05.

Results

The mean ages of OWBPs and Non-OWBPs were 22.35±6.34 years and 21.24±3.4 years respectively, and their mean BMI was 23.35±13.7kg/m^2 and 20.16±2.92kg/m^2 respectively. The OWBPs had a mean work experience of 2.4±1.61 years, a mean work duration of 8.87±2.13 (hours/day), and a mean work volume of 5.4±1.25 (days/week) (Table 1).

The left foot (26.5±1.35cm) of OWBPs is longer ($p<0.001$) than the right foot (26.28±1.24cm), while the right foot (10.16±0.55cm) is wider ($p<0.001$) than the left foot (9.91±0.56cm). Also, greater values of ankle circumference ($p<0.001$), ankle height ($p<0.001$), dorsal arch height ($p=0.003$), and forefoot width ($p=0.001$) were noted on the left foot than the right foot. Similarly, the right heel ($p=0.032$), midfoot ($p<0.001$), and rearfoot ($p<0.001$) were wider than the left heel, midfoot, and rearfoot respectively (Table 2).

Table 3 and 4 shows that the foot length (right =26.28 ± 1.24cm; left =26.5±1.35cm) of OWBPs were longer than Non-OWBPs (right= 24.46±1.34; left=24.69±1.5) at $p<0.001$..

Table 1: Demographic and Job Characteristics of Participants.

	OWBPs. (Mean±SD)	Non-OWBPs (Mean±SD)
Age (years)	22.35 ± 6.34	21.24 ± 3.47
Body Mass Index (Kg/m2)	23.35 ± 13.7	20.16±2.92
Work duration (Hours/day)	8.87 ± 2.13	-
Work duration (days/week)	5.4 ± 1.25	-
Work experience (years)	2.4 ± 1.61	-

Table 2: Comparison of Foot Anthropometric Measurements of OWBPs Using Paired T-test.

	Right Foot mean±SD	Left Foot mean±SD	t-value	p-value
Foot length(cm)	26.28 ± 1.24	26.5±1.35	-4.554	<0.001
Foot width(cm)	10.16±0.55	9.91±0.56	7.546	<0.001
Ball of the Foot Circumference(cm)	26.96±1.34	27.03±1.38	-1.826	0.069
Ankle Circumference (cm)	23.85±1.48	24.05±1.64	-4.089	<0.001
Ankle height(mm)	8.3±1.22	8.57±1.1	-6.748	<0.001
Heel width(mm)	5.62±0.35	5.57±0.48	2.162	0.032
Dorsal arch height(mm)	6.26±0.71	6.61±0.8	3.041	<0.001
Plantar arch height (mm)	0.14. ±1.5	0.15±0.19	-1.538	0.126
Forefoot width(mm)	10.23±1.06	10.42±0.5	-3.517	0.001
Midfoot width(mm)	9.7±0.6	9.5±0.6	7.030	<0.001
Rearfoot width(mm)	6.7±1.06	6.31±0.64	6.138	<0.001

KEY: SD = Standard Deviation; t-value = Paired t-test; p-value = 0.05 level of significance.

Table 3: Comparison of Right Foot Anthropometric Characteristics between OWBPs and Non-OWBPs Using Independent T-Test

	OWBPs mean±SD	Non-OWBPs mean±SD	t-value	p-value
Right Foot length(cm)	26.28 ± 1.24	24.46±1.34	- 14.208	<0.001
Right Foot width(cm)	10.16±0.55	9.5±0.7	-10.501	<0.001
Right Ball of the Foot Circumference(cm)	26.96±1.34	25.6±1.54	-9.508	<0.001
Right Ankle Circumference (cm)	23.85±1.48	22±1.66	-5.450	<0.001
Right Ankle height(mm)	8.3±1.22	7.65±1.24	-5.286	<0.001
Right Heel width(mm)	5.62±0.35	4.77±0.88	-12.834	<0.001
Right Dorsal arch height(mm)	6.26±0.71	5.45±1.04	-9.176	<0.001
Right Plantar arch height(mm)	0.14. ±1.5	0.28±0.22	7.561	<0.001
Right Forefoot width(mm)	10.23±1.06	9.86±0.68	-4.176	<0.001
Right Midfoot width(mm)	9.7±0.6	6.3±1.96	-23.427	<0.001
Right Rearfoot width(mm)	6.7±1.06	5.92±0.75	-8.479	<0.001

KEY: SD = Standard Deviation; t-value = independent t-test; p-value = 0.05 level of significance.

The OWBPs also had wider foot width (right =10.16±0.55cm; left = 9.91±0.56cm), ball of the foot circumference (right =26.96±1.34cm; left =27.03±1.38cm), heel width (right =5.62±0.35mm; left =5.57±0.48mm), ankle circumference (right =23.85±1.48mm; left =24.05±1.64mm), midfoot width (right =9.7±0.6mm; left =9.5±0.6mm), forefoot width (right =10.23±1.06mm; left =10.42±0.54mm), and rearfoot width (right = 6.7±1.06mm; left =6.31±0.64mm) than OWBPs at p<0.001. It was also noted that OWBPs had higher ankle height (right =8.3±1.22mm; left =8.57±1.1mm), and dorsal arch height (right =6.26±0.71mm; left =6.61±0.8mm) than Non-OWBPs at p <0.001.

Significant differences were noted in Staheli indices between right feet (1.47±0.2mm) of OWBPs and right feet (1.07±0.35mm) of Non-OWBPs at p = 0.001. Also, variations were seen on the left feet (1.52±0.17mm) of OWBPs and left feet (1.03±0.32mm) of Non-OWBPs at p<0.001 (Table 5).

Table 6 shows that 5% and 7% of OWBPs had pes planus in the right and left feet respectively while 3% (left) and 5% (right) did in Non-OWBPs.

Discussion

This study explored the impact of occupational wheelbarrow pushing on foot anthropometric dimensions and plantar indices among occupational wheelbarrow pushers (OWBPs) at selected markets in Enugu.

Table 4: Comparison of Left Foot Anthropometric Characteristics between OWBPs and Non-OWBPs

	OWBPs mean±SD	Non-OWBPs mean±SD	t-value	p-value
Left Foot length(cm)	26.5±1.35	24.69±1.5	-12.781	<0.001
Left Foot width(cm)	9.91±0.56	9.66±0.76	-3.791	<0.001
Left Ball of the Foot Circumference(cm)	27.03±1.38	25.57±1.57	-9.915	<0.001
Left Ankle Circumference (cm)	24.05±1.64	22.83±1.71	-7.368	<0.001
Left Ankle height(mm)	8.57±1.1	7.81±1.29	-6.347	<0.001
Left Heel width(mm)	5.57±0.48	4.77±0.85	-11.675	<0.001
Left Dorsal arch height(mm)	6.61±0.8	5.5±1.22	-6.442	<0.001
Left Plantar arch height (mm)	0.15±0.19	0.32±0.29	7.247	<0.001
Left Forefoot width(mm)	10.42±0.54	9.94±0.89	-6.640	<0.001
Left Midfoot width(mm)	9.5±0.6	6.17±1.99	-22.841	<0.001
Left Rearfoot width(mm)	6.31±0.64	5.98±0.63	-5.242	<0.001

The findings that there were significant differences in the right and left foot anthropometric dimensions of OWBP may be attributed to the tendency to put stress more on the foot-controlled by the dominant side of the brain. However, inconsistent findings of some anthropometric dimensions being larger on either the left or the right side make it difficult to attribute the differences to side dominance. Considering that an overwhelming majority of any population is right-leg dominant, it should be expected that the anthropometric dimensions are consistently or generally larger in the right foot. On the contrary, a previous study reported that there was no difference in anthropometric measurements between the right and left feet among 23 male groups aged 30-40 years [20]. However, in this study, most anthropometric dimensions are larger on the left foot than the right foot. Also, the study showed that OWBPs had longer and wider feet than Non-OWBPs, and had higher values for the ball of the foot circumference, heel width, ankle circumference, midfoot width, forefoot width, and rearfoot width in OWBPs than in Non-OWBP. A study with similar findings [5] to this study, reported higher values in foot dimensions in the New Zealand Army than in the general population. This buttresses that higher values in OWBPs may be attributed to the prolonged standing and heavy load carriages. These findings suggest a need for customized footwear for OWBPs.

The Staheli index revealed that both groups had flatfeet according to the indices, with OWBPS having higher values. Few feet of Occupational and Non Occupational barrow pushers reported the presence of Pes-planus while the majority of the feet of both groups were normal according to the Paediatric Orthopaedic Society Evaluation Criteria, This may indicate that the occupation has no significant effect on foot types. Similar to this finding, a study conducted in Saudi Arabia [21] reported that Saudi Arabian army recruits had only a 5% prevalence of flat foot. The finding is, however, contradicted the report in the United States of America [22] that there is a tendency for certain foot anthropometric changes to occur with heavy loads. Furthermore, another study [14] explained that the effects of the temporary loading intensity on foot biomechanics have been shown to relate to certain dimorphism of the foot, particularly pes planus.

Table 5: Comparison of Staheli index of OWBPs and Non-OWBPs

	OWBPs mean±SD	**Non-OWBPs mean±SD**	**t-value**	**p-value**
Right Stahelli index(mm)	1.47±0.2	1.07±0.35	-14.042	<0.001
Left Stahelli index(mm)	1.52±0.17	1.03±0.32	-18.974	<0.001

KEY: SD = Standard Deviation; t-value = independent t-test; p-value = 0.05 level of significance.

Table 6: The Distribution of foot types among OWBPs and Non-OWBPs

	Normal foot n (%)	**Pes planus n (%)**
Occupational wheel-barrow pushers		
Right	193(95)	11(5)
Left	190(93)	14(7)
Non- Occupational wheel-barrow pushers		
Right	196(97)	7(3)
Left	193(95)	10(5)

During the study, it was discovered from the observation that some footprints that were visibly pes planus were not captured because they had values lower than the pes planus value obtained using the Paediatric Orthopaedic society evaluation criteria. However, the Staheli index reported that the majority of both groups have flatfeet in line with the observation from some footprint. Indeed, a standardized foot classification [23] has stated that the gold standard for determining foot types is yet to be established, and clinical observation remains the method most often relied upon in clinical diagnosis. However, the clinical observation will introduce research errors thereby reducing the study validity. Several studies utilized the Staheli index and Paediatric criteria, this informed the decision to use these methods to eliminate researchers' error. Also, an extensive comparison of findings on foot anthropometric measurements in this study is difficult due to limited literature in this occupational group as the majority of the previous studies were on children.

Limitation

Foot anthropometric characteristics were limited to the measurements of the under listed foot parameters only; foot length, foot width, ball of the foot circumference, heel-ankle circumference, ankle circumference, ankle height, heel width, dorsal arch height, plantar arch height, forefoot width, midfoot width, rearfoot width

Conclusion

The findings of this study indicate that there were significant differences between the right and left foot anthropometric measurements of OWBPs. Even though the foot anthropometric indices are greater in OWBPs than the non-OWBPs, the majority of both groups had normal feet. The also results suggest that occupational wheelbarrow pushing increases most foot anthropometric dimensions except plantar arch height. Occupational wheelbarrow pushers have larger feet than non-occupational wheelbarrow pushers and are also prone to developing pes planus.

Availability of Data and Study Materials

The data sets analyzed in this study are available from the corresponding author upon a reasonable request.

Competing interests

The authors declare that there is no conflict of interest associated with the material presented in this study.

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Authors' Contributions

All authors conceived, designed and conducted the study, analyzed the data, contributed materials/analysis tools and wrote the paper.

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