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BODY ANTHROPOMETRY EVALUATION OF SOUTH-SOUTHERN NIGERIA FARMERS FOR WORK IMPLEMENT DESIGN

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Abstract: Conformance of working tool design parameters to the workers body anthropometry guarantee optimal usage of the tools, enhance working posture and comfort, and maximization of output. This study examined the anthropometric body dimension of farmers (male and female) in South-southern Nigeria. The anthropometric characteristics of 360 farmers (230 males, 130 females) within the age limit of 20 to 65 years were randomly selected from the six states in South-southern Nigeria, namely: Rivers, Edo, Delta, Bayelsa, Akwa-Ibom, and Cross-River state. The survey was done to obtain structural body dimensions relevant for the design of farm implement/machines. Analysis of the data obtained showed that the human anthropometry assessed for the human-work tool interaction during farm work operations categorized into three clusters; length proportions, volume indicator and palm dimensions, showed that the male farmers that participated in this study had larger structural body dimension compared to their female counterparts but for the volume indicators. The structural body dimension variation across the gender should be considered in the design of the farm implement/machines for efficient human-work tool interaction during farm work operations.
Keywords: agricultural equipment, anthropometric data, farmers, machine design, South-southern Nigeria

1. INTRODUCTION

Over the centuries, human have used tools to accomplish a variety of tasks. Today, there is increasing demand among professional hand tools users for ergonomically designed products (Amine and Owhor, 2016). Reliability of agricultural equipment can be greatly improved when they are designed with due consideration to the anthropometric dimensions of target users/operators.

In Nigeria, farmers play significant role in several agricultural operations, starting from land preparation to post harvest operations. Efficiency in the use of applicable farm tools, machineries and equipment during the farming processes require a good knowledge and utilization of workers body anthropometry in the design of equipment. This is necessary for the improvement of the work efficiency, and farmers' safety and comfort, as the overall body size, shape, proportion of the farmers vary, thus necessitating a critical analysis of their work station, implements and other related factors.

Nag *et al.*, (1988) analyzed the effect of sickle design on manual harvesting and the harvester. The study was justified on the basis that manual harvesting is a moderately heavy task, which requires agricultural workers to adopt many awkward postures. Hence, handle height, length of handle and handle inclination of hand held agricultural tools are the key design elements to be considered for maximum force exertion during the equipment operation with less effort, comfort and work output from the operator.

Preliminary investigation conducted in the six South-southern states of Nigeria namely, Rivers, Edo, Delta, Bayelsa, Akwa-Ibom, and Cross-river, showed that the hand tools broadly used for various farm operations in these areas are locally fabricated by the artisans and small scale manufacturers without due consideration to ergonomic principles thereby resulting in reduced efficiency, farmers discomfort, increased drudgery and risks during the use of the tools. Therefore, there is the need for the local hand tools adopted in the area to be modified to match the body anthropometry of the farmers using the hand dimensions limits of the local population (Amine and Owhor, 2016).

According to Kar *et al.* (2003) and Onuoha *et al.* (2012) some hand tools require a fairly small force for precise handling while other large tools require higher force for its handling. A maintained efficient hand tools grip during task performance need suitable wrist and arm posture for proper fitting to the contours of hand (Okunribido, 2000; Courtney *et al.*, 1984 and Buchholz *et al.*, 1992). Agrawal *et al.* (2010) and Nag & Nag (2004) added that anthropometric body dimensions play a significant role in human-work tool interaction. The authors revealed that the overall working efficiency of human-machine environment and resultant discomfort has severe impact while using farm tools and machinery. The study noted that anthropometric dimensions vary considerably across gender, race and age. Within a particular group, the anthropometry differs due to nutritional status and nature of work. To achieve better workers' comfort, safety, performance and efficiency, it is necessary to design tools, equipment and workplaces keeping in view of the anthropometric data of the agricultural workers.

Hand tools though simple, but the design is a complex ergonomic task and requires hand anthropometry. According to Davis (1990), anthropometric dimensions are one of the essential factors in designing machines and devices. Onuoha *et al.* (2012), Schmidtke, (1984) and Taiwo, & Olajide, (2002) noted that the design and dimensions of agricultural tools and implements have great bearing on the body dimensions and physical built of the users, requiring compatibility essentially between machine devices and worker body dimensions. Snow (1984) suggested that the only way to fulfill this objective is to create database of anthropometric dimensions of the user population. Courtney and Ng (1984), Davies (1990) and Kar *et al.* (2003) added that due to paucity of female anthropometric data, the anthropometric data of male workers are extrapolated to define women at work whenever necessary but Amine and Owhor (2016) opposed this assumption and said that such an approach is likely to be inaccurate due to obvious anthropometric, physiological and biological differences between male and female subjects. According to Hsiao *et al.* (2005), Fernmandez *et al.* (1989) and Agrawal *et al.* (2010), there is considerable difference between the anthropometric data of India and Western population emphasizing the need for generating anthropometric database for agricultural workers as it is not feasible practically to design equipment for an individual sex (male and female). It was against this background that this study was conducted to evaluate the body anthropometry of farmers relevant for the design of farm implement/machines.

2. MATERIALS AND METHOD

— Participants

The participants in this study were three hundred and sixty (360) (230 males and 130 female) willing farmers within the age range of 20 – 65 years randomly selected from three (3) local government areas in the six (6) South-Southern states of Nigeria namely: Rivers, Edo, Delta, Bayelsa, Akwa-Ibom, and Cross-river. The number of participants selected from each local government area of the study is as shown in table 1 below.

Table 1: Participants Selected from Each Local Government Area of the Zone

Name of States	Name of L.G.A	Nos. of Participants		Total
		Male	Female	
Rivers	Etche	14	6	20
	Emohua	13	7	20
	Ikwerre	13	7	20
Edo	Akoko-Edo	14	6	20
	Egor	13	7	20
	Esan Central	13	7	20
Delta	Sapele	13	7	20
	Aniocha North	13	7	20
	Aniocha South	13	7	20
Bayelsa	Ogbia	13	7	20
	Ekeremor	13	7	20
	Yenagoa	13	7	20
Akwa-Ibom	Eastern Obolo	12	8	20
	Abak	13	7	20
	Eket	13	7	20
Cross-Rivers	Boki	12	8	20
	Bekwarra	11	9	20
	Akpbuyo	11	9	20

— Apparatus and procedure

The instruments used for data collection were a wall mounted height stadiometer (model GK313, Glolink tools store, India) (Figure 1), a digital bathroom body weighing scale (Rahmah ventures, Nigeria) (Figure 2), and a digital vernier calipers (Mitutoyo 500-196-20, Japan) (Figure 3).

Figure 1: Stadiometer

Figure 2: A Digital Bathroom Body Weighing scale

Figure 3: A Digital Vernier Calipers

The human-work tool interaction variables data obtained were categorized into three; length proportions, volume indicator and palm dimensions. The twenty-two (22) structural body dimensions obtained were relevant for the design farm implement, principally the hand tools such as hoe handling operations for mound making and weeding, sickle for plant harvesting and machete for bush clearly. The demonstration of measurement exercise was illustrated to each subject for awareness and cooperation before commencement of the assessment.

— **Data analysis**

Data collected from the measurements were compiled and analyzed in descriptive statistics form (mean, standard deviation, variance, 5th and 95th percentiles). Data were analyzed using SPSS (version. 21.0).

3. RESULTS AND DISCUSSIONS

The descriptive statistics of the human-work tool interaction variables data of farmers relevant for the design farm implement/machines in this study were categorized into three clusters as length proportions, volume indicator, and palm dimensions is presented in Table 2. In Table 2, the mean, standard deviation, 5th and 95th percentiles of the height proportions and palm dimensions which represented the human-work tool interaction dimensions were presented. The 5th and the 95th percentile represented the least and maximum expectation from an ergonomically designed of the human-work tool interaction. The length proportions are the body anthropometry that indicates the subjects' lengths on the coronal plane such as the body height (stature), knee, waist and elbow heights (Azodo, 2021). The average stature of the male farmers (mean ± SD = 174.20 ± 9.35) was statistically higher than female farmers (mean ± SD = 171.99 ± 8.51). The extreme stature of the male using the 5th and the 95th percentile was 158.82 and 189.58 cm, respectively, while that of female is 157.99 and 185.99 cm, respectively.

Farm work operations involving hoe either for mound making, weeding, sickle handling for plant harvesting or machete for bush clearly demands stooping job posture. Stooping posture as described by Fathallah *et al.* (2004) is the bending forward and down from the waist and/or mid-back while maintaining relatively straight legs. Fathallah *et al.* (2004) stated that stooping posture in farm works are resorted to because it demands less energy expenditure as compared to kneeling or squatting. Ideally good biomechanical reason in these postures reduces the chances of musculoskeletal injury. However, this is with due consideration to the human-work tool interaction. This makes it essential to establish the relevant anthropometry dimension of the worker for the work posture. The mean stooping height of the male farmers' human-work tool interaction dimensions is 103.11 (SD = 5.57) cm having extreme stooping heights of 93.95 and 112.27 cm when analyzed using the 5th and the 95th percentile, respectively. The female farmers mean stooping height of the human-work tool interaction dimensions is 101.64 (SD = 5.04) cm. The extreme stooping height of the female farmers analyzed using the 5th and 95th percentile were 93.35 and 109.93 cm, respectively.

The human feet are the only contact the human body has with the ground during physical work activity involving standing, walking, and/or running postures. Footwear prevents the foot from injuries, offers fitness and comfortable foot support, and protects it against variations of ground surfaces texture and temperature adversities of the environment. It also facilitates the proper functioning of the foot for daily activities (Oladipo *et al.*, 2008). However, this is only guaranteed when the footwear fit with the shape of the foot as it is an essential determinant factor (Oladipo *et al.*, 2008). The results of the descriptive analysis for length and width of foot of the farmers showed that the males farmers foot length (mean ± SD = 26.36 ± 1.47) and width (mean ± SD = 9.56 ± 0.53) were larger than that of the females that has mean foot length of 26.36 (SD = 1.47) and mean foot width of 9.56 (SD = 0.53). The result obtained in this study is in agreement with the study of Ismaila (2009) that observed that feet anthropometry of male students in Southwestern Nigeria are larger (foot length and breadth) than those of their female counterparts. Similar results were obtained for the male length proportion of the structural body dimension evaluated as the dimensions obtained for male farmers were larger than those obtained for the females for knee height, waist height, elbow height, shoulder height, chin height, eye height and armpit height.

Every part of the human anatomy has a basic function it performs either at a static or dynamic posture. The hip anatomical region or joint of the human body primarily supports the human weight, helps to retain balance and maintain the pelvis inclination angle. The volume indicators which is the body circumferences and the transverse breadths of the subjects' body anthropometry, width of hips, the female farmers had statistically wider hip (mean ± SD = 37.59 ± 2.00) as compared to the males (mean ± SD = 34.86 ± 1.79). The values in this study were similar as compared to Taiwo and Olajide (2002) and Kodak (1999) studies, however, they are lower than those of Taiwo and Olajide (2002), but higher than those published by Kodak (1999).

Suitability determination of any product designed for specific types of consumers is possible through the effective use of anthropometric information. The design and construction of handles of tools and safety gloves for the farmers require that the palm dimensions should fit the product. The palm dimension is also necessary for effective holding and gripping of work tool during job operations. Continuous repetitive work with insufficient rest or recovery time among workers in an attempt to meet the set target causes aggravates, or precipitates the need to exert undesirable force and due to uncomfortable grips result to musculoskeletal injury in the work environment (Swift *et al*., 2001; Herberts and Kadefors, 1976; Burdorf *et al*., 1998). The palm dimensions assessed in this study necessary for palm injury prevention, fitness and comfortable handling of tools through effective gripping were grip diameter, forearm hand length, palm length, arm reach from wall, hand thickness, hand breadth, thumb thickness, length of arms and maximum hand breadth. The descriptive analysis of the data obtained showed that the male farmers had larger palm dimensions for the entire variable assessed as compared with the female farmers.

Table 2: Descriptive Analysis of the Human-Work Tool Interaction Variables for the Design of Farm Implement/Machines (Male And Female) (N = 360)

Body dimensions (cm)	Male					Female				
	Mean	SD	Var.	Percentile		Mean	SD	Var.	Percentile	
				5th	95th				5th	95th
Length proportions										
Height	174.20	9.35	82.74	158.82	189.58	171.99	8.51	69.62	157.99	185.99
Knee height	49.67	2.63	6.72	45.34	54	48.51	2.42	5.78	44.53	52.49
Waist height	82.53	4.31	17.64	75.44	89.62	85.16	4.52	19.85	77.72	92.6
Elbow height	110.04	5.88	33.18	100.37	119.71	108.26	5.25	26.57	99.62	116.9
Shoulder height	144.59	7.77	57.12	131.81	157.37	141.02	6.93	45.26	129.62	152.42
Chin height	151.52	8.09	62.58	138.21	164.83	149.00	7.35	51.03	136.91	161.09
Eye height	162.96	8.72	72.56	148.62	177.3	160.97	7.98	60.90	147.84	174.1
Armpit height	126.32	6.72	43.47	115.27	137.37	124.74	6.20	36.44	114.54	134.94
Length of foot	26.36	1.47	2.00	23.94	28.78	26.15	1.79	2.94	23.21	29.09
Stooping height	103.11	5.57	28.98	93.95	112.27	101.64	5.04	24.36	93.35	109.93
Volume indicators										
Weight	71.40	11.13	118.65	53.09	89.71	72.45	11.66	130.31	53.27	91.63
Width of foot	9.56	0.53	0.21	8.69	10.43	9.56	0.42	0.21	8.87	10.25
Width of hips	34.86	1.79	3.15	31.92	37.8	37.59	2.00	3.68	34.3	40.88
Palm dimensions										
Grip diameter	3.57	1.05	1.41	1.84	5.3	3.47	0.63	0.39	2.43	4.51
Forearm hand length	44.00	2.63	7.22	39.67	48.33	43.05	2.94	8.63	38.21	47.89
Palm length	18.06	1.58	2.8	15.46	20.66	17.75	0.74	0.54	16.53	18.97
Arm reach from wall	79.49	5.67	32.45	70.16	88.82	72.14	5.88	32.72	62.47	81.81
Hand thickness	2.94	0.21	0.35	2.59	3.29	2.84	0.21	0.03	2.49	3.19
Hand breadth	7.67	0.74	0.85	6.45	8.89	6.20	2.00	3.99	2.91	9.49
Thumb thickness	5.88	2.21	4.41	2.24	9.52	6.20	2.00	3.99	2.91	9.49
Length of arms	102.69	5.46	28.25	93.71	111.67	81.38	4.41	18.90	74.13	88.63
Maximum hand breadth	9.98	0.74	0.85	8.76	11.2	9.56	0.53	0.27	8.69	10.43

Note SD: standard deviation, Var.: Variance

Table 3 shows the comparison of relevant anthropometric variables of the male and female farmers in South-southern Nigeria obtained in this study with the male and female farmers in other countries such as USA, Korea, and Indian. This study observed some differences in the anthropometry mean values of data obtained and those from the three other countries of the world (USA, Korea, and Indian). Females elbow heights in this study are higher when compared with their Indian counterpart (AEDB, 2008), same difference was found for the Indian males. The height proportionality was calculated as a function of the overall height of males and females. It was discovered that the females have higher coefficient of height, Table 3. This result agrees with the findings of Konz (1978). Comparing the males' height proportions with those Nordics, Mediterranean and Americans in Table 3, it is clear that the males in this study have higher knee height (0.279H), than the Nordics (0.271H) and the Mediterranean (0.274H), but lower than the Americans (0.285H). The fingertip height of the males of (0.369H) is lower than that of the Mediterranean but, higher than the Americans. Wrist height of the males is the same with those of Americans, while it is higher than those of the Mediterranean's, but lower than the Nordics. The elbow height (0.629H) of males is only higher than that of the Mediterranean (0.621H), but lowers than the Nordic, (0.632H), and American (0.630H). The shoulder height in this research work is higher than the Mediterranean's, and the Americans, but lower than the Nordics. Male farmers have the same coefficient with American in eye height as shown in Table 3. The females height proportions are compared with those of the Nordics, and Americans in Table 3, it is clear that the females have higher knee height (0.284H), than the Nordics (0.263H) and the Americans (0.282H). The fingertip height of the females of (0.373H) is higher than the Americans (0.370H). The wrist height of the females (0.486H) is higher than the American but, lower than the Nordics (0.486H). The elbow height of the females (0.636H) is higher than the Nordics, and American of (0.624H), and (0.632H) respectively. The shoulder height of the females (0.832H) is higher than the Nordics (0.825) which is the same with the Americans. The female's eye height of (0.943H) is higher than the American (0.938H) and the Nordics (0.933H). Therefore, applying anthropometric dimensions of western world to design machines to be used by Nigerian may impose work hazard on the workers. This necessitates that establishment of national and international standard for work tool design and development is critical. The Federal government, engineers, designers and related agencies should give end-users of machines the opportunity to be involved in various stages of design and as well take the findings of this study as a reference. By doing this, repetitive injuries musculoskeletal injury in many workplaces will be reduced and healthier farm workers and safer work environment assured.

Table 3: Comparison of Male and Female Anthropometric Data of Present Study with Other Ethnic Population of the World

Body Dimension (cm)	Male				Female			
	Present Study	[a]USA	[b]Korea	[c]Indian	Present Study	[a]USA	[b]Korea	[c]Indian
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Grip diameter (internal)	3.57 ± 1.05	NA	NA	4.00 ± 1.10	3.47 ± 0.63	NA	NA	3.60 ± 0.30
Forearm hand length	44.00 ± 2.63	48.20 ± 2.10	NA	40.90 ± 8.10	43.05 ± 2.94	44.40 ±1.90	NA	39.50 ± 1.70
Hand length	18.06 ± 1.58	19.70 ± 1.00	NA	16.90 ± 3.80	17.75 ± 0.74	18.20 ± 0.90	17.00 ± 0.10	16.10 ± 0.80
Hand breadth	7.67 ± 0.74	9.10 ± 0.50	NA	9.10 ± 2.20	7.46 ± 1.16	8.00 ± 0.50	7.70 ± 0.40	8.60 ± 0.60
Arm reach from wall	79.49 ± 5.67	NA	NA	NA	72.14 ± 5.88	NA	NA	NA
Hand thickness	2.94 ± 0.21	3.0 ± 0.20	NA	NA	2.84 ± 0.21	2.50 ± 0.20	3.00 ± 0.20	NA
Maximum hand breadth	9.98 ± 0.74	10.80 ± 0.60	NA	NA	9.56 ± 0.53	9.50 ± 0.50	9.0 ± 0.40	NA

Note: [a]Hsiao *et al*, (2005), [b]Fernmandez *et al*, (1989), [c]Agrawal *et al.*, (2010), NA means not available

4. CONCLUSION

The purpose of this study is to provide the anthropometric dimensions of the farmers in South-southern Nigerian. This research study has made available some anthropometric data that will enable agricultural equipment designers improve on the design and manufacture of agricultural tools that will suit the farmers in South-southern Nigerian in order to optimize the farm tools usage, enhance posture and comfort of the users and maximize output.

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