

Anthropometric studies for designing to fit gari-frying workers

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Abstract: Work system and product design require anthropometric data of the user population relevant to the facility in order to have safe operation in service as well as increase user satisfaction and efficiency. Designing to fit gari-frying workers in each of the southwestern states in Nigeria is geared towards this end. The age, weight and twenty-five body dimensions of 120 gari-frying workers in Lagos, Ogun, Oyo, Osun, Ondo and Ekiti, selected by random sampling, were measured. The body dimensions include stature, shoulder height, sitting height, eye height, forward grip reach, buttock-popliteal height, buttock-knee length, knee height, thigh clearance, forearm-to-forearm breadth, waist depth, elbow rest height, knuckle height, elbow grip length, hip breadth, hand length, hand breadth, hand thickness, grip span and lumbar height. SPSS 20 software was used to perform statistical analysis to determine the mean, standard deviation, minimum and maximum values, 2nd, 5th, 25th, 50th, 75th and 95th percentiles for each state. Ogun state was used as a control, against which means of body dimension data, collected from other states, were compared using paired sample t-test. The results revealed that some of the body dimensions showed significant difference across the states at $P \leq 0.05$ with Oyo having more anthropometric parameters that differ from that of Ogun and Ondo having the least. Between 11.42% and 24.25% difference in the mean age, weight and lumbar height was observed in all the states. Osun state has the highest mean BMI and BSA values of 32.38 kg/m² and 1.82 m², respectively. These results are the required data for the design of facility and products for gari-frying workers as well as in similar women workspaces, especially in processing centres.

Keywords: anthropometry, workstation, gari-frying, cassava processing, design to fit, BMI, BSA

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1 Introduction

Ergonomics is sometimes defined as the science of fitting the work to the user, instead of forcing the user to fit the work. A good match can be obtained if anthropometric data are used. Meeting ergonomic design goals can only be accomplished by taking the potential human user into consideration and this involves their body dimensions. The potential user should not be generalized, but specific in terms of location and sex. Depending on the operation, some of the body measurements usually include; stature, shoulder height, sitting height, eye height, forward grip reach, buttock-popliteal height, buttock-knee length, knee height,

thigh clearance, forearm-to-forearm breadth, waist depth and circumference, elbow rest height, knuckle height, elbow grip length, hip breadth and circumference, hand length, hand breadth, hand thickness, grip span, lumbar height, push strength, pull strength, grip strength, bi-deltoid breadth, olecranon height, instep length, scapula-to-waist back length, bi-acromial breadth, functional leg length, foot breadth, foot length, middle finger palm grip diameter, wrist circumference, elbow flexed, fist circumference, body mass index (BMI), body space area (BSA), etc. BMI and BSA are body composition indices which are derived from other anthropometric measurements.

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Wibowo and Sonia's (2014) study of anthropometry and agricultural hand tool design for Javanese and

Madurese farmers in East Java Indonesia revealed that anthropometric measurements of Javanese farmers are mostly higher than that of Madurese farmers. For agricultural hand tools, farmers prefer utilitarian performance to hedonic performance. The results of the Relative Sitting Height (RSH) showed that Javanese and Madurese male and female are classified to be long-legged. Furthermore, the mean values of body surface area (BSA) and body mass index (BMI) of Javanese farmers are slightly higher than Madurese farmer's values.

It is obvious that little or no data is available for designers to make use of in designing a workplace for gari-frying operations. Hence, this paper is aimed at measuring and analysing the anthropometric data of gari-frying workers in the six southwestern states in Nigeria and to determine the variability between them, with a view to generating data for design to fit gari-frying facilities.

2 Materials and methods

2.1 Sampling, measurement and instrumentation

Anthropometric measurements of 20 subjects, selected by random sampling, were taken in each of the six states in the southwestern part of Nigeria (a total of 120 samples). The subjects selected did not have any form of physical deformity. The age of the population

under study ranged from 17 to 65 (mean = 42.36 years; SD = 2.8 years). The sample comprises women in all the states surveyed and they are actively involved in gari frying. Their consent had earlier being sought before taking the measurements. Age, weight and 25 body dimensions including stature, shoulder height, sitting height, eye height (sitting and standing), forward grip reach (sitting and standing), buttock-popliteal height (sitting), buttock-knee length, knee height, thigh clearance, forearm-to-forearm breadth, waist depth, elbow rest height, knuckle height, elbow grip length, hip breadth (sitting), hand length (at index), hand breadth (at thumb and knuckles), hand thickness, grip span and lumbar height} were taken. Figure 1 shows the anthropometric dimensions taken. The instruments used included Vernier Caliper, Stadiometer, folding rule, iron square and measuring tape. Each body dimension was measured three times and the average taken to ensure reliability. Similar to Jeje et al. (2014) and Nupo et al. (2013), body mass index (BMI) was estimated using Quetelet formula (Equation (1)) while, body space area (BSA) was calculated from the DuBois and DuBois formula (Equation (2)).

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height}^2 (\text{m}^2)} \quad (1)$$

$$\text{BSA} = \frac{71.84 \times \text{weight}^{0.425} \times \text{height}^{0.725}}{10000} \quad (2)$$

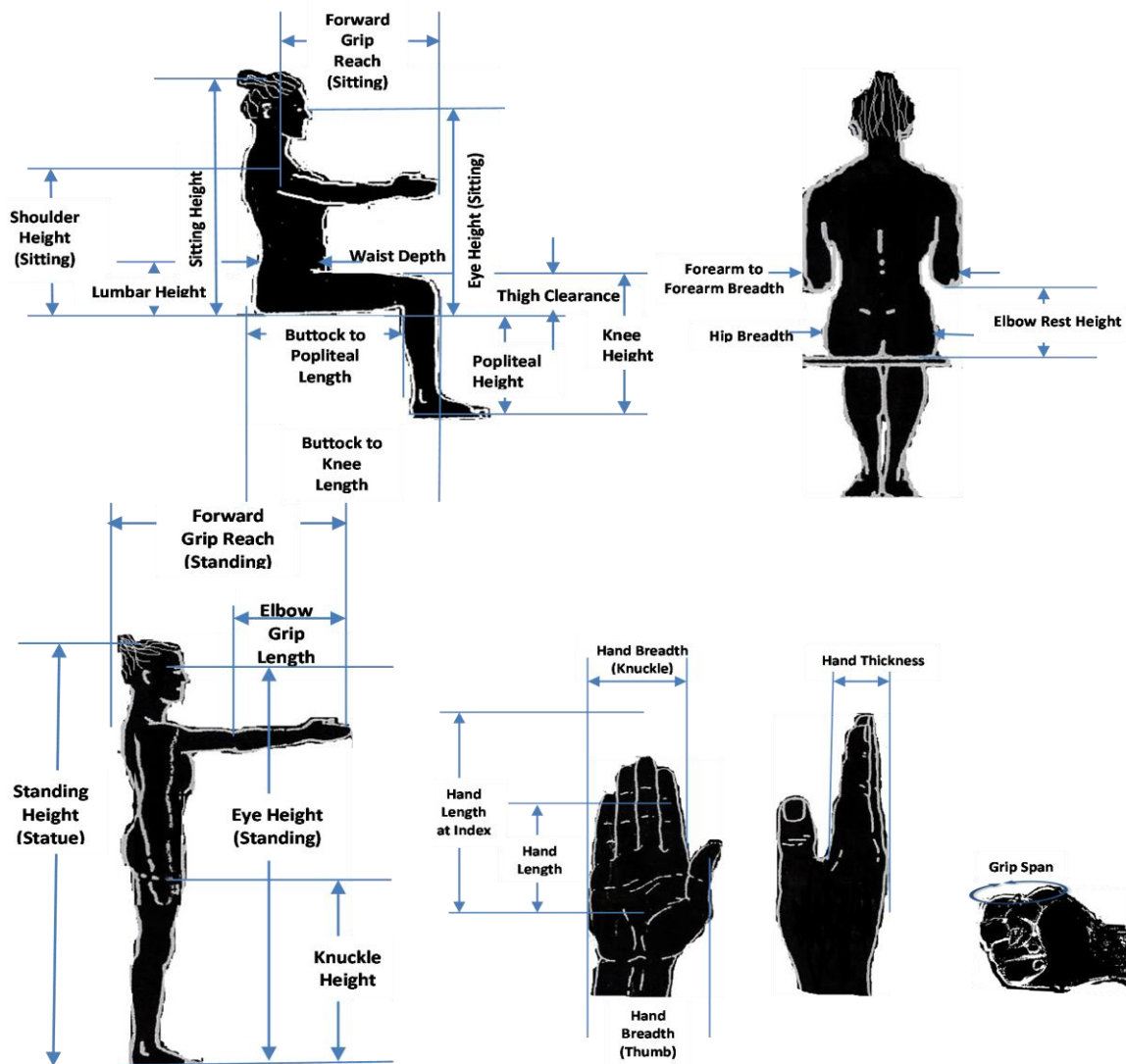


Figure 1 Anthropometric measurements taken

2.2 Statistical analysis

The data collected were analysed using descriptive and inferential statistical analysis with the aid of SPSS 20 software. The descriptive analysis and frequency distribution were carried out for each of the states under investigation. This involved the determination of the following: mean, mode, standard deviation, minimum and maximum values. In order to satisfy the different population targets workplace designers would have, different percentiles (2nd, 5th, 25th, 50th, 75th and 95th) were calculated for each of the states for all the data. This further assisted in investigating the discrepancy between the data collected from each of the states.

For the inferential statistical analysis, a t-test (paired samples) was carried out so as to know whether there was

any significant difference between the means of the anthropometric parameters of Ogun state and each of the other states. In carrying out the analyses, Ogun state was used as the reference factor during the comparison. This was done at 5% level of significance.

3 Results

3.1 Anthropometry of gari-frying workers in Ogun state

Table 1 shows the various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th, 75th and 95th) of female gari-frying workers in Ogun state, Nigeria. High deviation was observed for the age, weight height and eye height (standing), but other

anthropometric parameters had lower standard deviations ranging from 0.14 cm for grip span to 4.42 cm for forearm-to-forearm breadth. Most of the population were aged 40 years, with average weight of 43kg and a height of 1.44 m. Chinedu and Emiloju (2014) reported that the average weight and height of young female adults

in Ota Ogun state are 63.76 ± 1.77 kg and 1.66 ± 0.08 m respectively which is around the 75th and 95th percentile of this study, indicating that anthropometric data from a separate population within a target location is not suitable for workplace design for gari frying.

Table 1 Anthropometry of gari-frying workers in Ogun state, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	46.40	40.00 ^a	13.98	30.13	25.00	65.00	25.00	25.05	35.75	42.50	61.50	65.00
Weight (kg)	52.70	43.00 ^a	11.39	21.61	39.00	88.00	39.00	39.10	43.25	52.00	59.50	86.85
Height (cm)	153.05	144.00 ^a	6.84	4.47	141.00	164.00	141.00	141.15	147.50	153.00	159.25	164.00
Shoulder Height (sitting) (cm)	53.57	50.40 ^a	2.39	4.46	49.35	57.40	49.35	49.40	51.63	53.55	55.74	57.40
Eye height (standing) (cm)	141.35	132.00 ^a	6.62	4.68	132.00	152.00	132.00	132.00	135.25	141.00	147.75	152.00
Eye height (sitting) (cm)	65.19	65.10 ^a	3.79	5.81	58.40	70.40	58.40	58.41	62.80	65.25	68.23	70.39
Forward grip reach (standing) (cm)	67.50	67.00 ^a	2.97	4.40	61.00	72.00	61.00	61.05	65.25	67.75	70.00	71.95
Forward grip reach (sitting) (cm)	66.71	66.60	3.45	5.17	61.60	74.00	61.60	61.62	64.20	66.60	69.73	73.91
Sitting height (cm)	75.57	77.80	4.28	5.66	69.20	87.40	69.20	69.24	72.85	75.45	77.95	87.12
Buttock-popliteal length (cm)	47.52	46.00 ^a	3.04	6.40	41.70	54.10	41.70	41.71	45.68	48.00	49.10	53.97
Buttock-to-knee length (cm)	55.91	55.60 ^a	3.21	5.74	50.60	62.20	50.60	50.65	54.13	55.75	58.18	62.14
Popliteal height (sitting) (cm)	39.89	40.50	3.15	7.90	35.40	49.20	35.40	35.43	38.28	39.95	41.03	48.94
Knee height (sitting) (cm)	49.03	48.30	2.39	4.87	44.30	53.20	44.30	44.33	48.30	49.05	51.10	53.15
Thigh clearance (cm)	12.62	11.90 ^a	2.03	16.09	8.90	17.80	8.90	8.96	11.50	12.15	13.93	17.71
Forearm-to-forearm breadth (cm)	40.23	40.31	4.42	10.99	33.78	51.21	33.78	33.85	37.38	39.58	41.52	51.15
Waist depth (cm)	25.40	24.90	2.88	11.34	20.70	34.20	20.70	20.76	24.33	25.38	26.37	33.92
Elbow rest height (sitting) (cm)	17.34	17.90 ^a	2.43	14.01	12.20	22.00	12.20	12.32	15.58	17.35	19.08	21.92
Knuckle height (cm)	65.98	64.00 ^a	3.55	5.38	60.00	72.00	60.00	60.05	63.25	66.00	68.38	71.95
Elbow grip length (cm)	34.61	33.60 ^a	1.83	5.29	31.00	37.40	31.00	31.06	33.08	35.15	35.75	37.39
Hip breadth (sitting) (cm)	30.20	26.10 ^a	3.31	10.96	26.10	39.71	26.10	26.13	27.89	29.45	32.40	39.45
Hand length (cm)	10.42	10.30	0.52	4.99	9.60	11.40	9.60	9.61	10.00	10.35	10.85	11.40
Hand breadth at thumb (cm)	9.19	9.20	0.38	4.13	8.30	9.80	8.30	8.32	8.93	9.20	9.48	9.80
Hand breadth at knuckles (cm)	6.87	6.50	0.86	12.52	5.60	9.10	5.60	5.62	6.40	6.55	7.20	9.07
Hand thickness (cm)	4.23	4.00	0.45	10.64	3.20	5.20	3.20	3.23	4.00	4.15	4.50	5.19
Grip span (cm)	2.87	2.90 ^a	0.18	6.27	2.50	3.20	2.50	2.51	2.80	2.90	3.00	3.20
Hand length @ index (cm)	17.03	17.00	1.18	6.93	15.00	20.00	15.00	15.03	16.13	17.00	17.88	19.93
Lumbar height (cm)	14.96	13.60	2.90	19.39	10.50	22.00	10.50	10.53	13.45	14.35	17.38	21.86

Note: Multiple modes exist. The smallest value is shown

3.2 Anthropometry of gari-frying workers in Ekiti state

Table 2 shows the various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th, 75th and 95th) of female gari-frying workers in Ekiti, Nigeria. This population showed high standard deviation in their ages and weights, but lower deviation for other anthropometric parameters. The modal age,

weight and height were 40years, 51.50 kg and 1.59 m, respectively. Adeodu et al. (2014) reported 66.59 in (169.67 cm) and 17.41 in (44.22 cm) for the stature and popliteal height of some hospital patients in Ekiti state. Their results fall around 95th percentile of this study. This also shows that a workplace designed based on anthropometric data from another population (even in the same location) will not be ergonomically suitable for the target population.

Table 2 Anthropometry of gari-frying workers in Ekiti state, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	35.15	40.00	10.14	28.85	25.00	63.00	25.00	25.00	26.25	32.00	40.00	62.35
Weight (kg)	59.63	51.50 ^a	9.42	15.80	46.50	83.50	46.50	46.53	52.25	58.50	64.75	83.00
Height (cm)	157.80	159.00	4.74	3.00	147.50	167.00	147.50	147.68	155.00	157.75	160.88	166.90
Shoulder Height (sitting) (cm)	55.23	55.65	1.66	3.01	51.63	58.45	51.63	51.69	54.25	55.22	56.31	58.42
Eye height (standing) (cm)	145.73	146.00	4.77	3.27	135.00	154.00	135.00	135.15	143.00	146.00	148.75	154.00
Eye height (sitting) (cm)	67.99	64.60	3.12	4.59	64.30	75.70	64.30	64.31	64.75	68.00	70.60	75.51
Forward grip reach (standing) (cm)	71.08	70.00	2.94	4.14	62.50	75.50	62.50	62.75	70.00	70.50	73.38	75.45
Forward grip reach (sitting) (cm)	66.45	63.40 ^a	2.83	4.26	62.40	72.10	62.40	62.45	64.33	65.45	68.90	72.04
Sitting height (cm)	80.11	79.20 ^a	2.53	3.16	75.20	87.10	75.20	75.30	78.38	80.05	81.18	86.92
Buttock-popliteal length (cm)	49.63	49.10	2.18	4.39	46.20	54.50	46.20	46.21	48.75	49.40	50.83	54.44
Buttock-to-knee length (cm)	58.07	56.40 ^a	2.57	4.43	50.90	62.20	50.90	51.08	56.43	58.60	59.70	62.15
Popliteal height (sitting) (cm)	40.49	40.40 ^a	2.78	6.87	34.30	46.90	34.30	34.43	38.53	40.80	41.85	46.76
Knee height (sitting) (cm)	51.24	52.40	2.23	4.35	45.60	55.20	45.60	45.74	49.68	51.30	52.55	55.18
Thigh clearance (cm)	13.09	13.90 ^a	2.01	15.36	9.60	17.90	9.60	9.65	11.45	13.05	14.35	17.82
Forearm-to-forearm breadth (cm)	42.46	40.01	3.53	8.31	36.81	49.31	36.81	36.83	40.00	41.59	45.51	49.21
Waist depth (cm)	25.69	25.90	1.61	6.27	21.50	30.09	21.50	21.63	25.13	25.46	26.31	29.96
Elbow rest height (sitting) (cm)	17.60	18.90	2.05	11.65	14.10	23.60	14.10	14.17	15.95	17.60	18.90	23.41
Knuckle height (cm)	69.28	68.00	2.45	3.54	65.00	74.00	65.00	65.05	68.00	69.00	70.50	73.98
Elbow grip length (cm)	35.06	34.10	1.30	3.71	32.40	38.40	32.40	32.44	34.13	35.05	35.78	38.33
Hip breadth (sitting) (cm)	29.79	26.15 ^a	2.49	8.36	26.15	34.45	26.15	26.16	27.66	30.07	31.57	34.43
Hand length (cm)	10.31	9.52	0.68	6.60	8.85	11.50	8.85	8.88	9.73	10.35	10.82	11.49
Hand breadth at thumb (cm)	9.42	9.20 ^a	0.41	4.35	8.75	10.50	8.75	8.75	9.14	9.41	9.75	10.47
Hand breadth at knuckles (cm)	6.94	6.04 ^a	0.51	7.35	6.04	7.94	6.04	6.05	6.58	6.82	7.27	7.93
Hand thickness (cm)	4.18	4.21	0.35	8.37	3.30	4.81	3.30	3.32	3.94	4.22	4.36	4.80
Grip span (cm)	2.93	2.75 ^a	0.36	12.29	2.00	3.57	2.00	2.03	2.74	2.89	3.12	3.57
Hand length @ index (cm)	17.42	17.50	0.72	4.13	16.00	18.80	16.00	16.03	17.00	17.50	17.95	18.79
Lumbar height (cm)	16.95	11.90 ^a	2.14	12.63	11.90	21.30	11.90	12.03	15.45	17.05	17.88	21.24

Note: a. Multiple modes exist. The smallest value is shown

3.3 Anthropometry of gari-frying workers in Lagos state

Table 3 shows the various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th,

75th and 95th) of female gari-frying workers in Lagos Nigeria. The modal weight and height are 62 kg and 1.6 m, respectively. The age and weight also showed high deviation, unlike the anthropometric parameters.

Table 3 Anthropometry of gari-frying workers in Lagos state, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	41.10	18.00 ^a	14.91	36.28	18.00	60.00	18.00	18.00	26.75	43.50	55.00	60.00
Weight (kg)	59.80	62.00	12.52	20.94	45.00	93.00	45.00	45.00	49.25	60.50	68.75	92.20
Height (cm)	157.60	160.00	4.02	2.55	150.00	164.00	150.00	150.00	154.25	158.25	160.00	164.00
Shoulder Height (sitting) (cm)	55.16	56.00	1.41	2.56	52.50	57.40	52.50	52.50	53.99	55.39	56.00	57.40
Eye height (standing) (cm)	146.05	145.00	4.21	2.88	138.00	154.00	138.00	138.05	142.50	145.50	149.75	153.90
Eye height (sitting) (cm)	65.63	67.60	3.19	4.86	58.40	71.60	58.40	58.49	63.93	65.90	67.55	71.53
Forward grip reach (standing) (cm)	67.54	67.00	3.01	4.46	59.50	73.50	59.50	59.68	66.63	67.25	69.13	73.43
Forward grip reach (sitting) (cm)	68.86	66.10 ^a	2.34	3.40	65.20	74.20	65.20	65.25	66.60	68.90	70.70	74.10
Sitting height (cm)	77.64	75.20 ^a	2.87	3.70	70.40	81.40	70.40	70.52	75.38	78.25	79.58	81.40
Buttock-popliteal length (cm)	49.19	49.40	1.96	3.98	46.10	52.40	46.10	46.11	47.88	49.25	50.95	52.39
Buttock-to-knee length (cm)	58.43	58.20 ^a	2.38	4.07	55.10	62.70	55.10	55.11	56.38	58.20	60.85	62.67
Popliteal height (sitting) (cm)	39.60	39.20	2.07	5.23	36.10	43.40	36.10	36.12	38.35	39.30	41.35	43.35
Knee height (sitting) (cm)	51.16	50.10 ^a	1.98	3.87	48.10	55.60	48.10	48.11	49.88	51.20	52.50	55.55
Thigh clearance (cm)	13.34	11.10 ^a	2.25	16.87	10.30	18.20	10.30	10.31	11.53	13.00	15.05	18.14
Forearm-to-forearm breadth (cm)	43.76	47.05	4.80	10.97	35.39	56.04	35.39	35.45	40.05	43.72	46.97	55.64
Waist depth (cm)	26.57	24.20 ^a	2.66	10.01	22.30	34.10	22.30	22.35	24.50	26.31	28.39	33.85
Elbow rest height (sitting) (cm)	16.77	14.90 ^a	2.36	14.07	12.50	22.20	12.50	12.54	15.18	16.30	18.25	22.14
Knuckle height (cm)	69.59	70.00	2.11	3.03	67.00	73.50	67.00	67.00	67.50	70.00	71.03	73.48
Elbow grip length (cm)	34.85	33.20 ^a	1.34	3.85	32.60	37.70	32.60	32.63	34.13	34.70	35.60	37.69
Hip breadth (sitting) (cm)	30.77	23.63 ^a	3.63	11.80	23.63	40.05	23.63	23.81	28.07	29.99	33.30	39.83
Hand length (cm)	10.38	10.45	0.90	8.67	8.50	11.94	8.50	8.52	9.86	10.48	11.19	11.91
Hand breadth at thumb (cm)	9.37	9.15 ^a	0.55	5.87	8.35	10.25	8.35	8.35	9.08	9.36	9.83	10.25
Hand breadth at knuckles (cm)	7.20	7.05 ^a	0.61	8.47	6.37	8.25	6.37	6.37	6.61	7.18	7.75	8.24
Hand thickness (cm)	4.24	3.80 ^a	0.45	10.61	3.63	5.10	3.63	3.63	3.91	4.12	4.53	5.10
Grip span (cm)	2.92	2.50 ^a	0.36	12.33	2.40	3.90	2.40	2.41	2.66	2.85	3.13	3.88
Hand length @ index (cm)	17.66	17.50	0.81	4.59	16.20	19.20	16.20	16.22	17.00	17.65	18.20	19.18
Lumbar height (cm)	16.69	15.80 ^a	2.31	13.84	11.80	20.10	11.80	11.86	15.65	17.00	18.18	20.07

Note: a. Multiple modes exist. The smallest value is shown

3.4 Anthropometry of gari-frying workers in Ondo state

Table 4 shows various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th, 75th and 95th) of female gari-frying workers in Ondo, Nigeria. Most of them are 1.51 m tall and weigh 49 kg. The standard deviation was observed to be high for the age, weight and height and lower for other

anthropometric parameters ranging from 0.20 cm for grip span to 5.75 cm for eye height (standing) Olayiwola et al. (2013) reported the height and weight of elderly adults in Ondo State as 1.57 ± 0.08 m and 54.87 ± 12.01 kg, respectively which are in line with this study. On the other hand Oladapo et al. (2013) reported a mean stature and weight as 1.69 ± 0.05 m and 70.82 ± 9.60 kg respectively for females in Owo, Ondo state.

Table 4 Anthropometry of gari-frying workers in Ondo, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	40.70	35.00 ^a	8.79	21.60	27.00	60.00	27.00	27.20	35.00	40.00	44.50	60.00
Weight (kg)	67.20	49.00 ^a	19.89	29.60	44.00	115.00	44.00	44.03	49.00	64.00	86.00	113.75
Height (cm)	155.95	151.00 ^a	6.02	3.86	147.00	170.00	147.00	147.05	152.00	154.50	159.50	169.85
Shoulder Height (sitting) (cm)	54.58	52.85 ^a	2.11	3.87	51.45	59.50	51.45	51.47	53.20	54.08	55.83	59.45
Eye height (standing) (cm)	144.05	145.00	5.75	3.99	136.00	160.00	136.00	136.10	140.25	143.00	145.00	159.65
Eye height (sitting) (cm)	66.89	68.10	2.65	3.96	61.10	72.40	61.10	61.15	65.95	67.75	68.18	72.24
Forward grip reach (standing) (cm)	67.78	64.50 ^a	4.06	5.99	61.00	75.50	61.00	61.05	64.50	67.50	70.88	75.43
Forward grip reach (sitting) (cm)	66.55	68.20	3.62	5.44	60.40	75.10	60.40	60.50	63.63	66.70	68.20	75.05
Sitting height (cm)	78.69	79.40	2.62	3.33	74.40	83.30	74.40	74.44	76.03	78.75	81.20	83.24
Buttock-popliteal length (cm)	49.09	45.70	2.83	5.76	45.70	55.30	45.70	45.70	47.25	48.75	49.63	55.29
Buttock-to-knee length (cm)	58.19	57.40 ^a	3.25	5.59	53.20	66.20	53.20	53.25	57.20	57.60	58.70	66.15
Popliteal height (sitting) (cm)	39.41	36.90 ^a	2.52	6.39	36.10	46.20	36.10	36.14	37.23	38.95	41.00	46.05
Knee height (sitting) (cm)	49.90	51.20	3.70	7.41	40.92	58.40	40.92	41.18	47.95	49.55	51.20	58.28
Thigh clearance (cm)	13.14	12.40	2.00	15.22	7.40	16.10	7.40	7.54	12.40	13.30	14.45	16.09
Forearm-to-forearm breadth (cm)	41.83	29.24 ^a	6.36	15.20	29.24	59.81	29.24	29.50	38.47	41.11	44.04	59.45
Waist depth (cm)	26.35	26.20	2.79	10.59	21.10	33.15	21.10	21.14	25.31	26.35	27.00	33.09
Elbow rest height (sitting) (cm)	17.59	17.20	1.70	9.66	14.90	21.60	14.90	14.93	16.73	17.20	19.03	21.53
Knuckle height (cm)	68.61	65.00 ^a	3.57	5.20	63.00	75.00	63.00	63.05	65.00	68.20	71.80	74.98
Elbow grip length (cm)	34.65	33.20 ^a	1.73	4.99	32.40	38.80	32.40	32.42	33.25	34.50	35.43	38.80
Hip breadth (sitting) (cm)	31.13	25.45 ^a	3.06	9.83	25.45	36.41	25.45	25.49	28.33	31.08	33.74	36.35
Hand length (cm)	10.60	10.90	0.72	6.79	9.40	12.20	9.40	9.41	10.21	10.65	11.00	12.17
Hand breadth at thumb (cm)	9.43	8.56 ^a	0.52	5.51	8.56	10.30	8.56	8.57	8.99	9.34	9.88	10.30
Hand breadth at knuckles (cm)	6.89	6.84 ^a	0.31	4.50	6.15	7.56	6.15	6.16	6.68	6.88	7.08	7.54
Hand thickness (cm)	4.13	3.47 ^a	0.33	7.99	3.47	4.61	3.47	3.47	3.93	4.11	4.42	4.61
Grip span (cm)	2.94	2.75 ^a	0.20	6.80	2.60	3.34	2.60	2.60	2.78	2.95	3.10	3.34
Hand length @ index (cm)	17.48	17.00 ^a	0.90	5.15	16.20	20.00	16.20	16.22	16.85	17.35	18.00	19.94
Lumbar height (cm)	16.92	18.10	3.01	17.79	11.40	22.60	11.40	11.47	14.50	17.05	18.93	22.58

Note: a. Multiple modes exist. The smallest value is shown

3.5 Anthropometry of gari-frying workers in Osun state

Table 5 shows various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th, 75th and 95th) of female gari-frying workers in Osun, Nigeria. It was observed that the modal weight and height are 77kg and 1.57 m respectively. The result is

comparable to that of Ojo and Mohammed (2013) who reported the height of retirees and non-retirees in Ile-Ife, Osun state as 1.6 ± 0.101 m and 1.6 ± 0.1 m respectively with a mean weight of 74.3 ± 10.9 kg and 73.5 ± 8.7 kg respectively. The standard deviation within this population ranged from 0.39 cm for grip span to 17 kg for the weight.

Table 5 Anthropometry of gari-frying workers in Osun state, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	47.70	40.00	11.54	24.19	30.00	67.00	30.00	30.25	40.00	43.00	61.50	66.90
Weight (kg)	80.75	77.00 ^a	17.91	22.18	52.00	126.00	52.00	52.20	63.00	82.00	92.75	124.60
Height (cm)	158.35	157.00 ^a	5.84	3.69	146.00	170.00	146.00	146.20	154.25	158.50	161.75	169.80
Shoulder Height (sitting) (cm)	55.42	54.95 ^a	2.04	3.68	51.10	59.50	51.10	51.17	53.99	55.48	56.61	59.43
Eye height (standing) (cm)	146.20	149.00	6.14	4.20	134.00	159.00	134.00	134.15	142.25	147.00	149.75	158.75
Eye height (sitting) (cm)	66.43	65.10	2.96	4.46	60.70	73.40	60.70	60.83	64.63	65.35	68.25	73.31
Forward grip reach (standing) (cm)	66.45	69.00	3.07	4.62	60.50	71.00	60.50	60.55	63.88	66.75	69.00	71.00
Forward grip reach (sitting) (cm)	67.72	67.90 ^a	2.53	3.74	61.40	71.20	61.40	61.54	66.18	68.55	69.20	71.20
Sitting height (cm)	76.70	79.30	4.83	6.30	60.80	82.20	60.80	61.35	74.75	78.00	79.38	82.19
Buttock-popliteal length (cm)	48.91	47.20 ^a	3.42	6.99	40.90	56.70	40.90	41.09	47.03	48.90	51.05	56.56
Buttock-to-knee length (cm)	57.85	58.20	3.57	6.17	50.40	66.80	50.40	50.56	55.13	58.20	59.05	66.63
Popliteal height (sitting) (cm)	39.74	36.40 ^a	5.29	13.31	35.20	59.40	35.20	35.25	36.63	38.55	41.18	58.70
Knee height (sitting) (cm)	51.60	51.20	1.83	3.55	47.20	54.40	47.20	47.30	50.48	51.30	53.20	54.38
Thigh clearance (cm)	14.31	12.10 ^a	1.87	13.07	10.20	18.10	10.20	10.30	12.95	14.15	15.75	18.04
Forearm-to-forearm breadth (cm)	47.59	49.34	4.65	9.77	39.45	56.05	39.45	39.51	43.62	47.48	51.58	55.95
Waist depth (cm)	28.08	21.45 ^a	2.53	9.01	21.45	32.75	21.45	21.68	26.58	27.85	29.82	32.72
Elbow rest height (sitting) (cm)	18.14	17.80 ^a	2.30	12.68	13.90	22.10	13.90	13.93	16.35	18.30	19.88	22.08
Knuckle height (cm)	69.73	72.00	3.50	5.02	65.00	75.00	65.00	65.00	65.88	70.00	72.38	74.95
Elbow grip length (cm)	35.16	33.20 ^a	1.63	4.64	31.80	37.90	31.80	31.87	33.95	35.25	36.50	37.89
Hip breadth (sitting) (cm)	34.27	38.84	3.45	10.07	27.34	41.34	27.34	27.45	31.54	34.39	35.93	41.22
Hand length (cm)	10.22	9.80	1.10	10.76	8.04	12.34	8.04	8.06	9.50	10.23	10.97	12.31
Hand breadth at thumb (cm)	9.47	9.50 ^a	0.60	6.34	8.00	10.65	8.00	8.03	9.02	9.58	9.80	10.62
Hand breadth at knuckles (cm)	6.83	6.80 ^a	0.59	8.64	5.45	7.94	5.45	5.48	6.50	6.84	7.19	7.93
Hand thickness (cm)	4.22	3.50 ^a	0.42	9.95	3.50	5.00	3.50	3.50	3.91	4.25	4.49	5.00
Grip span (cm)	3.00	2.70 ^a	0.39	13.00	2.00	3.84	2.00	2.03	2.73	3.03	3.24	3.82
Hand length @ index (cm)	17.12	16.50	0.87	5.08	15.50	18.50	15.50	15.52	16.50	17.20	17.80	18.50
Lumbar height (cm)	16.20	18.40	2.57	15.86	12.60	21.10	12.60	12.62	13.88	16.25	18.40	21.01

Note: a. Multiple modes exist. The smallest value is shown

3.6 Anthropometry of gari-frying workers in Oyo state

Table 6 shows various body dimensions and estimates of the mean, mode, standard deviation, minimum, maximum and percentiles (2nd, 5th, 25th, 50th,

75th and 95th) of female gari-frying workers in Oyo, Nigeria. A height of 1.6 m and weight of 38 kg was common in this population while a low standard deviation of 0.30 cm for hand thickness and a high standard deviation of 15.81 kg for the weight were recorded.

Table 6 Anthropometry of gari-frying workers in Oyo state, Nigeria

Parameters	Mean	Mode	Std. Dev.	CV%	Min	Max	Percentiles					
							2	5	25	50	75	95
Age (yrs.)	43.10	50.00	8.15	18.91	28.00	58.00	28.00	28.20	36.00	43.00	50.00	57.95
Weight (kg)	60.13	38.00 ^a	15.81	26.29	38.00	88.00	38.00	38.00	47.50	56.50	74.50	88.00
Height (cm)	157.90	160.00	5.82	3.69	144.00	167.00	144.00	144.15	154.25	159.00	161.00	166.95
Shoulder Height (sitting) (cm)	55.27	56.00	2.04	3.69	50.40	58.45	50.40	50.45	53.99	55.65	56.35	58.43
Eye height (standing) (cm)	145.10	148.00	5.27	3.63	133.00	154.00	133.00	133.15	142.00	145.50	148.00	154.00
Eye height (sitting) (cm)	70.47	67.20	4.06	5.76	59.50	76.90	59.50	59.87	67.73	70.40	73.13	76.89
Forward grip reach (standing) (cm)	70.93	70.50	3.35	4.72	65.50	77.00	65.50	65.53	67.63	71.25	73.00	76.95
Forward grip reach (sitting) (cm)	67.57	71.10	4.92	7.28	51.80	74.90	51.80	52.33	65.70	68.75	70.90	74.77
Sitting height (cm)	79.95	78.40 ^a	4.19	5.24	70.10	86.20	70.10	70.11	78.40	81.00	82.33	86.18
Buttock-popliteal length (cm)	50.97	44.90 ^a	3.10	6.08	44.90	56.40	44.90	44.97	49.23	51.00	53.75	56.35
Buttock-to-knee length (cm)	60.44	58.90	3.16	5.23	53.20	65.60	53.20	53.32	58.53	60.70	62.95	65.53
Popliteal height (sitting) (cm)	41.09	39.90	2.46	5.99	36.20	46.10	36.20	36.25	39.53	40.80	43.05	46.01
Knee height (sitting) (cm)	51.52	49.90 ^a	2.30	4.46	46.10	55.00	46.10	46.18	49.98	51.40	53.35	54.99
Thigh clearance (cm)	14.15	14.90 ^a	2.77	19.58	9.40	18.90	9.40	9.43	12.50	14.20	16.18	18.90
Forearm-to-forearm breadth (cm)	42.03	50.89	6.17	14.68	30.06	51.25	30.06	30.24	37.36	41.53	48.13	51.25
Waist depth (cm)	25.09	12.30 ^a	4.50	17.94	12.30	32.17	12.30	12.60	24.13	25.77	27.37	32.11
Elbow rest height (sitting) (cm)	20.31	19.80	5.25	25.85	14.30	39.60	14.30	14.33	17.18	19.80	21.83	38.82
Knuckle height (cm)	70.10	69.00 ^a	3.14	4.48	62.00	77.00	62.00	62.15	69.00	70.50	71.88	76.80
Elbow grip length (cm)	35.53	37.10	2.10	5.91	28.20	37.70	28.20	28.48	35.03	35.75	37.10	37.70
Hip breadth (sitting) (cm)	30.69	25.30 ^a	3.60	11.73	25.30	37.02	25.30	25.31	27.13	30.33	34.02	36.94
Hand length (cm)	10.82	10.60 ^a	0.85	7.86	9.50	12.55	9.50	9.52	10.11	10.60	11.20	12.54
Hand breadth at thumb (cm)	9.44	8.90	0.46	4.87	8.83	10.20	8.83	8.83	9.00	9.41	9.84	10.20
Hand breadth at knuckles (cm)	6.92	6.70 ^a	0.52	7.51	5.75	7.86	5.75	5.77	6.66	7.02	7.29	7.84
Hand thickness (cm)	4.24	4.30	0.30	7.08	3.80	4.80	3.80	3.80	3.98	4.28	4.38	4.80
Grip span (cm)	3.12	2.90 ^a	0.33	10.58	2.55	3.93	2.55	2.55	2.92	3.09	3.29	3.92
Hand length @ index (cm)	17.64	16.50 ^a	0.86	4.88	16.50	19.50	16.50	16.50	17.00	17.50	18.38	19.47
Lumbar height (cm)	18.25	18.10 ^a	2.80	15.34	13.20	22.50	13.20	13.25	15.68	18.45	21.10	22.46

Note: a. Multiple modes exist. The smallest value is shown

3.7 BMI and BSA of gari-frying workers

Table 7 and Table 8 respectively reveal the BMI and BSA variations within and between each of the six states under study. The results are close to those reported by other researchers who studied other populations within each state. Based on World Health Organization classification (WHO, 2006) of adult underweight, overweight and obesity according to BMI, the 2nd, 5th, and 25th percentiles fall within the range of mild thinness

and normal range (i.e. 17.00 – 24.99 kg/m²) except for the 25th percentile for Osun state (which falls into the overweight class) while the 75th and 95th percentiles are overweight (above 25.00 kg/m²) except for Oyo state. Even though the 95th percentiles for the six states can be classified under obese, that of Osun state falls under obese class III (≥ 40.00 kg/m²) which is consistent with the findings of Adebayo et al., (2014) and Chukwuonye et al. (2013).

Table 7 BMI variation between gari-frying population in southwestern Nigeria (kg/m²)

States	Mean	Mode	Std. Dev.	CV %	Min	Max	Percentiles					
							2	5	25	50	75	95
Ekiti	24.03	17.47 ^a	4.14	17.23	17.47	33.45	17.47	17.52	20.82	23.82	26.22	33.35
Lagos	24.07	20.00 ^a	5.03	20.90	18.36	39.21	18.36	18.40	20.11	23.05	27.27	38.72
Ogun	22.40	17.51 ^a	4.10	18.30	17.51	36.63	17.51	17.54	20.04	21.59	24.23	36.10
Ondo	27.43	18.29 ^a	7.07	25.77	18.29	39.79	18.29	18.33	20.78	27.58	32.72	39.73
Osun	32.38	33.56	7.87	24.31	20.83	52.45	20.83	20.89	26.83	32.40	35.82	51.98
Oyo	24.07	13.96 ^a	6.04	25.09	13.96	36.63	13.96	14.15	19.88	22.49	29.20	36.50

Note: a. Multiple modes exist. The smallest value is shown

Table 8 BSA variation between gari-frying population in southwestern Nigeria (m²)

States	Mean	Mode	Std. Dev.	CV %	Min	Max	Percentiles					
							2	5	25	50	75	95
Ekiti	1.60	1.56 ^a	0.11	6.88	1.42	1.85	1.42	1.42	1.51	1.57	1.66	1.84
Lagos	1.59	1.37 ^a	0.15	9.43	1.37	1.90	1.37	1.37	1.48	1.58	1.72	1.90
Ogun	1.48	1.30 ^a	0.16	10.81	1.27	1.87	1.27	1.27	1.35	1.45	1.61	1.86
Ondo	1.66	1.40 ^a	0.24	14.46	1.36	2.23	1.36	1.36	1.42	1.61	1.85	2.22
Osun	1.82	1.78 ^a	0.17	9.34	1.51	2.17	1.51	1.51	1.67	1.81	1.96	2.16
Oyo	1.60	1.53 ^a	0.19	11.88	1.24	1.92	1.24	1.25	1.44	1.57	1.78	1.92

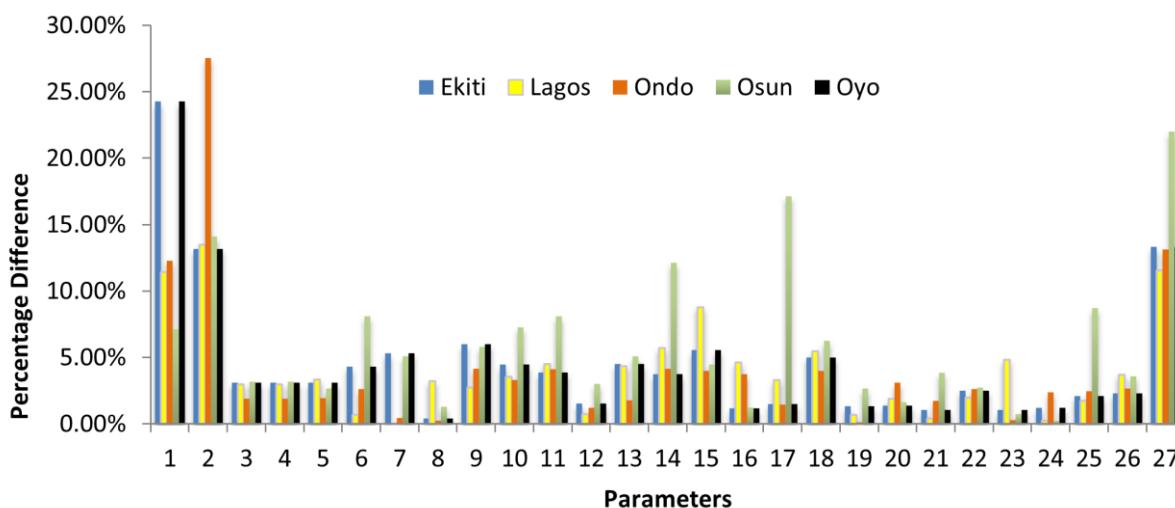
Note: a. Multiple modes exist. The smallest value is shown

A maximum BSA value of 2.23 m² was observed in Ondo state. This does not tally with that of the BMI thereby confirming the report by Adler et al. (2012) who reported that BSA values are less accurate at extremes of height and weight. Osun state has the highest mean BMI and BSA values of 32.38 kg/m² and 1.82 m² respectively. The BSA result confirms the report that average BSA of a woman is 1.6 m² (Ray et al., 2012).

3.8 Comparative analysis

Figure 2 shows the extent of variation of each measured parameter between each state of Ekiti, Lagos, Ondo, Osun and Oyo against Ogun (reference state).

The result showed that for all the states, there was a notable variation of around 11.42% – 24.25% in the mean age, weight and lumbar height except for Osun state with 7.11% difference, compared to Ogun state. The mean values for forward grip reach (standing), sitting height, forearm-to-forearm, breadth and knuckle height for most of the five states were 5% – 6%, different from that of Ogun state. Six anthropometric parameters from Lagos state were less than 1%, different from that of Ogun state while for Osun state; eight parameters were between 7% and 22%.



1-Age; 2-Weight; 3-Height; 4-Shoulder Height (sitting); 5-Eye height (standing); 6-Eye height (sitting); 7-Forward grip reach (standing); 8-Forward grip reach (sitting); 9-Sitting height; 10-Buttock-popliteal length; 11-Buttock-to-knee length; 12-Popliteal height (sitting); 13-Knee height (sitting); 14-Thigh clearance; 15-Forearm-to forearm breadth; 16-Waist depth; 17-Elbow rest height sitting; 18-Knuckle height; 19-Elbow grip length; 20-Hip breadth (sitting); 21-Hand length; 22-Hand breadth at thumb; 23-Hand breadth at knuckles; 24-Hand thickness; 25-Grip span; 26-Hand length @ index; 27-Lumbar height.

Figure 2 Variation between anthropometric data of different states in southwestern Nigeria

Table 9 shows the result of the paired sample t-test carried out. It is obvious that some variation exist in some of the parameters analysed between the states. Considering Ekiti state, Table 9 shows that 44% of the

parameters were significantly different from that of Ogun state. Lagos and Osun state both had 48% of their parameters significantly different from Ogun state’s anthropometric parameters. Oyo state had the highest

significance percentage (62%) while Ondo state had the lowest (15%). The parameters which had no significant difference between the reference state and each of the remaining states in Southwest Nigeria include; grip span,

hand thickness, elbow grip length and popliteal height (sitting). The buttock-to-knee length was the only anthropometric parameter that was significant between Ogun state and the other states considered.

Table 9 Paired sample t-test of anthropometry between gari-frying workers (5% level of significance)

Parameters	Ekiti and Ogun			Lagos and Ogun			Ondo and Ogun			Osun and Ogun			Oyo and Ogun		
	t	p	I	t	p	I	t	p	I	t	p	I	t	p	I
Age (yrs.)	-2.47	0.01	S	-1.33	0.10	N	-1.68	0.05	N	0.29	0.39	N	-1.13	0.14	N
Weight (kg)	2.25	0.02	S	1.72	0.05	N	2.65	0.01	S	7.28	0.00	S	1.70	0.05	N
Height (cm)	2.72	0.01	S	2.65	0.01	S	1.21	0.12	N	2.35	0.01	S	2.19	0.02	S
Shoulder Height (sitting) (cm)	2.72	0.01	S	2.65	0.01	S	1.21	0.12	N	2.35	0.01	S	2.19	0.02	S
Eye height (standing) (cm)	2.41	0.01	S	2.93	0.00	S	1.28	0.11	N	2.09	0.03	S	1.85	0.04	S
Eye height (sitting) (cm)	2.64	0.01	S	0.42	0.34	N	1.38	0.09	N	1.18	0.13	N	4.08	0.00	S
Forward grip reach (standing) (cm)	5.12	0.00	S	0.03	0.49	N	0.21	0.42	N	-1.18	0.13	N	2.71	0.01	S
Forward grip reach (sitting) (cm)	-0.30	0.39	N	2.51	0.01	S	-0.15	0.44	N	1.15	0.13	N	0.54	0.30	N
Sitting height (cm)	4.13	0.00	S	1.86	0.04	S	2.52	0.01	S	0.82	0.21	N	3.20	0.00	S
Buttock-popliteal length (cm)	2.65	0.01	S	2.59	0.01	S	1.37	0.09	N	1.80	0.04	S	3.00	0.00	S
Buttock-to-knee length (cm)	2.42	0.01	S	3.23	0.00	S	2.20	0.02	S	1.90	0.04	S	4.01	0.00	S
Popliteal height (sitting) (cm)	0.70	0.25	N	-0.34	0.37	N	-0.46	0.33	N	-0.10	0.46	N	1.18	0.13	N
Knee height (sitting) (cm)	3.16	0.00	S	3.32	0.00	S	0.81	0.21	N	3.88	0.00	S	3.40	0.00	S
Thigh clearance (cm)	0.80	0.22	N	0.93	0.18	N	0.72	0.24	N	2.69	0.01	S	1.94	0.03	S
Forearm-to-forearm breadth (cm)	1.70	0.05	N	2.13	0.02	S	0.79	0.22	N	5.86	0.00	S	1.02	0.16	N
Waist depth (cm)	0.38	0.35	N	1.40	0.09	N	1.03	0.16	N	3.01	0.00	S	-0.22	0.41	N
Elbow rest height (sitting) (cm)	0.38	0.35	N	-0.76	0.23	N	0.43	0.34	N	1.42	0.09	N	2.55	0.01	S
Knuckle height (cm)	1.10	0.14	N	4.44	0.00	S	2.08	0.03	S	2.85	0.01	S	4.10	0.00	S
Elbow grip length (cm)	1.02	0.16	N	0.39	0.35	N	0.06	0.48	N	0.96	0.17	N	1.75	0.05	N
Hip breadth (sitting) (cm)	-0.51	0.31	N	0.48	0.32	N	0.84	0.21	N	4.28	0.00	S	0.46	0.33	N
Hand length (cm)	-0.55	0.30	N	-0.18	0.43	N	0.95	0.18	N	-0.68	0.25	N	1.80	0.04	S
Hand breadth at thumb (cm)	1.69	0.05	N	1.19	0.12	N	1.62	0.06	N	1.93	0.03	S	2.21	0.02	S
Hand breadth at knuckles (cm)	0.37	0.36	N	1.83	0.04	S	0.09	0.46	N	-0.17	0.43	N	0.26	0.40	N
Hand thickness (cm)	-0.43	0.33	N	0.10	0.46	N	-0.73	0.24	N	-0.04	0.48	N	0.12	0.45	N
Grip span (cm)	0.60	0.28	N	0.59	0.28	N	1.24	0.11	N	1.33	0.10	N	3.05	0.00	S
Hand length @ index (cm)	1.20	0.12	N	2.07	0.03	S	1.17	0.13	N	0.30	0.39	N	2.29	0.02	S
Lumbar height (cm)	2.46	0.01	S	1.89	0.04	S	1.99	0.03	S	1.38	0.09	N	3.81	0.00	S

Note: t = t statistics, p = P-Value (one tail), I = Inference, N = Not significant, S = Significant

4 Conclusions

Anthropometric measurements of six states have been carried out and analysed while significant differences in some of the measured parameters were observed between the states. From this study, it is clear that the populations are not exactly the same in terms of some anthropometric measurements and body compositions. The variation observed shows that anthropometric data are not only operation-/job-specific but also location-specific, especially in terms of agricultural operations. Hence, it is pertinent and expedient for designers to make use of appropriate anthropometric data for the target location and population since significant difference in anthropometric data can

result in unsafe workplace which will not only affect the gari-frying workers, but also the productivity. The information provided in this paper will help in solving problems of fit in respect of the gari-frying working population, because it presents data that can be used to design an appropriate gari-frying workplace in each of the six southwestern states of Nigeria with its attendant safe operation of workers and higher productivity which could not have been without it.

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