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Anthropometric Characterisation Of Manual Workers In The Food Manufacturing Industry In Nigeria

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Abstract – Manual lifting is a necessary job duty that is frequently associated with occupational damage. The main goal of strategies to lower the risk of injuries is to make sure that workers are physically capable of performing essential job duties safely. The aim of this study was to investigate anthropometric characteristics associated with manual lifting activities. Three hundred and eighty-four (384) subjects comprising 337 males and 47 females from three (3) food manufacturing companies participated in the survey. Measurement of the body segments was done using anthropometer, vernier caliper and the weighing scale and analysed using statistical analysis of measures of dispersion and 2 tail t-test analysis at 5% significance level to find the relationship between the male and female population. The results indicated that there is no significant difference between the Wrist-to- Foot and the Knee-Joint-to-Leg-Wrist. However, the other twelve (12) body segment measurements show there are significant differences in the means of the male and the female population. Conclusively, the human body plays a crucial role in the design of human-machine interfaces (HMI). This study has highlighted the necessity of conducting a robust anthropometry survey in Nigeria for the user population. Such information can be utilised to set up the workspace in a way that will improve its ergonomic suitability, functional efficacy, and human convenience.

Keywords – Anthropometry, Characterisation, Musculoskeletal, Ergonomics,

I. INTRODUCTION

Anthropometric data are the basis of the ergonomic design used in size systems and are therefore used extensively in the development of products and equipment such as clothes, helmets and other wearable products, as well as for furniture and work equipment (Cakit *et al*., 2014). A lot of ergonomic risk factors are associated with manual materials handling (Di Natali *et al*, 2021). Due to the demands, it places on clothing, furniture, workspaces, engineering services, and the design of all manually controlled devices, human body characteristics have become a particularly important research subject. Despite its importance to the comfort, safety, and productivity of human operators in any facility, anthropometric survey is a field that receives little investigation. Anthropometry refers to the science of measurement and the art of application that determines the physical geometry, mass properties, and strength capacity of the human body (Andriani, 2019). It is focused with the scientific study of human subjects for the development of standards and the emergence of specific needs associated particularly with manufactured goods and services in order to increase product usability and suitability for the user population (Taifa and Desai, 2019). The bare minimum requirement for an ergonomically designed workplace is the ability to support extreme users, who typically range from a 5th percentile female to a 95th percentile male. Almost every piece of equipment, tool, vehicle, piece of clothing, pair of shoes, etc. that a human uses or operates on has some application for anthropometric data. In their comparative analysis of the anthropometric data variability between two communities, Ghosh *et. al*. (2005) noted that several of the variables, such as abdominal disposition, differ dramatically, suggesting the high level of sensitivity that certain morphological traits take. Sultan, *et. al.,* (2013) identified awkward working postures, extreme loads, and excessive temperatures as a major risk factor in manual material handling. When a worker is required to do a task while stretching, bending, twisting, or reaching because of poor workstation design and job procedure, this results in an awkward working posture. Materials handling is defined as handling, moving, lifting, lowering, or carrying equipment, materials, or goods from one place to another either by using supporting equipment or hand (Berie *et al*., 2009). Walking, standing, crouching, bending, twisting, and other repetitive or prolonged static and dynamic body movements are all part of manual handling operations. These are prominent causes of Work-Related Musculoskeletal Disorders (WRMSD) affecting almost all the parts of the body (Sado *et al*., 2018). Manual material handling plays a crucial role in carrying out multifarious activities in manufacturing plants which includes lifting, bending, pulling, pushing, and carrying (Bhatia and Kalra and Randhawa, 2021). Even if mechanisation is becoming increasingly advanced, physical material handling tasks are still crucial to the industrial sector of the economy. A major issue associated with such actions is that they are the main cause of over-exertion injuries. In many cases, manufacturing companies use forklifts to perform material handling tasks within the plant, which can also handle loading and transportation tasks (Fükő, *et al*, 2020). St-Vincent *et al*. (2005) indicated that averagely manual tasks took up 74.4% of 8-hour shift activities while handling tasks involving the pallet jack consumed 16% of the time in a particular store. This indicated the prevalence of manual handling activities. The current ergonomic challenges faced by generally developing nations and Nigeria in particular include the absence of sustainable and structured anthropometric data bank (Onawumi *et. al*. 2016). There are several anthropometric studies on Nigerians that have been published but have not been widely considered for implementation. Studies indicated that in many real-world industrial settings the workspace available to perform manual material handling activities is limited by many factors such as space limitation, workstation geometry etc. (Fükő, *et al*, 2020). Prior research on the biomechanics of manual lifting tasks mostly focused on situations where the lifting duties were performed in an open workspace. When there is an imbalance between a worker's body size and the demands of his or her employment, restricted and awkward postures develop. These lifting techniques frequently require asymmetry, a small headroom height, and access restrictions. Such stresses are mostly encountered in industries such as underground coal mines, warehousing, shipping, mining, maintenance etc. (Kumar *and Kumar, 2008*). According to biomechanical study, whenever there is a high internal stress exerted on the spinal structure as a result of inadequate movement patterns and a high external load, the risk of discomfort and injury is enhanced. Bad movement patterns primarily involve the trunk being bent or twisted. When lifting and reaching for an object to be placed on a high surface from a low one, bending occurs. The lack of enough workspace is the main cause of the trunk's twisting. Excessive trunk bending and twisting are associated with increased physiological and biomechanical costs as well as musculoskeletal problems (Bigos and Battie, 1991). The connection of back and abdominal muscles in lifting activities has been established over a long period of time. (Kumar and Mital, 1996). However, the industry's low back pain and injury issues have necessitated the search for any leads that can help in problem-solving.

II. Materials And Methods

A total of three food manufacturing companies covering both Lagos and Ogun States South-West Nigeria were studied. Ogun, Osun, and Oyo States (all in the South-West Nigeria) are progressively hosting manufacturing locations, however, over 88% of Nigeria's leading food and beverage industries have their headquarters in Lagos State. The food sub-sector employs 60% of the businesses, while the beverage sub-sector employs 28%. (Flanders Investment and Trade Survey, 2020). Ogun State's proximity to the largest market and the busiest ports in the country has contributed to it becoming a fast-growing industrial hub. (World Bank Report, 2020). The total population size of workers at these factories were 504 people comprising 160, 144 and 200 workers at the soft drink, beverage and candy plants, respectively. At a confidential level of 95% from Table 1, using the interpolation method for each of the factories, the sample size obtained is 392. A confidence level of 95% was suggested by Kothari *et al.* (2005) to be 95 % certain that the population contains the true mean of the population and to have data that are statistically significant. Enumerators were employed to provide surveys to participants in manual handling tasks. Surveys involving a large number of samples require a group of skilled and trained people to do the measurements to minimise errors (Ulijaszek and Kerr, 1999). Enumerators were trained on administering the questionnaire, which included going through each portion, identifying the critical manual lifting tasks, and conducting mock interviews and evaluations with the participants.

Table 1: Sample Size, Confidence Levels and Confidence Intervals for Random Samples

Population	Confidence Levels (90 %)			Confidence Levels (95 %)			Confidence Levels (99 %)		
	Confidence	Confidence	Confidence	Confidence	Confidence	Confidence	Confidence	Confidence	Confidence
30	27	28	29	28	29	29	29	29	30
50	42	45	47	44	46	48	46	48	49

75	59	64	68	63	67	70	67	70	72
100	73	81	88	79	86	91	87	91	95
120	83	94	104	91	100	108	102	108	113
150	97	111	125	108	120	132	122	131	139
200	115	136	158	132	150	168	154	168	180
250	130	157	188	151	176	203	182	201	220
300	143	176	215	168	200	234	207	233	258
350	153	192	239	183	221	264	229	262	294
400	162	206	262	196	240	291	250	289	329
450	170	219	282	207	257	317	268	314	362
500	176	230	301	217	273	340	285	337	393
600	187	249	335	234	300	384	315	380	453
650	192	257	350	241	312	404	328	400	481
700	196	265	364	248	323	423	341	418	507
800	203	278	389	260	343	457	363	452	558
900	209	289	411	269	360	468	382	482	605
1,000	214	298	431	278	375	516	399	509	648
1,100	218	307	448	285	388	542	414	534	689
1,200	222	314	464	291	400	565	427	556	727
1,300	225	321	478	297	411	586	439	577	762
1,400	228	326	491	301	420	606	450	596	796
1,500	230	331	503	306	429	624	460	613	827
2,000	240	351	549	322	462	696	498	683	959
2,500	246	364	581	333	484	749	524	733	1,061
5,000	258	392	657	357	536	879	586	859	1,347
7,500	263	403	687	365	556	934	610	911	1,480
10,000	265	408	703	370	566	964	622	939	1,556
20,000	269	417	729	377	583	1,013	642	986	1,688
30,000	270	419	738	379	588	1,030	649	1,002	1,737
40,000	270	421	742	381	591	1,039	653	1,011	1,762
50,000	271	422	745	381	593	1,045	655	1,016	1,778
100,000	272	424	751	383	597	1,056	659	1,026	1,810
150,000	272	424	752	383	598	1,060	661	1,030	1,821
200,000	272	424	753	383	598	1,061	661	1,031	1,826
250,000	272	425	754	384	599	1,063	662	1,033	1,830
500,000	272	425	755	384	600	1,065	663	1,035	1,837
1,000,000	272	425	756	384	600	1,066	663	1,036	1,840

Source: Cohen *et al*. 2007

III. Results And Discussions

The results of the anthropometric or physical measurements of fourteen (14) different body dimensions with three hundred and ninety-two (392) persons consisting of 305 males and 87 females involved in manual handling activities across three (3) food manufacturing industries in Nigeria. Table 1 shows the descriptive statistics of the anthropometric measurements of manual lifters across these food industries. The table presented the mean, standard deviation, range and the percentiles (5th, 50th and 95th) of each of the fourteen (14) variables which include the fourteen body measurements, weights and age of respondents. Tables 2 and 3 shows the anthropometric measurements of the male and female population of the studied data showing the mean, standard deviation, range and the percentiles (5th, 50th and 95th) of each of the variables. All participants were physically active and able-bodied while being free from any injuries at the time of the data collection. T-test carried out with the null hypothesis, H_0 being that there are no differences in the means of the two populations and the alternative hypothesis, H_I, indicating that there is significant difference in the means for the both populations. The significance level is 5 %, that is 0.05. From Table 1, there are no significant difference between two of the anthropometric measurements, the Wrist-to- Foot and the Knee-Joint-to-Leg-Wrist. However, the other body segment measurements show there are significant differences in the means of the male and the female population. They are the standing height, eye to foot, shoulder to foot, arm length/span, shoulder to elbow, elbow to wrist, wrist to the tip of the middle finger length, elbow to foot, tip of the middle finger to the foot, hand to the hip/waist region, hip/waist to the knee joint, and the foot.

Table 2: Mean, Standard deviation, Range and Percentiles of Manual Worker's Data (Male)

Anthropometric Measurement (N=305)	**Min**	**Max**	**Mean**	**Standard Deviation**	**Range**	**5th Percen-tile**	**50th Percen-tile**	**95th Percen-tile**
Standing Height	161	190.5	171.50	8.53	29.5	161	172	190.5
Eye-to-Foot	149	178	160.89	8.13	29	161	161	178
Shoulder-to-Foot	132	155	142.34	7.22	23	132	142	155
Arm Length	74	91	80.92	4.81	17	74	80	91
Shoulder-to- Elbow	30	42	34.48	3.25	12	31	33	42
Elbow-to-Wrist	27	35	29.17	2.29	8	27	28	34
Wrist-to-Finger	17	23	20.83	1.63	6	17	21	22.7
Elbow-to-Foot	99	122	108.85	6.60	23	99	108.5	122
Wrist-to-Foot	76	90	82.49	3.98	14	76	82	90
Finger-to-Foot	56	70	61.49	4.05	14	56	61	70
Hand-to-Waist	39	52.5	44.30	3.86	13.5	39	43	52.5
Waist-to-Knee Joint	50	66.5	54.95	3.16	16.5	51.5	54	60
Knee Joint-to-Leg Wrist	40.5	111	47.69	15.87	70.5	40.5	43	111
Foot Length	24	30	29.63	1.63	6.0	24	26	30

Dimensions are in centimeters

Table 3: Mean, Standard deviation, Range and Percentiles of Manual Worker's Data (Male and Female)

Anthropometric Measurement (N=392)	**Min**	**Max**	**Mean**	**Standard Deviation**	**Range**	**5th Percentile**	**50th Percentile**	**95th Percentile**
Weight (kg)	58	95	75.59	9.36	37	59.54	77.81	91.45
Age (Years)	18.00	61.00	44.50	7.56	43.00	22.00	37.00	54.60
Standing Height	161.00	190.5	170.24	8.40	29.5	161	171	184
Eye-to-Foot	149.00	178	159.80	8.03	29	150	163	172
Shoulder-to-Foot	132.00	155	141.53	7.10	23	132	141.3	151.5
Arm Length	74.00	91	80.38	4.61	17	74	79.5	80.0
Shoulder-to- Elbow	30	42	32.21	3.19	12	31	33	39.0
Elbow-to-Wrist	27.00	35.00	28.90	2.20	7.00	27.00	28.00	34.00
Wrist-to-Finger	17.00	23.00	20.63	1.66	6.00	17.55	21.00	22.70
Elbow-to-Foot	99.00	122.00	108.26	6.38	23.00	99.00	107.50	120.50
Wrist-to-Foot	76.00	90.00	82.44	3.80	14.00	77.10	82.00	89.00
Finger-to-Foot	56	70	61.09	3.99	14	56	61	67.5
Hand-to-Waist	39	52.5	43.88	3.73	13.5	39	43	51.125
Waist-to-Knee Joint	50	66.5	54.70	2.95	16.5	51.5	54	60
Knee Joint-to-Leg Wrist	40.5	111	46.81	14.6	59.5	40.1	43	51
Foot Length	24	27.5	25.87	1.03	3.5	24	26	29.5

Dimensions are in centimeters

Table 4: Mean, Standard deviation, Range and Percentiles of Manual Worker's Data (Female)

Anthropometric Measurement (N=87)	Min	Max	Mean	Standard Deviation	Range	5th Percentile	50th Percentile	95th Percentile
Standing Height	171	161	164.11	3.78	10	161	162	171
Eye-to-Foot	162	149	154.40	4.73	13	149	152.5	162
Shoulder-to-Foot	145.9	132	137.53	4.83	13.9	132	135.5	145.9
Arm Length	70.5	80.5	77.73	2.01	5.0	75	77	80.5
Shoulder-to- Elbow	31.0	38.5	32.90	2.48	7.5	31	32	38.5
Elbow-to-Wrist	27	29	27.58	0.85	2.0	27	27	29
Wrist-to-Finger	18	21.5	19.65	1.48	3.5	18	18.5	21.5
Elbow-to-Foot	99.01	113	105.38	4.17	14.0	99	105	113
Wrist-to-Foot	78.0	86.7	82.16	2.57	8.7	78	82.2	86.7
Finger-to-Foot	56	65	59.13	2.99	9	56	58	65
Hand-to-Waist	40	46	41.89	2.06	6	40	41	46
Waist-to-Knee Joint	52	54	53.46	0.74	2	52	54	54
Knee Joint-to-Leg Wrist	40.5	45	40.51	1.36	4.5	40.5	42	45
Foot Length	24.0	27.5	28.87	1.03	3.5	24	26	27.5

Dimensions are in centimeters

Table 5: 2-Tail t-test analysis of the Male and Female Anthropometric

Anthropometric Measurement (392)	Mean (Male)	Mean (Female)	Standard Deviation (Male)	Standard Deviation (Female)	t_{cal}	P-Value	Decision
Standing Height	171.50	164.11	8.53	3.78	0.00000002	0.000004	Reject
Eye-to-Foot	160.89	154.40	8.13	4.73	0.0000003	0.00005	Reject
Shoulder-to-Foot	142.34	137.53	7.22	4.83	0.0000218	0.00056	Reject
Arm Length	80.92	77.73	4.81	2.01	0.0000144	0.00028	Reject
Shoulder-to- Elbow	34.48	32.90	3.25	2.48	0.001788	0.02	Reject
Elbow-to-Wrist	29.17	27.58	2.29	0.85	0.0000050	0.00009	Reject
Wrist-to-Finger	20.83	19.65	1.63	1.48	0.0000084	0.0005	Reject
Elbow-to-Foot	108.85	105.38	6.60	4.17	0.0007	0.004	Reject
Wrist-to-Foot	82.49	82.16	3.98	2.57	0.587	0.66	Accept
Finger-to-Foot	61.49	59.13	4.05	2.99	0.00022	0.001	Reject
Hand-to-Waist	44.30	41.89	3.86	2.06	0.000056	0.002	Reject
Waist-to-Knee Joint	54.95	53.46	3.16	0.74	0.001504	0.02	Reject
Knee Joint-to-Leg Wrist	47.69	40.51	15.87	1.36	0.028017	0.05	Accept
Foot Length	29.63	28.87	1.63	1.03	0.0026	0.02	Reject

IV. CONCLUSIONS

The anthropometric characterization of fourteen body segments of manual employees in Nigeria's food production industry was provided in this paper. Food manufacturing industry stakeholders are still looking for a system that can handle current problems with user population requirements, established technological standards, and other fundamental criteria for research usage. To achieve these necessary design considerations, a complete Participatory Ergonomic Intervention (PEI) method can serve as a foundation. A crucial technique to identify the population of potential customers is anthropometry, nevertheless, in order to ensure that items and physical equipment are ergonomically appropriate. Essentially, the human body plays a crucial role in the design of human-machine interfaces (HMI). Also, this study has highlighted the necessity of conducting a robust and all-encompassing anthropometry survey in Nigeria for the user population. Such information can be utilised to set up the worker's workspace in a way that will improve its ergonomic suitability, functional efficacy, and human convenience. Despite the fact that several research on the musculoskeletal and low back diseases of workers have been conducted, a comprehensive evaluation of the workstation is necessary to determine how ergonomically viable and user-friendly the current design is. The findings of this study can be used to guide the design of manual handling equipment and workplace layouts in Nigeria's food industry.

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