Anthropometric characteristics of roadside auto-mechanics: a case study

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Abstract

Aim: The study evaluated the relevant/corresponding anthropometric characteristics of the people involved in engine-repair activities. The study was carried out on the selected roadside auto-engine repairers along Lagos-Ibadan express way, in Nigeria. This was with a view to providing ergonomic design data for optimal working condition among this set of workforce and redesigning the mechanics inspection-pit. *Material and methods*: The static and the functional anthropometric characteristics of the mechanics were measured. The data obtained from 110 auto-mechanics, randomly selected, were employed to evaluate efficient design parameter for roadside workstations. *Results:* The results indicated that inspection-pit is about 1626 mm deep; seat height ranges between 375 mm and 405 mm; optimal work posture sitting is between 483 mm and 622 mm. *Conclusions:* Adopting the data presented in this paper in optimizing the auto-mechanics working conditions for effective workplace comfort and productivity among the roadside auto-mechanics in Nigeria will be of immense advantage.

Keywords

Engine-repair; Inspection-pit; Posture; Workstations; Ergonomics; Measurement; Automotive; Roadside

Introduction

The health of the automotive industry in Nigeria depends on the effectiveness and capabilities of roadside auto-mechanics. In Nigeria, auto-mechanics are usually low-waged people, illiterate or semi-illiterate workforce, (those without formal education), often without adequate innovative and managerial skills for the trade [1, 2]. The male workforce dominates the trade and it is associated with high rates of occupational health hazards compared to workers in other professions [3]. Engine-repair auto-mechanics move around to carry out on-the-spot repair of broken down vehicle, and where on-the-spot repair is not possible they tow such vehicle to workstations along the road for repair. A typical workstation used by the roadside auto-mechanics is shown in Figure 1.

Figure 1. *A typical automobile mechanic workstation along Lagos-Ibadan expressway*

The roadside auto-mechanics lack appropriate equipment and therefore settle for improvising which was cumbersome to use. Some of such improvised equipment used are: files instead of grinding machine, their teeth instead of pliers, stone instead of a hammer, stone/rim instead of a chair and load lifting with hand. Improvised equipment and techniques are usually awkward and strenuous to use [3], and being manually operated has necessitated the need for the mechanics to work in the awkward postures. Keyserling et al. [4] have made similar submission. The inspection-pits were self-made with irregular shape and dimension, tools are kept far from the repair points and car-for-repair parked at irregular intervals. Incidentally, standards for the treading auto-mechanics inspection-pit dimension are scarce in literature; the only one found is from Beccastrini [5] who stated that the depth of inspection-pit should be between 140 and 160 cm with a ladder or steps for access. Auto-mechanics perform tasks such as lifting, reaching, hammering, cutting, boring, turning, scraping, riveting, tapping, threading, screwing, bolting, bonding, gluing, clamping, chipping, dipping, inserting, lubricating, pressing, pulling, replacing of components, washing or cleaning, welding, grinding, filing or chiseling, heating, burning, blowing, dismantling, aligning, assembling, servicing, general work, inspection and test driving.

In Nigeria today, the educated young people who are well positioned to fully appreciate the challenges of roadside auto repairs are not attracted, because current practice is arduous, techniques are crude, and workstations are not well structured. The use of improper tools has been identified as a cause of fatigue, pain in the muscles and [4, 6], particularly when used repetitively or for a prolonged period. When tools necessary to perform the various tasks are not properly selected, used or cared for, their advantages are lost to the auto-mechanics. Automobile engine-repair workers during a typical day adopt different work postures, are exposed to poor working environments, and are engaged in repetitive work, which might impose stress and further lead to injury [3].

In determining the performance of mechanics, the output is a critical parameter. In order to improve on the output, it is important to ensure that the operating environment is both effective and efficient. The intent is that minimum manpower and efforts are used by the mechanics to achieve optimum productivity; while outputs in terms of the quality and quantity of the serviced vehicles are enhanced. One area that is used in the industrial engineering profession to achieve this is the subject of ergonomics.

Ergonomist aims at designing work and environment for people so that they can work easily, effectively and safely. Ergonomics uses various tools and techniques, as well as the long-established anthropometry. Anthropometric measurements are essential as basic descriptive information on body composition and nutritional status. They are linked to energy intake, physical activity, energy metabolism, and metabolic efficiency. Through anthropometry, ergonomists collect information about people so that work, machines, tools and environment are fitted to humans [7].

Burdurlu et al. [8] and Oke et al. [9] revealed that body measurements of individuals vary with factors like age, gender, nutritional status, genetic structure, etc. For this reason, in designing equipment or workstations, it is necessary to consider the differences in body measurements and adjust the product sizes accordingly. These measures may be the upper, average or lower values of the anthropometrical findings [9, 10, 11].

Thus, the focus of this work was to consider the interaction between the engine-repair personnel otherwise called auto-mechanics and their workstations (broken down engine, seat and inspection-pit). It is expected that the availability of the anthropometric data will facilitate the design of a more efficient workstation (inspection-pit, seat height and optimal work level), and provide information required to improve auto-repair techniques among roadside mechanics. Currently, there are no such data addressing the current workplace conditions of roadside auto-mechanics in Nigeria, hence this study.

Materials and methods

Study sample

The workstations of roadside automobile engine-repair mechanics along Lagos-Ibadan expressway in Nigeria were purposefully selected for the study because according to Abiola et al. [12], the area has a high volume of vehicular traffic of about 250,000 vehicles plying the road on a daily basis. The traffic motorway runs through Lagos, Ogun and Oyo states of Nigeria. The road comprises of several roadside auto-mechanic workstations; located in Berger Area, Mowe, Arepo, Ibafo, Redemption camp, Shagamu, Ogere, Methodist, Felele, Soka, Sonyo, Boluwaji, Academy, Olorunsogo, Ayekale and Oremeji and distributed along the expressway as shown in Figure 2. The mechanics provide cheap and emergency services, for road users who have their vehicle broken down.

A fraction of not less than 80.3% of the total population of the auto-mechanics along the surveyed area that gave consent was randomly selected for the study as shown in Appendix A. The sample size of auto-mechanics selected for the study followed a confidence interval of 3.3 at 95% confidence level. The distribution of the personnel at the workstations comprised of master mechanics, journeymen (apprentices who had undergone training but had no workshops of their own), and apprentices, still undergoing training. They were then classified into five age groups, such as, below 25, 25-34, 35-44, 45-54, and above 54 years.

Figure 2. *Distribution of roadside auto-mechanics on Lagos-Ibadan Expressway: Berger (E1); Arepo (E2); Ibafo (E3); Mowe (E4); Redeem (E5); Sagamu (E6); Ogere (E7); Methodist (E8); Felele (E9); Soka (E10); Sanyo (E11); Boluwaji (E12); Academy (E13); Muslim (E14); Olorunsogo (E15); Ayekale (E16); Oremeji (E17); Sawmill (E18); Iwo road (E19)*

Anthropometric method and data collection

A thorough assessment of the activities of the auto-mechanics in the study areas was surveyed. During the survey, the predominant tasks and corresponding work postures adopted by the auto-mechanics during engine repairs were physically inspected and noted. The researchers went to all the auto mechanics workshops along Lagos-Ibadan expressway in Nigeria with comprehensively designed questionnaire (Appendix B) to elicit information from the personnel. With the consent of those who were given the questionnaire, they were also interviewed to gather more information about their work condition. Permission was also sought to do physical observation of their workplace while they were at work. Sizeable number of them consented and the information and physical inspection were carried out. The questionnaire was divided into two different sections, such as personal data and anthropometric measurements. This was to obtain information such as age, gender and body size of the auto-mechanics; following the method described by Oke et al. [9].

The questionnaires used in this research were filled out by the questioner. The questions were read out to the illiterate auto-mechanics in either *Yoruba* or *Pidgin* English, which are the languages mostly understood by the mechanics in the study area.

The body sizes of each auto-mechanic were measured using traditional measuring techniques as described by other researchers [7-13]. Other methods used for measuring the human body dimensions, such as the three-dimensional scanners are expensive, highly sophisticated, and were not available. The traditional measurements have however been used for many years [14] and anthropometric data so obtained have been shown to be as reliable and accurate as those obtained by some of the high-tech methods [7].

As previously described [9-15], the following human body (static) dimensions were measured with respect to the different work postures common to roadside auto-mechanics in Nigeria, during repair work:

- Body Stature: the vertical distance from the top of the head to the foot resting surface (BS, Figure 3a).
- Shoulder Height Standing: the vertical distance from the top of the shoulder to the foot resting surface when in standing position (SHS, Figure 3a).
- Shoulder Height Bending: the vertical distance from the top of the shoulder to the foot resting surface when in bending position (SHB, Figure 3b)
- Knee Height Sitting: the vertical distance measured from the foot resting surface to the knee cap when in standing position (KHSi, Figure3c).
- Knee Height Supine: the vertical distance measured from the foot resting surface to the knee cap when in supine position (KHSu, Figure 3d).
- Optimum Manual Work Level: vertical distance from the foot resting surface to the aimed object when in standing position (OWL, Figure 3a).
- Optimum Manual Work Level Sitting: vertical distance from the foot resting surface to the aimed object when in sitting position (OWLSi, Figure 3c).
- Height Reach: vertical distance from the foot resting surface to the aimed object (HR, Figure 3a).
- Body Width: horizontal distance from the popliteal to the aimed object (BW, Figure 3b)
- Supine Width: vertical distance from the finished floor level to the aimed object (SuW, Figure 3d)

- Popliteal Height: vertical distance from the foot resting surface to the bottom of the Popliteal (PH, Figure 3a).
- Base Height of a Typical Passengers' Car: vertical distance from the bottom of the automobile to the finished floor level of the roadside automobile workstations. Average BHC of various automobile found under repair along the study area was 275mm (BHC, Figure 4).

The body mass of each roadside auto-mechanics in standing posture was taken on a digital clinical weighing scale (TD-2551, TaiDoc Technology, Taiwan) measured in kilograms. Their body dimensions were taken in four important work (functional) postures, as shown in Figure 3, measured in millimeter with a measuring tape and an improvised stadiometer (an adjustable shaped wooden improvised tool) used by Oke et al. [9] to enable perpendicularity of the measured surface and the datum. Each member of a two-man team took these measurements twice with an accuracy of ±1mm and the average value was calculated.

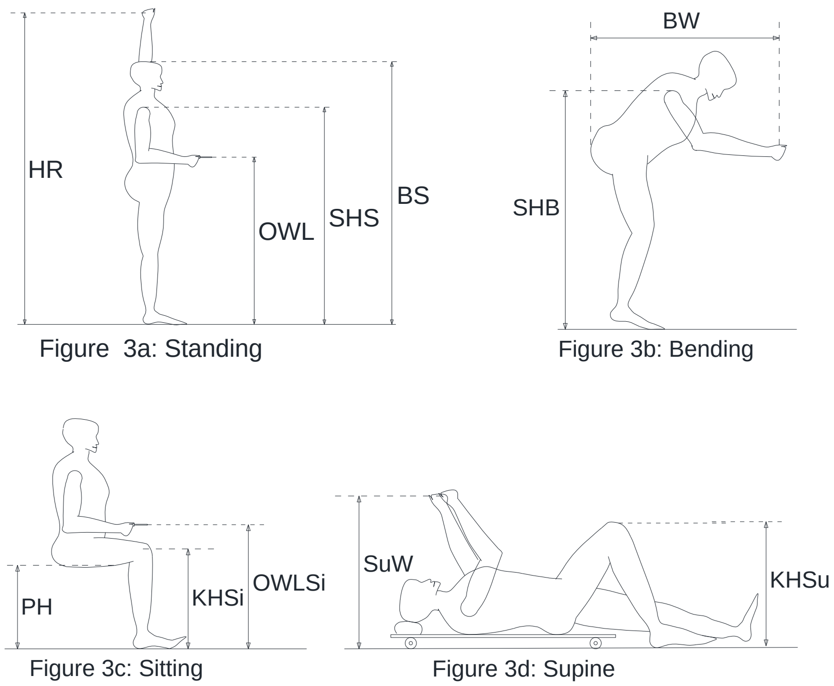

***Figure 3**. Anthropometric characteristics: Body stature (BS); Shoulder Height standing (SHS); Shoulder Height Bending (SHB); Knee Height Sitting(KHSi); Knee Height Supine (KHSu); Optimum manual Work Level (OWL); Optimum manual Work Level Sitting (OWLSi); Height Reach (HR); Bending Width (BW); Supine Width (SuW); Popliteal Height (PH) [9, 10]*

Statistical analysis

Data were analyzed using Microsoft Excel. Descriptive and analytical statistics were used to analyzed and compare the data. Anthropometrical data were analyzed by finding the average, standard deviation, minimum and maximum according to fit auto-mechanics to their job.

In order to achieve a good fit and more suited work friendly environment, the anthropometric measurements were used to derive height of inspection-pit (IPH), seat height (SH) and optimal work level (OWL) for auto-mechanics in standing and sitting posture to prevent discomfort which may arise from stooping and other awkward posture [16] as shown in figure 3 and 4.

The height of inspection-pit for the assessment of the automobile under-side was computed as the difference of the auto-mechanics height reach and the base height of a typical passengers' car, including an allowance of -212 mm for the worker's headroom, as:

$$IPH = (HR\text{-}BHC) - 212 \text{ mm} \quad (1)$$

where *IPH* = Inspection-Pit Height, *HR* = Height Reach, *BHC* = Base Height of a typical passengers' Car.

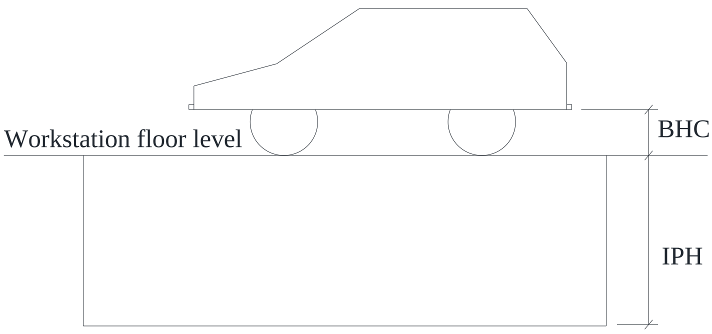

Figure 4. *A sectional view of a workstation; Base Height of a typical passengers' Car (BHC); Inspection-Pit Height (IPH)*

The inspection-pit height is gotten from mean height reach as this will provide enough headroom for the auto-mechanics no matter their body stature. The minimum and maximum seat height were derived from the idea established by [9] as follow:

Seat height (SH) = $0.88(PH) \leq SH < 0.95(PH)$

This allows for clearance of between 5% and 12% and with the assumption that most auto-repairers in the study area do not wear shoes.

Optimal work level sitting (OPWSi) = $0.94(KHSi) \leq OPWSi < 1.21(KHSi)$.

This is with the assumption that 'X' which is the difference between the Knee Height Sitting (KHSi) and the Optimal Work Level Sitting (OWLSi) is between 15mm and 45mm.

Results

Sample population

The distribution of the 110 engine-repair auto-mechanics randomly selected from the population is shown in Figure 5. It is shown that (39.1%) of the sample fall within the age range of 25-34 years; while those above 55 years is the least (3.6%) in population as indicated in Appendix C. Furthermore, approximately 52% of the mechanics are above 34 years.

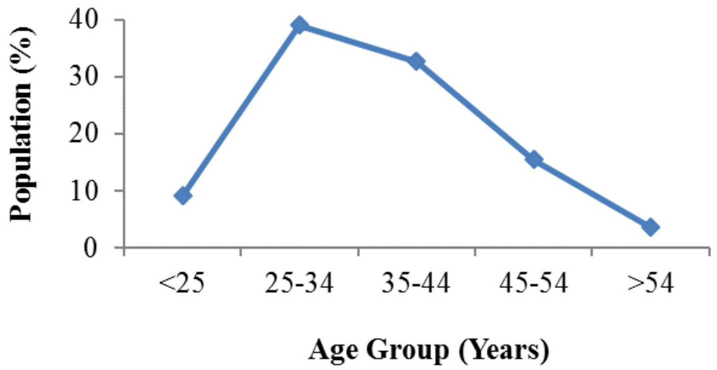

Figure 5*. Distribution of the age groups of the auto-mechanics in the study*

Anthropometric characteristics

A total of ten anthropometric characteristics, such as, Body stature (BS); Shoulder Height standing (SHS); Shoulder Height Bending (SHB); Knee Height Sitting(KHSi); Knee Height Supine (KHSu); Optimum manual Work Level (OWL); Height Reach (HR); Bending Width (BW); Supine Width (SuW); Popliteal Height (PH) and Weight of the roadside auto-mechanics in the study are shown in Table 1.

Design parameters

The IPH developed relative to the anthropometric measurement was 1626 mm that is appropriate for all the roadside auto-mechanics in the study area without exception.

Table 1. Summary of anthropometric characteristics of the auto-mechanics (all dimensions are in mm, and weight in kg)

Posture	Anthropometric measurement (mm)					
	Mean (SD)	Min	Max	Percentiles		
				5%	50%	95%
Body stature	1701 (77.3)	1530	1840	1575	1705	1820
Shoulder height Standing	1452 (76.1)	1210	1600	1335	1460	1560
Shoulder height Bending	1270 (70.2)	1130	1470	1160	1280	1390
Knee height Sitting	514 (24.3)	470	600	490	500	560
Knee height Supine	438 (15.4)	410	500	420	440	470
Optimal work level	1071 (67.3)	840	1190	970	1070	1180
Optimal work level Sitting	625 (13.6)	614	648	614	622	643
Height reach	2113 (87.2)	1950	2310	2000	2100	2290
Bending width	650 (38.7)	580	730	600	650	720
Supine width	456 (33.1)	400	520	410	450	520
Popliteal height	426 (13.1)	416	448	416	422	444
Weight	69.8 (5.1)	56	78	60	71	76

Considering the average PH as shown in Table 1, the SH of auto-mechanics in the study area ranges between 375 mm and 405 mm. It will be assumed that over 95% of the auto-mechanics will find the SH most suitable.

In standing posture, the minimum OWL was 840mm while the maximum was 1190 mm as in Table 1. OWLSi was evaluated as between 483 mm and 622 mm. X which was the minimum vertical clearance between the knee and work level was 13 mm to 21 mm.

Discussion

As can be seen in Figure 5, analysis of the results shows that most of the roadside mechanics are in their middle-aged and above. Meanwhile, it is well recognized that over 70% of Nigerian demographic populations are youth [17, 18]. They are currently not well represented in roadside automobile repair work. However, one of the greatest challenges facing the Nigeria economy is youth unemployment, which has maintained a rising trend over the years. Youth unemployment is a global issue, and one of the most serious socio-economic problems confronting many African nations [19, 20]. Apart from representing a threat to a country's manpower resources, unemployment impedes social progress, and leads to lower income and low social well-being [19].

The data collected on the anthropometric characteristics of the mechanics, as presented in Table 1, are useful in specifying design parameters for the roadside mechanic workstations. It is also useful in designing the ergonomic specifications for imported or outsourced equipment for the roadside auto-mechanics.

Our interaction with the roadside auto-mechanics along the study area shows that they lack formal education and financial sustainability [1, 2]. This form one of the reasons they have mostly settle for improvised equipment, irregular inspection-pit (such as the one shown in Figure 1), and unfriendly work environment. Improvised equipment and techniques have proved to be awkward and strenuous to use [3].

Hand tools may seem harmless, but they are the cause of many injuries [4] and when it is self-made or improvised, it can result in major accident in the workstations, since they lack standard and have no appropriate use. The unpleasant workstations of the auto-mechanic will no doubt lead to a stressor, health failure and loss of man hour [3, 21]. The resultant effects enumerated as the cause of the current working conditions can be alleviated by fitting the repair tasks and the workstations to the auto-mechanics.

The result of comparison of body stature of roadside auto-mechanics along Lagos-Ibadan express way, Nigeria with workers in other countries is presented in Figure 6. Mean body stature of local roadside mechanics is 1701 mm as shown in Appendix D with a standard deviation of 77.3 mm which is taller than the average stature of Indian workers by 94 mm as well as Chinese and Philippine workers by about 24 mm [22]. But, it was found that Iranian workers are taller by 36 mm. Meanwhile, when compared to Nigeria, the popliteal height of Iranian, India and China worker is lesser by 37 mm, 9 mm and 13 mm respectively. Whereas, the popliteal height of Philippine workers is higher by 7mm compare to their Nigeria counterpart.

These data will be of great help when designing workstations suitable for workers outside engine repairers' group. This data is also useful in the morphological features of Nigeria as a whole and should be considered in economical exchanges among countries [22, 23].

A close look at the results of all the anthropometric measurements taken in this study and presented in Table 1, reveals that more suitable and ergonomically designed workstations can be developed in other to optimize the ergonomics of working conditions. This will mitigate hazard among auto-mechanics, stimulate comfort and increase productivity.

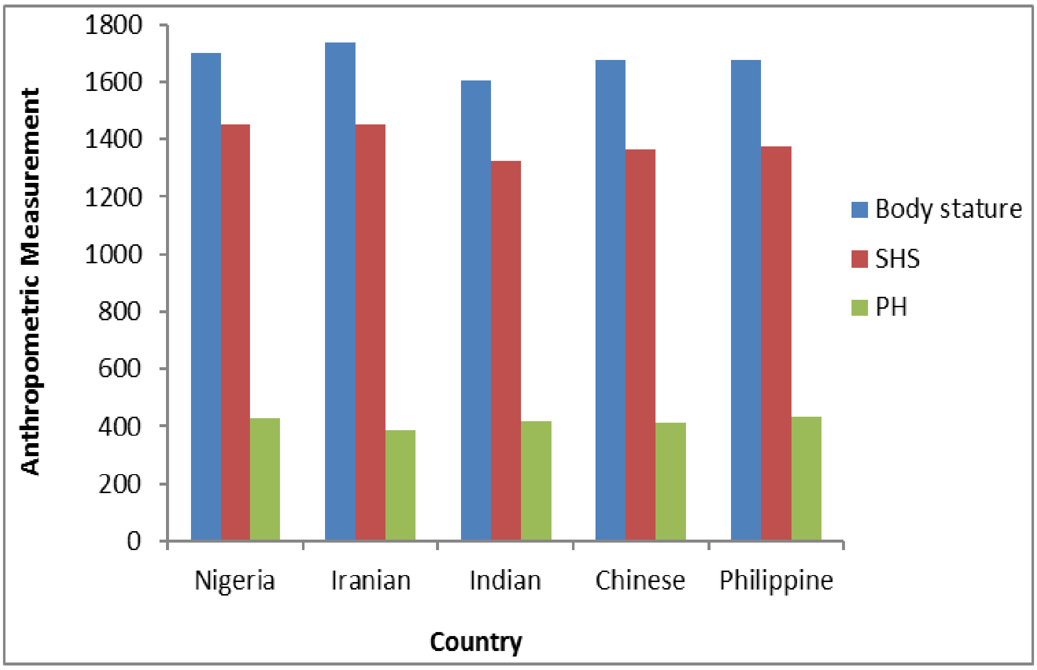

Figure 6. *Comparison of body stature, shoulder height standing, and popliteal height of the roadside mechanics in the study area with workers in other countries*

The inspection-pit, seat height and optimal work level developed were more suited almost all the auto-mechanics. For auto-mechanics working in a supine posture, job or automobile should be raised to leave a clearance of about 520 mm (maximum supine width) between its bottom and the floor level.

Conclusions

Our results showed that Lagos-Ibadan Expressway had at least 1 auto-mechanic per kilometer of the expressway. The predominant tasks undertaken by roadside auto-mechanics were reaching, lifting, pressing, and screwing. The corresponding work postures are standing or bending, sitting and supine. The mode of handling involved in accomplishing these tasks can be considered as strenuous, exerting considerable discomfort.

Roadside auto-mechanic workstations should therefore be designed based on the assembled anthropometric data. This is with a view to reducing stresses associated with the current workplace conditions and optimizing the conditions for effective workplace comfort and productivity among the roadside auto-mechanics in Nigeria.

Acknowledgment

The authors are grateful to all the roadside auto-mechanics along Lagos-Ibadan Expressway and 'Unique' auto-repair center at Ile-Ife for their support in data collection for the study.

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Appendix A

Table 2. Summary of study population

S/N	Roadside Mechanic Locations	Survey	
		Auto-Mechanics Population	Used for Study
1	Berger	13	9
2	Arepo	4	4
3	Ibafo	12	8
4	Mowe	24	23
5	Redeemed	3	3
6	Shagamu	8	5
7	Ogere	27	23
8	Methodist	4	3
9	Felele	9	5
10	Soka	2	2
11	Sonyo	5	3
12	Boluwaji	6	2
13	Academy	-	-
14	Muslim	-	-
15	Olorunsogo	11	11
16	Ayekale	6	4
17	Oremeji	3	3
18	Saw mill	-	-
19	Iwo road	-	-
	Total	137	110 (80.3)*

* Percentage of total population mechanics surveyed

- No consent for study

Appendix B

QUESTIONNAIRE SAMPLE

Questionnaire on Anthropometric Characteristics of Roadside Auto-Mechanics

(Please, thick appropriately where necessary)

SECTION 1: Personal Data

1. Age: [Below 25] [25-34] [35-44] [45-54] [Above 55]

2. Gender: [Male] [Female]

3. Body mass: [ ]

4. Daily working hour: [ ]

5. Auto-mechanic location: ………………………………………………...

SECTION 2: Anthropometric Measurement (mm)

6. Body stature (S) [ ]
7. Shoulder height standing (SHS) [ ]
8. Shoulder height bending (SHB) [ ]
9. Shoulder height stooping (SHSt) [ ]
10. Knee height Standing (KHS) [ ]
11. Knee height supine (KHSu) [ ]
12. Optimal manual work level (OPW) [ ]
13. Height reach (HR) [ ]
14. Bending Width (BW) [ ]
15. Supine Width (SuW) [ ]
16. Stooping Width (StW) [ ]
17. Popliteal Height (PH) [ ]

Appendix C

Table 3. Distribution of the age groups of the auto-mechanics in the study

Age Group (Yrs)	Population (%)
<25	9.1
25-34	39.1
35-44	32.7
45-54	15.5
>54	3.6

Appendix D

Table 4. Comparison of body stature, shoulder height standing and popliteal height of the roadside mechanics in the study area with workers in other countries

Country	Body stature	SHS	PH
Nigeria	1701	1452	426
Iranian	1737	1453	389
Indian	1607	1327	417
Chinese	1677	1367	413
Philippine	1677	1375	433