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Ergonomic Evaluation of Tricycles and Riders in Akure, Nigeria

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ABSTRACT

Tricycles are an established mode of transportation in many parts of Nigeria. However, little attention has been given to ergonomic interaction between it and its users. Therefore, this study focuses on ergonomic evaluation of tricycles and riders in Akure, Nigeria. Anthropometric dimensions (AD) of 200 commuters (90 males and 110 females) were obtained. Measurement of five dimensions of the Tricycle: seat height, seat depth, seat width, backrest height and clearance height were carried out. These dimensions were compared with popliteal height, buttock popliteal length, hip width, sitting shoulder height and sitting stature respectively using match equations. Results showed agreement between the responses of the commuters and the outcome of the analysis obtained from the match equations that the tricycles are not suitable or comfortable for most riders. A large number, (62%) of commuters complained of leg pain due to inappropriate seat height while 42% of commuters complained of back pain. The analysis of the match equations revealed that seat height was inappropriate for about 54% commuters, while backrest height was inappropriate for about 33% commuters. The study revealed that commuters using tricycles are liable to future health issues due to repetitive cumulative trauma disorders and awkward postures. Anthropometric dimensions (AD) of the intended users, if considered, may help to reduce the cumulative trauma disorders as recommended by this study.

1. INTRODUCTION

Transportation, the movement of goods and people from place to place and the different means by which the movement is accomplished is a field of activity that is very important in people's lives. The importance is caused by many factors, one of which is the geographical condition of an area which allows transportation to be carried out either by land, sea or air to reach all segments of the areas (Ilham, 2020). However, the importance must not overshadow the convenience of commuters.

Ergonomics is the science that deals with the achievement of an optimal relationship between workers and their work environment (Kroemer, *et al*., 2003). That is, ergonomics is the study of aligning the requirements of a job with the ability of the worker and work environment in order to set up the most efficient workspace possible while at the same time abating the possibility of the occurrence of injury. In terms of product design, it is making sure the product fits the people who will be the end users, and it is important because if the product does not work well for the customer, the product has failed in its purpose. The age long and the chief goal of ergonomics has been to curtail the rate of work-related repetitive cumulative trauma disorders (WRCTDs) and that all human-made tools, devices, equipment, machines, and environment should directly and indirectly boost the efficiency, quality, quantity, safety, appeal, fit, usability, well-being, comfort and performance of human beings while curtailing workers' injury, turnover, and burnout/strain (Andersen, *et al*., 2021; Barnard, *et al*., 2021; Cornwell, *et al*., 2021; Chu, *et al*., 2021).

The demarcating attribute of ergonomics is the consideration of human and the machine components from a system view point. Its guiding principle aim to design things to "fit" the anatomy of man (his capabilities, abilities and limitations), and therefore attain its paramount objective of generating "optimal" conditions so that the physical, mental, and social well-being of man is accomplished (Jin, *et al*., 2022; Keyaerts, *et al*., 2022). Such design stands in need of anthropometry, a discipline that deals with the measurement of human body, which is one of the foundations of ergonomic design. As a result of this, Ergonomics is utilized in manifold industrial areas that include transportation. It is very obvious that some of the essential artefacts of our daily lives are employed to aid the movability and activity of man. Production of cars, trains, ships, boats, planes, workstation adjustment, etc. is exhibited to allow the users an efficient, effective, and safe transportation (Lee, *et al*., 2021; Wåhlin *et al*., 2022).

In Nigeria, there are numerous forms of public transportation that commuters use on a daily basis. These range from small type vehicles to the larger types that can accommodate a large number of people at a particular time. All around the country, these modes of transportation are frequently seen along roads, and they serve as the primary form of getting from one place to another (Adeyemi and Yusuf, 2019). These included various types of buses, omnibus, vans and motorcycles (Onawumi and Lucas, 2012). In recent times, however, the use of tricycles as means of transportation is becoming popular especially in developing countries of Asia and Africa, and Nigeria is not an exception. This may not be unconnected with the fact that the mode of transportation depends on the size and characteristics of the population (Solanke, 2013). Metropolitan cities in the recent time have grown to the point where they threaten to strangle the transportation that made them possible. Up to the 1970s in Nigeria, it was relatively easy to move from one part of the city to the other (Ikya, 1993). Within a period of two decades or so, urban transportation dramatized into chaotic, complex and almost intractable nature such that most cities almost reached a level of relative immobility.

In Nigeria of today, every urban centre is confronted with transportation challenges that seem to grow worse as these areas continue to grow. That is, type of transport system that is used is dependent to a great extent on the level of technological development and standard of living of the people and the society; how the people perceive the quality of life they want, the organizational structure of the city and also the available of sufficient transportation means (Solanke, 2013). In essence, the urban transport challenges in Nigeria today include traffic congestion, parking problems, accidents and environmental pollution. In some major cities, vehicles are seen crawling on the roads especially in both the morning and evening peak periods. This amounts to daily loss of time and energy in our various urban centers. Behind these challenges are some basic factors. Population and spatial forms of the city are growing at fast rate creating a greater demand for transport infrastructure and services. Compared with other means of transportation, tricycles are readily available, affordable and can easily beat traffic jam (Sun, 2009). Other reasons for its growing popularity included poor public transport system, poor road network and its capability to bring passengers closest to their desired destinations (Dorado *et al*., 2015). Due to its growing popularity as a means of transportation, it is important to evaluate its level of compliance to ergonomic principles.

It is a known fact that anthropometric data is the foundation on which ergonomic design of all products depends (Okunribido, 2000). The level to which anthropometric data of intended users is taken into consideration during the design process will determine the extent of comfort, appeal, safety, fit and usability of the product by the intended users. This is necessary in order to prevent health risk such as cumulative-trauma disorders and musculoskeletal disorders. Therefore, this paper focuses on the assessment of ergonomic consideration of the two commonly use tricycle (TVS and Bajaj) in Akure, Nigeria.

2. MATERIALS AND METHODS

2.1. Materials

A preliminary investigation was conducted at the Federal University of Technology Akure, Nigeria. It was found out that two brands of tricycles are commonly used for transportation (TVS and Bajaj). The materials employed in this study are Bajaj and TVS Tricycles, measuring tape, and anthropometric chair.

2.2. Methods

A total of 200 passengers voluntarily participated in the study. Questionnaire adapted from the Nordic Musculoskeletal Questionnaires screen risk factors (Low Back Questionnaire and the Neck and Shoulders Questionnaire) (de-Barcos and Alexandre, 2003) were administered to the participants in order to collect data relating to comforts and/or discomforts derived by using the tricycle.

2.2.1. Measurements of tricycle dimensions

The dimensions of Tricycles which were considered are thus defined:

Seat Height (SH): Measured as the vertical distance between the floor of the facility and the highest point on the front edge of the seat (Oladapo and Akanbi, 2016).

Seat depth (SD): Measured as the horizontal distance between the back and the front edge of the sitting surface (Dianat *et al.*, 2013).

Seat Width (SW): Measured as the horizontal distance between the lateral edges of the seat (Dianat et al., 2013).

Back rest Height (BH): Measured as the vertical distance between the sitting surface and the top edge of backrest (Dianat *et al.*, 2013).

Clearance Height (CH): Measured as the vertical distance between the floor of the tricycle and the highest point on the underneath roof of the tricycle.

2.2.2. Acquisition and description of anthropometric measures

The following measurements were taken and defined thus:

Popliteal Height (PPH): Defined as the vertical distance between the floor/footrest surface and the popliteal space (which is the posterior surface of the knee) at 90° Knee flexion (Agha, 2010) (Figure 1)

Buttock-Popliteal Length (BPL): Defined with the knee flexed at 90°, as the distance between the posterior surface of the buttock and the posterior surface of the knee or popliteal surface (Panagiotopoulou, *et al.*, 2004) (Figure 2)

Hip Width (HPW): Measured as the highest horizontal expanse across the hips in the sitting position (Tunay and Melemez, 2008) (Figure 3)

Sitting Shoulder Height (SSH): Defined as the vertical distance from the seat pan to the top of the shoulder, that is, at the acromion process (Panagiotopoulou et al., 2004) (Figure 4).

Sitting Stature (SST): defined as the vertical distance from the floor of the tricycle to the highest point of the head in sitting position, when the participant stood erect and looked straight ahead. Figure 5.

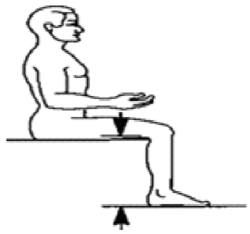

Figure 1: Popliteal height

Figure 2: Buttock-popliteal length

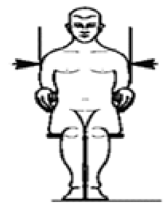

Figure 3: Hip width

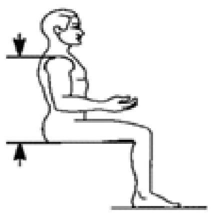

Figure 4: Sitting shoulder height

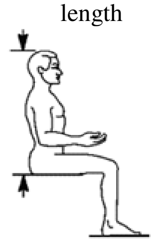

Figure 5: Sitting stature

2.3 Determination of Potential Mismatch

Match is defined as compatibility between the dimensions of tricycle and anthropometric characteristics of the commuters while mismatch is defined as incompatibility between the dimensions of tricycle and anthropometric characteristics of the commuters. According to Agha (2010), a match/mismatch implies that the users' dimensions are within/outside the upper and lower limits set by the researchers for the appropriateness of the existing facility dimensions. However, since the current study deals with ergonomic evaluation of tricycle and its riders, a match/mismatch was adapted to imply that the commuters' dimensions are within/outside the upper and lower limits set by the researchers for the appropriateness of the existing tricycle dimensions. In order to evaluate a potential mismatch or otherwise in the present arrangement between commuters and the tricycle available to them, dimensions of tricycle were compared with anthropometric measures of the studied population. The match criteria (product dimensions against the users' measures) which were used in this study are presented in Table 1.

Table 1: Tricycle dimensions versus relevant user dimensions

Tricycle dimensions	User dimensions
Seat height (SH)	Popliteal height (PPH)
Seat depth (SD)	Buttock-popliteal length (BPL)
Seat width (SW)	Hip width (HPW)
Backrest height (BH)	Sitting shoulder height (SSH)
Clearance height (CH)	Sitting stature (SST)

Seat height (SH): This is the most essential dimension for the development of a mismatch criterion (Qutubuddin *et al*., 2013; Castellucci *et al*., 2014). It is the starting point and the most essential variable for the design of the facility (Molenbroek *et al*., 2003; Castellucci *et al*., 2010). The equations presented here were adapted to evaluate the ergonomic compliance in the design of Bajaj and TVS tricycles. *SH* needs to be provided relative to popliteal height, *(PPH)* (Occhipinti *et al*., 1993; Corlett and Clark, 1995; Helander, 1997; Dul and Weerdmeester, 1998), and such that the knees can be flexed with the lower legs at no more than maximum of 30^o angle to the vertical axis (Molenbroek *et al*., 2003). The equation requires that seat height is lower than popliteal height so that: (1) the lower leg is at a 5-30^o angle relative to the vertical and (2) the shin-thigh angle is between 95 and 120^o (Evans *et al*., 1988; Occhipinti *et al*., 1993; Sanders and McCormick, 1993).

Therefore, to evaluate potential match/mismatch of *SH*, an equation reported by Agha (2010) was adopted with slight modification as presented in Equation (1).

$$(PPH + Shh) \cos 30^o \leq SH \leq (PPH + Shh) \cos 5^o \quad (1)$$

where *PPH* is popliteal height, *Shh* is shoe height and *SH* is seat height.

Seat Depth (SD): This is the second most common measurement (Castellucci *et al.*, 2014). Most researchers reported that seat depth should be designated for the fifth percentile of popliteal-buttock length distribution, including even the shorter users (Pheasant, 1991; Khali *et al.*, 1993; Sanders and McCormick, 1993; Occhipinti *et al.*, 1993; Orborne, 1996; Helander, 1997; Milanese and Grimmer, 2004). Therefore, to evaluate potential match/mismatch of *SD*, an equation reported by Chung and Wong (2007) was adopted and presented in Equation (2).

$$0.800\,BPL \leq SD \leq 0.950BPL \quad (2)$$

where *BPL* is buttock-popliteal length and *SD* is seat depth.

Seat Width (SW): *SW* should be sufficient to support ischial tuberosities in order to provide stability and allow space for lateral movements (Khali *et al.*, 1993; Corlett and Clark, 1995). It should be large enough to accommodate even the users with the largest hip breadth (Evan *et al.*, 1988; Occhipinti *et al.*, 1993; Sanders and McCormick, 1993; Orborne, 1996; Helander, 1997). Therefore, to evaluate potential match/mismatch of SW, an equation reported by Dianat *et al.*, (2013) was adopted and presented in equation (3).

$$HW < SW \quad (3)$$

where *HW* is hip width and *SW* is seat width.

Backrest height (BH): *BH* is considered appropriate when it is below scapula (Evans *et al.*, 1988; Orborne, 1996) to facilitate mobility of the trunk and arms (Khali *et al.*, 1993). Therefore, to evaluate potential match/mismatch of BH, an equation reported by Gouvali and Boudolos, (2006) was adopted and presented in Equation (4).

$$0.60\,SSH \leq BH \leq 0.80\,SSH \quad (4)$$

where *SSH* is sitting shoulder height and *BH* is backrest height.

Clearance Height (CH): *CH* should be sufficient to accommodate the sitting height in order to provide stability and allow space for up and down movements of the head. It should be high enough to accommodate even the users with the highest sitting stature. To evaluate potential match/mismatch of *CH*, the equation that was used is as shown in equation (5).

$$SST < CH \quad (5)$$

where *SST* is sitting stature and *CH* is clearance height.

3. RESULTS AND DISCUSSION

3.1. Questionnaires Response

One hundred and eighty (90%) of the two hundred passengers that participated in the study completed the questionnaire. All respondents confirmed their frequent usage of Tricycle for transportation in not less than four years. The questionnaires' response rate is presented in Table 2.

Table 2: Questionnaires Response Rate

Description of respondent	Sample size	Response rate	% of Response
Male	90	84	93.33
Female	110	96	87.27
Total	200	180	
% of Total	100%	90%	

3.2. Commuters' Assessment of Compatibility of Tricycle

Table 3 presents the opinions of passengers regarding the use of Tricycle as means of transportation. Over 62% of the total commuters who responded to the questionnaire attributed the discomforts experienced any time while boarding the Tricycle to lack of space to adjust their legs and 42.22% mentioned lack of facility for head rest as contributing to neck pains they experienced.

Table 3: Opinions of passengers regarding the use of tricycles as means of transportation

Description of findings	Total Response	Percentage (%)
A. Self-opinion cause of reported pain:		
i. Seat not comfortable	58	32.22
ii. Vibration	72	40.00
iii. No space for legs adjustment	112	62.22
iv. No head rest	76	42.22
v. Unguided from fall/weather condition	46	25.56
vi. Body rubs component	88	48.89
B. Reason for boarding a tricycle:		
i. Cheaper	52	28.89
ii. Beat traffic	96	53.33
iii. Local availability	80	44.44
C. How do you always feel while in a tricycle:		
i. Proud	18	10.00
ii. Insecure	92	51.11
iii. Happy	10	5.56
iv. Inferior	40	22.22
D. Which other vehicle do you prefer to Tricycle:		
i. Bus	55	30.56
ii. Car	94	52.22
iii. Bike	28	15.56

Furthermore, 40% complained of discomfort due to vibration and about 49% of the passengers complained of hitting their body parts against Tricycle body whenever the seat is fully occupied. The major reason advanced by the commuters (53.33%) for boarding Tricycle is its capability to beat traffic jam as a result of bad road. Other reasons stated for using Tricycle include local availability and affordability. However, many (52.22%) reported that they prefer travelling in cars to other means of transportations while about 22.22% feel inferior while using Tricycle and 51.11% feel unsafe using Tricycle.

3.3. Anthropometry Dimensional Results

The way study results are presented will affect their accessibility and applicability (Mokdad and Ansari, 2009). For this reason, the measured anthropometric dimensions of commuters in this study are presented in percentiles for ease of use by Tricycle manufacturers (Table 4). The 5th and 95th percentiles depicted the extreme (low and high, or too narrow and too wide) situations, while the 50th percentile is the average that could take care of both extremes without adversely affecting commuters. This agrees with the work of Godoy, (2015).

Table 4: The anthropometry dimensions and statistical features of tricycle commuters (cm)

	Average	Lowest	Highest	Std. dev	95th Percentile	50th Percentile	5th Percentile
SST	75.03	69.50	78.50	4.59	77.43	74.98	68.56
PPH	40.47	31.00	45.50	2.29	43.40	40.85	36.48
SSH	49.99	40.30	56.50	3.06	54.02	50.15	44.86
BPL	48.74	41.00	87.00	5.18	52.62	48.50	43.96
HPW	30.92	23.90	37.40	2.75	35.41	31.05	26.40
Shh	1.41	0.30	3.00	0.68	2.51	1.25	0.50

The results of the Match equations in relation to the various Tricycle dimensions (Seat height (SH), Seat depth (SD), Seat width (SW), Backrest height (BH) and Clearance height (CH)) are presented in Figure 6.

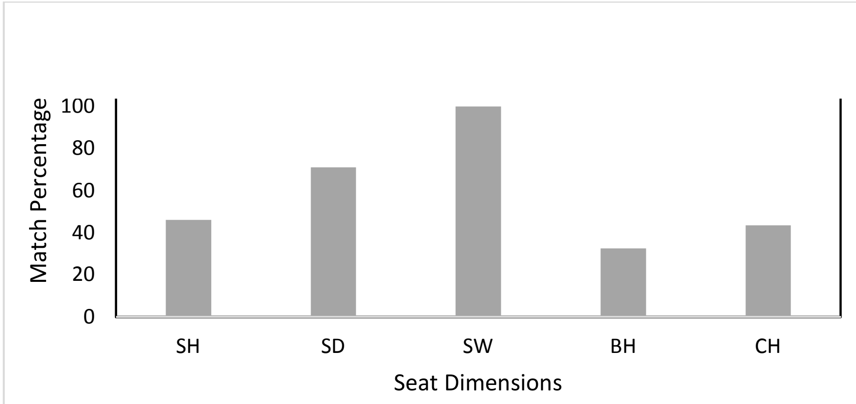

Figure 6: Match percentage of seat dimensions for the commuters

3.3.1. Match between seat height and popliteal height

This study revealed that seat height was appropriate for 46.25% of the commuters, (Figure 6). The rest commuters were using seats that are either too high or too low. Passengers who sit on a seat that is too high are likely to experience high number of stresses on the popliteal arc that runs through the underside of the thigh which may lead to increase in tissue pressure on the posterior surface of the knee (Milanese and Grimmer, 2004) and this may cause serious discomfort and possibly risk of injury (Agha, 2010). However, commuters that sat on a seat too low may have increased risk of low back pain due to the fact that such seat may lead to increased angles of lumbar flexion while the commuters sat (Pheasant, 2003; Milanese and Grimmer, 2004). Figure 7 shows a commuter seated on a lowered seat. Sitting on a lowered seat caused leg pain to commuters. Associated pain such as abdominal pain occurs with this kind of position. In this case the "large knee and hip angles became uncomfortable and the spine is flexed as the pelvis rotates backward when a seat is too low. Also, abdominal organs are compressed when sitting in a too low seat because the commuters have the tendency to lean forward (Sarpota, 2000).

3.3.2. Match between seat depth and buttock popliteal length

Figure 6 show that seat depth was appropriate for 71.25% of the passengers. Other commuters were sitting on seats that are either larger or shorter for them. The mismatch indicated that buttock popliteal length of some commuters is larger than the seat depth and as a result, thigh are likely to be compressed and blood circulation may not be possible (Milanese and Grimmer, 2004; Gouvali and Boudlos, 2006). The effective use of the back rest may not be guaranteed if Seat depth is shorter than buttock popliteal length (Pheasant, 2003; Niekerk *et al.*, 2013). Furthermore, Seat depth that is too short give indication that the thighs would be unsupported while in the sitting posture and this may lead to loss of stability and discomfort (Pheasant 1991, 2003; Castellucci *et al.*, 2010; Dianat *et al.*, 2013).

3.3.3. Match between seat width and hip width

This study showed that the seat width was suitable for commuters across the board, (Figure 6). This finding agrees totally with previous study by Dike (2012) and Adeyemi and Yusuf, (2019). The seat width is neither narrow nor wide. Narrower seats have the tendency of causing discomfort, unsteadiness and restriction of movement (Evans *et al.*, 1988; Khalil *et al.*, 1993; Orborne, 1996; Helander, 1997) but wider seats occupy more space and cannot be said to be unsuitable (Gouvali and Boudolos, 2006; Castellucci *et al.*, 2014).

3.3.4. Match between backrest height and shoulder height

Backrest was appropriate for 32.68% of the commuters, (Figure 6). Backrest that is higher than the users' scapular will likely restrict arm mobility (Evans *et al.*, 1988; Orborne, 1996). The high mismatch observed in this study (about 88%) denoted that most commuters are required to flex their shoulders more than 25º and abduct them more than 20º so as to rest their back, a situation that promotes discomfort.

3.3.5. Match between clearance height and sitting stature

Clearance height was appropriate for 43.50% of the commuters. This implies that the clearance height was too low for the majority and as a result their heads were in contact with the roof of the Tricycle. This situation may not allow any movement of the head. Figure 8 shows a passenger who bend forward in order to enter the Tricycle due to its insufficient clearance height. While sitting under this condition, the commuter may experience neck pain due to awkward sitting position.

Figure 7: Commuter seated on a lowered seat

Figure 8: A passenger in bending posture while entering the tricycle due to limited clearance height

Table 5 presents the recommended dimensions of the Tricycle arising from the match equations. The dimensions in Table 5 are the results of the analysis of the match/mismatch equations. The minimum and maximum values are for the extreme situations (low and high, or too narrow and too wide), while the average values are the recommended values that could take care of both extremes without adversely affecting commuters. This agrees with the work of Milanese and Grimmer, (2004). This study established that there is a substantial mismatch between commuters and the dimensions of the Tricycle. The use of Tricycle that is not ergonomically compatible with the users could impair their health and may lead to poor posture and cumulative-trauma disorder among the passengers. Hence, production of Tricycle for commuters should be based on ergonomic consideration and anthropometric data.

Table 5: Recommended Dimensions of the Tricycle

Tricycle variables	Minimum (cm)	Maximum (cm)	Average (cm)
Seat height (SH)	39.78	43.22	41.50
Seat depth (SD)	25. 60	30.00	27.80
Seat width (SW)	77.90	82.90	80.40
Backrest height (BH)	41.10	43.30	42.20
Clearance height (CH)	65.50	69.10	67.30

4. CONCLUSION

This study evaluated ergonomic issues in Tricycles used for public transportation in Akure, Nigeria. Majority of the commuters in the study reported discomforts while riding on the Tricycle. The study revealed from match equations that the tricycles are not comfortable for most riders. It showed that a large number, (62%) of commuters complained of leg pain due to inappropriate seat height while 42% of commuters complained of back pain. The analysis of the match equations revealed that seat height was inappropriate for about 54% commuters, while backrest height was inappropriate for about 33% commuters. Dimensions of Tricycle which were deemed optimal were recommended. to reduce the cumulative trauma disorders experienced by the commuters using the Tricycles.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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