Standard Scientific Research and Essays Vol2 (6): 251-259, June 2014 (ISSN: 2310-7502)
http://www.standresjournals.org/journals/SSRE

Research Article

Ergonomic design of Nigerian motorcycle and its vibrational analysis

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Accepted 28 June 2014

Abstract

The process of designing single-track, engine-powered, two-wheeled motor vehicles for various task performances due to the absence of Nigerians rider's anthropometric data has been a challenge. Prolonged exposure to sitting posture in motor cycle gives rise to musculoskeletal disorders of the lower back and other related pains around the body. The characteristics angles of 9 body zones were determined and a prototype designed for control experiment. Our experimental design to determine vibration called for four riders to be recruited. All four of them were males with a mean weight of 712N (Standard Deviation: 94.7N). Two different roads were used for experiments: the fast and the slow road, while old and newer motor cycles were also utilized. The survey showed that 79% of the motorcycle riders have lower back pain; the anthropometric data showed that the existing motorcycles and the riders characteristics angles do not match which necessitated the generation of anthropometric data for Nigeria riders and their motorcycles redesign. The motorcycle condition severely affects the exposure action time and exposure limit time for WBV. The most unfavourable combination of factors is: old motorcycle, small engine, and slow road where EAV=1.1 hours and ELV = 6.0 hours. The most favourable combination of factors is: new motorcycle, big engine, and fast road where EAV =3.1 hours and ELV=16.5 hours. EAV is higher for newer motorcycles, fast roads and large engine size. The vibration measurements were performed with reference to ISO – 2631 and an Artificial Newer Network (ANN) was derived to estimate vibration exposure time.

Keywords: Anthropometric Data, Low Back Pain (LBP), Musculoskeletal Disorder (MSD), Exposure Action time Value (EAV), Exposure Action Limit Value (ELV)

INTRODUCTION

A motorcycle is a single-track, engine-powered, two-wheeled motor vehicles. Their design vary considerably depending on the task they have to perform e.g long distance travel, navigating in congested urban traffic, cruising, sport and racing, or off-road condition. It has a petrol powered engine typically consisting of one to four cylinders coupled to a manual fire-or six-speed sequential transmission drives having swing arm-mounted rear wheel connected by a chain, driveshaft or belt (Setriht, 1979; de Cet and Micro, 2002)

Dynamics of Motorcycle

Different types of motorcycles have different dynamics which influences their performance in given condition. A longer wheelbase provides the feeling of more stability by responding less to disturbances.

Motorcycle Rider's Posture:

Motorcycle riding posture used by riders should take into consideration musculoskeletal and biomechanical factors, and ensure that all riding tasks are conducted within a comfortable reach range. The posture of the seated person is dependent on the design of the seat itself, individual seating habits and the work to be performed.

Seated postures are defined as the body posture in which the weight of the body is transferred to a supporting area-the ischial tuberosities of the pelvis and their surrounding soft tissues (Chaffin *et al.,* 1991; Marcus *et al.,* 2012; Malanga *et al.,* 2013; McHugh *et al.,* 2012).

Vibration Overview

Vibration is oscillatory motion where the motion is not constant but alternately greater and less than some average value. The magnitude of the vibration is determined by the extent of oscillation, while the frequency is determined by the repetition rate of the cycles of oscillation. Vibration is divided between deterministic and stochastic motions. Deterministic vibration is that which can be predicted; stochastic vibration is a random motion. Both deterministic and stochastic vibration can be subdivided further. The deterministic class of oscillatory motion can be broken down into periodic, which is comprised either sinusoidal or multi-sinusoidal, and non-periodic motion, which is comprised transient motion and shock. Vibratory motion is periodic, and is usually expressed in hertz, the number of complete cycles in one second. In an occupational setting, workers on vehicles are nearly always exposed to stochastic whole-body vibration (WBV), which must be considered as broad-band vibration, i.e. 'vibration occurring in more than one-third-octave band' (ISO 1978 a) (Meister, 1984).

This work addresses the systematic experimental design to study the statistically significant effect of rider weight, road type, engine size, and motorcycle age, on the Exposure Action time Value (EAV). These factors will be used as inputs to a neural network for estimating the admissible exposure times.

What is Whole-Body Vibration?

The possible effects of WBV exposure include herniated and degenerative lumbar disc diseases, low back pain, and other musculoskeletal disorders (Wasserman, 1996; Seyed *et al.,* 2012). Also, cases of spontaneous abortion in some female vehicle operators have been recently reported. This makes it clear to the reader that the exposure of whole body vibration to occupational drivers is a risk factor for developing low back pain and other medical problems.

Helmkamp *et al.* (1984), point out that a typical occupational driver would be exposed to over 40,000 hours of occupational vibration over a 30-year period. Therefore, information regarding the chronic effects of this vibration is important and must be investigated. However, to do this one must clearly understand what exactly whole-body vibration is.

Resonance

Every object possesses the ability to vibrate freely on its own after it has been disturbed which is called free vibration. The behavior is determined by the dynamic personality of the system. Resonance vibration can cause failure and disaster, and is generally carefully avoided in engineering designs. Resonance is best put to good use, for instance, it is natural to mount it on springs and to obtain the assistance of a resonant condition.

Vibration Amplitude

The main objective of engineering system designer is to control vibration when it is objectionable and to enhance the vibration when it is useful, although mechanical vibration in general is undesirable. Motor cycles have their normal vibration level which is the vibration amplitude at its normal running speed other than the ones created by the roads and riders.

The frequency response curve of a vibratory system has some points to note:

- Vibration amplitude is most sensitive to damping of resonance
- Vibration amplitude deceases with increase in damping at all frequency.
- Vibration amplitude is very small at high frequencies and decreases with increases in damping.

Mirbod *et al.* (1997) carried out studies on symptoms among motorcycling transit policemen in one city of Japan. They found that shoulder stiffness and low back pain were frequently encountered. There is an evident need for developing preventive measures to address the WBV exposure. Although WBV is a complex phenomenon involving engineering, biomedical and psychological issues, some measures can be taken based on averaged studies. The European Parliament, for example, has established the minimum requirements for the protection and safety of workers exposed to WBV (European Directive 2002/44/EC 2002). The frequency-weighted Root Mean Squared (RMS) acceleration, based on eight hours per day, is limited in this Directive to a Threshold Action Value (TAV) of 0.5 m/s2 and a Threshold Limit Value (TLV) of 1.15 m/s2.

The European Directive suggests carrying out the measurements according to the International Standard ISO 2631-1 (Mechanical vibration and shock evaluation of human exposure to whole body vibration) (ISO-2631-1 1997).

METHOD

Comparism between Existing and Proposed Work station

The human linkage representation is placed on the basic frame of the motorcycle, so as to help specify the relative positions as well as to determine the key dimensions of the motorcycle design. The positions “Point e, Point g, and Point I” are very important since they can be regarded as the contact points between the rider and the workstation (motorcycle). Moreover, the three points are more relevant to appearance design of the motorcycle, and they can be used to determine the location of handlebar, the location of seat, the location of footrest-board, and the space of footrest-board. That is an essential improvement in riding comfortable requirements.

A test run using back position for riders that will prove satisfactory for ergonomic parameters of adjustability, stability, solidity, durability and safety from various design concepts and criteria was selected for the design.

Therefore, it is important to evaluate comfort ratings, adjustability, stability, solidity, durability and safety by conducting test on actual user group (Jung, 2005).

Investigation on Whole Body Vibration/Experimental design

Whole Body Vibration/Experimental design

The International Organization for Standardization, in its ISO-2631 standard, sets a procedure for evaluating human exposure to WBV, where the direction of measurements, durations, locations, sensors to use, and data to report, are detailed.

The aforementioned standard states that the acceleration signal should be measured with three-axis accelerometers in the frequency range from 0.5 Hz to 80 Hz. The signal is then subjected to weighting filters in order to take into account the greater or lesser influence of different frequencies in the human body. The overall weighted acceleration shall then be calculated with equation 1.

$$- a_w = \left[\sum_i (w_i a_i)^2\right]^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

Where “a_w” is frequency-weighted acceleration, “W_i” is weighting factor for the i-th one-third octave band and “a_i” is the RMS acceleration for the i-th one-third octave band.

Since transversal vibrations (with respect to a body-fixed coordinate system for seated persons) create more discomfort than vibration along the body-fixed z axis (the axis running from hip to head), the transversal RMS components are magnified 40% whereas the “z” component is left unamplified. The directional weighting factors are then: kx=1.4, ky=1.4 and kz=1, and the weighted RMS acceleration is taken as the maximum of all three weighted components as indicated in equation 2.

$$a_v = Max\left[1.4a_{wx,} 1.4a_{wy,} a_{wz}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

The value of “a_v” is limited for workers exposed to WBV during their eight hour shift. There is a threshold above which some action needs to be taken (to drive on paved roads, to use special dampers or to reduce the ride time), the Threshold Action Value (TAV), which is set to be 0.5 m/s^2 in the European Directive 2002/44/ CE, and another threshold which should not be surpassed, the Threshold Limit Value (TLV) which is set to be 1.15 m/s2 in this directive.

These limits can be increased when the exposure time is lower than eight hours per day or, equivalently, the calculated RMS acceleration (a_v) can be decreased to compare with the eight hour based thresholds TAV and TLV. When this second approach is taken, the reduced acceleration, referred to as A(8), is determined from equation 3.

$$A(8) = a_v\sqrt{\frac{t}{T}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

Where “a_v” is overall weighted acceleration (equation 2) “t” is exposure time and “T’ is the reference time, 8 hours. In general, “a_v” is determined from a time series which is statistically representative of the vibration but shorter than the overall exposure time. In this case, one may be interested in obtaining the time required to reach Threshold Action Value (TAV) or Threshold Limit Value (TLV). These times, referred to as Exposure Action time Value (EAV) and Exposure Action Limit Value (ELV) are readily obtained by comparing A(8) (equation 3) with either TAV or TLV, the resulting times are given in equation 4 and equation 5.

$$\text{EAV} = \left[\frac{TAV}{a_v}\right]^2 \text{T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

$$\text{EAV} = \left[\frac{TAV}{a_v}\right]^2 \text{T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

A multifactor experimental design was conducted to determine the influence of the following factors: motorcycle age, driver weight, engine size and road type on the diagnosis variable EAV (equation 4). Experiments were carried out for two levels of each factor and were replicated twice resulting in a total of 32 (24x2) experiments.

The number of replicates was estimated based on similar previous factorial design. This number of replicates is enough to evaluate the random variability (or “pure error”) and the repeatability. Each experiment yielded a long data signal to be analyzed. Proper randomization of the experiments was employed seeking independence (no correlation between factors).

The statistical significance of each factor on the frequency weighted RMS acceleration was assessed via an analysis of variance. (Montgomery 2005).

The levels for each factor are specified in table 1. The average weight of riders is taken to be 686 N (70 kgf), and this value allows us to differentiate between high weight (>686 N) and low weight (<= 686 N).

Table 1. Factors and levels used for experiments

Level/Factor	Motor Cycle Age	Cylinder Volume	Riders weight	Road Type
1	> 3 years (Old)	100 cc	<= 686 N	Fast (F)
2	<= 3 years (New)	125cc	> 686 N	Slow (S)

Selected Riders

Our experimental design called for four riders to be recruited. All four of them were males with a mean weight of 712N (Standard Deviation: 94.7N). Two of the riders were heavier than 686N (Rider 1= 813N, Rider 2= 774N), whereas the other two were lighter than 686N (Rider 3= 627N, Rider 4= 637N). Each motorcycle rider had at least 4 years of recent experience in motorcycle riding and was familiar with the test routes selected for this study. Background information for each rider was filled out by the support staff (contact information, weight, height, age, years of motorcycle riding experience, and health status).

Selected routes

Two different roads were used for experiments: the fast and the slow road. The fast road is composed of highways, only a few stops, and flat and smooth lanes (10 km, 97% flat, 10 speed bumps, no traffic lights and mainly straight route). The slow road with many stops, sloped lanes and cracked asphalt (6.85 km, 80% sloped, including slope >10%, 14 speed bumps and 2 traffic lights and more than 15 turns in route).

Selected motorcycles

Most motorcycles begin to show some wear after 3 years of work and they are considered old after this time period. Frequently, 100 cc and 125 cc motorcycles are used for delivery and courier services in Nigeria (more than 1.000.000 motorcycles with these engine sizes were sold in Nigeria between 2004 and 2013, www. publimotos.com/informes.html-). The motorcycles used are shown in table 2.

Table 2. Motorcycles used for experiments

Model	Age	Motor Size
Motor Cycle 1	1 Year (New)	125 cc (Big motor size)
Motor Cycle 2	3 Year (New)	100 cc (Small motor size)
Motor Cycle 3	5 Year (Old)	125 cc (Big motor size)
Motor Cycle 4	13 Year (Old)	100 cc (Small motor size)

Data acquisition

The following devices were used for data acquisition: Quest VI-410 Advanced Analyzer with seat pad tri-axial accelerometer (sensitivity 100mV/g) for human exposure to WBV. Frequency range 0.5 Hz – 20 kHz. RMS, VDV and 1/1 and 1/3 Octave-Band analysis, W_d and W_k filters (ISO 2631). In Plate 1 is possible to see the installation of the accelerometer on the motorcycle

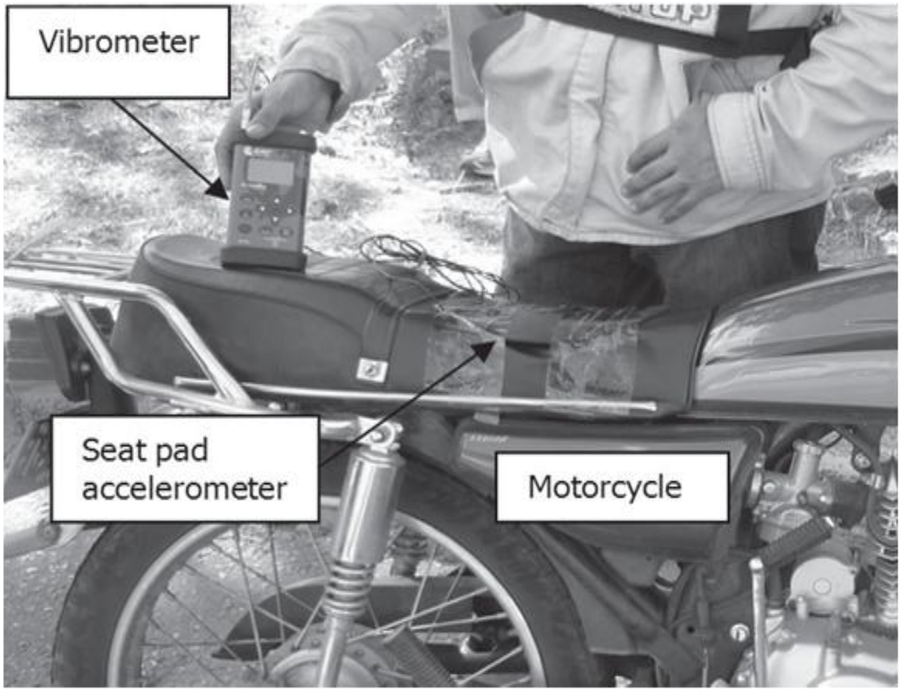


Plate 1. The installation of the accelerometer on the motorcycle

RESULTS

Table 3. Experimentally Obtained Characteristic Angles of Ideal Riding Postures

Subject	Sex	Stature	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6
Total Average	-	167.1	160.6	42.6	139.7	171.0	104.5	79.3
Under 160cm	-	156.5	158.1	42.6	131.8	171.7	107.1	82.8
160-165cm	-	162.7	159.5	40.9	135.3	171.3	103.9	79.7
165-175cm	-	171.5	162.3	39.1	143.5	171.6	104.8	78.6
Over 175cm	-	176.0	158.3	37.6	145.2	165.3	99.3	74.9

M=Male, F=Female

The experimentally obtained Nigerians characteristic angles of the 160 motorcycle rider's ideal riding posture as guided by figure 1 are stated in table 4 showing the average angle of each height category.

Analysis of Proposed Characteristics Angles of a Motorcycle Workstation

A motorcycle can be considered a constrained workstation in which there is very limited available adjustment to suit different needs of riders. To develop satisfactory motorcycle, anthropometric data should be used to improve and specify the physical dimensions of workstations as well as applied to the motorcycle design using average characteristics angles to get the proposed characteristics angles.

The height of the human linkage representation is about 165 cm hypothetically, and the characteristic angles are: $\theta 1 = 160°$, $\theta 2 = 41°$, $\theta 3 = 144°$, $\theta 4 = 171°$, $\theta 5 = 102°$ and $\theta 6 = 81°$ respectively as presented in Table 4 and fig 1 below with the highlighted points/angles (Point e, Point g, and Point i) as very important as they are the contact points between the rider and the workstation. They can be used to determine the location of handlebar, the location of seat, the location of footrest-board, and the space of footrest-board.

Table 4. Characteristic Angles of Proposed Motorcycle

Characteristic Angles	Proposed Motorcycle (x^0)
θ_1	160^0
Point e. θ_2	41^0
θ_3	144^0
Point g. θ_4	171^0
θ_5	102^0
Point i. θ_6	81^0

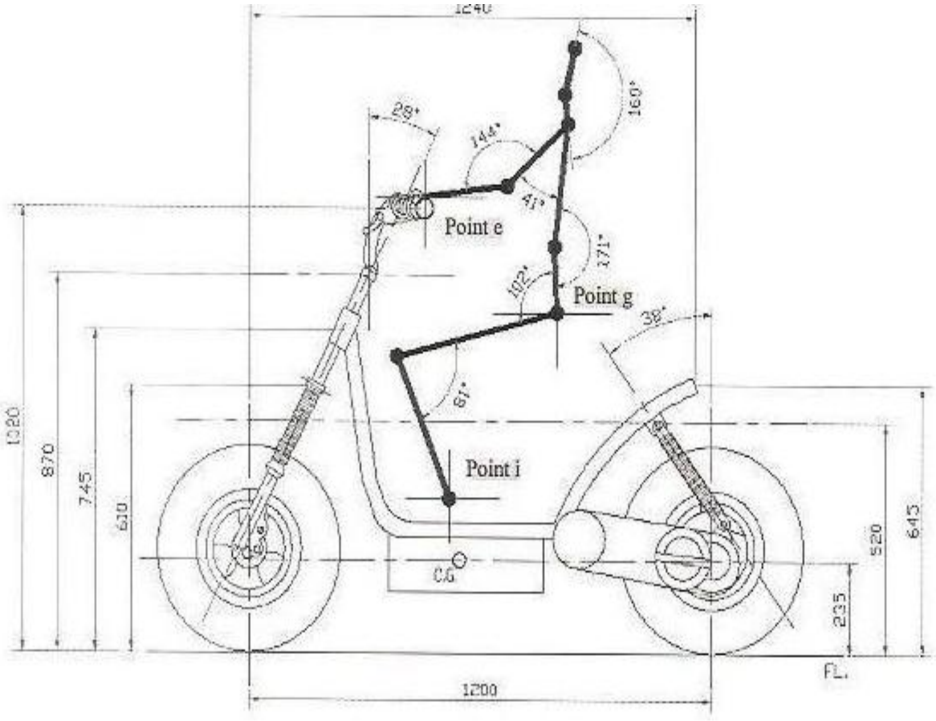


Figure 1. Physical Dimensions of a Motorcycle for Nigeria Specification

Investigation Results on Whole Body Vibration/Experimental design

Whole Body Vibration/Experimental design

Acceleration records were acquired using the equipment described previously. The Exposure time limits (EAV and ELV) are readily obtained for each experiment. Table 5 shows the nomenclature used for the experiments and table 6 shows the frequency weighted acceleration (a_v) and the averaged values of EAV and ELV for each experiment. Consider, for example, the first experiment in table 6. The experiment is tagged NBHS which, according to table 6, means New motorcycle, Big engine, High rider weight and Slow road. In this experiment, the EAV was 1.9 hours and the ELV was 10.2 hours. An individual subjected to this type of vibration should take some action after 1.9 hours of riding, and should not exceed the 8 hour limit (although the ELV calculated was 10.2 hours). It is clear that in this case, the overall weighted RMS acceleration has to be between TAV (0.5 m/s^2) and TLV (1.15 m/s^2), and as seen in the table 6, a_v.=1.02 m/s^2.

Table 5. Nomenclature used for the experiments

Experiments Nomenclature	
Age (N=0, O=1)	N(New <= 3 years) - O (Old >3 years)
Motor size (B=0, S=1)	B (Big = 125 cc) - S (Small =100 cc)
Driver weight (H=0, L=1)	H (High >= 70 kgf.) - L (Low< 70 kgf.)
Road type (f=1, s=0)	F (fast road) – S (slow road)
Example: NBHS	New, big motor size, high weight, slow road

Table 6. Frequency weighted acceleration, averaged EAV and ELV for each experiment

Frequency weighted RMS acceleration (m/s^2)					Exposure time	
	EAV ELV			**Max Value (m/s^2)**	**EAV**	**ELV**
Experiment	1.4ax	1.4ay	a_z	a_v	(hrs)	(hrs)
NBHS	0.75	0.30	1.02	1.02	1.9	10.2
NBHF	0.40	0.21	0.80	0.80	3.1	16.5
NBLS	0.76	0.32	1.09	1.09	1.7	8.9
NBLF	0.53	0.26	0.83	0.83	2.9	15.4
NSHS	0.61	0.27	1.24	1.24	1.3	6.9
NSHF	0.42	0.21	1.08	1.08	1.7	9.1
NSLS	0.69	0.38	1.09	1.09	1.7	8.9
NSLF	0.55	0.24	0.89	0.89	2.5	13.4
OBHS	0.56	0.16	1.31	1.31	1.2	6.2
OBHF	0.42	0.17	0.92	0.92	2.4	12.5
OBLS	0.60	0.33	1.30	1.30	1.2	6.3
OBLF	0.48	0.26	1.18	1.18	1.4	7.6
OSHS	0.51	0.15	1.19	1.19	1.4	7.5
OSHF	0.44	0.16	1.17	1.17	1.5	7.7
OSLS	0.76	0.40	1.33	1.33	1.1	6.0
OSLF	0.64	0.34	1.15	1.15	1.5	8.0
NBHS	0.74	0.26	1.09	1.09	1.7	8.9
NBHF	0.41	0.25	0.86	0.86	2.7	14.3
NBLS	0.68	0.34	1.04	1.04	1.8	9.8
NBLF	0.56	0.23	0.91	0.91	2.4	12.8
NSHS	0.57	0.25	1.23	1.23	1.3	7.0
NSHF	0.44	0.23	1.11	1.11	1.6	8.6
NSLS	0.75	0.43	1.15	1.15	1.5	8.0
NSLF	0.58	0.31	0.88	0.88	2.6	13.7
OBHS	0.62	0.16	1.37	1.37	1.1	5.6
OBHF	0.42	0.13	0.97	0.97	2.1	11.2
OBLS	0.54	0.32	1.17	1.17	1.5	7.7
OBLF	0.47	0.20	1.05	1.05	1.8	9.6
OSHS	0.50	0.19	1.24	1.24	1.3	6.9
OSHF	0.42	0.16	1.18	1.18	1.4	7.6
OSLS	0.77	0.43	1.24	1.24	1.3	6.9
OSLF	0.53	0.27	1.16	1.16	1.5	7.9

The analysis of variance decomposes the variability of EAV into contributions due to each factor, having removed the effects of all others. The ANOVA table shows the results of the statistical tests conducted to determine which factors have a statistically significant effect on EAV. Table 7 shows the results for the experiments. The F-test is used to identify the significant factors and since three P-values are lower than 0.05 they have a statistically significant effect on EAV at 95% confidence level.

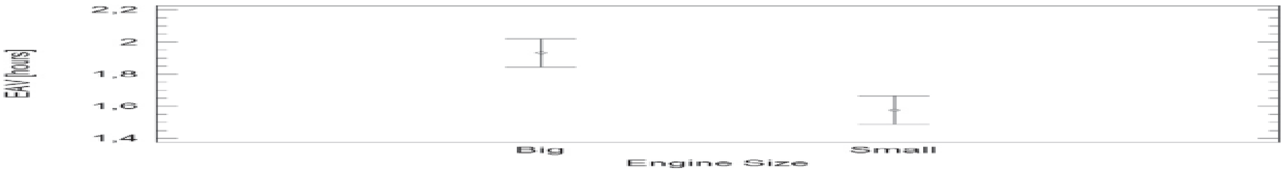
Table 7. Analysis of Variance for EAV - Type III Sums of Squares

Source	Sum of Square	Df	Mean Square	F-Ratio	P-Ratio
Mean Effect					
A: Age	2.38	1	2.38	45.41	0.0000
B: Eng Size	0.95	1	0.95	18.15	0.0003
C: Road	3.35	1	3.35	63.94	0.0000
D: Weight	0.02	1	0.02	0.41	0.5280
Interaction					
AB	0.17	1	0.17	3.28	0.0845
AC	0.30	1	0.30	5.80	0.0253
AD	0.25	1	0.25	4.86	0.0388
BC	0.41	1	0.41	7.88	0.0106
BD	0.36	1	0.36	6.96	0.0154
CD	0.01	1	0.01	0.25	0.6244
Residual	1.10	21	0.05		
Total (corrected)	9.33	31			

The first, second and third factors had significant influence on EAV. The ANOVA results show some interaction between factors. Presence of interaction means that the difference in response between the levels of one factor is not the same at all levels of other factors. It is necessary to check the interaction plot to understand the interacting factors behaviour. Figure 2 shows the mean values of EAV for each factor at the 95% confidence level.

EAV is higher for newer motorcycles, fast roads and big engine size. The rider weight doesn't have a significant effect on EAV. This figure is very useful because it provides the reference values for recommended exposure times. From the figure, one may conclude, for example, that a new motorcycle can be ridden about 2.02 hours per day before reaching the EAV while an old motorcycle only can be ridden about 1.48 hours. In the same way, it is possible to ride about 2.06 hours on fast roads while only about 1.43 hours in slow roads.

(a) Factor: Motorcycle age



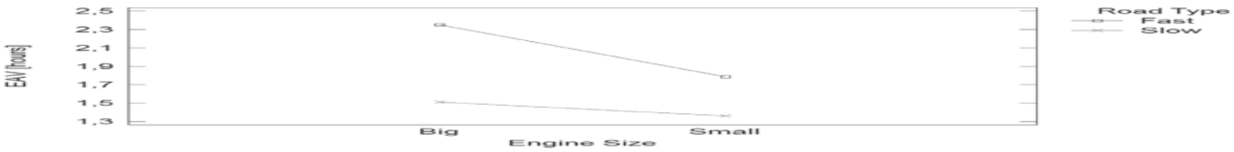
(b) Factor: engine size

(c) Factor: road type

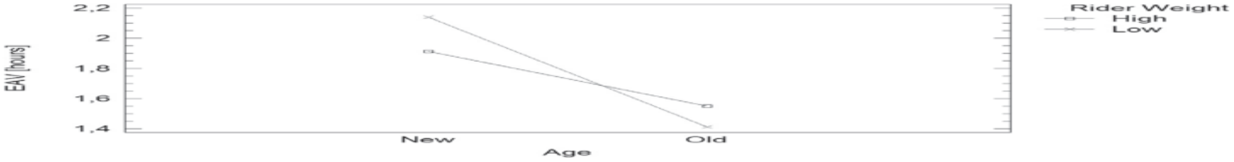
(d) Factor: rider weight

Figure 2. EAV behaviour with factors: (a) Motorcycle age, (b) engine size, (c) road type and (d) rider weight

The interaction plot must be analyzed to support the comparison between the main effects. Otherwise, misleading conclusions may be drawn. For example, Figure 3a shows that EAV variations due to "engine size" are larger when the road is "fast route" type. As another example consider Figure 3b. The plot shows that EAV variations due to "motorcycle age" are larger when "rider weight" is lower than 686 N.



(a) Road type and engine size



(b) Road type and driver weight

Figure 3. Interaction plot: (a) Road type and engine size. (b) Motorcycle age and rider weight

Data from table 6 can be processed by multiple regressions to obtain a mathematical expression that helps obtain the estimated EAV and ELV for different combinations of parameters: motorcycle age, engine size, road type and rider weight. The regressions we obtained are written in equation 6 and equation 7. For example, to estimate the EAV and ELV for case NBHS (New motorcycle, Big engine size, High rider weight, Slow road) one has to plug in the following values in equations 6 and 7: Age=0, Cylvol=0, Weight=0 and Road=0 according to the values and levels defined in table 5. The results are EAV=1.86 hours and ELV= 9.9 hours (for convention, the maximum ELV value for reporting is 8 hours), which are very similar to the measured values shown in table 6 (EAV=1.9 hours and ELV= 10.2 hours). These results derived from multiple regressions are only valid when applied to the type of experiments from which they were obtained.

EAV = 1.86 - 0.54 Age - 0.35.Cylvol + 0.63.Road + 0.04.Weight R =71% ……………….6

ELV = 9.90 - 2.93 Age - 1.87.Cylvol + 3.37.Road + 0.22.Weight R =71% ……………….7

The correlation coefficients in these regressions are low due to transient and non linear processes which occur during vehicle transportation, and due to the strong interactions between different factors. A better approach would be to use Artificial Neural Networks (ANN) instead of multiple regressions.

Neural networks are models inspired by biological neurons and the nervous system. Large number of interconnected processing elements (neurons), working as “weighted regression coefficients”, try to learn by example for solving specific problems. The ANN structure usually has one input layer, some hidden layers and one output layer. Neurons located in hidden layer sum the weighted inputs and apply the specific activation function f (Σ) (linear, sigmoid, step, Gaussian, etc.). Data samples must be selected, from suitable examples, so that ANN can learn the process and be trained in this manner. During training, inputs and target outputs are set, and the weights and bias values are adjusted (in ways that depend on the training method) in several iterations.

The results show that, using part of the data from table 6 for estimating EAV and ELV, Neural Networks had higher correlation than multiple regressions. A two layer feed-forward network with 20 sigmoid hidden neurons and linear output neurons was trained with Levenberg-Marquardt back-propagation algorithm, using 32 samples from table 6, 22 samples for training, 5 samples for validating and 5 for testing. Table 8 shows the correlation R2 for EAV and ELV estimations obtained using the ANN.

Table 8. Artificial Neural Networks Results

Results	Samples	R2 EAV	R2 ELV
Training	22	99.1	97.8
Validation	5	93.9	99.3
Test	5	95.7	94.9

Sample size and experimental replicates required were calculated using the type II error probability of a statistical test (previous variance was available) (Montgomery.2005).

Two replicates of all possible combinations were enough in this case. Neural networks show significant improvement over linear regression because the ability to handle complex data sets with many inputs and few data points Weckman *et al.* (2010).

CONCLUSION

This study identifies the problem of musculoskeletal disorders (MSD) among motorcycle riders in Nigeria. The results of this study show that the agreement between a questionnaire on musculoskeletal disorders for the low back and other parts of the body. It is the physical examination definition that included pain manifestations that offered the best agreement with the questionnaire. A shorter time interval between the administrations of the two tests also yields a better agreement. Investigators should consider these results before choosing a method to measure the presence of musculoskeletal disorders of the low back pain, neck and all other regions.

The ranges of suggested characteristic angles concerning riding postures are acceptable for motorcycle riders in Nigeria and can be used as reference data for motorcycle design for Nigerians. This proposed anthropometric measurement may result practically to pinpoint the joints of lower back and hip. However, it is still recommendable as it provides researcher a convenient and inexpensive anthropometric measurement. The survey shows that 79% of the bike riders have lower back pain; the anthropometric date showed that the existing motorcycles and the riders do not match which require the generation of an anthropometric data for the riders and their motorcycles (workstation). The height of the human linkage representation is about 165 cm hypothetically, and the characteristic angles are: θ1(head/Neck) = 160°, θ2(Elbow/Chest) = 41°, θ3(Elbow) = 144°, θ4(Waist/buttocks) = 171°, θ5(Waist/Laps) = 102° and θ6(Laps/Ankle = 81° respectively.

In the course of this research work, it was evident that there are other factors responsible for the causes of musculoskeletal disorders (MSD) such as prolonged sitting, smoking, vibration (both deterministic and stochastic), manual intensive work, mechanical pressure concentration etc, the impacts of these factors on the riders tend to reduce when the right anthropometric data is consulted for the design of the motorcycles. This investigation led to the generation of anthropometric data for the population under consideration for a better design of the anticipated motorcycles.

These findings are of concern to the researcher, in that, the motorcycle producers should take sample of a country's anthropometric data before embarking on production for any consumer and both are receptive to ideas on how they might prevent and alleviate such symptoms.

Anthropometry for Design for Nigerians

At present, there are no population data on the anthropometric of motorcycle riders in Nigeria. One of the objectives of the study is to collect data on reasonable number of body dimensions, which can be useful for the design of motorcycle for riders. It is expected that this study will provide help to designers, who have been unable to design specifically suited products (motorcycles) for motorcycles rider's population for lack for proper data.

As a result of the prevalence of MSD, it became imperative to generate data for conceived idea of improving the motorcycle work station thereby giving room for an anthropometric data for Nigeria motorcycle riders due to operational conflict detected between man and machine as experienced in Nigeria motorcycle riders and their work station.

Whole Body Vibration/Experimental design

The vibration measurements were performed according to ISO-2631 and, as a novel contribution, an artificial neural network was derived for estimating the vibration exposure time using the predictors as input variables. Neural Networks presented better correlation than multiple regressions.

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