

Design of an Ergonomic back-leaning posture support for motorbike riders

Imaekhai Lawrence

Department of Materials and Production Engineering, Faculty of Engineering and Technology, Ambrose Alli University, Ekpoma. Edo State, Nigeria

*Corresponding Author E-mail: oboscog@gmail.com

Accepted 17 October 2013

Abstract

Nigeria experienced an industrial transformation which led to exchange in technological ideas and infrastructural development that boosted international trade which benefited greatly the transportation sector. This paper aims at designing ergonomic prototype to achieve a corrective functional back lean posture support to avoid low back pain that results to the collapse of the inter-vertebral disc. (Slipped disc) The methodology will improve the sustainability of the inter-vertebral disc (Slipped disc); it requires the development of ergonomics prototype of back leaning posture support for motorbike riders which is based on total "Design Activity Model" DAM. Questionnaire was administered to workers/motorbike riders in this regard. The musculoskeletal symptoms of 8,000 bike riders in Nigeria between the ages of 20 and 60 years of age, with a numerical figure of 2000 motorbike riders each from North, South, East, Western Nigeria, in the public service sector were assessed by the Questionnaire. One, out of several designed prototypes will be chosen as the most suitable motorbike posture support to solving the low back pain in most motorbike riders in Nigeria from the ages of range 20 to 60 years. This paper focuses on designing and testing of generated prototypes with an exhaustive utility of important criteria of product design specification to achieving an adjustable and movable posture support to enhance high level of comfortability and health protection particularly in the lumber areas of bike riders where inter-vertebral disc easily collapse leading or causing low back pain which is common within bike riders in Nigeria.

Keywords: Low back pain, Posture support, Motorbike riders, Slipped disc, Design.

INTRODUCTION

Musculoskeletal ergonomics is concerned with the way in which work postures, working movements, physical loads and other conditions affect the muscles and joints in the body. Factors include, for example, the design of work facilities, workplaces, work objects and tools. The way in which work is organized also makes a difference.

Today, in the industrialized world, sitting is the most common working posture and perhaps the most frequent leisure posture. It is well-recognized that constrained sitting postures can lead to discomfort and health disorders (e.g., back pain, neck-shoulder complaints, etc.) causing a major cost to the society through missed work and reduced work-effectiveness/productivity (Johansen and Jöhren, 2002).

Accurate data on the incidence and prevalence of musculoskeletal disorders are difficult to obtain, and official statistics are difficult to compare across countries. Nevertheless, MSDs are the single largest category of work-related illness, representing a third or more of all registered occupational diseases in the United States, the Nordic countries, and Japan (Pope, et al., 1991, Sjøgaard, et al., 1993; Bernard, 1997, National Research Council 2001). Numerous surveys of working populations have reported upper extremity symptom prevalences of 20 to 30% or even higher. In the United States, Canada, Finland, Sweden, and England, musculoskeletal disorders cause more work absenteeism or disability than any other group of diseases (Pope, et al., 1991; Badley, et al., 1994; Riihima, 1995; Rempel, et al., 1997;

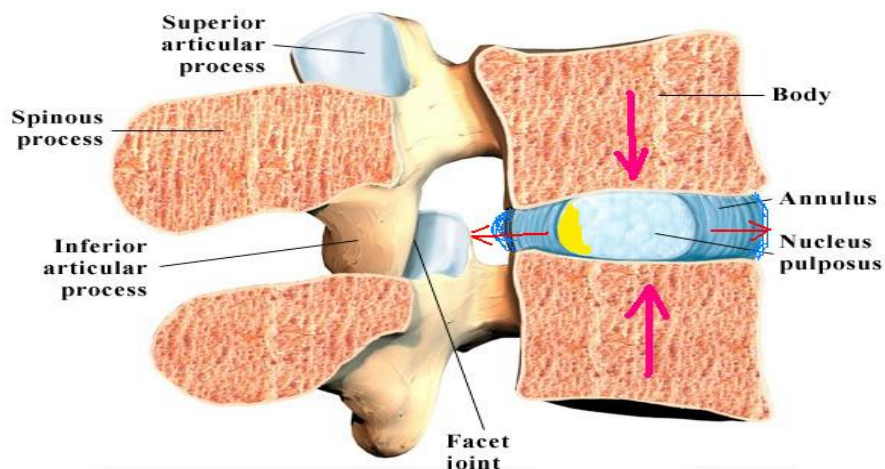


Figure 1. Motion segment, 2 adjacent vertebrae connected through the intervertebral disc

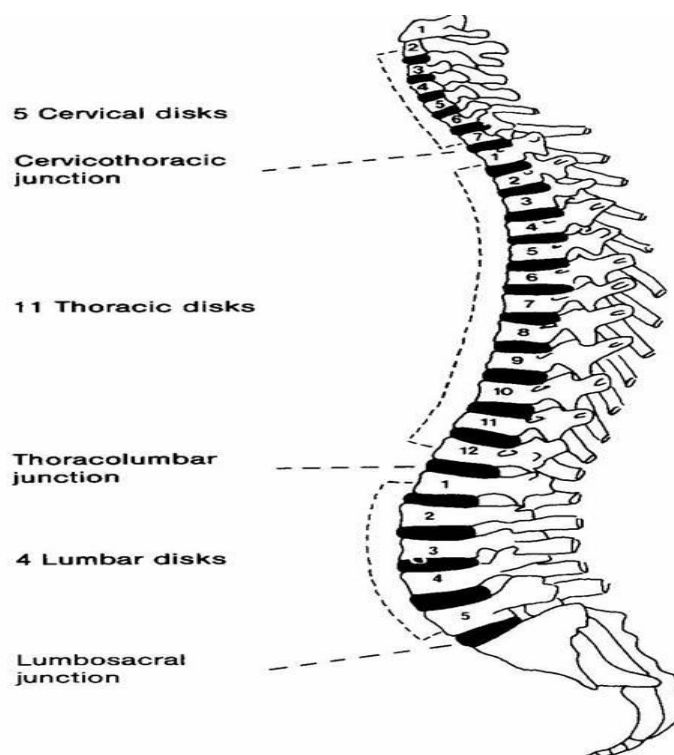


Figure 2. Schematic drawing of spinal Colum and disc (adapted from Kramer 1981)

Feeney, et al., 1998; Leijon, et al., 1998). MSDs occur in certain industries and occupations with rates up to three or four times higher than the overall frequency. High-risk sectors include nursing facilities; air transportation; mining; food processing; leather tanning; and heavy and light manufacturing (vehicles, furniture, appliances, electrical and electronic products, textiles, apparel and shoes) (Bernard, 1997).

Upper extremity musculoskeletal disorders are also highly prevalent in manual-intensive occupations, such as clerical work, postal service, cleaning, industrial inspection and packaging (Rempel, et al., 1997). Back and lower limb disorders occur disproportionately among truck drivers, warehouse workers, airplane baggage handlers, construction trades, nurses, nursing aides and other patient-care workers, and operators of cranes and other large vehicles (Pope, et al., 1991). In 1998, the National Research Council (NRC) convened a workshop on work-related musculoskeletal disorders, at which the first author was an invited speaker. The charges to the multidisciplinary panel included “to evaluate contribution of jobs and job tasks to the occurrence of musculoskeletal disorders” of the lower back and upper extremities (National Research Council 1998).

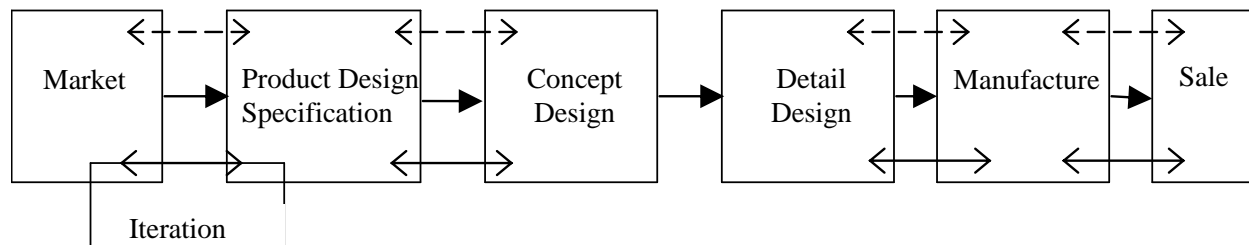


Figure 3. Total Design Activity Model

The human spine is a complex structure with regard to anatomy and physiology, consisting of hard and soft tissues (Figure 1). In general the 24 vertebrae (Figure 2) consist of a massive vertebral body and the posterior elements that enclose the vertebral foramen.

Vibration Overview

Vibration is divided between deterministic and stochastic motions.

Both deterministic and stochastic vibration can be subdivided further. 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). The stochastic (or random) class of oscillatory motion can be broken down into stationary ergodic (which can be further subdivided into strongly self stationary and weakly self stationary), and non-stationary oscillatory motion (Griffith, 1990).

To simplify analysis only linear motion is considered in human vibration (Wasserman, 1995). Objects subjected to vibration, frequently exhibit a phenomenon called resonance, which may damage or actually destroy the vibrating object (Wasserman, 1995). When an object is exposed to vibration and resonance occurs, the object experiencing the vibration will amplify or increase the peak signal, or magnitude of the vibration within the object. Unfortunately, human beings are not exempt from experiencing this phenomenon at certain resonant frequencies. It is thought that the WBV resonance in the vertical direction is 4 to 8 Hz (nominally 5Hz) and in the horizontal and lateral directions WBV resonance thought to be between 1 to 2 Hz (Wasserman, 1996).

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). The term Whole-body Vibration is used to describe a situation when the whole environment is undergoing motion and the effect of interest is not local to any particular point of contact between the body and the environment (Griffith, 1990). It occurs when the body is supported on a surface that is vibrating.

There are three main possibilities of WBV: sitting on a vibrating seat, standing on a vibrating floor, or lying on a vibrating bed (Griffith, 1990). This paper will investigate the first of these, seated whole body vibration.

Whole-Body Vibration and Occupational Back Pain

It is believed that WBV may cause back pain and injury. This belief is based on both controlled studies and epidemiological data. The epidemiological evidence supporting this belief is quite extensive.

Epidemiological Studies

In 1974, Gruber and Zipermann studied the morbidity experiences of 1448 male interstate bus drivers. Several disorders of the spine and supporting structure, including displacement of the intervertebral disc, ankylosis of the spine and vertebrogenic pain syndrome were found to be more prevalent among the experienced drivers when compared to the control groups (Hulshof, 1987). This study was followed by another study by Gruber in 1976 of interstate truck drivers. The diagnoses of vertebrogenic pain syndrome, premature degenerative deformations of the spinal column and displacement of the intervertebral disc were observed to have a higher incidence among the truck drivers than the control group. The incidence rates were also significantly higher when compared to the bus drivers from the earlier study (Hulshof, 1987).

In a study of the effect of work induced WBV on occupational drivers (tractor, and fork lift) and helicopter pilots, it was found that in less than favorable circumstances vibration exposure may lead to more sick leave and disability pensioning (Boshuizen, 1990).

Investigators who studied the functional disorders at the spine after long lasting whole-body vibration found that deviations of the shape of the spine occurred in the group exposed to WBV. The incidence of the deviation of the shape of the spine in the exposed groups in the thoracal and lumbar sections were 60% and 55%, respectively. This is contrasted by values 6.6% and 1.6%, respectively for the non-exposed groups. Also, radiographical examinations confirmed that the decreased mobility of the thoracal/lumbar sections of the spine for exposed workers. Of the workers in the exposed group, 76.5%, 81%, and 64.5% showed decreased mobility in the thoracal/lumbar section of the spine during extension, flexion and lateral flexion, respectively. This can be compared to mobility reductions in the non-exposed group of 36%, 54.1%, and 41%, respectively (Ruppel, et al., 1993). Few studies are able to report a dose-response relationship between vibration exposure and low back symptoms in bus drivers. One exception however, is a study of low back symptoms in urban bus drivers, conducted by Bovenzi and Zadini. This was possible because they were able to measure vibrations from nearly all types of buses used from 1968 to 1991. And since bus drivers have a rigid work organization with precise time schedules each day, it was possible to determine the vibration dose of a given individual based on years in service and the type of bus driven each year.

After considering potential confounders, significant associations were found between vibration dose and LBP for lifetime, as well as for the previous year and week. Drivers who had accumulated more than 4.5 years had high adjusted odds ratios, when compared to the controls. Also, the prevalence of disc protrusion was found to be 16.6%, with a corresponding odds ratio of 2.61 (Bovenzi and Zadini, 1992).

Controlled Studies of WBV

Experimental exposures to whole-body vertical vibration have been shown to cause a temporary body height reduction ranging from 1 – 2 cm with a return to the height expected for the time of day within a few hours (e.g. Klingenstierna and Pope, 1987). These changes are assumed to arise from reductions in the height of the viscoelastic intervertebral discs which can be caused by load and may be similar to reduction which occur with static loading while sitting or standing (Griffith, M.J., 1990) Musculature fatigue will result in a shift of loads to the ligamentous tissues (Wilder et al., 1985).

It is hypothesized that WBV exposure causes muscular activity that increases the load on the spine, and leads to muscular fatigue, which may destabilize the spine (Bongers, 1992).

It was found that when workers with LBP were compared to those without LBP, cumulative load measurements of the lumbar spine were significantly higher for the LBP group (Sherlerud, 1998).

Physical ergonomics

There is evidence from two systematic reviews. Westgaard and Winkel found a general lack of success from mechanical exposure interventions (Westgaard and Winkel, 1997), whilst Linton and van Tulder offered a negative conclusion about the role of ergonomic interventions (Linton and van Tulder, 2001). Three subsequent good quality studies (Evanoff et al., 1999; Brisson et al., 1999; Yassi et al., 2001) reported that physical ergonomics interventions may reduce the prevalence and severity of LBP.

Two other recent good quality studies did not report an improvement following changes intended to reduce exposure to physical risk factors (Fredriksson et al., 2001; Smedley et al., 2003). Physical ergonomic interventions that include an organisational dimension, actively involving the workers and leading to substantial changes in exposure to the risk factors, might (in principle) be the most effective. However, there is limited supportive evidence from one systematic review (Westgaard and Winkel, 1997). In respect of reducing [reported] back injuries, occupational or compensable LBP in particular, there are several studies (Evanoff, et al., 1999; Marras, et al., 2000; Broph,y et al., 2001; Koda, et al., 1997; Owen et al., 2002), reporting physical ergonomics interventions to be successful, though only one (Evanoff, et al., 1999) was of high quality. The only RCT (Yassi, et al., 2001) did not find lower injury rates in the intervention groups.

Spinal curves, asymmetry and motion

There was the lack of association between postural spinal asymmetry, thoracic kyphosis and lumbar lordosis in teenagers and developing LBP in adulthood (Papaioannou, et al., 1982; Dieck, 1985; Poussa, 2005). Even obvious increases in lordosis and sagittal pelvic tilt during pregnancy lack an association with back pain (Franklin and Conner-Kerr, 1998). Stronger predictors of the development of back pain during pregnancy were body mass index, history of

hypermobility and amenorrhea, low socioeconomic class, previous LBP, posterior fundal location of placenta and fetal weight to LBP with radiation to leg (Orvieto et al., 1990; Mogren and Pohjanen, 2005).

In adults, the extent of lumbar lordosis as well as the presence of scoliosis failed to show an association with back pain (Dieck, 1985; Norton, 2004; Haefeli, et al., 2006; Christensen and Hartvigsen, 2008). Also differences in regional lumbar spine angles or range of motion between the segments failed to show an association with the future development of LBP (Helsing, 1988b; Burton and Tillotson, 1989; Hambergvan, 2007; Mitchell, et al., 2008).

METHODOLOGY

Development of ergonomic prototype of back-leaning posture support for motorbike riders using different design concepts and will be based on total Design Activity Model (DAM) (Pugh, 1991)

Questionnaires are drafted in order to collect data on musculoskeletal problems in different body areas (neck, shoulders, elbow, hand, upper back, lower back, hip, kneel, feet) and some detailed questions about neck, shoulder and lower back pain.

Another questionnaire was to collect data on bike riders working conditions required for assessment of possible connections with reported pains which will specially be developed. This contain questions on frequency and duration of riding, shift working, routes and driven, psychosocial related questions be sort, such as (waiting time, violence, as well as relevant personal details e.g. age, weight, height, eye sight, diet and health

Development of ergonomic prototype of back learning posture support for motor-bike riders is based on Design Activity Model (Pugh, 1991).

Figure 4 Show that motorbikes are commonly used in Nigeria society for commuting. Motorbikes with and without back support in Nigeria have been studied under existing market product of DAM. Existing motorbike design does not contain back posture support for riders. For back posture support design, there are 32 important criteria as in figure 5 of product design specifications (Pugh, 1991) of which relevant criteria are chosen in table 1

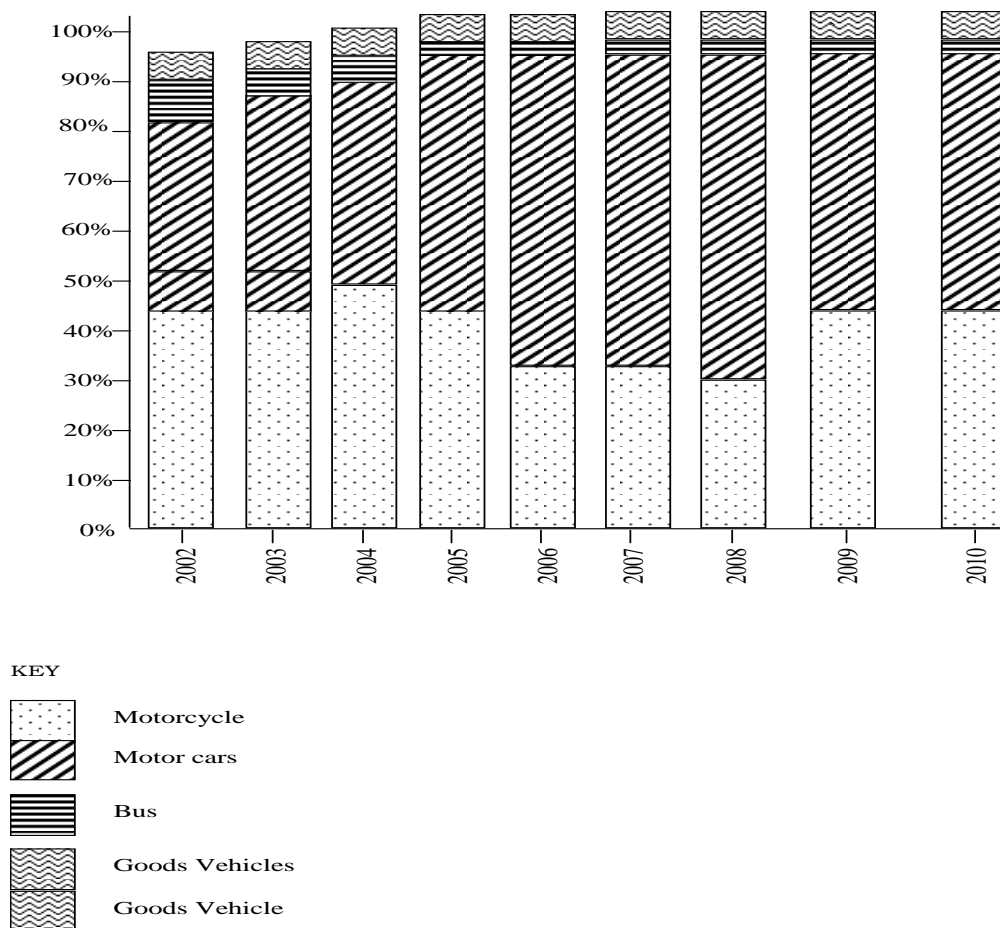


Figure 4. New registered Motor Vehicle by type in Nigeria 2002 -2010

Environment	Patent	
Testing	Shelf life storage	
Safety	Quality reliability	
Legal	Packing	
Documentation	Competition	
Quantity	Maintenance	
Product life span	Design Core	Weight
Materials		Market Constraint
Ergonomics		Politics
Standard specification Facility	Manufacturing	
Aesthetics	Disposal	
Installation	Company constrain	
Life in service	Shipping	
Performance	Size	
Product cost	Processes	
Time Scale	Customer	

Figure 5. Elements of Product Design Specification (PDS)

Table 1. Product Design Specification (PDS) for back learning position support

S/N	Criteria	Parameter
1	Performance	A good rigid frame, it can support maximum body weight (90kg). it can be adjustable upward and downward according to lumber height and forward and backward according to rider's comfort ability.
2	Environment	It can withstand hot an cold temperature, vibration, corrosion (rain water) shock loading of riders and dirt and dusty environment.
3	Life in Service	It can withstand for 4 -5 years
4	Maintenance	Twice a year; does not need special tools for maintenance and spare parts are cheap and easy to obtain
5	Size	It should fit into present motorbike seats dimension
6	Weight	<1kg
7	Materials	Light, strong, antirust, easy to form shape less expensive and easy for machining
8	Aesthetics	Bright colours, reflect light during right riding, curved edges, simple and fulfill needs and sporty look.
9	Ergonomics	Cushion (contour shape) will support back posture. Adjustable seat height according to rider's lumber height has shape –edge.

RESULTS

The reliability of the Questionnaire, found the number of different answers ranged from 0 to 99%. Validity tested for clinical history and the Questionnaire found a range of 0 to 92% agreement. The authors concluded this was acceptable in a screening tool and worth researching to generate anthropometric data for the **CONCEPTUAL DESIGN AND PROTOTYPE OF AN ERGONOMIC BACK-LEANING POSTURE SUPPORT FOR MOTORBIKE RIDERS** as a corrective measure.

The motor-bike riders in the south of Edo state typically has a longer exposure time to work than those in other parts of the state, both in public and private riders as shown in table 2

The number of motor-bike riders who had seen a physician because of musculoskeletal symptoms was significantly larger. The prevalence of long-lasting (more than 30 days) lower back is higher than that of the neck troubles. The sick rate due to musculoskeletal symptoms in lower back pain was significantly higher than all other body parts considered.

By the Questionnaire, bike riders had significantly higher prevalence of pain in the lower back. These results show the medical ascertainment and also fit the musculoskeletal symptoms and clearly differentiate between the prevalence in

Table 2. Prevalence of lower back pain in motor-bike riders by Questionnaire on Body parts In the North, South, East, West and Central of Edo state

Body parts.	N (n=2,000)	S (n=2,000)	E(n=2,000)	W(n=2,000)
Neck Pain	111 (5.55)	123 (6.15)	98 (4.9)	101 (5.0)
Upper back pain	121 (6.05)	154 (7.7)	98 (4.9)	122 (6.1)
Lower back pain	1,989 (99.45)	1,994 (99.7)	1,653 (82.6)	1,498 (74.9)
Waist pain	1,487 (74.35)	1,477 (73.8)	1,239 (61.9)	1,364 (68.2)
Spinal cord pain	564 (28.2)	769 (38.4)	899 (44.9)	979 (48.9)
Eye pain	1,008 (50.4)	987 (49.3)	1,122 (56.1)	863 (43.1)
Hips/thighs pain	330 (16.5)	435 (21.7)	567 (28.3)	356 (17.8)
Knees	342 (17.1)	343 (17.1)	445 (22.2)	344 (17.2)
Chest pain	211 (10.5)	237 (11.8)	333 (16.6)	542 (27.1)

Note: Percentage (%) given in parentheses.
B(North), S(South), E(East), W(West), C(Central)

Table 3. Severity of troubles by Physicians in low back in motor-bike riders as reported by this Questionnaire

Severity	N (n=2,000)	S (n=2,000)	E(n=2,000)	W(n=2,000)
Has seen Doctor	654 (32.7)	723 (36.1)	537 (26.8)	521 (26.0)
Reduced leisure activity	176 (8.8)	111 (5.5)	119 (5.9)	202 (10.1)
Reduced work activity	98 (4.9)	22 (1.1)	10 (0.5)	87 (4.3)
Hospitalized	510 (25.5)	634 (31.7)	434 (21.7)	411 (20.5)
Changed jobs	33 (1.6)	121 (10.6)	56 (2.8)	77 (3.8)

Note: Percentage (%) given in parentheses.
N(North), S(South), E(East), W(West), C(Central)

motor-bike riders in the southern part of Edo state as shown in table 3. The Questionnaire enabled us to identify the severity, the duration, the treatment, the disability and the design solution. For that reason some Questionnaire items should be applied to workers exposed to musculoskeletal disorder.

By means of the Questionnaire, the prevalence's of pain in the eyes and heap/thighs were also significantly higher in motor-bike riders. These correspond with the results of many studies on drivers/workers performing repetitive or sustained static work with a wrong body posture. (Vihma, et al., 1982; Punnett, et al., 1985; Hagberg, et al., 1987; Ohlsson, et al., 1989; Kamwendo, et al., 1991).

Application of anthropometric data to design

There are four basic steps required for current use of anthropometric in this thesis. They are as follows;

- 1 Definition of the design problem
- 2 Determination of the combination of body dimensions relevant to fitting the design to its target users. This is known as case selection.
- 3 Definition of the anticipated user's population.
- 4 Acquisition of appropriate anthropometric data on the relevant body measurements (or multivariate summary statistics) for a specific sample of people representing the body size variation of the user population.

CONCLUSION

This study focused on designing and testing a prototype of an adjustable back learning positive support for motor bike riders in Nigeria. The developed back positive support enhances level of comfortability and health protection particularly in lumber area for riders' back positive support helps riders to maintain a proper body positive during riding. Also, these back posture supports are designed with criteria of ergonomic and aesthetic to attract riders to use it. The design is also suited for any type of motorbike models as component can be adjustable according dimension without away modifications on motorbike. Fitting trials are proved to satisfy riders on test runs.

References

- Bernard BP(1997). Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, OH.
 Bongers PM, Boshuizen HC(1992). *Back disorders and exposure to whole body vibration*: Thesis summary, Clinical Biomechanics., Volume 7,

Number 3, August 1992. ©1992 Butterworth-Heinemann Ltd.

- Boshuizen Hendriek C, Paulien M Bongers, Carel TJ Hulshof(1990). *Back Disorders and Occupational Exposure to Whole-Body Vibration.*, *Int. J. Ind. Ergonomics*. 6: 55-59. Elsevier Science Publishers. © 1990.
- Bovenzi M, Antonella Z(1992). *Self-Reported Low Back Symptoms in Urban Bus Drivers Exposed to Whole-Body Vibration*. *Spine* Volume 17, Number 9 September 1992, Lippincott-Raven publishers.
- Burton AK, Tillotson KM (1989). Is recurrent low back trouble associated with increased lumbar sagittal mobility? *J. Biomed. Eng.* 11(3):245–248.
- Christensen ST, Hartvigsen J (2008). Spinal curves and health: a systematic critical review of the epidemiological literature dealing with associations between sagittal spinal curves and health. *J. Manipulative Physiol. Ther.* 31(9):690–714.
- Dieck GS (1985). An epidemiologic study of the relationship between postural asymmetry in the teen years and subsequent back and neck pain. *Spine*, 10(10):872–877.
- Franklin ME, Conner-Kerr T (1998). An analysis of posture and back pain in the first and third trimesters of pregnancy. *J. Orthop Sports Phys. Ther.* 28(3):133–138.
- Haefeli R, Elfering A, Kilian R (2006). Non operative treatment for adolescent idiopathic scoliosis: a 10- to 60- year follow-up with special reference to health-related quality of life. *Spine*, 31(3):355–366.
- Hamberg-van Reenen HH (2007). A systematic review of the relation between physical capacity and future low back and neck/shoulder pain. *Pain*, 130(1-2):93–107.
- Hellsing AL (1988). Passive lumbar mobility. A prospective study of back pain in young men during their military service. *Ups. J. Med. Sci.* 93(3):255–265.
- Hagberg M, Wegman DH. (1987). Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. *Br. J. Ind. Med.*44: 602–610.
- Mogren IM, Pohjanen AI (2005). Low back pain and pelvic pain during pregnancy: prevalence and risk factors. *Spine*, 30(8):983–991.
- Norton BJ (2004). Differences in measurements of lumbar curvature related to gender and low back pain. *J. Orthop. Sports Phys. Ther.* 34(9):524–534.
- Orvieto R, Keyserling W (1990). Low-back pain during pregnancy. *Harefuah*, 119(10):330–331.
- Ohlsson K, Arrewall R, Skerfving S. (1989). Self- reported symptoms in the neck and upper limbs of female assembly workers. *Scand. J. Work Environ. Health*.15: 75–80.
- Punnett L, Robins JM, Wegman DH, Keyserling WM(1985). Soft tissue disorders in the upper limbs of female garment workers. *Scand. J. Work Environ. Health* 1985; 11: 417–425.
- Kamwendo K, Linton SJ, Moritz U (1991). Neck and shoulder disorder in medical secretaries, part I: pain prevalence and risk factors. *Scand. J. Rehab. Med.* 23: 127– 133.
- Hagberg M, Wegman DH(1987). Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. *Br. J. Ind. Med.* 44: 602–610.
- Mitchell T, O'Sullivan PB, Burnett AF(2008). Regional differences in lumbar spinal posture and the influence of low back pain. *BMC Musculoskeletal Disord.* 9:152.
- Pugh S(1991). *Total Design, Integrated methods for Successful Product Engineering*. (Addison Wesley Publishing Company Workingham, England), 5 – 11: 44 –66.
- Papaioannou T, Stokes I, Kenwright J (1982). Scoliosis associated with limb-length inequality. *J. Bone Joint Surg. Am.* 64(1):59–62.
- Poussa MS (2005). Anthropometric measurements and growth as predictors of low-back pain: a cohort study of children followed up from the age of 11 to 22 years. *Eur. Spine J.* 14(6):595–598.
- Griffith MJ(1990). *Handbook of Human Vibration*, Academic Press Harcourt. Brace Jovanovich, Publishers. © 1990
- Helmkamp JC, Talbott EO, Marsh GM(1984). *Whole Body Vibration – A Critical Review*. American Ind. Hygiene Assoc. J. Vol. 45, No.3.
- Hulshof C, Brinio V VZ(1987). *Whole-body vibration and low-back pain.*, International Archives of Occupational Environmental Health, Volume 59, Number 3, 1987. © 1987 Springer-Verlag
- International Organization for Standardization (1985a). Evaluation of human exposure to whole-body vibration-Part 1:General Requirements. ISO2631/1-1985. International Organization for Standardization, Geneva.
- Meister A, Bräuer D, Kurerov NN, Metz AM, Mucke R, Rothe R, Seidel H, Starozuk IA, Suvorov GA(1984). *Evaluation of responses to broad band whole-body vibration*: *Ergonomics*. 27(9): 959-980.
- Nakata M, Nishiyama K, Watanabe S(1987). *The Low-Back Pain Prevailing Among The Freight-Container Tractor Drivers in Japan*. Department of Preventive Medicine, Shiga University of Medical Science, Seta, Tsukinowa-cho, Otsu, 520-21 Japan. Proceedings of a conference held at The University of Surrey, Guildford 13-15 April 1987.
- Ruppe K, Mucke R(1993). *Functional Disorders At The Spine After Long lasting Whole-Body Vibration*, Institute of Occupational Health, Humboldt-University, Berlin. *Advances in Industrial Ergonomics and Safety*, Taylor and Francis, 1993
- Shelerud R(1998). *Epidemiology of Occupational Low Back Pain*, Occupational Medicine: State of the Art Reviews- Vol. 13, No.1, January-March 1998. Philadelphia, Hanley and Belfus, Inc.
- Wasserman DE(1996). *An Overview of Occupational Whole-Body Vibration and Hand-Arm Vibration*. Applied Occupational and Environmental Industrial Hygiene, Vol. 11, No. 4, pages 266- 270. © 1996
- Vihma T, Nurminen M, Mutanen P(2003). Sewing machine operators' work and musculoskeletal complaints. *Ergonomics* 1982(25): 295–298.
- Wasserman DE(1995). *Vibration*. Environmental Medicine. Mobsy-Year Book, Inc., St. Louis, Missouri. Pp. 557-562.
- Wilder DG, John WF, Malcolm HP(1985). *The effect of vibration on the spine of the seated individual*. *Automedica*. 6: 5-35.
- Johansen U, Johren A(2002). *Personalekonomi Idag*. Uppsala Publishing House. ISBN 9170052026. E.M. Badley, I. Rasooly, G.K. Webster, Relative importance of musculoskeletal disorders as a cause of chronic health problems, disability, and health care utilization: Findings from the 1990 Ontario Health Survey, *The J. Rheumatology*. 21(3): 505–514.