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Conceptual design of motorcycle's lumbar support using motorcyclists' anthropometric characteristics

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Abstract: This study presents the design and development of a prototype of lumbar support for motorcyclists corresponding to their anthropometric dimensions. The total design process model was used for this purpose. The critical design dimensions for the lumbar support (height, width, adjustable range and thickness) were obtained from the anthropometric dimensions of motorcyclists (1032 samples). The initial testing (trial runs) of the prototype proved to be successful as it was capable of providing comfort to the motorcyclists' lumbar region during their riding process. However, further evaluation needs to be done in order to evaluate the stability, solidity, durability and safety of the prototype.

Keywords: design, ergonomics, anthropometrics, motorcycle, lumbar support

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INTRODUCTION

'Engineering design' and 'ergonomics' are two important terms in the design process. The primary purpose of engineering design is to devise a system, component or process to meet the desired needs by utilising the basic knowledge (basic sciences, mathematics and engineering sciences)

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

and the available resources. The International Ergonomics Association (IEA) defines ergonomics as the discipline that involves the understanding of the interaction between humans and other elements of a system and the profession that applies theory, principles, data and methods to designing in order to optimise human well-being and overall system performance [1]. Thus, the primary purpose of the interdisciplinary subject of engineering design and ergonomic design is to devise a system or product with added human value.

There are four basic criteria in an ergonomic product design, namely increasing production, decreasing injuries, decreasing human error and increasing user satisfaction [2-3]. These criteria are applied to the relevant industries to meet particular human needs. However, to design a product or system that can accomplish these criteria is very demanding as the advancement in technology has made the products/systems more sophisticated and complex. An example of such a complex (human-machine) interaction can be seen in the production of motor vehicles, especially motorcycles [4].

The ergonomic design involving motorcycles is a complex process as it involves a very constrained space between the motorcyclist and the motorcycle. In any adjustment of the design of the motorcycle, the different needs of the motorcyclist must be considered [5-7]. Generally, the main aspect of a motorcycle design is to provide for the safety and comfort of the motorcyclist by reducing or eliminating fatigue during the riding process. Previous research [8] has shown that motorcyclists in Malaysia experience during the riding process symptoms of discomfort on various parts of their bodies, particularly the lower part of the back (lumbar) area. Similarly, other researchers have also found that sitting for a prolonged duration of time in a vehicle can cause great intradiscal pressure in the lumbar region and consequent low back pain [2, 9-10]. The lumbar region is also the most vulnerable part of the spine as this part is suspended between the upper heavy part of the body including the rib cage and the lower and lighter part starting from the hip bone [11].

Therefore, this lumbar region should be supported by a backrest. However, in Malaysia the current design of motorcycles does not incorporate this feature. Consequently, motorcyclists assume a variety of postures (Figure 1) during their riding to balance the intradiscal pressure in their lumbar region. In our earlier study, we managed to design and develop a prototype of portable back support [12]. However, the developed design was lacking in some important ergonomic characteristics, i.e. anthropometric dimensions, owing to the unavailability of this information during the study period. This study is undertaken to design and develop an improved version of the earlier lumbar support prototype for motorcyclists by taking into consideration their anthropometric dimensions.

METHODS

The design and development of a new lumbar support for motorcyclists is based on Pugh's total design process model [13]. There are six important components in this model, viz. market study, product design specification (PDS), conceptual design, detail design, manufacturing, and sales (Figure 2). An important guide in designing the lumbar support is the information on anthropometric dimensions of the motorcyclists, which are needed to ensure that the designed product can be adapted to suit the majority of users (5^{th} percentile to the 99^{th} percentile).

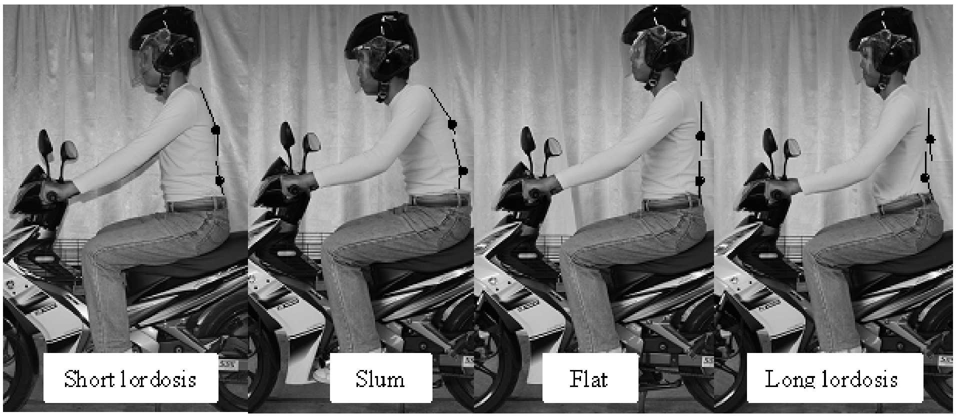


Figure 1. Variety of riding postures

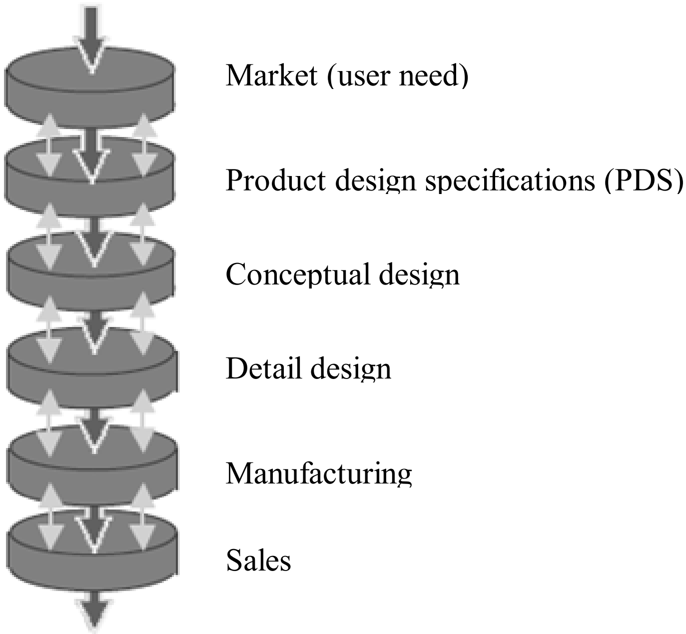


Figure 2. Total design process model

The anthropometric data were obtained from an earlier survey conducted in the Polytechnic of Sultan Azlan Shah in Malaysia [14]. The data were collected and analysed based on Malaysian standards [15-16]. The sample consisted of 1032 students (595 males and 437 females). Their ages ranged from 18 to 24 years, with a mean of 19.82 years and a standard deviation of 1.07. A total of 11 anthropometric dimensions were extracted in line with the current study's purpose (Table 1 and Figure 3).

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

Table 1. List of body dimensions selected for measurement including age and weight

Dimension Number	Dimension	Description
1	Age (year)	
2	Weight (kg)	Total mass (weight) of the body
3	Stature	Vertical distance from the floor to the highest point of the head (vertex).
4	Shoulder (biacromial) breadth	Distance along a straight line from acromion to acromion
5	Hip Breadth, sitting	Breadth of the body measured across the widest portion of the hips
6	Shoulder height, sitting	Vertical distance from a horizontal sitting surface to the acromion
7	Elbow height, sitting	Vertical distance from a horizontal sitting surface to the lowest bony point of the elbow when it is bent at a right angle with the forearm horizontal
8	Buttock-popliteal length (seat depth)	Horizontal distance from the hollow of the knee to the rearmost point of the buttock
9	Lower leg length (popliteal height)	Vertical distance from the footrest surface to the lower surface of the thigh immediately behind the knee, bent at right angles
10	Upper hip bone height, sitting	Distance from floor to the uppermost point of the left hipbone. The hipbone is traced by palpating [11, 16].
11	Lowest rib bone height, sitting	Distance from floor to the bottom of the lowest left rib. The lowest left rib is traced by palpating [11, 16].

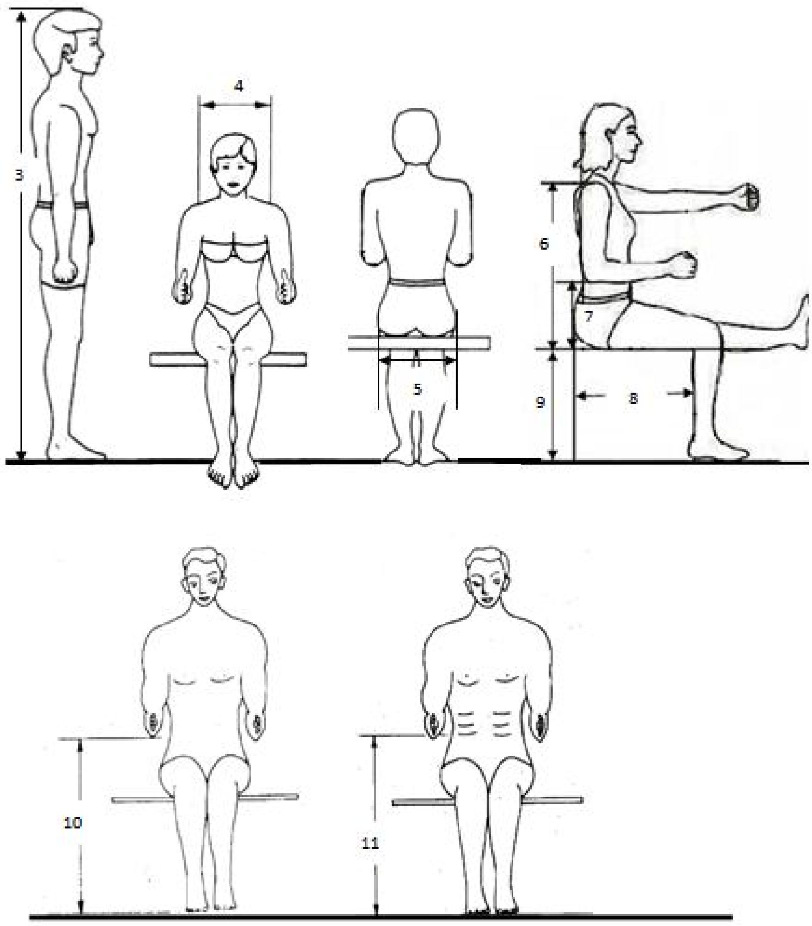


Figure 3. Illustrations of anthropometric dimensions corresponding to Table 1

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

Product design specifications (PDS) are used for analysis, design, manufacturing and construction of a structure or a component in order to achieve a specified degree of safety, efficiency, performance or quality as well as a common standard of good design practice [17]. A total of six PDS criteria, viz. safety, material, weight, performance, installation and ergonomics, were chosen for the development of the lumbar support (Table 2).

Table 2. Product design specifications for lumbar support

No.	Criterion	Specification
1	Performance	• Can support maximum body weight of 120 kg • Can be adjustable upward and downward according to lumbar height • Can be adjustable forward and backward according to rider's comfort • A good rigid frame
2	Safety	• Should obey the legislation of the local road safety requirements • Should not harm the rider or other road users
3	Installation	• Should fit to seat dimensions of present motorbike • Can be easily fixed with the existing holes and lugs in the motorcycle • Installation can be done using simple tools (such as screwdriver or spanner)
4	Weight	• Below 5 kg
5.	Material	• Light • Strong • Anti-Rust • Easy to form shape • Low cost • Easy to machine
6.	Ergonomics	• Cushion (contour shape) will support the back posture • Design features dimension based on the anthropometric dimensions of the motorcyclists • No sharp edges

In the conceptual design stage, conceptual sketches based on the PDS requirements are generated. A total of three conceptual designs (Figures 4-6) were developed for the lumbar support with detailed characteristics as described in Table 3. The matrix method [13] was used to select the best conceptual design. This method compares the generated conceptual designs, one with the other, against the criteria of evaluation (PDS). The result is shown in Table 4. The best conceptual design (with the highest score of +'s) was selected and then forwarded to the detail design section. In this case, Design 3 with the best performance, safety, weight, material and ergonomics was selected.

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

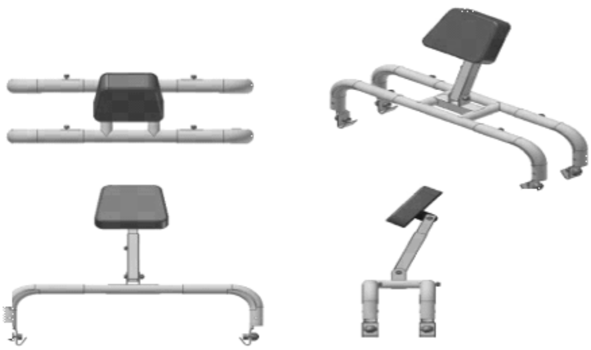


Figure 4. Conceptual design 1

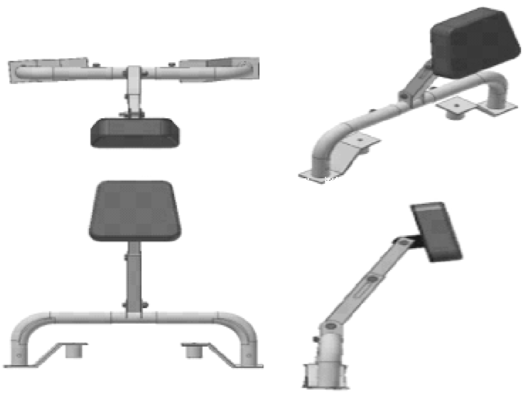


Figure 5. Conceptual design 2

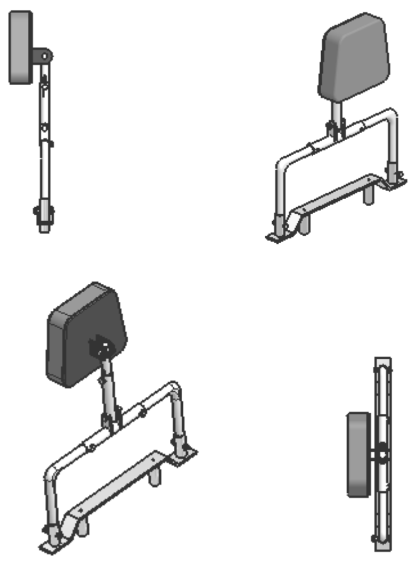


Figure 6. Conceptual design 3

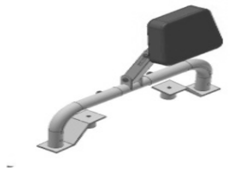
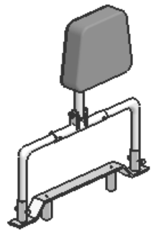
Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

Table 3. Characteristics of the conceptual designs

Characteristic	Design 1	Design 2	Design 3
Performance	• Can support the back posture (lumbar) during the riding process. • The height of support (upward and downward) can be adjusted. • The support can be adjusted forward and backward to suit the rider's comfort. • The angle of support (seat) can be adjusted. • Good rigid frame	• Can support the back posture (lumbar) during the riding process. • The height of support (upward and downward) can be adjusted. • The support can be adjusted forward and backward to suit the rider's comfort. • The angle of support (seat) can be adjusted. • Good rigid frame	• Can support the back posture (lumbar) during the riding process. • The height of support (upward and downward) can be adjusted. • The angle of support (seat) can be adjusted. • Good rigid body and base frame • The top frame (which consists of the support) can be removed from the bottom frame (which is fixed to the motorcycle) if desired.
Safety	• Does not offend the local road safety requirements.	• Does not offend the local road safety requirements. • The base frame is firmly fixed to the bottom of the motorcycle.	• Does not offend the local road safety requirements. • The base frame is firmly fixed to the bottom of the motorcycle.
Installation	• Can be easily fixed to current motorcycle's seat dimension. A separate belt and hook with slot concept is used to hold the base frame with the seat. • Simple tools are used to fix.	• Needs to be fixed to the motorcycle seat (at the underneath of the seat itself). • Simple tools are used to fix.	• Needs to be fixed to motorcycle seat. The bottom frame is fixed to the motorcycle body at the underneath of the seat while the top frame is slotted in from the top. • Simple tools are used to fix.
Weight	• In range of 5-6 kg	• In range of 4-5 kg	• In range of 4-5 kg
Material	• Alloy steel (frame) and foam (support)	• Aluminum (frame) and memory foam (support)	• Aluminum (frame) and memory foam (support)
Ergonomics	• Design based on anthropometric dimensions [14]	• Design based on anthropometric dimensions [14]	• Design based on anthropometric dimensions [14] • Can withstand greater force (user weight) due to body leaning on support.

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

Table 4. Conceptual design evaluation using the matrix method

Conceptual design / Criterion	1	2	3
			
Performance	-	-	+
Safety	-	+	+
Installation	+	-	-
Weight	-	+	+
Material	-	+	+
Ergonomics	-	+	+
∑ +	1	4	5
∑ −	5	2	1

Note: + (plus) = better than; - (minus) = worse than; ∑ + = score of +'s; ∑ − = score of –'s

In the detail design, the results obtained from the anthropometric dimensions [mean, standard deviation (SD), standard error of the mean (SEM), coefficient of variation (CV), minimum value (Min), 1^{st} percentile (1^{st}), 5^{th} percentile (5^{th}), 50^{th} percentile, 95^{th} percentile, 99^{th} percentile (99^{th}) and maximum value (Max)] of motorcyclists, shown in Tables 5-7, were utilised. Based on these dimensions, important design features were determined (Table 8). The lumbar support should be 16.0 cm in height and 38.5 cm in width. It should also be adjustable between 14.2 -30.2 cm from the motorcycle seating surface. In addition, 5.0 cm was recommended as the minimum thickness for the lumbar support [9, 11]. The results of the detail design are shown in Figure 7.

Table 5. Anthropometric data for Malaysian males, aged 18–24 years (n= 595) [14]

No.	Measurement (cm)	Mean	SD	SEM	CV (%)	Min	1st	5th	50th	95th	99th	Max
1	Age (year)	19,70	1,00	0,04	5,05	18,00	18,00	19,00	19,00	21,00	23,00	24,00
2	Stature	168,01	6,08	0,25	3,62	150,50	152,90	159,38	167,40	178,34	183,50	186,18
3	Weight (kg)	64,33	15,2	0,62	23,6	41,00	43,00	46,00	60,00	99,00	115,08	120,00
4	Shoulder (biacromial) breadth	43,28	2,95	0,12	6,81	35,20	36,40	39,26	42,80	49,30	51,51	52,80
5	Hip Breadth, sitting	31,35	3,31	0,14	10,5	22,10	22,50	27,28	30,90	37,62	40,61	40,80
6	Shoulder height, sitting	55,74	3,21	0,13	5,77	46,70	47,28	50,50	55,60	61,42	63,81	65,30
7	Elbow height, sitting	19,20	3,25	0,13	16,9	11,80	12,70	14,50	18,90	25,40	27,42	40,50
8	Buttock-popliteal length (seat depth)	49,05	3,52	0,14	7,17	38,60	40,07	42,40	49,30	54,40	56,30	59,40
9	Lower leg length (popliteal height)	41,44	1,42	0,06	3,44	37,60	38,20	39,30	41,30	44,00	45,30	45,70
10	Upper hip bone height, sitting	56,43	3,60	0,15	6,38	47,60	49,19	51,00	56,20	62,52	65,90	76,30
11	Lowest rib bone height, sitting	67,55	4,11	0,17	6,09	58,20	59,79	61,48	67,20	74,82	78,51	89,60

Table 6. Anthropometric data for Malaysian females, aged 18–24 years (n= 437) [14]

No.	Measurement (cm)	Mean	SD	SEM	CV (%)	Min	1st	5th	50th	95th	99th	Max
1	Age (year)	19,98	1,14	0,05	5,71	18,00	19,00	19,00	19,00	22,00	24,00	24,00
2	Stature	156,07	5,32	0,25	3,41	141,50	143,08	146,49	155,90	163,91	170,06	170,70
3	Weight (kg)	55,88	10,7	0,51	19,1	36,00	38,00	41,00	55,00	76,00	92,24	100,00
4	Shoulder (biacromial) breadth	37,51	2,74	0,13	7,32	30,20	30,34	33,29	37,30	42,40	44,42	45,10
5	Hip Breadth, sitting	31,75	3,68	0,18	11,6	22,70	23,21	26,49	31,30	39,00	41,90	42,80
6	Shoulder height, sitting	52,32	4,17	0,20	7,97	42,40	42,83	44,49	52,30	60,01	63,30	64,70
7	Elbow height, sitting	19,30	3,21	0,15	16,6	11,40	12,15	14,30	18,90	24,91	26,96	27,80
8	Buttock-popliteal length (seat depth)	45,70	3,82	0,18	8,35	35,80	38,44	40,30	45,30	53,22	54,96	55,80
9	Lower leg length (popliteal height)	39,31	2,46	0,12	6,25	33,10	33,40	34,40	39,90	42,81	43,90	44,50
10	Upper hip bone height, sitting	55,74	3,98	0,19	7,14	42,80	45,68	47,79	56,20	61,30	65,70	67,70
11	Lowest rib bone height, sitting	65,56	4,81	0,23	7,34	51,30	54,18	56,29	65,90	72,70	77,00	79,20

Table 7. Anthropometric data for Malaysian males and females, aged 18–24 years (n= 1032) [14]

No.	Measurement (cm)	Mean	SD	SEM	CV (%)	Min	1st	5th	50th	95th	99th	Max
1	Age (year)	19,82	1,07	0,03	5,39	18,00	18,33	19,00	19,00	21,00	23,00	24,00
2	Stature	162,95	8,25	0,26	5,06	141,50	144,87	150,27	163,00	177,14	182,40	186,18
3	Weight (kg)	60,75	14,1	0,44	23,26	36,00	40,00	44,00	58,00	91,00	107,67	120,00
4	Shoulder (biacromial) breadth	40,84	4,04	0,13	9,89	30,20	32,50	34,30	41,10	47,80	50,83	52,80
5	Hip Breadth, sitting	31,52	3,48	0,11	11,04	22,10	22,80	26,60	31,10	38,57	40,80	42,80
6	Shoulder height, sitting	54,30	4,02	0,13	7,40	42,40	43,67	47,20	54,40	60,80	63,57	65,30
7	Elbow height, sitting	19,24	3,23	0,10	16,79	11,40	12,50	14,40	18,90	25,04	27,30	40,50
8	Buttock-popliteal length (seat depth)	47,63	4,01	0,12	8,41	35,80	38,90	40,83	48,00	54,20	55,47	59,40
9	Lower leg length (popliteal height)	40,54	2,20	0,07	5,42	33,10	33,50	35,50	40,80	43,60	44,70	45,70
10	Upper hip bone height, sitting	56,14	3,78	0,12	6,73	42,80	46,10	49,70	56,20	61,74	65,90	76,30
11	Lowest rib bone height, sitting	66,71	4,53	0,14	6,79	51,30	54,60	59,47	66,60	73,84	78,23	89,60

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

Table 8. Recommended dimensions of lumbar support for motorcyclists based on anthropometric dimensions

Lumbar support design feature	Anthropometric measurement	Design dimension (cm)			Determinant
		Male	Female	Combined	
Bottom of back rest height	Upper hip bone height, sitting	14.7	13.4	14.2	5^{th} of upper hip bone height
Top of back rest height	Lowest rib bone height, sitting	30.8	29.9	30.2	95^{th} of lowest rib bone height
Lumbar support height	Distance between top and bottom of back rest height	16.1	16.5	16.0	Distance between top and bottom of back rest height
Lumbar support width	Hip breadth, sitting	37.6	39.0	38.5	95^{th} of hip breadth, sitting

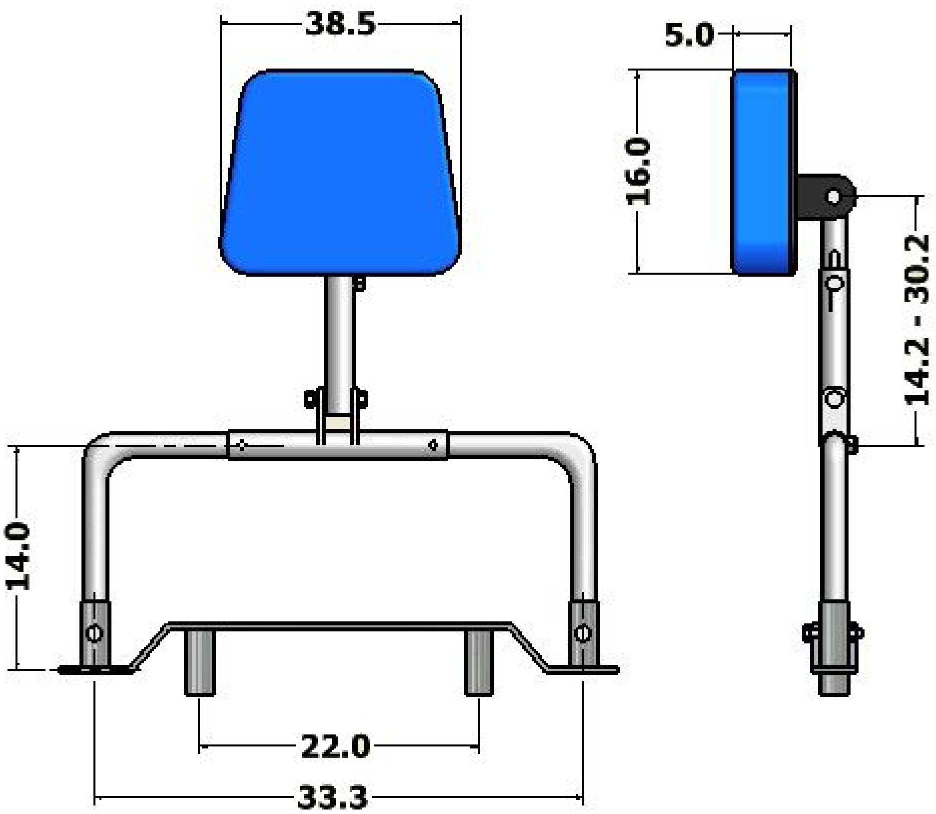


Figure 7. Detail of selected conceptual design (Design 3) (dimension in cm)

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

The manufacturing process was undertaken in order to construct the proposed prototype of the lumbar support. The process involved three stages: fabrication of the lumbar support frame (Figure 8) and lumbar support cushion (Figure 9) and assembly process (Figure 10).

Figure 8. Fabrication of lumbar support frame

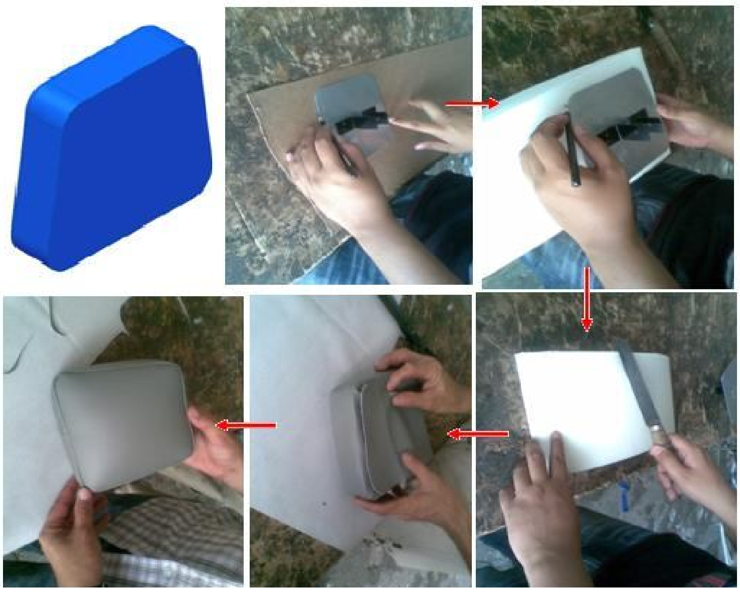


Figure 9. Fabrication of lumbar support cushion

Figure 10. Assembly of lumbar support

The testing of the fabricated lumbar support prototype was conducted. The initial results indicated that the motorcyclists were satisfied with the prototype as it provided comfort to their lumbar region during the riding and reduced the frequency of their posture changes. Furthermore, the lumbar support could be adjusted to suit their lumbar height dimensions. However, further evaluation on the prototype needs to be conducted to determine their stability, solidity, durability and safety over prolonged use.

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Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

REFERENCES

1. W. Karwowski, “The discipline of ergonomics and human factors”, in “Handbook of Human Factors and Ergonomics” (Ed. G. Salvendy), Wiley, New York, **2005**, pp.3-32.
2. E. M. Stevens, “Design guidelines and evaluation of an ergonomic chair feature capable of providing support to forward-leaning postures”, *PhD Thesis*, **2004**, Texas A&M University, USA.
3. W. H. Cushman and D. J. Rosenberg, “Human Factors in Product Design”, Elsevier Science, Oxford, **1991**, pp.32-41.
4. D. W. Eby and B. H. Kantowitz, “The discipline of ergonomics and human factors”, in “Handbook of Human Factors and Ergonomics” (Ed. G. Salvendy), Wiley, New York, **2005**, pp.1538-1561.
5. S. A. Robertson and A. Minter, “A study of some anthropometric characteristics of motorcycle riders”, *J. Applied Ergon.*, **1996**, *27*, 223-229.
6. S. A. Robertson and J. M Porter, “Motorcycle ergonomics: An exploratory study”, in “Contemporary Ergonomics” (Ed. E. D. Megaw), Taylor and Francis, London, **1987**, pp.173-178.

7 S. A. Robertson, “An assessment of the ergonomic problems of motorcyclists with special reference to the riding position and seat height”, *MSc Thesis*, **1986**, Loughborough University of Technology, UK.

8. K. Karmegam, M. Y. Ismail, S. M. Sapuan, N. Ismail, M. T. Shamsul Bahrib, S. Shuib and P. Seetha, “A study on motorcyclist’s riding discomfort in Malaysia”, *J. Eng. e-Trans.*, **2009**, *4*, 39-46.

9 B. J. G. Anderson and R. Ortengren, “Lumbar disc pressure and myoelectric back muscle activity during sitting. Studies on an office chair”, *Scand. J. Rehab. Med.*, **1974**, *3*, 115-121.

10. J. W. Frymoyer, M. H. Pope, M. C. Costanza, J. C. Rosen, J. E. Goggin and D. G. Wilder, “Epidemiologic studies of low-back pain”, *Spine*, **1980**, *5*, 419-423.
11. J. D. A. Abeysekara, “Design requirements and dimensions for a comfortable work seat for Sri Lankans”, *J. Nation. Sci. Counc. Sri Lanka*, **1985**, *13*, 77-88.
12. K. Karmegam, M. Y. Ismail, S. M. Sapuan and N. Ismail, “Conceptual design and prototype of an ergonomic back-leaning posture support for motorbike riders”, *J. Sci. Ind. Res.*, **2008**, 67, 599-604.
13. S. Pugh, “Total Design: Integrated Methods for Successful Product Engineering”, Addison-Wesley, Wokingham, **1991**, pp. 21-45.

14 K. Karmegam, G. K. M. Krishnan, P. Thiyagu, J. N. Ilmi, A. W. M. Noorazuan, N. Anis and K. L. Han, “Design and fabrication model of ergonomics chair and desk for classrooms in polytechnic”, Project Report , Polytechnic of Sultan Azlan Shah, Malaysia, **2009**.

15. Malaysian Standard, “MS ISO 7250-1:2008 Basic human body measurements for technological design (ISO 7250-1: 2008, IDT)”, Department of Standards Malaysia, **2008**.
16. Malaysian Standard, “MS ISO 15535:2008 General requirements for establishing anthropometric databases (ISO 15535:2006, IDT)”, Department of Standards Malaysia, **2008**.

Maejo Int. J. Sci. Technol. **2011**, *5*(01), 69-82

17. S. M. Sapuan, M. A. Maleque, M. Hameedullah, M. N. Suddin and N. Ismail, "A note on the conceptual design of polymeric composite automotive bumper system", *J. Mater. Process. Technol.*, **2005**, *159*, 145-151.
18. M. G. M. Thariq, H. P. Munasinghe and J. D. Abeysekara, "Designing chairs with mounted desktop for university students: Ergonomics and comfort", *Int. J. Ind. Ergon.*, **2010**, *40*, 8-18.