A Study on the Construction of a Computer Simulation Model with Riding Comfort on Bicycle

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Abstract

Ergonomic consideration is an important consideration for a well-designed bicycle. The aim of this study was to evaluate the influence of seat height on the rider's physiological and psychological responses during riding. Riding comfort was assessed based on an electromyogram measurement from the lower limbs, upper limbs, hips, and trunk of the body. A questionnaire utilizing Borg's scale and SD scale were also used to determine riders' subjective opinions regarding riding comfort. The relationship between riding comfort and seat height was then established from the regression curve of the physiological and psychological responses with respect to the seat height. Using these regression curves, one can determine the optimum seat height for the comfortable riding posture. The results of this study can be used to develop a riding simulation model on a computer, which may benefit the manufacturers and the designers in the area of ergonomic bicycle design. The research using CAD systems looks for the standard parameters of bicycle construction to set up a computer-simulated riding model. After creating a data bank of riders' physiological and psychological responses, one can analyze the parameters of the comfortable riding model with computer simulation, including seat height and height of handlebars.

The results of this research were listed below. (1) The iEMG of lower body decrease with seat heights significantly. The Borg's values of total comfort sensation decrease with seat heights also. (2) Both the iEMG of lower body and the Borg's values of total comfort sensation decrease with handle heights. (3) By using the comfortable riding model with computer simulation, we can catch the optimum seat heights, handle heights, the iEMG of lower body and the Borg's values of total comfort sensation. Those will benefit the design of bicycle. The computer simulation model established by this system will improve the development of ergonomic analysis of bicycles and help design more comfortable bicycle for riding.

Key words: Bicycle, Ride comfort, Computer simulation model.

1. Introduction

Riding comfort is closely related to human factors. Long-duration-riding induced fatigue and its subjective sensations must be considered in the design of a bicycle. For an ergonomic study, measurements of EMG for evaluating fatigue can find a wide application in different areas. Borg's scale and the SD scale have also been widely used for human psychological reactions, but few applications have been made to bicycle riding. This study utilizes the aforementioned techniques to establish a database of human physiological responses and psychological responses while riding a bicycle. The database will be used for establishing a computer simulation model for riding, to assist bicycle manufacturers in ergonomic design.

Although the development and manufacturing of bicycles has been going on for more than forty years in Taiwan, the riding comfort and related human factors are still not well investigated. One article mentions the specialty of the bicycle construction with regard to the human body (Chen, 1995). Then another article reports on a calculation of relative human factors in bicycle riding and a discussion of referable size and angles of joints (Juang, 1993).

As for the design of the frame system of a bicycle, some schemes have used CAD systems, but none of them have been united with human factors. This research will create criteria for the evaluation of bicycle design for comfortable riding, which will serve as a reference for and judgment of the frame design of bicycle, if these are the best values obtained from the computer simulation model. The following discussion of parameter design will combine the frame with comfortable riding situation, and determine the height of the seat and handlebars within the best riding values.

2. Human factors in bicycle riding

As for the human factors in bicycle riding, these can be approached in three directions, namely (1) anthropometry, such as calculations of the length and angle of the joints; (2) physiological responses, such as motion study, pressure analysis, and EMG analysis; and (3) psychological responses, such as subjective sensations.

Because of the promotion of quality of life, the average height also is increasing annually. In the century from 1900 to 2000, the average height has increased to 7.5 cm (Sanders et. al., 1987). Just from 1975 to 1990, the average height has increased at least 1.5 cm. Therefore, the average height is currently more than 170 cm. The body size of demonstration of computer simulation model is based on a height of 170 cm, and all the other relative calculations are for every portion of the body. Similar calculation has been mentioned in Japan (Noro, 1991).

As for the human factors of riding comfort, the research in this section merely discusses the joint angles in the first stage. These riding joints belong to two groups of movable joints, namely 1) functional exercise and 2) dissected exercise. Only functional exercise is discussed in this study, since this is the state of normal joints in exercise. Most articles on human factors typically discuss the movable joints. With regard to comfort, few articles can be found; and they are typically very subjective. Table 1 is a comparison of the calculations of joints with regard to comfort between Juang (1992) and Chen and Wu (1994). Here demonstrated the limitation for the angles the joints of bicycle seat tubes. In order to make it more objective for comfort, this research will determine the variable angles of joints and the result of a subjective analysis to obtain a more objective range for the comfort of joints in the future.

From the above relative research on bicycles, it is not difficult to observe that human engineering on riding comfort typically receives less attention. The major aim of this research is to investigate a comfortable range in various angles of joints and the best height for the seat and the handlebars while riding a bicycle. This research takes the opportunity to review all the relative research about bicycles, looking for the most comfortable joint angles of the bicycle from the body, hands and feet. Then we discuss how the size of the bicycle matches the body, thereby determining a well-matched relationship between the rider and the bicycle in this research.

As for physiological and psychological responses to riding a bicycle, two types of bicycle have been selected for the experiment, one general and the other, suspension. Seat and handlebar heights of the experimental bicycles are shown in Table 2. In this experiment, the muscles which measured were eight muscles, namely musculus flexor carpi ulnaris, musculus triceps brachii, trapezius muscle, muscles of lower lumbar, anterior tibial muscle, gastrocnemius muscle, lateral vastus muscle, semitendinosus muscle. The experimental riding time is 30 seconds, and the recording time is 20 seconds, extending from the 5th second till the 25th second. Eight testers participated in the experiment. The pedaling speed was kept at around 15 Km/hr. The EMG data was directly recorded by the EMG amplifier; and computer analysis system which can directly analyze the EMG data.

Table 1. Comparison of Comfortable Angle of Body Joints when Riding Bicycles

	1993 Juang M	1993 Juang SD	1995 Chen, Wu
Angle of Trunk Joint	3.8°	7.2°	-5°~ 75°*
Angle of Shoulder Joint	58.1°	10.3°	35°~ 90°
Angle of Elbow Joint	155.7°	11.8°	95°~ 180°
Angle of Hip Joint	94.1°	6.0°*	30°~ 80°
	44.6°	7.3°*	
Angle of Knee Joint	65.9°	6.7°	60°~ 130°
	131.6°	13.2°	
Angle of Ankle Joint			78°~ 102°

Remark: * means after adjustment so that these two comparable bases can be unified.

The overall comfort sensation was obtained by use of Borg's category-ratio scale (Borg, 1982). Borg's category-ratio scale was used for testing the total comfort sensation in the present study since this scale is a ratio scale. Let the total comfort sensation be easily estimated, the value of this scale was increased 10 times (e.g. 0 is "Nothing at all", 100 is "Very very uncomfortable"). The comfort sensations in four portions of the riders' bodies were also obtained by use of the semantic differential method.

Table 2 Experimental conditions

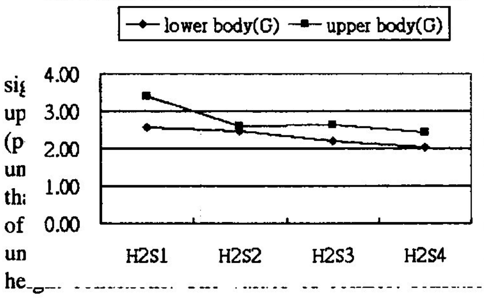
	Seat height				Handle height	
	S1	S2	S3	S4	H1	H2
General bicycle	730	674	618	562	1005	968
Suspension bicycle	706	674	642	610	991	913

Unit: mm

An electromyogram shows the state of the muscles' movements. To compare the amount of the load on each muscle, the electromyogram was integrated with respect to time within the recorded time interval. This quantity is denoted as iEMG.

For the gastrocnemius muscle, the values of iEMG under experimental condition S1/H1 was higher than that under other the experimental conditions ($p<0.05$) when riding a general bicycle. However, the results of ANOVA showed no significance for the iEMG of other muscles of the lower limbs. The total value of the iEMG from the upper body tended to increase with respect to seat height when riding a general bicycle, although it was not significant. The trend of the lower body was similar to that of the upper body.

Fig 1 Plot of total iEMG in H2 handle heights



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from the body showed higher at seat height S1 than at seat height S4. The subject felt more uncomfortable in the hips at seat height S1 and S2 than at seat height S3 and S4.

When riding a general bicycle, the total comfort sensation significantly depends on seat height ($p<0.001$) and handle height ($p<0.05$). Especially, the comfort sensation showed more uncomfortable in higher seat heights or in higher handle positions.

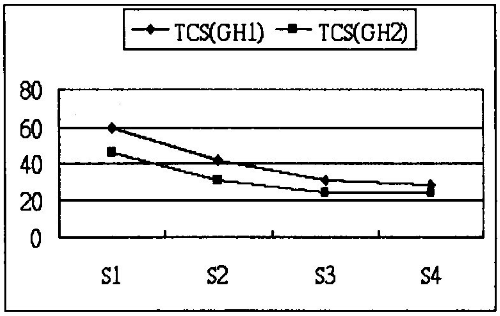

Fig 2 Total comfort sensations with different bicycle seat and handle heights

Results of the ANOVA showed that seat height had significant effects on the comfort sensation of the upper limbs ($p<0.05$) and hips ($p<0.001$) when riding a suspension bicycle. The subject felt more uncomfortable in the upper limbs and hips at seat height S1 than at other seat heights. Furthermore, handle height also had significant effects on the comfort sensations of the upper limbs ($p<0.05$) and body ($p<0.05$) when riding a suspension bicycle. The subject felt more comfortable with a higher handle condition.

When riding a suspension bicycle, the total comfort sensation was significantly dependent on seat height ($p<0.05$), but not dependent on handle height. The comfort sensations showed more uncomfortable at higher seat heights than at other seat heights.

3. Introduction to computer simulation model for riding comfort on bicycle

The riding model with computer simulation is based on both the results of the anthropometry of bicycle riding and the data bank of riders' physiological and psychological responses. The main task of this computer simulation model is to determine the comfortable seat height and the height of handlebars. This research uses Auto CAD as the visual screen, Auto LISP language for programming and constructing the parameter design system, a DCL language program as an interacting speech icon. The process of computer simulation program's running

will be following the steps as below:
(1) Choose the item of "Load model" in Riding model menu, then the computer will transfer the image directly into AutoCAD system
(2) Choose "Human body size" tool on the menu. There are ten kinds of body sizes, and one kind free set for free selection.
(3) To choose "Bicycle frame" size, there were already established 5 kinds frame of bicycle, and one kind free frame size for free selection.
(4) To choose "Miscellaneous" tool. This can change display process from other option on the window. Execute the procedure and image, there are six ways to offer. .
(5) To choose "Run" tool, it will start calculate the best fitting angle for seat height and handle height.

We select two different body sizes and bicycle sizes. The one is standard body size, and best fitting angle. It uses 600 styles bicycle frame. The other is already change body size, and changed the best fitting angle value. It uses 500 styles bicycle frame. Then we started run the program. Input the bracket shell point on the AutoCAD drawing area. After choosing an appropriate position for the height of handlebar and saddle seat, the system will be on the stage of execution automatically.

Program execution result as figure 3 and figure 4. We can see the display on the screen. It has three main categories. One is man figure of drive bicycle. Other is bicycle height of handle bar. Three is Seat height, electromyography (EMG) value and Borg's scale value.

The handle bar of bicycle has two different results. The 500 styles handle bar height value is from 0 to 350mm. But 600 styles handle height value is from 0 to 550mm. So range of 600 style is wild for fitting handle bar height.

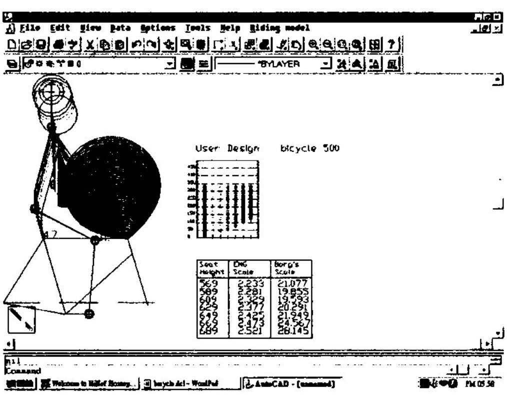

Fig3 Output of running results

The 500 styles fitting range is from 569 to 689mm for seat height. Its EMG value from 2.233 to 2.521. Sometimes its Borg's scale value is lower 28.145. The Borg's scale value is subjective physiology evaluate. So we can know the standard man what is normal status ride 500 styles of bicycle. But the subjective physiology evaluate of 600 styles is over 28 on 697mm of seat height. So we can judge its best fitting seat height is from 629 to 680mm.

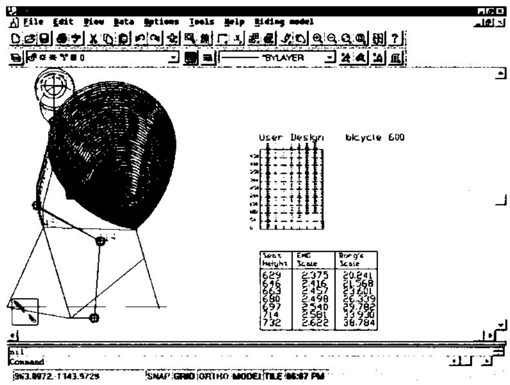

Fig4 Output of running results with different human body size

4. Conclusion

In conclusion, the psychological responses were more affected by seat height during riding bicycle. The total comfort sensation during riding bicycle could be calculated by the regression equation of the psychological responses. Using those regression equations, the best seat height can be evaluated for the most comfortable riding posture. The data of this study can also be used to set up the riding simulation model of bicycle on computer to improve the development of ergonomics on bicycle and help design the most comfortable riding bicycle.

The research is to analyze the riding model of bikes with computer simulation and to find the contrast position for suitable saddle seat and the handlebar. As to the manufacturer, the design of Human Factors Engineering and the evaluation on riding are definitely the kind of assistance and positive meaning. Except to attain the request of the above functions, this research will satisfy the users with the convenience of the enjoyment and learning this computer system. The system has the following uniqueness after testing and evaluating as,
1) The function of offering the message to the operating assistance: During executing, the program will always supply the message of feedback to users to help finish the analysis as soon as possible.
2) The design of highly friendly interface for users: The display of icon image will let the user understand

the information easily and increase the friendliness and choice of the program.

3) The environment of easily operating parameter design: The speech icons of human body information in parameters will let the users to finish the environment of information input fast.

4) The creativity of specialist system: To create specialist system of bikes and the relative calculation of human body can execute and investigate the requested target based on its bikes and human body by its accumulation and exercise of information under the control direction from the users.

The direction of following-up research will create the information for human standard riding size, the evaluation of tiredness and subjective comfort for bikes' designers, adjust the relative operating interface and make the operation more correspond to humanity. Finally this adjustment of riding model of bikes with computer simulation will be expanded flexibly to other cars or models and thus to improve and to develop the above information for the design of bikes' construction surely benefits the sale of the domestic and foreign marketing.

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自行車騎乘舒適性之電腦動態模型建立之研究

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摘　要

由於自行車主要是針對人們的騎乘而設計，因此自行車的設計除了車架本身結構的考量外，尚需考慮到騎乘者身體各部的尺寸的配合及舒適程度等人因工程相關要素。本研究除運用已建構之國內外人體騎姿尺寸資料庫外，更於不同座高條件下，擷取受測者腳部主要肌肉踩踏之動態肌電圖，及手部、軀幹之靜態肌電圖；同時以 Borg's 尺度及 SD 尺度，分別詢問受測者手部、腳部、軀幹及臀部等相關部位及整體的舒適程度與負荷程度。據此探討騎乘舒適性、座高及身體各部位間之相關程度，進而推估其迴歸曲線，以求得自行車騎乘之最佳舒適範圍值。綜合前述生理反應及心理反應等數值資料，更可彙整建立成人體騎乘疲勞度評量及主觀舒適性評量資料庫，提供以 Auto CAD 電腦動畫方式進行人體騎姿之動態模擬之參照，據以求得較適座高及其與把手之相對位置，同時並修正相關操作介面為多層次下拉式，使更符合人性化之操控。經由上述結論所發展出來的電腦騎姿動態模型，將可提供自行車設計人員對發展中之自行車進行人因工程分析，以利設計師設計出最適合人體騎乘之自行車。

本研究結果顯示 1)隨著座位高度的降低，足部積分值有明顯的減少，整體舒適度亦呈現逐漸舒適的趨勢，惟座高過低時仍會有不舒適的主觀感受。2)隨著把手高度的降低，足部積分值有減少的趨勢，整體舒適程度亦呈現逐漸提升的趨勢。3)透過電腦動態模擬程式，獲得最適座位高度，並推算出最適把手高度、腳部 EMG 積分總和及整體舒適性主觀評價推估值，提供自行車設計之參考。

關鍵詞：自行車、舒適性、CAD、電腦騎姿動態模型