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MATHEMATICAL MODELING OF ERGONOMICALLY DESIGN BICYCLE HANDLEBAR FOR OPTIMIZING THE COMFORT AND DISCOMFORT PARAMETERS

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ABSTRACT

An effort has been made to understand the muscular problem and other difficulties faced by male and female riders while riding the traditional bicycle. To overcome their problems an ergonomic bicycle handle is designed and fabricated to impart comfort to both male and female riders. This paper deals with the comfort and discomfort analysis of ergonomically design bicycle handlebar. Also a mathematically model is prepare to find out muscular fatigue, overall oxygen consumption and the discomfort analysis of male and female rider. The outcome of this analysis is discussed for optimization of handlebar parameters such as handle width, handle height and handle inclination angle. The results show a variety of modulations related to muscle fatigue and the overall oxygen consumptions proves the comfort zone and discomfort zone of the bicycle rider. The coefficient of correlation found in the mathematical analysis by comparing the experimental analysis proves the validity of results obtained.

Keywords: *Comfort analysis, handlebar, muscle fatigue, oxygen consumption, discomfort value*.

I. INTRODUCTION

With the advancement in the new era the resources we use need to be in a proper way for utilization. This century is called as century of modern machines and fast moving automobile vehicles, but bicycle has its own identity and importance, it is known as bike of poor peoples. Bicycles as such though called as a vehicle of poor is now being used to maintain the health and posture. After it introduction to common, it is gaining importance to all the people.
In this work an anthropometric design of bicycle handle is prepared which is based on the body dimensions of male and female riders in the Western Vidarbha region.An effort has been made to understand the muscular problem and other difficulties faced by male and female riders while riding the traditional bicycle. To overcome their problems an ergonomic bicycle handle is designed and fabricated to impart comfort to both male and female riders.Any work activity performed over long period can cause fatigue in the body and discomfort. Fatigue is the most frequently reported work related illness.

To study this problem, it was decided to conduct survey in Western Vidharbha region for different gender with different age group. About more articles have been reviewed relevant to the handle design from the consideration of ergonomics and consideration of human factors. These articles are presented from the point of view of their aims and objectives, adopted methodology, important findings and conclusions.

II. METHOD & MATERIAL

Brief acknowledgement of terms and concepts is done in previous part. Here, concentrating on ergonomic analysis of bicycle rider while cycling, especially with respect to the bicycle handle. The major factors for comfort are:-

- Position on bike
- Adjustable Saddle
- Adjustable handle

- Fitness
- Existing Injuries
- Energy available at cycling
- Length of ride
- 6. Distance planned

Anthropometric Design of Bicycle handle

The anthropometric design of bicycle handle based on collected anthropometric data of 5th and 95th percentile male and female being the prerequisite of this work .

It is intended to study the interactive influence of (a) anthropometry of the male and female,(b) the geometric parameters of the bicycle handle (d) the condition (track decided) road and (e) environment. It is also decided to establish the quantitative relationship of the interaction of these inputs (viz. a, b, c, d and e) mentioned above on the human energy consumption during the task and cycling efficiency.The advantage of such quantitative relationship is to ascertain the relative influence of inputs on the responses.

In order to design bicycle handle ergonomically, it is important to collect anthropometric data of bicycle riders in the region.

Fifteen anthropometric measures of bicycle riders which are found related to this work system are identified. These are height (H), Arm length (La), Fore arm length (Lf), Length of palm (Ra),Grip Length of palm (Ra/2), Total Length of Arm (Lt), Shoulder distance (Sd), Elbow angle (α), Distance between Elbow (Ld), Wrist flexion (β), Stomach Abduct (c + s i.e. height of chest and height of stomach), Bent angle (ϕ), Grip diameter (dg), angle between the chest and Arm (ϒ) Distance between the handle arm and saddle (Lh). Human body weight (W) was also considered. A sample study was conducted on 102 male and 54 female of age group from 20 years to 40 years was selected. Design considerations are identified as positioning of rider's hand, necessary leverage, platform for brake and gear levers as well as various accessories, being strong, positional changes to prevent fatigue,

Anthropometric design calculations includes the adjustability between elbows Bent angle , adjustability in bicycle handle , seat and grip diameter, etc. to calculate minimum and maximum adjustability of above parameter normal distribution curve method is used. Ergonomic designed handle bar is fabricated to assessment of comfort of male and female riders. Few adjustments are given in the fabricated handle bar such as adjustability in the width of handle bar , bent angle adjustability and grip diameter , etc. this handle was then compared with traditional handle .

In the present research, a new fatigue detection parameter will be presented for isometric and isotonic contraction. Work performed muscle during its isotonic contraction is used to indicate the state of muscle fatigue. It is mechanical indicator based on muscle force and the velocity of isotonic contraction. However, fatigue detection based on work performed by muscle is not possible in isometric contraction because of zero velocity of muscle contraction. Hence, median frequency and slope of regression of median frequency are used to quantitatively indicate muscle fatigue for isometric contraction. In both muscle contractions, the required data is extracted from S-EMG signals. The feasibility of this approach evaluated using the S-EMG signals is recorded under both isometric and isotonic contractions from healthy male and female subjects.

After performing the statistical analysis on anthropometric data of male and female cyclist following features are considered for the design of bicycle handle viz. shoulder distance, distance between elbow, bent angle, grip diameter, distance between handle arm and saddle, arm length. The aim of this measurement is to find out the correlation between the muscle fatigue and the overall oxygen consumed.All three environmental parameters are measured at the beginning, in the middle and at the end of every reading.It is important to predict fatigue state of skeletal muscle during the contraction in order to avoid injuries during cycling. Hence muscle fatigue measurement deals with the detection of muscles fatigue of skeletal muscle of the trained and untrained subjects.

III. DESIGN OF EXPERIMENTATION & MODEL FORMULATION

Treating the cycling task as a phenomenon the experimentation is designed. In the present research, a new fatigue detection parameter will be presented for muscle contraction. Work performed muscle during its isotonic contraction is used to indicate the state of muscle fatigue. It is mechanical indicator based on muscle force and the velocity of isotonic contraction. However, fatigue detection based on work performed by muscle is not possible in isometric contraction because of zero velocity of muscle contraction. Hence, MDF and slope of regression of MDF are used to quantitatively indicate muscle fatigue for isometric contraction. In both muscle contractions, the required data is extracted from S-EMG signals using EMG setup. The feasibility of this approach is evaluated using the S-EMG signals recorded under both contractions from 26 healthy subjects.

The data of the independent and dependent parameters of the system has been gathered during the experimentation. It is necessary to correlate quantitatively various independent and dependent parameters involved in this man-machine system. This correlation is nothing but a mathematical model as a measuring tool for fatigue and overall oxygen consume. The optimum values of the independent terms can be decided by optimization of these models for minimum muscle fatigue, grip strength and minimum oxygen consume. One of the main issues in research is prediction of future results. The experimental data based modeling achieved this through mathematical models 18 male and 8 female was calculated using QI Macros statistical tool (freeware open source software). The tool implies a regression analysis gives the coefficient of correlation using ANOVA technique and also gives predicted values of dependant parameters. The output of this can be evaluated by comparing it with observed data and the data calculated from the mathematical models.

The multiple regression analysis helps to evaluate the effects of two or more independent variables on the single dependent variable.

IV. RESULT & DISCUSSION

To derive the expression for dependant and independent parameter regression analysis of 702 observations is done.

Mathematical Model for Fatigue

The equation (1) gives the muscle fatigue value and the experimental and mathematical correlation obtained was 0.9304

$$f = -273.571 - 0.794W + 0.629H + 0\alpha + 0.48T - 0.156y - 0.185v + 0.116Hb \qquad (1)$$

Using the equation, f = Muscle fatigue = 273.571 - 0.794W +0.629H +0α +0.48T -0.156 y -0.185 v +0.116 Hb (W-width of handle,H-height of handle, α-handle inclination angle, T-dry bulb temperature, y-humidity, v-relative velocity of air and Hb-heart beat of operator), It can predict the muscle fatigue based on the above independent parameters.

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Mathematical Model for Oxygen Saturation

The equation (2) gives the oxygen saturation value and the experimental and mathematical correlation obtained was 0.908

$$Os = 133.661 - 0.001W + 0.0234H + 0.345\alpha - 1.072T - 0.67y + 0.322v + 0.243Hb \qquad (2)$$

Using the equation, Os= Oxygen Saturation percentage = 133.661 -0.001W+0.0234H+ 0.345α -1.072T -0.67y +0.322v +0.243Hb (W-width of handle,H-height of handle, α-handle inclination angle, T-dry bulb temperature, y-humidity, v-relative velocity of air and Hb-heart beat of operator), It can predict the muscle fatigue based on the above independent parameters.

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V. CONCLUSION

Mathematical models were developed using QI Macros statistical tool (freeware open source software). The tool implies a regression analysis that gives the regression coefficient using ANOVA technique for muscle fatigue, grip strength and oxygen saturation percentage. The validity of models was found to be 93.04%, and 91.48% for muscle fatigue and oxygen saturation percentage respectively. The optimal values of handle width, handle height, and handle inclination angle obtained by ANOVA are found to be 440 mm, 1015 mm, and 120 degree respectively. These values correspond to minimum muscle fatigue and stable oxygen saturation percentage.

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