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AN ERGONOMIC STUDY TO INVESTIGATE THE EFFECT OF COMFORT AND DISCOMFORT FACTORS OF BICYCLE HANDLE BAR

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Abstract-

This article present an ergonomic study related to design of bicycle handle, increasing the cyclist's comfort has become an additional aspect in the design process of conventional bicycles. Several attempts have been made to increase the cyclist's comfort while riding a conventional bicycle, but for the designer it is difficult to estimate the effect on the riding quality of the bicycle and whether the comfort perception of the cyclist increases. This work proposes an ergonomic study to investigate the effect of comfort and discomfort factor for during outdoor field testing for bicycle handlebar design. This data is analyzed by means of the ergonomic study for handle bar design on the basis of comfort factors. The initial test results show that the rider having comfort position depending on the handle position seems to correlate best with the cyclist's comfort. This method will help for finding optimal position of handle bar, but the combination of ergonomic data and rider opinion will give best outcome for obtaining optimal results.

Keywords—Bicycle, comfort positions, ergonomic study

INTRODUCTION

The term 'comfort' might be used to describe a feeling of contentment, a sense of cosines or a state of physical and mental wellbeing. In engineering term, comfort is generally presumed to be a definable human condition or attribute, with each new innovation bringing society closer to the achievement of ideal indoor conditions [1, 2]. Comfort is a concept of rather subjective nature but it can generally be defined as the absence of pain and any other similar nuisance and is usually associated in the relevant literature with the design and adjustment [3]. Based on the two statements taken from Riding a bike for long distances will cause pain in the hand [4]. The padding on handlebars bicycle is one of the easiest and most effective ways of make bike a more comfortable ride. Some tapes contain a gel-like material integrated into the fabric to make it even more forgiving [5]. Tires are most important part in vehicle using wheels [6]. Type and sizes of tires is important to make riding comfort for rider. All this element is depends on surrounding and area for competitions [5]. Creativity is very important for design process [3]. A design process is usually complex. Ergonomic design for bicycle handle bar is important to ensure cyclist in comfort and safe [7]. Ergonomics are implemented in every form of design [8]. It is paramount importance that ergonomic factor are taken into consideration while designing product. Ergonomics design means irrespective of the type of product and its function [3].

The principles of ergonomic design are considered in five levels are determined below [9].

(1) An equipment / machinery must be safe while contact with human beings.

(2) An equipment / machinery must not produce harmful effects in human beings over longer periods.

(3) An equipment / machinery must be physically comfortable that is, it should not require excessive efforts, both physical and mental or visual.

(4) An equipment / machinery should provide mental satisfaction or give a feeling of pleasure to the human being using the same. This must also include the cost price of equipment against the function of the same.

(5) Determining the degree of modernity of an equipment / machinery ergonomic considerations must constitute an essential factor of the social profitability of the equipment / machinery. Even at the stage of establishing the design assumptions of an equipment / machinery it is necessary to introduce both ergonomic.

The design of bicycles involves the definition of frames of different size and dimensions as well as the definition of the corresponding adjustment ranges for the seat and the handlebar. To successfully ride a bicycle in a seated position, many elements should be considered. A minimized frontal area and shape should be presented by the combination of the bicycle and the bicycle rider. The position of the bicycle rider must be comfortable so that the rider can produce requisite high level of effort and performance for long distance. Racing type bicycle handlebar is generally constructed of rigid, tubular metal that transfers the vibration from the bicycle directly to rider hands [10].

Form the above it is observed that, most of the researchers are doing their research in the field of changing the saddle position and weight reduction of bicycle frame. Thus the attempt is made to design a bicycle handlebar for the rider's comfort.

COMFORT ELEMENT

There are many element should be consider to ensure rider comfort during ridding bicycle based on research, the cyclist makes contact with the bicycle at three locations the handlebar, the saddle and the pedals. It is believed that most discomfort is felt near the handlebar and the saddle when riding over a rough surface [5]. Frontal areas and rider positions are greatly affected by the position, shape and arrangement of the bicycle handlebars [6]. Handlebar grips located in a relatively raised position will encourage a rider to assume a relatively upright riding position. A large frontal area is presented to be comfortable and the relatively large ensuing wind resistance minimizes top speed through the rider may be producing a large amount of pedaling effort [11]. The quality of a racing wheel is related to the combination of several performance parameters with the level of comfort during long cycling tracks. Comfort riding is related to the radial behavior of the wheel assembly, intended as combination of tire and rim. Radial properties of wheels are believed to be dependent on tire pressure and construction, rim profile and materials, spoke design and disposition, hub shape and materials. Despite the common opinion among cyclists that the wheel radial properties affect the rider's back comfort [7]. There are many elements need to be consider in order to get comfort riding for long distance rider or competition rider. In this project, only saddle based element will be analysis and discuss. A poorly designed seat will not distribute body weight or reduce pressure effectively over the perineum and thus increase the risk of seat discomfort or injury, which seems to be a common occurrence among cyclists [8]. Following are the element consider for the design of bicycle for the comfort.

(1) Frame material

(2) Environment

(3) Riders behavior

(4) Bicycle components

The findings from the survey reveals that the frame material did not contribute to the factors related to comfort. But the speed belongs to the material of the frame. The environment and behavioral elements will affect the comfort but not in terms of ergonomically aspects. The bicycle components were rated as much contributes comfort are saddle design, handle bar and the frame [12].

COLLECTION OF ANTHROPOMETRIC DATA OF MALE & FEMALE RIDER

It is very difficult to measure the dimension of human body related with bicycle handle bar with conventional measuring instruments. Fifteen anthropometric measures of bicycle rider which are found related to the present 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 shown in TABLE I. The following are the some of instruments used for measuring anthropometric measures.

(1) Measuring tape
(2) Compass
(3) Protractor
(4) Grip diameter & Bent angle measuring instrument.

TABLE I. DETAILS OF ANTHROPOMETRIC FEATURES OF CYCLIST

S. No	Dimension	Related to	Measuring instrument
1	Height (cm)	Seat height	Measuring tape
2	Arm Length (mm)	Distance between body and elbow	Measuring tape

3	Fore arm length (mm)	Force between elbow to palm	Measuring tape
4	Length of palm (mm)(Ra)	Grip	Measuring tape
5	Grip Length of palm (mm) (Ra/2)	Handle grip diameter	Calibrated cone
6	Total Length of Arm	Distance between body clavicle on seat and handle	Measuring tape
7	Shoulder distance (mm)	Handle width	Venire scale
8	Elbow angle(◦)	Inclination of handle	Special protractor
9	Distance between Elbow (mm)	Width of handle	Ergo handle
10	Wrist flexion (˚)	Inclination of handle	Ergo handle
11	Stomach Abduct (c+s) (mm)	Inclination of body with respect to handle.	Measuring tape
12	Bent angle (˚)	Wrist to the handle.	Ergo handle
13	Grip diameter (mm)	Palm	Vernier caliper
14	Angle between the chest and Arm	Position of inclination of handle	Special protractor
15	Distance between the handle arm and saddle. d (mm)	Body posture	Measuring tape

Statistical Analysis

In this analysis only six anthropometric features out of fifteen are found to be important and taken for the handlebar design. Fig. 1 shows the anthropometric measures of male and female rider considered for the analysis. A sample study was conducted on 102 male and 54 female of age group from 20 years to 40 years was selected. However, anthropometric measures which are not directly related to the design of bicycle handle. Table 3.2 and table 3.3 shows the anthropometric data of male and female respectively.

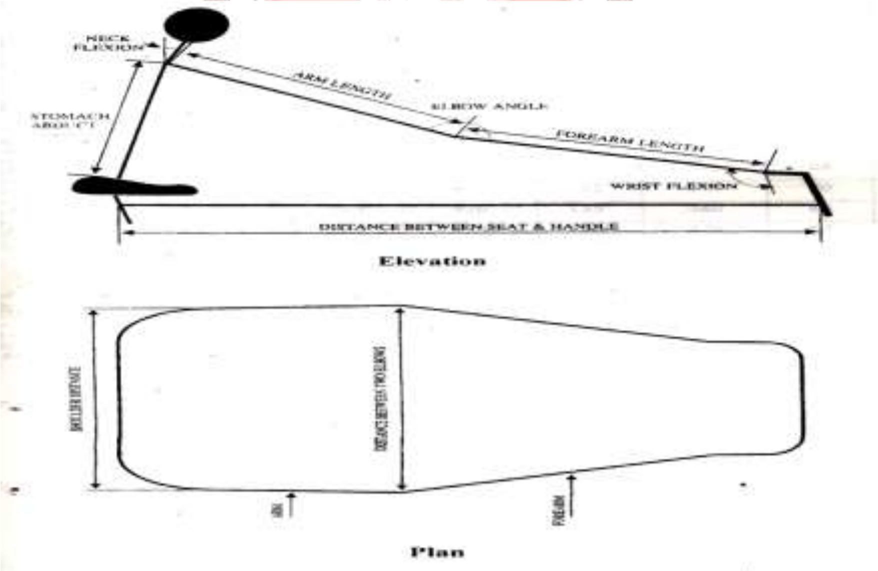


FIGURE 1. ANTHROPOMETRIC MEASURES OF CYCLIST (MALE AND FEMALE)

TABLE II. STATISTICAL ANALYSIS OF ANTHROPOMETRIC DATA OF MALE CYCLIST

	Shoulder distance	Distance between elbow	Bent angle	Grip Diameter	Distance between handle arm and saddle	Arm length
Range	340-407	418-441	61-82	26-32	612-962	133-245
Total male	38634	44926	7847	3075	80570	24058
Mean	379	440	77	30	790	236
Std. deviation	43.05	43.32	9.62	3.31	109.23	30.90
5th percentile	308	369	61	25	610	185
50th percentile	379	440	77	30	790	236
95th percentile	450	512	93	36	970	287

TABLE III. STATISTICAL ANALYSIS OF ANTHROPOMETRIC DATA OF FEMALE CYCLIST

	Shoulder distance	Distance between elbow	Bent angle	Grip Diameter	Distance between handle arm and saddle	Arm length
Range	350-406	418-439	61-80	26-32	636-936	229-245
Total female	20217	23171	23171	3809	1586	12684
Mean	374.38	429.09	70.54	29.37	708.12	234.89
Std. deviation	410	427	89.48	31.82	946.36	236.62
5th percentile	299	275	74	23	790	155
50th percentile	377	430	74	29	772	235
95th percentile	1054	1135	221	82	2333	626

Ergonomic design Principles to be considered in Handle bar

(1) Maintain neutral wrist positions: Design handles to reduce extreme flexion or deviation of the wrist.

(2) To avoid inward outward rotation of the forearm when the wrist is bent to minimize elbow disorders.

(3) Reduce the force or pressure on the wrists and hands.

- Keeping proper wrist position.
- Depending upon anatomical structure of an individual.
- Providing proper griping material on handle.
- Depending on road condition.
- Keeping proper size of the handle, so that power grip will be used to grasp the handle & it will reduce the tresses on the finger than other grip.

(4) To avoid the stresses on the wrist and hands by adjustable seating posture arrangement.

(5) Reducing the distance between handle position and brake leaver, so that it will reduce the forces on hands.

(6) Select proper suspension system to reduce vibrations and to provide comfort state.

(7) Handle size should be suitable to the majority of operation.

(8) Avoid extra pressure on the base of the palm which can obstruct blood flow and the nerve function by adjusting the

grip diameter.

(9) Providing some protective material on the handle if bicycle is riding in a cold atmospheric condition.

(10) Avoid stress on the soft tissues.

(11) Maintain optimal grip span.

(12) Avoid sharp edge and pinching point on the handle.

(13) Avoid repetitive trigger- figure action for operating braking system.

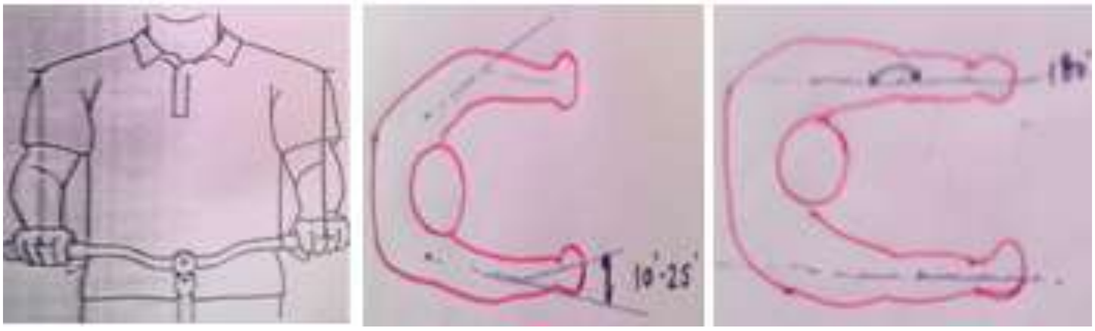
(14) Eliminate or minimize the effect of undesirable environmental conditions such as excessive humidity and cold as well

as poor road condition.

Design parameters in ergonomic handle

There are several size and parameters to consider while designing a handle bar. These principles can add in reducing the risk of musculoskeletal disorders (MSD). Also it provides comfort condition proactive ergonomics, by stressing these principles at the early designing stage of developing the product.

Handle width: Drop bars widths vary from 34 cm. to 50cm. As per the proximity of the user and needs of the arms and shoulder, the bar is chosen and used. Some measure from outside edge to outside edge such as Cinelli, profile design, Ritchey, and Salsa. Measures of handlebar are: outside to outside 2 cm or more than 2 cm, whereas center to center is the same. According to Human Factors and Ergonomic Society specification the horizontal adjustment of the cycle handle should nearly equal to the shoulder width of the person. The fig. 2 (A) shows the front view top view position of the cyclist.



(A) (B) (C)

FIGURE 2. (A, B, C) FRONT VIEW, TOP VIEW AND SIDE VIEW OF CYCLIST

Clearly two types of arm position from top view is shown for gripping the handle bars

1. Type A
2. Type B

In Type A as shown in fig. 2 (B) the position of the arm is inclined. This makes ride more comfort friendly due to less confinement. It's another biggest advantage is that it helps in vibration absorption. The inclined arm absorbs vibration as it resists vibration to pass from handle to shoulder thus limits shoulder pain. This position is achieved only when the rider is in proper fit with the handle and the saddle. This posture is the desired position of rider what so ever be his anthropometric data. The angle between the arm and the forearm of an individual is state should always less than 30^0.

Type B as shown in fig. 2 (C) is not desirable as people feel. Person is constrained while riding as body is stretching for the grip to and get restrained. So it has been taken as a critical posture for the distance between the handle and the saddle. The above deviation for minimum distance of saddle to handle is based on this position. This is the minimum position required for proper body assessment on the cycle while riding. Set of 102 male 54 female anthropometric data is collected. The mean value of the handle width is 440 mm and the allowable adjustment provided is 50 mm respectively, on both sides i.e. inwards and outwards as shown in the fig. 2 (B, C). Therefore the three adjustments of minimum 390 mm, middle 440 mm and maximum 490 mm handle width are considered in the experimentation.

Handle height: The handle height is decided on the basis of length from due to fore arm length and the height of the

male and female rider. As per the anthropometric data of 102 male and 54 female the average height of male and female rider 1552.4 mm and 1628 mm respectively and average fore arm length for male and female 264.92 mm and 262.67 mm respectively. The mean of average height of male and female is 1590.2 mm and female 527.59 mm. Thus the height of the handle from ground is 952 mm and the allowable adjustment provided is 64 mm respectively. Therefore the three adjustments of minimum 889 mm, middle 952 mm and maximum 1016 mm handle height considered in the experimentation.

Handle inclination angle: The handle inclination angle is considered on the neutral wrist angle also the bent angle is

consider while the considering the inclination angle. As the normal wrist angle is upto 120 degree. Thus the tree adjustments of minimum 60 degree middle 90 degree and maximum 120 degree angle inclination are considered in the experimentation.

Anthropometric features / variables of male and female cyclist

Fifteen anthropometric measures of bicycle riders which are found related to this work system are identified are discussed in section III. 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 represented in fig. 3

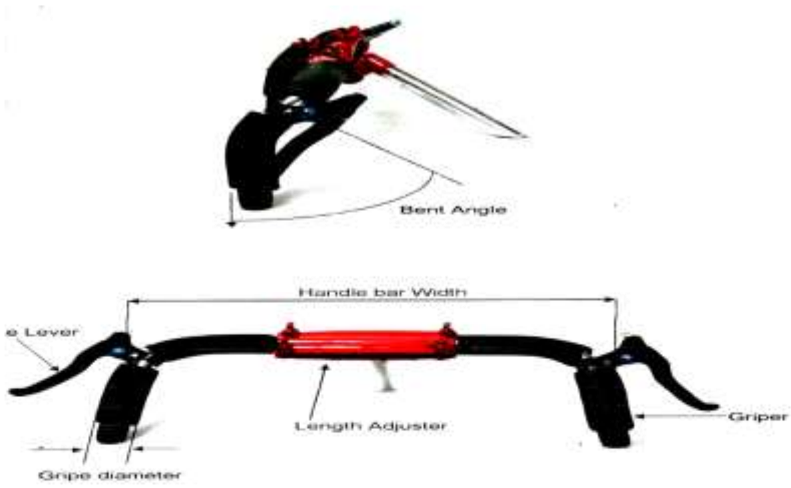


FIGURE 3. GEOMETRIC FEATURES OF HANDLEBAR

DISCOMFORT STUDY (QUALITAIVE)

Test for assessment of discomfort during riding condition

The male and female (total twenty six subjects) are selected to perform this test. Each of them will undergo twenty seven trials of cycling task for three settings of handle. In these three settings the handle width (w1,w2,w3) handle height (h1,h2,h3) and handle inclination ($\alpha 1$,$\alpha 2$,$\alpha 3$) are taken as per the ergonomic design of handlebar. For the design of experimentation the full factorial method is considered. For the design of experimentation the 27 combination of the handle width, handle height, and handle inclination angle are considered. Each trial will be of twenty minute duration.

Overall Discomfort

As shown in fig. 4 the technique adopted for Overall discomfort rating using a ten point psychophysical rating scale (0= no discomfort, 10= extreme discomfort). A scale of about 70 cm length shall be fabricated having 0 to 10 digits marked equidistant on it. A movable cursor shall be provided to indicate the rating. At the end of trial the subject shall be asked to indicate the overall discomfort rating on this scale. The overall discomfort ratings given by different subjects will be added and averaged to get the mean rating.

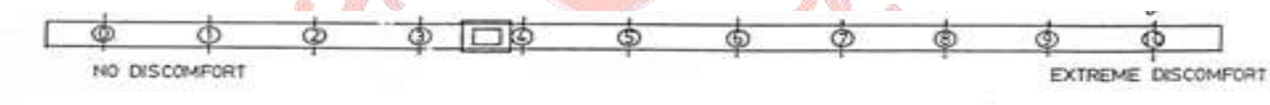


FIGURE 4. VISUAL ANALOGUE DISCOMFORT SCALES FOR ASSESSMENT OF OVERALL BODY DISCOMFORT

Body part discomfort score

To measure the localized discomfort, technique will be used. In this technique, the subject will be asked to indicate the region which is most painful. The subject then will be asked to indicate the number for the painful region depending on the intensity level of pain. Having noted this, the most painful area will be asked again and so on until no further area is reported. Each separately reported region could be seen as being separated by a recognizable difference in the level of discomfort. The data will be collected at the end of each trial. All these scores for different subjects will be added and averaged to get the mean total score [13].

CONCLUSION

Thus, from the quantitative studies on bicycle handle the following conclusions appear to be justified. The data in the present work is collected by performing actual field experimentation. The average grip diameter of proposed handle is found to be 29.5 mm. Minimum & maximum handle width is found to be 340 mm and 540 mm. Minimum and maximum handle height is found to be 889 mm and 1016 mm. Minimum and maximum handle inclination angle is found to be 60 and 120degrees.It is found that Mean overall discomfort ratings for traditional and suggested position of handle were found to be 6.83 and 5.64 (male) respectively and 7.12 and 5.81 female. It is also found that Mean body part discomfort ratings for traditional and suggested position of handle were found to be 57.77 (male) and 57 (female) and 40.33 (male) and 39.87 (female) respectively.

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