# Ergonomic Design of a Bicycle- A bike of Rural People

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## ABSTRACT
This paper discusses the ergonomic improvements that can be incorporated in the design of a bicycle, a bike of rural people. The suggested design modifications for the improved ergonomics in the bicycle are lateral movement of the seat to ensure optimum distance between the rider's body and the handle, introduction of a back rest while simultaneously maintaining an industrial design. Human aspects play an important role in the ergonomic considerations. An effort has been made to understand the muscular problems faced by the riders while riding the bicycles. Optimum metrics were obtained for riders of different heights and a customizable design of the bicycle was proposed to enhance the ergonomics of the bicycle. All design modifications were made based on anthropometric data of an average Indian.

## Keywords
Bicycle, Ergonomics, awkward postures and Human performance

## 1. INTRODUCTION
Even in this 21st century, the century of modern machines and fast moving automobiles, the bicycle has its own identity and importance. Also, it is known as bike of rural people. Apart from the fact that it is eco-friendly and economical it also helps the riders to keep fit and healthy. There have been several changes in the bicycle design since its inception; many attempts were made over the years. The first Paris velocipede show, at which rubber tires, variable gears, free-wheels, tubular frames, sprung wheels, and band brakes were shown, was held in 1869. But the direct ancestors of today's bicycles evolved rapidly in the one or two years before 1885, when several were shown in Britain's annual Stanley Bicycle Show [1]. Today various designs and styles of bicycles have been introduced like sport/road bicycles, mountain bicycles, BMX cycles, Standard Utility bicycles and more recently hybrid cycles [2].

Throughout the world bicycles are used by school students to go to school, University students to go around in the University campus, proletariats to go to work and old aged people for physiotherapy. It is important to keep in mind the diverse population using the bicycle because the design should match the anthropometric data to be ergonomic. It is also important to keep a check on the production costs of the bicycle because it is generally considered a economic product. It is crucial to ensure a good industrial design output of the bicycle while making substantial ergonomic changes in the original design. In this paper, an effort has been made to identify the possible inconvenience caused to the rider and propose a design to solve the problems, reduce the inconvenience of the bicycle riders.

## 2. IMPORTANCE OF ERGONOMICS IN DESIGN
Creativity is the key for any design process. A design process, which is usually complex, is best simplified by inculcating creative design ideas. Thus it is of extreme importance that the ergonomic design is highly interdependent on the design factors. Ergonomics are implemented in every form of engineering design. It is of paramount importance that ergonomic factors are taken into consideration while designing a product. Human factors play a crucial role in the productivity of any activity. For example, for a person working on an assembly line in a automobile company needs to have all the available components for assembly at the right distance and the tools should be located at the correct places to avoid tangling of hands, moving from place to another. If these ergonomic considerations are made the worker would be enabled to make the assembly faster and therefore improving the overall efficiency of the company. This field of ergonomic design has spread to all areas including computer desktops, cell phone software, pens, banking, housing and farming sectors.

Ergonomic design means irrespective of the type of product and its function, evaluating it in terms of maximizing the interaction between product and user to make it more appropriate for use. The principles of ergonomic design are considered in five levels [4] are determined below-

In the first level an equipment/ machinery must be safe while in contact with human beings.

In the second level an equipment/ machinery must not produce harmful effects in human beings over longer periods.

In the third level an equipment/ machinery must be physically comfortable that is, it should not require excessive efforts, both physical and mental or visual.

In the fourth level an equipment/ machinery should provide mental satisfaction i.e. give a feeling of pleasure to the human being using the same. This must also include the cost price of the equipment against the function of the same.

The fifth level is the 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 requirements and limitations.

## 3. PROBLEM DESCRIPTION

A detailed survey done with the help of bicycle riders at local rural region attained data, which was used to understand and analyze the common problems encountered by the riders. These problems were understood, analyzed and correlated to the biological factors. The problems mainly related only to ergonomics are considered and solved in this paper.

The ergonomics issues that are identified are mentioned below

1. The riders are forced to sit a highly inclined trunk position due to the large distance between the seat and the handle. This trunk position is causing back pain and severe discomfort.
2. The absence of a back rest makes long distance rides uncomfortable.
3. Pillion drivers have to sit on the hard metal carriage fixed behind the bicycle. This causes pain in the buttocks when bumps are experienced.
4. The pressure on the toe is high because of the short foot pedal
5. The positioning of the hands is not at the optimum levels for all riders because of the non customizable design of the existing bicycles.

## 4. SOLUTION

Based on the anthropometric data collected the ergonomics of a bicycle and the detailed study on the human comfort factors while riding and sitting on a bicycle the following solutions were proposed.

### 4.1 Lateral movement of the seat

In the vast diversity of the human race there are people of different heights and it is not possible that a single non customizable design would satisfy all the ergonomic requirements of everyone. Hence to solve the problem of high trunk inclination and improper hand posture a laterally movable seat has been proposed.

It was identified that that the most comfortable elbow position of the rider is between 1500 – 1650. So in order to maintain this angle for the rider the need of the laterally adjustable seat is shown in Fig. 1. The seat has three modes of adjustment from which the rider can choose according to his/ her height [6].

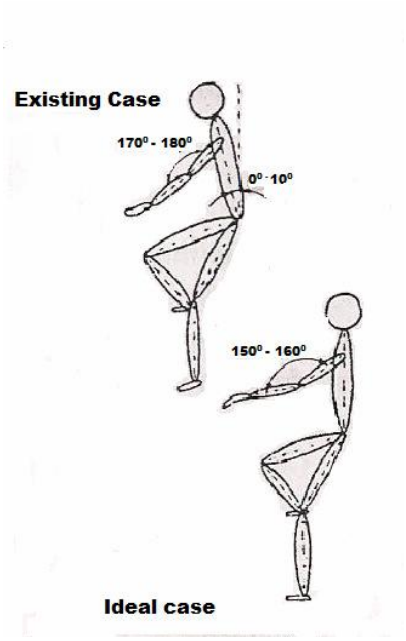


**Fig. 1 Optimum position of the hands while riding**

The first mode is for the riders between the height ranges of 1.60 to 1.68 meters. From the anthropometric data collected the average arm length ranges from 0.40 – 0.47 meters. Optimum seat to handle distances are computed for the first mode as shown below in Fig 2.

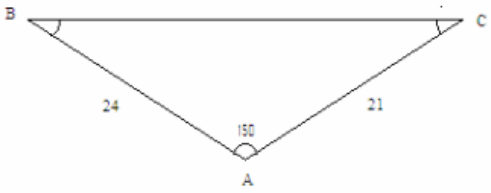


**Fig.2 Hand position in First mode**

Applying the cosine rule

$$\text{Cos } A = (b2 + c2 – a2) / 2bc$$

Here, $b = 21$; $c = 24$ $A = 150^0$

$$\cos 150 = (21^2 + 24^2 - a2) / 2\times21\times24 \quad (1)$$

From (1), $a = 0.43m$

From the obtained solution the optimum distance between the seat and the handle of the bicycle should be 0.43 meters for riders ranging between the heights 1.60 m – 1.68 m.

Similar to the calculation mentioned above, using the average arm lengths of 0.45m – 0.53m and 0.50m – 0.60m obtained from the anthropometric data for the height ranges of 1.65m – 1.75m and 1.75m – 1.85m respectively are used to calculate the optimum distances between the seat and the handle of the bicycle in the second and third modes. The values obtained are presented in Table 1.

**Table 1. Optimum Seat to Handle Distance in various modes**

| Mode Number | Height of the Rider | Optimum distance between the seat and the rider |
|---|---|---|
| 1 | 1.60 m – 1.68 m | 0.43 m |
| 2 | 1.68 m - 1.75 m | 0.48m |
| 3 | 1.75m – 1.85 m | 0.54m |

## 4.2 Design of Foot Pedal

The design of the pedal is important as it is the part which the driver has to put the force in order to drive the bicycle. When the force is applied on the pedal there is an equal and opposite force which is acts on the foot. In the standard bicycle the pedal is designed in such a way that the total force is exerted at the toe of the foot. If the bicycle is pedaled for a long time then the stress concentration on the toe would cause pain to the rider.

In order to solve this problem the pedal has to be designed in such a way that the force is evenly distributed on the foot. The proposed design of the pedal is like a foot rest so that it more convenient for the rider to ride the bicycle. The foot rest is also designed using acupuncture data to ensure good blood circulation.

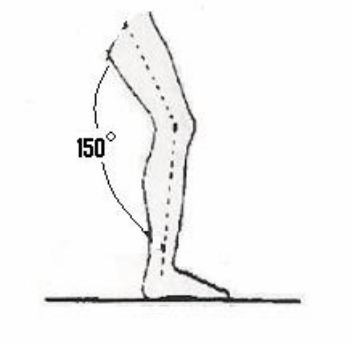


**Fig. 3 Included angles between thigh and calf**

The most desired angle between the calf and thigh of the rider for comfortable sitting position is 1500. It was observed that the angle between the thigh and the calf is 1500 of more number of positions than the regular pedal of the normal bicycles [7].

## 4.2 Introduction of Back rest

One of the most common muscle pains is the back pain. In a bicycle the back is subjected to different positions which cause pain in the riders back. The general trunk angle of the rider while riding a bicycle is 100 - 150 as shown in Fig. 5 and due to the absence of a support for the back there is high stress is a high stress concentration on the back which leads to back pain in the riders [8, 9]. This problem is eliminated by the introduction of a back rest.

The back rest is placed on the carriage of the cycle. It is made of stainless steel material of about 0.04m thick and this is padded with a foam material of 0.02m thickness. The back rest's height should approximately half of the sitting shoulder's height. The back rest is attached to the carriage with the help of a push type ejector. The back rest has two positions, they are

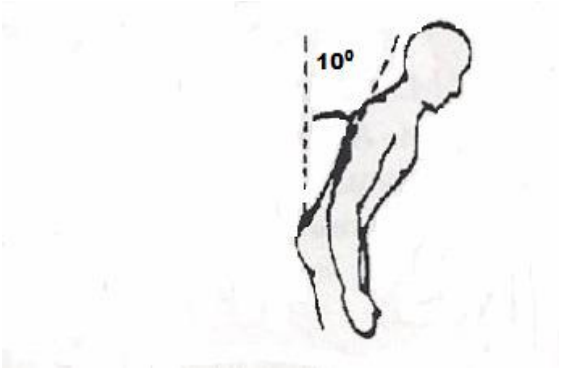


**Fig .4 Trunk Posture**

First – The non - activated position

In this position the back rest is parallel to the carriage as shown in Fig. 5 and the push button is not activated. In this position the foam of the back rest is at the top. When a load is placed on the back rest it the foam acts as a damper to the load. So when the bicycle is being ridden on a rough terrain the vibration which is produced on the bicycle is reduced because of the foam. Even when a pillion rider is sitting the foams adds to his comfort.

**Fig. 5 Seat rest in the non activated position**

Second – The activated position

When the ejector button is pressed the back rest comes to the activated position. In this position the back rest is perpendicular to the carriage as shown in Fig. 6. One end of the back rest is connected to the carriage with the help of a hinge. In this position the back rest is just behind the rider's seat allowing him/her to rest his/her back on it.

**Fig. 6 Seat rest in the activated position**

## 5. CONCLUSION

In this paper the general ergonomic related problems while riding a bicycle were identified. The solutions obtained by different calculations and analysis done in this paper will be able to solve the general human discomforts encountered while riding a bicycle. The goal of this paper was to improve the ergonomics of a bicycle by simultaneously putting a check on the cost. In order to do this innovative design ideas were used.

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