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Development of Ergonomic Design Procedures for Cycle Manufacturer

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Abstract: ***Bicycles have evolved significantly over the past decades in pace with technological advancement. However the comfort of cyclists has not much attempted in many designs. Although ample research has been reported on comfort for other means of transportation, cyclist's perception of comfort has received scant attention in the scientific literature. This project discusses the ergonomic improvements that can be incorporated in the design of a cycle, a bike of rural people. The first step is to determine which factors contribute to comfort when riding a bicycle which results in awkward postures and Human performance. It has been found out by means of a survey with enthusiast cyclists that comfort is influenced by factors related to the cyclist (position, adjustments, body parts). Respondents indicated that comfort is a concern when riding a bicycle in most situations and they believed that comfort is compatible with performance. A specific design has been modeled in 3D software on the actual dimensions. The posture analysis tool was used, which shows there are deviations from the permissible value of head flexion, upper arm flexion, wrist ulnar deviation, trunk and knee angles causing fatigue and discomfort. The general solutions for this problems are 1) Introduction of a back rest 2) Design of foot pedal 3) lateral movement of seat 4) Reclining posture. Incorporating all these, this work proposes a solution for design of cycle. Several design solutions varying in design parameters were attempted with the commercial software for posture analysis. It was found that introducing an additional roller support and within a narrow deviation of dimensions in the head flexion, wrist ulnar and trunk deviation, normally seen in upright are within the acceptable standards.***

Keywords: Bicycle, Ergonomics, Awkward postures and Human performance.

1. Problem Definition

Cycles are commonly used for short distance transportation especially plain and regions where consumption of natural resources and environment pollution are zero. The discomfort and fatigue of the cyclists is the main reason for using bikes and other motorised means. This work report and ergonomic design procedures for the design of cycles considering human factors in design. Typical cycle design is evaluated, where upright posture of the cyclists is followed, and proposed suggestion for the improved solution for the cycle.

2. Introduction

Even in this 21st century, the century of modern machines and fast moving automobiles, the cycle 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, helping 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. Today various designs and styles of bicycles have been introduced like sport/road bicycles, mountain bicycles, BMX (Bicycle Motocross) cycles etc.

Throughout the world bicycles are used by school students, 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 widespread use of bicycles necessitates 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 an economic product. It is crucial to ensure a good industrial design procedure for the bicycle while making substantial ergonomic changes in the conceptual 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 reducing the inconvenience of the bicycle riders. A concise overview of relevant studies is presented here. According to three distinct areas contribute to comfort when riding a bicycle i.e.; environmental, mechanical and biomechanical factors, and physiological factors.

The present study focuses on enthusiast cyclists. We define enthusiast cyclists as amateur adults cycling 1000 km per year or more. More specifically, the goal is to look at the notion of dynamic comfort.

Bicycle is a popular and economical mode of human-powered transportation. This also enables it to be used as effective equipment towards fitness and rehabilitation. However, bicycling demands one to bend forward while pedaling; this prolonged forward flexion posture may increase the risk of chronic injuries such as musculoskeletal disorders (MSD), compression neuropathies, and so on. Hence, proper bicycle design is necessary to reduce MSD and enhance comfort for rider. Cyclists adopt a round-back or flat-back posture to reach the handlebars by flexing their pelvis and spine. Cyclists who maintain a prolonged awkward posture experience pronounced stress on their shoulder, neck and low back pain.

3. Objectives & Methodology

The objectives of this project are the

- Assessment of musculoskeletal hazards (MSD) in upright cycles.

- Analysis of risk factors which affects riders in the upright bicycles.
- Investigate the posture aspects in upright cycling.
- Analysis of upright bicycle.
- Reclining posture aspects in cycling.
- Design an efficient form of a cycle considering ergonomics.

The methodology adopted for this project includes
1) Data collection
2) Posture aspects in upright cycle
3) Identification of design parameters
4) Reclining posture aspects in cycling
5) Analysis of reclining posture

3.1 Data Collection

In order to find out the musculoskeletal hazards an interview with a medical practitioner was conducted. A survey was conducted among 50 riders of Cycle Club Thrissur. A questionnaire consisting of 30 questions taken from literature was used in the survey. By direct interview with 55 riders, it was answered. The current trends in market have been found out by means of telephonic communication with various departments of Tube Investments (TI) cycles and also with some retail shops. It was found that the Muskulo Skeletal Hazards (MSD) especially in the wrists, backbone, head flexion and knee. The situation in Kerala was enquired from different stores in Kochi and Thrissur. The results show that there is a massive increase in sales of cycles. The cost associated with cycles having gears and suspensions are not affordable to common people. Altogether the people are very much concerned about their comfort more than performance in an affordable price.

3.1.1 *Survey*

The survey connecting Hari Pamboor (Ambassador of Kerala Health Services , Palakkad) , five riders who travelled from Kerala to Khardung La (Mountain peak near Ladakh) having a distance of 2500 KM in 52 days . The Cycle Club Thrissur having 50 riders were also included in this survey. The format of the questionnaire was given in the appendix.

The survey carries a Questionnaire having questions regarding
1. Frame material
2. Environment
3. Behaviour
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 behavioural elements will affect the comfort but not in terms of ergonomical aspects. The bicycle components were rated as much contributes comfort are the saddle design, handle bar and the frame.

4. Posture Aspects in Upright Bicycle

The three important areas to look at in cycle ergonomics are
1. The strain on arms and shoulders
2. The muscle support and position of lower back
3. The work of proper pedaling.

Figure 2: Three areas in cycle ergonomics

4.1 The Position of Hands While Riding

The existing case while riding a cycle reveals that the angle between upper arm and lower arm is 170 – 180 degree. The ideal value of the angle between the upper arm and lower arm is 150 – 160 degree. In the existing case of position of hands imparts more pressure on wrist.

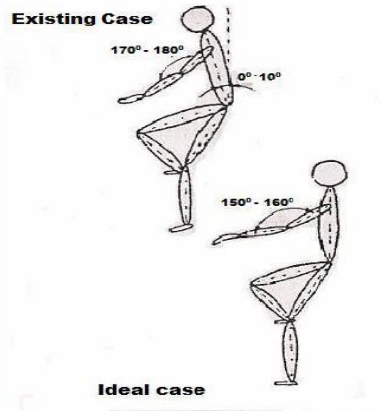

Figure 2: Position of hands while riding

4.2 Trunk Posture

The ideal angle of torso is 10 degree from vertical .To hold the S-Shape of the spine, the curve in the lower back is the key!! If you lose this concave curve (the lordosis or hollow back) you cannot find the s-shape: Your upper body bends more towards the ground and then you have to bend your head backwards. The muscles in the lordosis-curve need to be in a good shape to hold your body straight. Most people do not use these muscles. They sit in their office chairs like in a TV-armchair, so the muscles start to become weak.

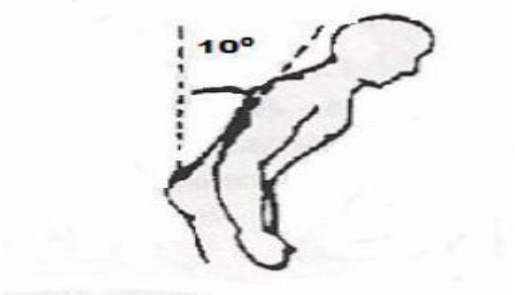

Figure 3: Trunk posture

4.3 Angle between Thigh and Calf

The angle between thigh and calf must be 150 degree when the crank is at bottom dead centre. The variations in the angle will bring more pressure on knees. The knee is not a simple joint. It moves in different directions, when it is opened or closed. For this you need another joint working against the knee. Only the ankle could do this. If the ankle is fixed, the knee will be forced in a wrong direction and start hurting. It is important not to use the heel or the whole foot for pedaling

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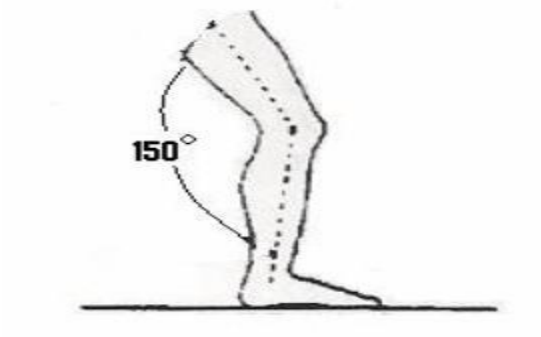

Figure 4: Angle between thigh and calf

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) The pressure on the toe is high because of the short foot pedal.
4) The positioning of the hands is not at the optimum levels for all riders because of the non-customizable design of the existing bicycles.

5. Identification of Design Parameters

The analysis of upright form of cycle has been done by using commercial ergonomical software. The analysis also includes the modeling of a cycle having the same dimensions which available in the market.

5.1 Making of Upright Cycle

The dimensions of a standard cycle has been taken and based on that a 3D model was designed.

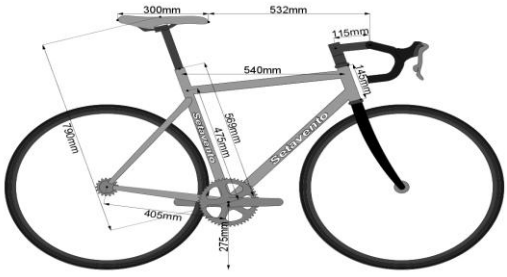

Figure 5: Dimensions of a standard upright cycle

6. Analysis Using Jack Software

Siemens Jack software is a premier human simulation tool for populating designs with virtual people and performing human factors and ergonomic analysis. Jack is a human modeling and simulation tool that enables you to improve the ergonomics of your product designs and to refine industrial tasks. Jack, and its optional toolkits, provides human-cantered design tools for performing ergonomic analysis of virtual products and virtual work environments. Jack enables you to size your human models to match worker populations, as well as test your designs for multiple factors, including injury risk, user comfort, reachability, line of sight, energy expenditure, fatigue limits and other important human parameters. Using Jack facilitates significant cost and time savings by enabling you to improve product quality and process feasibility early in the product lifecycle.

6.1 Jack Outputs

The front view and side view was so important in order to find out the position and posture of the rider while cycling.

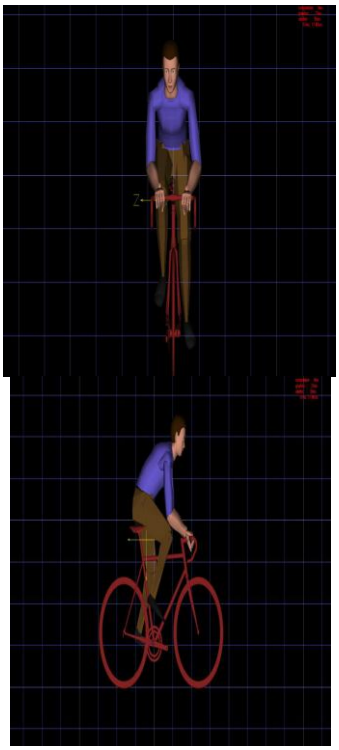

Figure 6: Front & Side view of a man riding a cycle

6.2 Comfort Assessment Using Jack Software

The posture analysis using Jack software in the cycle shows the deviations in the body parts and joints. The software has a default range of deviation for each of the joints of our body parts. The values which are more or less the default range shows the body part is in serious trouble. For example the upper and lower limits for the deviation in Head Flexion are + 30 and - 30 respectively. The value which we got after comfort assessment is - 42.4. This shows that the Head Flexion was improper and led to Muskulo Skeletal Hazards (MSD). The Yellow colour in Comfort Assessment shows

the value is somewhat more or less from the limits. The Green colour shows that the value is in comfort range.

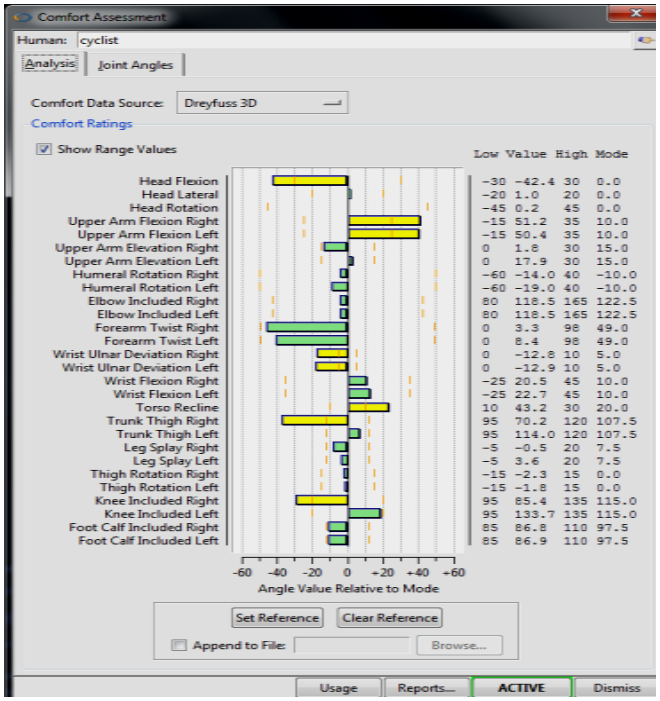

Figure 7: Comfort assessment using JACK software

Table 1: Comfort Assessment Evaluation Results

NO	Body Parts & Angles	Low	Value	High
1	Head Flexion	-30	-42.4	30
2	Upper Arm Flexion Right	-15	51.2	35
3	Upper Arm Flexion Left	-15	50.4	35
4	Wrist Ulnar Deviation Right	0	-12.8	10
5	Wrist Ulnar Deviation Left	0	-12.9	10
6	Torso Recline	10	43.2	30
7	Trunk Thigh Right	95	70.2	120
8	Knee Included Right	95	85.4	135

There is a great deviation from the Upper and Lower limits in
1. Head flexion,
2. Upper arm flexion,
3. Wrist ulnar deviation,
4. Torso inclination and
5. Knee angles.

7. Solutions

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 solution was proposed.

5.1 Reclining Posture Aspects in Cycling

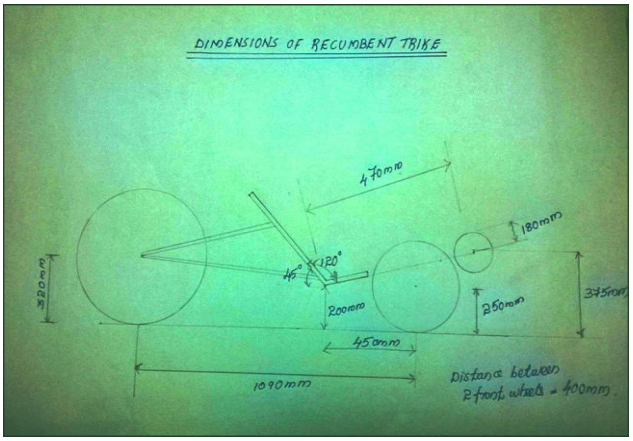

Figure 8: Dimensions of the recumbent cycle

The front view of recumbent cycle to know the posture aspects in recumbent form and the comfort assessment are given below .

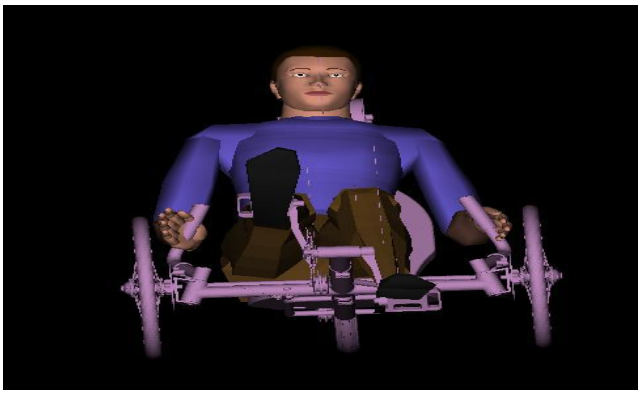

Figure 9: Front view of the recumbent cycle

Table 2: Results of comfort assessment in recumbent cycle

No	Body Parts & Angles	Low	Value	High
1	Upper Arm Flexion Right	19	-10.2	75
2	Upper Arm Flexion Left	19	-16.3	75
3	Foot Calf Included Right	80	113.4	113
4	Knee Included Right	99	155.1	138

8. Conclusion

The feedback from the interview and survey reveals that the upright form of cycle causes too many Muskulo Skeletal hazards in riders. The studies regarding the posture aspects shows that the ideal postures which protects us from hazards. 1. Out of 12 joints, only 4 of them show deviation. The main problems which we found in the analysis of upright cycling such as

1. Head flexion
2. Torso inclination
3. Wrist ulnar deviation has been resolved.

The recumbent form of cycle solved all problems which happened in upright form of cycle except the arm flexion. It can be solved by assembling resting pads for arms in the frame of the cycle.

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APPENDIX

Questionnaire

The questionnaire used for the survey is given below

Please indicate how much you think it contributes to your own comfort while cycling.
Please answer on a scale from "not at all" to "strongly".

	Contribute to your own comfort					I don't know
	Not at all				Strongly	
FRAME MATERIAL	**1**	**2**	**3**	**4**	**5**	**0**
Steel frame						
Aluminum frame						
Carbon frame						
Titanium frame						
BICYCLE COMPONENTS						

Frame (geometry, height …)						
Saddle design (shape, dimensions…)						
Saddle padding						
Seat position						
Handle bar (shape, ergonomics…)						
Shifters						
Brake levers						
Pedals						
Forks						
Tires						
Wheels (excluding the tires)						
BEHAVIOUR AND DECISIONS						
Your level of fitness						
Your level of energy (before the ride)						
Your level of energy (during the ride)						
The length of the ride						
The distance you planned						
Existing injuries or physical limitations (if applicable)						
Your position on the bicycle						
Adjustments on the saddle (height, angle…)						
Adjustments on the handle bar (height,angle…)						
ENVIRONMENT						
Road surface (concrete,smooth,cracked…)						
Road conditions						
Terrain (hills,curves…)						
Time of the ride (morning, evening…)						
Weather conditions (sunny, cloudy, winty, rainy…)						
Outdoor temperature						
Clothing you wear						