BIOMECHANICS OF CYCLING—THE ROLE OF THE FOOT PEDAL INTERFACE

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The information in this paper is drawn from clinical and research studies of touring and competitive cyclists and triathletes. The competitive cyclists include regional, national team, and professional riders.

The genesis for inquiry into cycling biomechanics was an attempt to assess the cause(s) of knee pain in cyclists. Knee pain is endemic in cycling and the medical profession has experienced little success in treatment. Cyclists, as a group, have received little help from health care practitioners and generally do not seek help but rather cut back on their training or stop riding during symptomatic periods. Naturally, this adversely effects their fitness levels, competitiveness and the enjoyment of cycling.

A break through in understanding cycling biomechanics and pathomechanics occurs when the cyclist is viewed form the front. Previous biomechanical assessments have concentrated upon viewing the cyclist form a side or lateral view. While the lateral view offers some understanding of limb kinematics it offers little value for assessment of knee pain.

When the cyclist is viewed form the front and knee movement is observed during the cycling stroke, a variety of movement patterns can be observed. It becomes readily apparent that some of these patterns are pathomechanical in that excessive torque and stress is present and force is produced at unproductive angles resulting in reduced efficiency.

The patterns that are seen include; angling on the downstroke, either toward or away from the frame, looping, such as an inward movement of the knee at the top of the downstroke, and inward or outward loop at the bottom of the downstroke, and various combinations, such as a figure-8 pattern or a figure-8 pattern with angling.

To document the knee patterns, the cyclist's bike was mounted on an exercise stand such as a Turbo-Trainer or Mag-Trainer. A marker was then placed on the tibial tuberosities and the tracking of the marker observed and recorded.

During the initial study a low motion/stop action video recorder was used to collect and analyze the data. A thin plastic (mylar) sheet was placed over the viewing monitor and the path of the tibial tuberosities were tracked frame by frame to provide a diagram of the path of the knees. This sheet was then placed on a duplicating machine to provide a research record (Figure 1).

An analysis of the video and charts revealed that very few individuals track in a straight up and down motion. They demonstrated varying degrees of combinations of looping and angling in the tracking pattern.

An assumption was made early in the study that a linear, straight up and down pattern is more efficient and produced less skeleto-muscular and ligamentous stress than a pattern that demonstrated significant looping and angling (Figure 2).

The next step was to see if these variant patterns could be modified toward a more straight up and down pattern. Three methods of altering the foot (shoe)—pedal interface were used.

1) wedge between the shoe and pedal or between the cycling cleat and the shoe.

2) an orthotic device in the shoe.

3) an adjustable bicycle pedal - Biopedal TM that allowed for 3-plane adjustment.

Each of these methods proved successful in altering the tracking patterns of the knees toward a more straight up and down pattern (Figure 3).

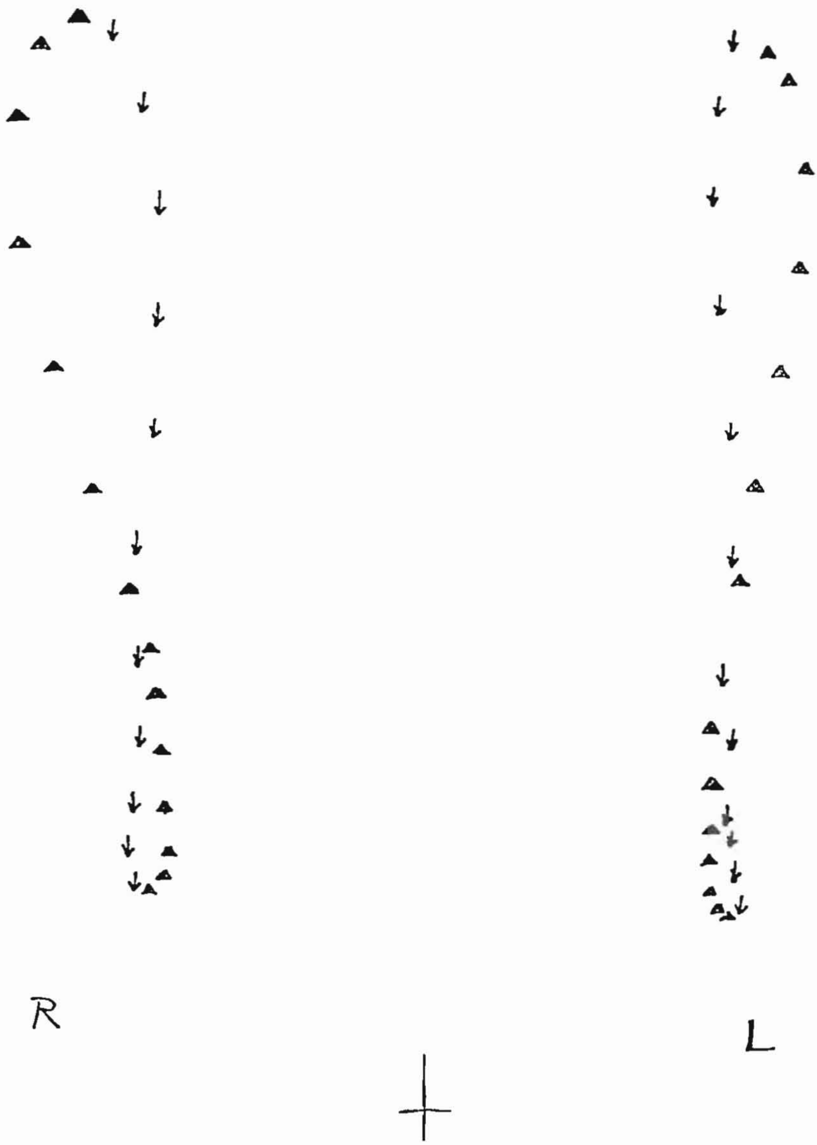


Fig. 1. Tracking of Tibial Tuberosity
Slow Motion/Stop Action Video

Theoretical Ideal
Cycling Stroke.

Fig. 2.

In the initial study conducted in 1984, 32 subjects demonstrated an improvement in their cycling mechanics as a result of alteration of the foot pedal interface. Twenty (20) of the subjects were symptomatic with knee pain and each reported elimination or reduction of pain. Each of the symptomatic subjects (20) and the asymptomatic (12) subjects indicated a perception of greater power in their cycling stroke with the modifications. The subjects indicated that they could ride in a higher gear with the same perceived effort.

Since 1984, an additional seventy plus cyclists have been evaluated. To date, more than 200 knee patterns (100 cyclists) have been observed. Improvements in the stroke mechanics of each subject has occurred with modification of the foot-pedal interface.

Because of the versatility and objectivity in measurement, the Biopedal was the method of choice for modification. The pedal allowed for three-plane corrections.

1) Tilt-up to 12 degrees of varus or valgus correction.

2) Angle-up to 6 degrees of toe-in or toe-out, in addition to the existing cleat or shoe position.

3) Height-up to 1 inch adjustment in 1/2 inch increments to correct limb length differences.

To assess rotational changes that were observed but not quantifiable with a two-dimensional motion analysis system, a pilot study with 1 subject was undertaken at Childrens' Hospital, San Diego with a three-dimensional Vicon system. Using this 3-D system, analysis demonstrated that tibial rotation did in fact occur during the cycling stroke and that it could be modified with the Biopedal (interface) adjustment (Figure 4 shows a front view).

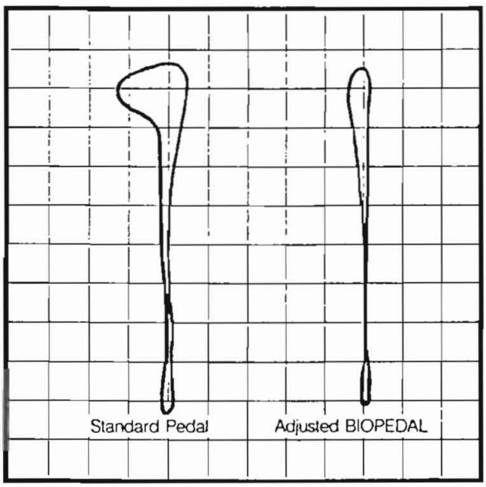
In order to further evaluate the observed and reported changes, a three-part study was undertaken in the Fall of 1987 at the University of Oregon. The purpose of the study was to:

1) Evaluate biomechanical changes with high-speed video.

2) Assess efficiency changes by means of an energy-cost study.

3) Evaluate differences in muscle use patterns by means of electromyographic (EMG) monitoring.

The results of this three-part study should be ready for presentation and submission for publication in the Fall-Winter of 1988. There are still many questions to be answered by future research, such as what effect hill riding has on tracking mechanics and what effect recumbent bicycles have on cycling biomechanics. The evaluation method described in this paper, Biosports Analysis Method or "BAM", offers a simple and low-cost method of evaluating and treating cyclists. It is also readily adaptable for use with more sophisticated data acquisition and analysis systems.



SIMULATION ADAPTED FROM VIDEO TAPE ANALYSIS

Figure 3

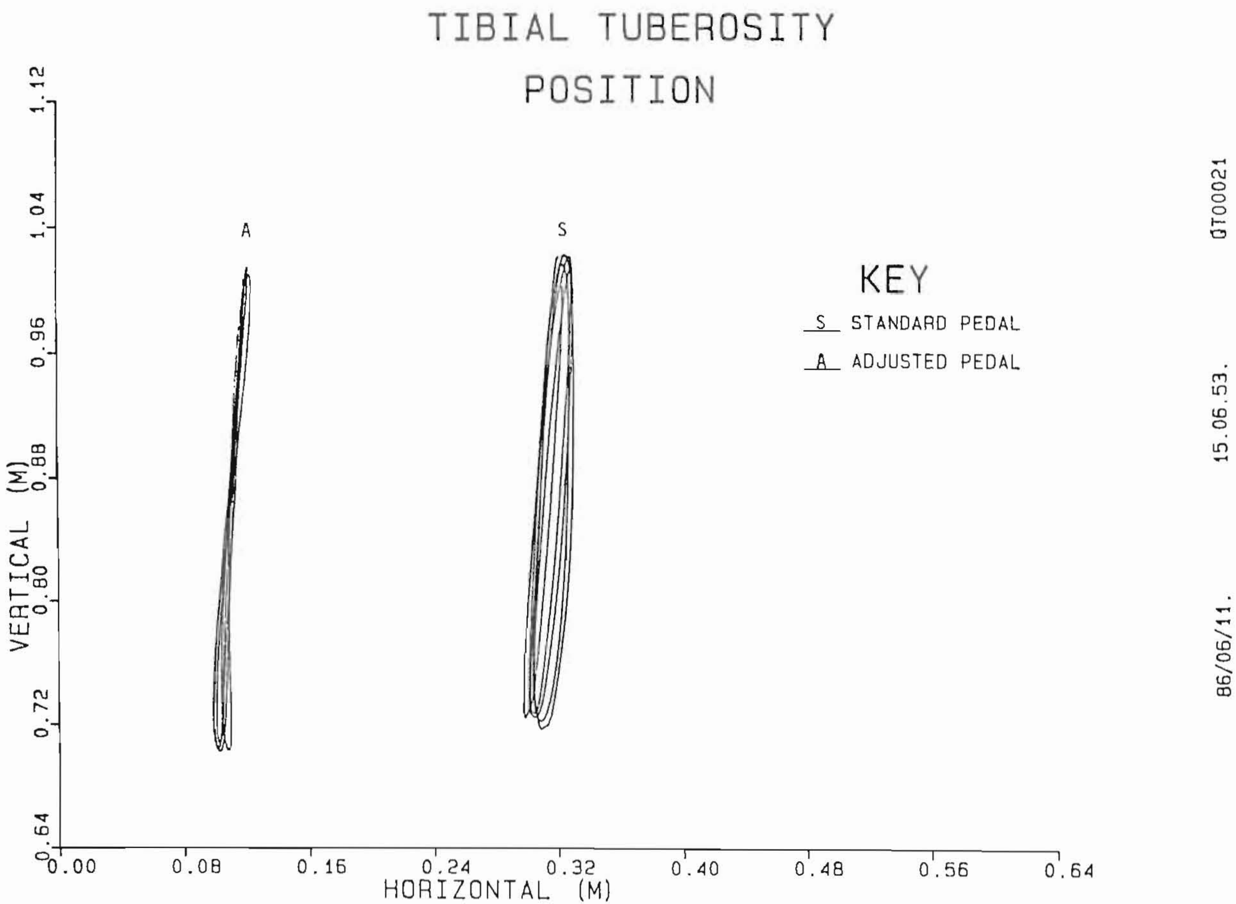

TIBIAL TUBEROSITY
POSITION
KEY
S STANDARD PEDAL
A ADJUSTED PEDAL
A
S
VERTICAL (M)
0.64
0.72
0.80
0.88
0.96
1.04
1.12
HORIZONTAL (M)
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
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Fig. 4.