THE EFFECT OF VARIATIONS IN THE FOOT PEDAL INTERFACE ON THE EFFICIENCY OF CYCLING AS MEASURED BY AEROBIC ENERGY COST AND ANAEROBIC POWER

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INTRODUCTION

This paper examines the effect of variations of the foot pedal interface by means of an orthopaedically adjustable pedal (BIOPEDAL™) and the resultant effect on cycling efficiency as measured by aerobic energy cost and anaerobic power.

The paper draws on previous research by Hannaford, Moran and Hlavac,1985 (3) which examined overuse knee injuries in cycling by means of video analysis and biomechanical evaluation. Moran,1988 (4) examined the role of the foot pedal interface and cycling pathomechanics and discussed the relationship of varus/valgus, toe in/toe out, and limb length adjustments of the bicycle pedal and the interaction of these modifications in the three planes of movement. This work was supportive of Francis,1986 (1) and 1988 (2) in which he presented a biomechanical approach to preventing cycling injuries and examined the role of foot malalignment and cycling pathomechanics. Robertson and Moran,1989 (6) investigated electromyographic (EMG) activity of lower extremity musculature with varying pedal positions and found that muscle recruitment patterns changed with variations in varus/valgus alignment. Rehabilitation protocols for ankle and knee injuries utilizing biomechanically adjustable cycling pedals were presented by Moran, Robertson and Einhorn-Dicks in 1992 (5).

In a presentation to ISBS in 1992 Moran (5) discussed preliminary work on the evaluation of energy cost changes as related to changes in pedal positions. This preliminary work revealed that some subjects who chose a varus pedal correction, which places the inside of the pedal higher than the outside margin of the pedal, demonstrated less energy cost while cycling at a given pace and intensity, as compared to their energy cost, 02 consumption, with a standard pedal position. It was found that subjects who adjusted to a valgus pedal position, outside of the pedal higher than the inside, did not demonstrate changes in 02 consumption.

With these results in mind, this study was undertaken to further examine the relationship of varus pedal positions and changes in aerobic energy cost and also to evaluate the varus pedal positioning and its relationship to the development of anaerobic power as measured by the Wingate test.

METHODOLOGY

Subjects

Informed consent was obtained from each subject Each subject was also screened by means of a physical readiness questionnaire, PAR-Q, to ascertain any contraindications for testing. Physical parameters and cycling, athletic and injury histories were obtained for each subject. The subjects were pre-screened and found to utilize a varus correction with the adjustable pedal. This was a prerequiisite for the study as a pilot study had determined that individuals that chose a valgus correction showed-no significant changes in energy cost. The 13 subjects, 5 men and 8 women, included in the study were all experienced cyclists. In total 10 subjects successfully completed the aerobic energy cost test and 10 subjects successfully completed the Wingate anaerobic power test.

Aerobic Energy Cost Test

The subjects were tested while riding their own or a similarly fit bicycle on a stationary turbo trainer. After the rider became accustomed to the environment they were asked to cycle at the training pace and intensity that they would use for a typical 20-40 mile (30-65 km) training ride. When the riders were settled in to this work load, video filming and 02 consumption sampling was conducted.

Using video equipment with still frame. frame advance, and slow motion and a 14 inch monitor screen, a one minute sequence was filmed from directly in front of the rider showing frontal plane and rotational deviations.

V02 Measurement

Gas analysis was perfomed with a TEEM 100 metabolic analysis system. The TEEM 100 performs oxygen and carbon dioxide analysis on a continuous basis using proportional sampling and an electronic variable sampling system. The oxygen concentration was measured using a galvanic fuel cell to which was added temperature and pressure compensation. Expired flow was measured using a flat-plate orifice pneumotach and ventilatory volume calculated by digital integration. The carbon dioxide concentration was measured by non-dispersive infrared analysis, the same method that is used in conventional metabolic systems. The TEEM 100 was calibrated prior to each measurement by inserting a known quantity of carbon dioxide and oxygen into the system utilizing a "close circuit" calibration method to assure that no ambient air is introduced into the unit during gas calibration.

The subjects performed 2 test rides for the aerobic test. The first ride was with the pedals in a regular pedal position during which time 02 data was collected and video filming conducted. The subjects were given an 8 minute rest during which time the subjects chose a pedal position with the Biopedal that they felt was most comfortable. most powerful and most efficient. This was accomplished by loosening the Biopedal so that it was freely moveable in the varus/valgus tilt plane and in the toe-in/toe-out plane. A third plane of adjustment, a limb length adjustment available with the pedal was not utilized in this study.

After the subjects chose the desired position, the pedal adjustment was tightened to secure the pedal in the desired position. The study included only subjects who chose a varus correction. The subjects were then brought up to the intensity and cadence that was utilized in ride 1. During the second ride 02 data was collected and video filming conducted.

Anaerobic Power Test

A Wingate test was utilized to evaluate anaerobic capacity, that is the power produced over a 30 second time period of the test, as measured by the number of pedal revolutions completed. A Monarch bicycle ergometer was utilized with adjustable Biopedals. The resistance setting utilized for the test was body weight (KG) x .075 = resistance setting.

The procedure that was utilized was as follows: after the aerobic trials were completed the subjects were given a 10 minute recovery period. The subjects then were given a 3-5 minute warmup period on the Monarch bike with the pedals in a regular position. The subjects were instructed to give a full-out 30 second effort on the ergometer at the prescribed resistance setting. The total number of pedal revolutions for the 30 second period was counted. The subjects then recovered for a 5 minute period during which time the Biopedals were adjusted in the same manner as the aerobic test.

The second trial of the Wingate test was conducted in the same manner as the first trial except that the pedals were set in the subject-chosen adjusted position. Again the total number of pedal revolutions for 30 seconds of all-out effort was recorded.

RESULTS

Ten experienced cyclists were evaluated on V02 test for assessment of changes in energy cost with a varus pedal adjustment and also on a **Wingate** test to determine if a varus adjustment in the pedal position resulted in changes in anaerobic power.

Aerobic Energy Cost

Five of the ten subjects showed a decrease in energy cost with a varus adjustment of the pedals. The other five subjects did not show an increase in cycling efficiency. The results are presented in Table 1. The change for the group was not significant at the .05 level.

Table 1. V02 Test

Pedal position				
Subj.	Regular	Adj.	Diff.	Diff. SQRD.
1	0.757	0.678	-0.079	0.006241
2	1.345	1.314	-0.031	0.000961
3	1.192	1.216	0.024	0.000576
4	0.976	1,088	0.112	0.012544
5	1.219	1.248	0.029	0.000841
6	1.646	1.527	-0.119	0.014161
7	1.039	0.985	-0.054	0.002916
8	0.946	0.931	-0.015	0.000225
9	0.976	1.121	0.145	0.021025
10	1.186	1.244	0.058	0.003364
	Totals		0.070	0.062854

Anaerobic Power Test

Nine of the ten subjects showed an increase in power capacity with the pedals in a varus adjusted position. The results are presented in Table 2. These changes were significant at the .01 level.

Table 2 :**Wingate** Test C/P/ 30 Seconds

	Pedal position			
Subj.	Regular	Adj.	Diff.	**Diff.SQRD.**
1	40	43	3	9
2	37	3g	1	1
3	37	41	4	16
4	35	41	6	36
5	41	47	6	36
6	41	53	12	144
7	55	56	1	1
8	49	58	9	81
9	37	40	3	9
10	61	59	-2	4
Totals:	433	476	43	337

The data were analyzed utilizing a 1 tailed correlated T-Test.

DISCUSSION

Throughout the course of clinical evaluation of cyclists during the past 10 years, it has been repeatedly reported by cyclists that adjustments in the foot-pedal interface have resulted in some cyclists reporting what they perceive as an improvement in cycling efficiency. Many have indicated that they can ride in a higher gear at the same perceived efforts Over the course of years efforts have been made to verify the cyclists' perception. As part of a study in 1989 that looked at the biomechanics of cycling and electromyographic changes with differing pedal positions, energy cost was evaluated. Some of the subjects who chose a varus pedal adjustment showed a decrease in their energy cost at the same work load as compared to the regular pedal position. This finding was consistent with the biomechanics evaluation in that the subjects that chose a varus correction had less area within the curve of the path travelled by the tibial tuberosity through the cycling stroke. The subjects who chose a valgus position in that study showed an improvement in their cycling biomechanics in that the amount of inward or outward angling through the stroke was decreased but the overall area within the curve of the path of the tibial tuberosity was significantly less than the varus adjusted group even post adjustment for the varus group.

The aerobic part of this study was conducted with a varus correction group so as to better focus on the possible alteration in energy cost. Once again the results are equivocal.

The anaerobic power test however demonstrated an increased ability to produce force with the pedal adjusted in a varus position. This was found in 9 of the 10 cyclists. The result for the group was significant at the .01 level of confidence.

Evaluation of these results raise the following questions and considerations.

Aerobic Energy Cost

The previous research and this current research has focused on the role of the foot pedal interface and the production of force in cycling. This is appropriate as the pedal is the point of application of human force to the bicycle. Indeed, some subjects have shown a decrease in energy cost with alteration in this interface with a varus correction.

Another presently unexamined factor in cycling biomechanics may be operating here as well. That factor is the biomechanics of the hip joint and its role in cycling mechanics and possible contribution to cycling efficiency. It may be that rotational variants in the hip joint, femoral, anteversion, and retroversion, may be contributing to, or interacting with foot biomechanics in evaluating and assessing energy cost in cycling.

A second and perhaps likely consideration, is that in the aerobics test the relatively low state of exercise intensity was not adequate to elicit energy cost changes. It may be that subtle energy cost changes may only be manifest at work levels near the aerobic/anaerobic threshold of cycling intensity.

Anaerobic Power Test

The results of this test were more clear in that 9 of the 10 subjects showed significant increases in power capacity with a varus adjustment of the pedal. The remaining subject showed a decrease in anaerobic power while also choosing a varus correction. It may be that this subject experienced some fatigue in the second trial of the Wingate tests. This subject produced the most revolutions against resistance in both trials.

The difference for this group between the Trial 1 regular pedal position and Trial 2 varus adjusted position represents a 9.93% increase in anaerobic capacity. This result is consistent with the clinical observation that at higher work loads we see greater changes in EMG activity from a standard to an adjusted pedal position. It has also been observed clinically that at higher work loads greater pathomechanical variations are observed.

CONCLUSION

It has **not** been demonstrated in this study that variations in the foot pedal interface result in a decrease in energy cost while cycling at an aerobic pace. Some subjects did show improvements but overall these improvements were not significant.

This study did find an increase in anaerobic power with a varus adjustment in the cycling pedal. This change, significant at the .01 level of confidence, was a 9.93% increase in anaerobic power capacity.

It may be that the aerobic energy cost test was too low in intensity to elicit measurable energy cost changes. It may also be that hip musculature, structure, alignment and function are a separate or compounding factor with foot position and alignment in determining biomechanical efficiency in cycling. Both of these questions highlight the need for further investigation.

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