VIDEO ANALYSIS AND TREATMENT OF OVERUSE KNEE INJURY IN CYCLING: A LIMITED CLINICAL STUDY

David R. Hannaford
Oregon Podiatry Clinic
2893 Oak Street
Eugene, OR 97405

Gary T. Moran
1352 Ballena Bv
Alameda, CA 94501

Harry F. Hlavec
147-A Lomita Drive
Mills Valley, CA 94941

Though cycling is not considered an "impact" sport, forces of three times body weight are applied to the pedals during intermittent bursts of effort such as during take off and hill climbing (13, 25). Forces equal to body weight occur during steady cycling (3, 10, 20, 25). It is known that good cyclists "spin" at an optimum pedalling frequency of from 80 to 100 revolutions per minute (5, 20, 22). This causes an exceptionally rapid flexion-extension at the knee when compared to running sports. For example, a 4:00 minute per mile pace in running causes an angular velocity at the knee that equates to no more than a 40 rpm spin rate (16).

Knee pain is the most common overuse problem in cycling (6, 8, 13, 18), accounting for about 25% of reported injuries. The most common types of overuse knee problems are: infrapatellar tendon strain and/or bursitis (Jumper's knee), retropatellar tendon bursitis, prepatellar bursitis, infrapatellar fat pad syndrome, quadriceps insertion pain on the patella, true chondromalacia patellae, pes anserinus bursitis, iliotibial band syndrome, and medial or lateral collateral ligament strain (6, 13). These knee problems are similar to the overuse problems found in running sports (9, 15, 19). Symptomatic improvement can be achieved through the same treatments that are effective for running induced injuries, but because the cycling stroke is different than the running stride, therapeutic modifications to the shoe or orthotics require special attention.

Overuse cycling injuries have been successfully treated with pedal, shoe, or orthotic modifications (1, 3, 8, 9, 13, 18, 21, 24, 26). It is known that techniques such as neutral orthotics, pedal canting, or cleat adjustments relieve many of the knee symptoms previously mentioned. Unlike running, which has been studied more thoroughly, the specific effect of foot position changes upon the knee needs to be investigated more extensively (1, 3, 13). Davis and Hull, in a very extensive study using electronic force analysis, found that small changes in pedal frontal plane tilt position caused large changes in force distribution, but the findings were not representative for all riders consistently. It appeared that identical adjustments on different cyclists would cause dissimilar changes on their force analysis (3). As sports medicine specialists have found in running, the study did not take into account anatomical differences, such as foot types, which could account for such non-reproduceability. A different angular position of the foot and leg bones and muscles could cause individual patterns of force application that could complicate this analysis pattern. So, although it is clear that adjustments to the way the foot contacts the pedal are potentially useful, no standardization for optimal treatment exists.

During the investigation of the problem, the authors found that most experienced and skillful competitive cyclists exhibit a very linear pedalling stroke at the knee when viewed from the front. Their knees deviate very little toward or away from the midline of the bicycle frame. As with running form variances, there were rare exceptions to this finding, but as demonstrated in a separate research paper (in progress), the authors found that asymptomatic experienced riders showed less transverse and frontal plane deviation than less experienced or symptomatic experienced riders. Transverse plane rotational knee movement is a characteristic some coaches and cycling injury sports practitioners address, but it appears to be overlooked as a therapeutic guideline in knee injury evaluation and treatment (6).

METHODS.

Informed consent was obtained from the riders for this experimental study. After performing a screening evaluation including: medical history, systems review, current medications and related problems; the riders were asked about knee problems that were not of an overuse nature, such as history of traumatic injury. These riders were referred for orthopedic evaluation. Examination and questioning continued with evaluation of seat height which has been associated with knee pain and loss of efficiency (4, 13, 14, 17, 23, 24, 26), checking cleat position-excessively in or out toeing or not properly positioned over the pedal axle (3, 13, 21, 24, 26), improper frame size (13, 18, 26), improper riding habits as in too high of gear selection (6, 7, 13, 26), cold weather riding with no knee protection (13, 26), no warm up or cool down (13), increasing distance too rapidly (13, 26), too many hills (1, 7, 13, 22, 24), and previous attempts at shoe or pedal modifications. For the purposes of the study, no riders were accepted who had positive responses for any of the above questions.

A lower extremity biomechanical evaluation was performed to determine joint ranges of motion, structural deviations including limb length inequalities, and muscular strength and flexibility. Based on manual examination, all of the riders in the study exhibited normal strength and flexibility. Although there is increasing emphasis in the literature on improving these factors in cyclists (1, 11, 12, 13, 26), no strengthening or stretching programs were implemented for these volunteers.

The riders were then examined while riding their own or similarly fit bicycle on a stationary wind trainer. After the rider became accustomed to the apparatus and was pedalling at their training cadence (80-100 rpm) in a gear that provided resistance subjectively equivalent to their training effort on a level road surface, video filming began.

Using video equipment with still frame, frame advance, and slow motion, and a 19" monitor screen to provide good visibility, a one minute sequence was filmed from directly in front of the rider showing the frontal and transverse plane deviations. The camera was aligned so that the tubes of the bicycle frame were straight and the range of motion of the knees of the subject filled the screen. The videotape was played back with a transparent grid placed over the monitor screen. Using the mid-frame of the bicycle as a reference for the vertical axis of the graph, the excursion of the previously marked tibial tuberosities were plotted frame by frame to display the complete pedalling stroke of both knees. The tibial tuberosities were selected because the skin does not move significantly wi'h flexion as does the patella or other landmarks.

The authors used an adjustable bicycle pedal (Biopedal®), adjustable in all three planes, to make corrections for filming purposes. Changes were made in the cyclists foot position until the pedalling stroke was as linear as possible. Since none of the cyclists required treatment for leg length inequalities, adjustments were limited to the frontal plane (varus/valgus) and the transverse plane (in-toe/out-toe).

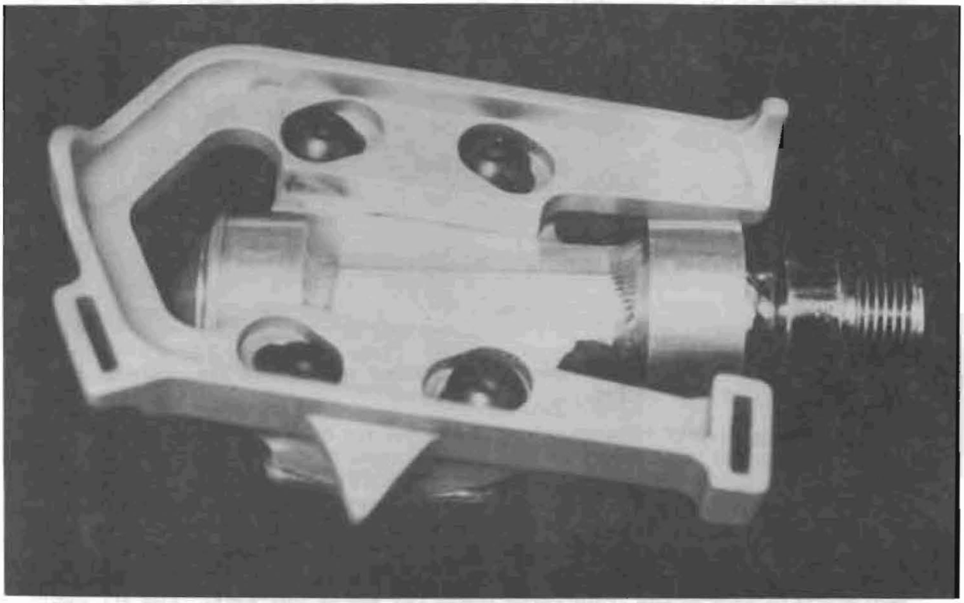

Figure 1. The Biopedal platform pedal may be adjusted and fixed in three planes intrinsically in the frontal and transverse plane, with spacers for adjustment in the sagital plane.

Initially, a position of pedal adjustment was selected comparable to the net amount of deviance from the neutral (normal) anatomical position of the knee, leg, and foot combined. This involved determining torsional transverse plane deviations in alignment of bones and joints as well as frontal plane positional differences. After an optimum position was determined, temporary shoe inserts, cleat modifications or pedal cants/lifts were fashioned to maintain the position on the riders own equipment. The riders are instructed to cycle experimentally with the modifications for two weeks, then return for adjustments or fabrication of permanent modifications as warranted.

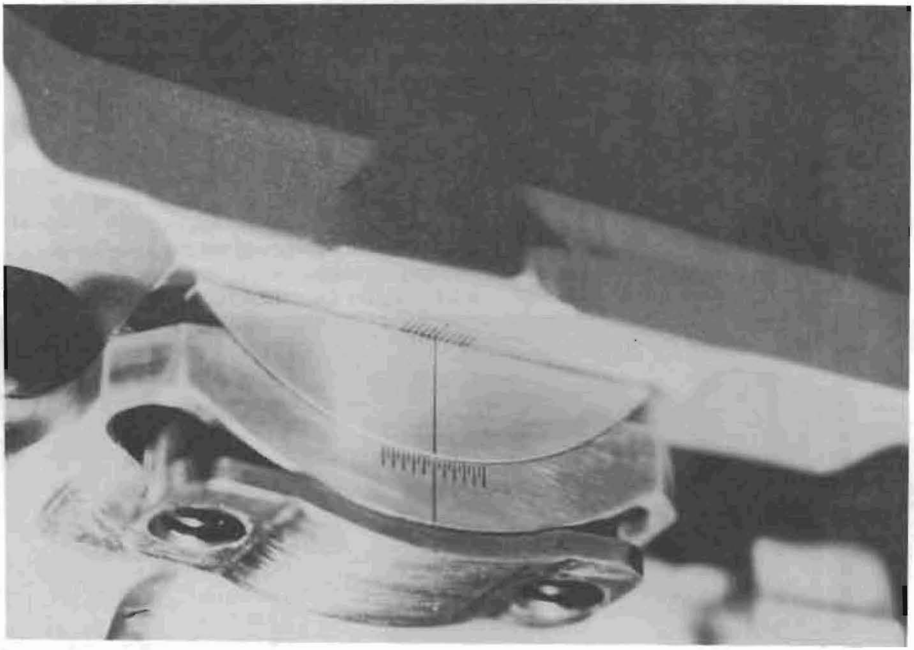

Figure 2. The Biopedal may be prescribed and set in the position of comfort for the cyclist.

The objective of biomechanical treatment for cyclists is to balance the foot on the pedal in order to neutralize abnormal forces and prevent compensation. The foot/pedal interface contacts across the ball of the foot at the level of the metatarsal heads. Treatment is most effective at this level. After the part-to-part measurements of the foot and leg are made in degrees, the resultant forefoot position is determined in terms of amount of lift (for limb length discrepancies), degrees of tilt in the frontal plane (varus or valgus), and angle of gait in the transverse plane (in-toe or out-toe). The tri-plane platform pedal (Biopedal®) is then fixed in this position of best function. In the frontal plane, for example, a rider with 5° of genu valgum ("knock-knee"), 10° of tibial varum ("bowed leg"), 5° of sub-talar (rearfoot) varus, and 3° of mid-tarsal joint (forefoot) valgus would receive 7° varus pedal position. Appropriate measurements and adjustments are made in the transverse and sagittal planes. The transverse plane adjustments are based upon rotational hip position, tibial torsion (malleolar position) and metatarsus adductus * measurements. It was found that the resultant transverse plane measurement should be added or subtracted from 0° (straight ahead) rather than the normal stance position. Using video analysis of the frontal plane recorded on clear acetate over the monitor screen, all of the riders in the study required adjustments to their originally selected foot/cleat/shoe positions to make the pedalling stroke linear.

---

* Metatarsus adductus is the transverse plane measurement of the relationship between a bisection of the second metatarsal and the bisection of the mid-foot. This requires weight bearing x-rays in the angle and base of gait. Consequently, for this study, the clinical measurement of the forefoot to the rearfoot was used instead.

SUBJECTS.

Sixteen competitive cyclists were evaluated as described under "Methods". Of the sixteen cyclists, the five who had knee pain and the three who had significant transverse plane knee movement but no pain symptoms of any type as described under "Methods" were utilized in this clinical study. All but one of their eight cyclists were treated with adjustments and corrections based on the video analysis and exam. The lone exception was filmed and evaluated, but no treatment was given establishing a control to determine if the filming itself provided any benefit.

The remaining eight cyclists were not treated because they were asymptomatic and their cycling stroke was technically sound.

The eight competitive cyclists in this study had been cycling an average of 7.9 years (range 2 to 15). The average age of the cyclists was 29.4 (range 21 to 40). There were 7 males and 1 female. None of the cyclists in the study showed severe positional foot or leg measurement deviations. Six of the cyclists showed a straight heel bisection in relation to the floor surface in a relaxed stance position. (Of the two that did not, 1 was symptomatic). All 8 cyclists had slight pronatory foot-leg functioning position (a combination of first ray, forefoot-midtarsal joint, subtalar joint, ankle joint, tibial frontal plane position, and knee frontal plane position). There were no cyclists with a net supinatory deviation requiring the pedal to be tilted in a valgus position raising the outer edge. Supinated foot types appear to be more stable and powerful than pronated foot types in cycling.

A follow-up questionnaire was distributed to the cyclists at 3 months post treatment. The questions were (on a scale of 1 to 10, with 10 being the worst pain possible and 1 being no pain). Give a numerical rating for each of the following:

(1) Present knee pain;

(2) Pain at the time of filming;

(3) Pain Three weeks post-filming;

(4) Pain at eight weeks post-filming;

(5) Pain at its most troubling period.

There were two questions with possible answers of "Yes", "Possibly" or "No":

A. Do you feel changes made during your filming were helpful in improving your knee problems?

B. Do you feel changes made during your filming were helpful in improving your pedalling efficiency?

RESULTS.

All eight questionnaires were returned. Four reported less knee pain and four remained the same. Of those with improved ratings, three stated that the changes made during the filming had been helpful in improving their knee problems. The rider who did not attribute his improvement to the changes, indicated that his knee problems were not caused by cycling - merely aggravated by it. He did feel his efficiency had improved because of the correction. The cyclist with the symptomatic knee that did not receive modifications (control cyclist) did not show an improvement in knee pain numerical rating, nor did he attribute to the filming session, any improvement in efficiency. He did mark that it "Possibly" was helpful with his pedalling efficiency. His explanation reflected visual feedback benefits.

Five of the eight cyclists reported that their cycling efficiency was improved by the changes made and three cyclists noted "Possible" improvement. No riders cited "No improvement in efficiency". Of the three cyclists who stated "Possibly" to the question concerning pedalling efficiency, one was the untreated control; one was a rider who had reduced knee pain; and one was asymptomatic throughout the evaluation and treatment.

Of the five cyclists who originally had knee overuse symptoms, three improved because of the adjustments that were made, one received no adjustments and did not improve, and one felt his knee pain was not caused by cycling, only aggravated by it, and did not improve.

The other three cyclists who were asymptomatic at the evaluation and treatment resulted in two cyclists who were enthusiastic about the efficiency benefits and one cyclist who is not certain the modifications are helping but continues to wear the modifications.

None of the eight cyclists reported increased knee symptoms.

In summary, of the eight cyclists, two did not gain significantly from the session. One of these was the non-treated control rider and one was the cyclist who felt his knee problem was non-cycling caused.

DISCUSSION.

Several important factors need to be explained with regard to the types of adjustments. The first is to be aware of the toe clip position. It can prevent cleat or cant adjustments if it does not allow the foot to properly position itself on the platform. By making contact with the shoe, it may override any positional adjustments made elsewhere and prevent the shoe from assuming its properly aligned position with the metatarsal heads directly over the pedal axle. Modifications with spacers for sagittal plane elevation or size changes may be needed.

Secondly, the video analysis technique has shown that even in the rigid soled cycling shoes used by competitive cyclists, simple longitudinal arch support as found in many over-the-counter orthotics or rearfoot-only types of orthotics cannot prevent abnormal knee motion at higher forces. If the knee alignment problem is because of an imbalance originating in the rear foot only, as in subtalar varus or valgus among others, then traditional support would be appropriate, but if the forefoot (beneath the metatarsal heads) is not parallel with the ground in a fully loaded position when the other adjustments are complete, the knee may still deviate when stressed with the loads of pedalling a bicycle. This is because the force of pedalling is applied through the metatarsal heads to the shoe to the cleat to the pedal. The rearfoot and other parts of the shoe only serve to modify the distribution of force slightly.

Under light or moderate loads the rearfoot type of support (eg., rigid orthoses in cycling shoes) might be adequate to prevent excessive transverse/frontal knee motion, but when the load increases and a higher percentage of the force is directly on the metatarsal heads the foot will collapse in the direction that allows the forefoot to become parallel with the cleat or pedal surface.

This may allow the knee to deviate from vertical and move excessively. Often, improper attempts are made to prevent this motion by overcorrecting the longitudinal arch or turning the cleat inwardly or outwardly. This can cause muscle strain and ligament strain as the body compensates by working to prevent the joints from moving outside their "neutra'" range. Commonly, the knee will move away from its optimum linear sagittal motion - especially during the unweighted part of the pedalling stroke.

It is not the intent of the correction to create a perfectly linear pedalling stroke. The corrections are intended to modify the cyclist's present stroke to a more linear one. For some riders the stroke is nearly linear, for others it is slightly oval, curved, or in a figure "8" shape. The importance of the adjustment is to find the position that gives greatest pedalling for that individual.

The authors' use of an adjustable pedal (Biopedal©) for the adjustment phase of the evaluation was convenient as it produced results similar to the results obtained by adjustments to the riders own equipment. The adjustable pedal is currently in testing and development. If it proves useful in a practical form, it could greatly simplify the adjustment process for the patient and practitioner.

CONCLUSION.

The video film analysis and treatment technique described in this study have been shown to be a beneficial method for evaluating and treating overuse knee problems in cyclists. It is clinically useful, requires commonly available equipment, and provides immediate visual results for the patient and practitioner.

The treatment effectiveness relies upon the expertise of the practitioner in making therapeutic modifications and biomechanical evaluation in order to eliminate time consuming trial and error.

It is the belief of the authors that this technique can be useful for sports medicine clinicians, researchers, trainers, athletes, coaches and for bicycling equipment and shoe design.