THE USE OF BIOMECHANICALLY ADJUSTABLE CYCLING PEDALS IN THE DEVELOPMENT OF REHABILITATION PROTOCOLS FOR ANKLE AND KNEE INJURIES

GARY T. MORAN, M.A., PhD., F.A.C.S.M.,
RICK N. ROBERTSON, PhD., SHARI EINHORN-DICKS, M.S., R.P.T.

INTRODUCTION

This paper examines the use of stationary cycling with a biomechanically adjustable pedal (Biopedal™) in the development of rehabilitation protocols for the knee and ankle.

This 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 patho-mechanics and discussed the relalionship 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 bio-mechanical approach to preventing cycling injuries and examined the role of foot malalignment and cycling pathomechanics. Robertson and Moran, 1989[5] investigated electromyographyic (EM6) activity of lower extremity musculature with varying pedal positions and found that muscle recruitment patterns changed with variation in varus/valgus alignment. This work supported clinical findings of Einhorn-Dicks and Moran.

METHODOLOGY

As a result of this work and clinical findings, rehabilitation protocols for selected ankle and knee injuries were developed utilizing the three plane adjustable pedal and stationery exercise bicycle. The goals for rehabilitation are presented in Table 1. Two elements, minimization of injury risk and reinforcement of structural stability, draw significantly on biomechanical considerations.

TABLE 1: REHABILITATION GOALS

*- minimize risk of injury during active recovery
*- reinforce stability with specific exercises based on biomechanical principles
- prevent or delay the onset of degenerative changes
- educate the patient
- reinstate to previous performance level

* = biomechanical considerations

The rehabilitation strategy is presented in Table 2. This strategy, in brief, attempts to protect the injured structures during the early phases of active recovery, and then to progressively move to a neutral pedal position as tissue integrity is reestablished and then to the strengthening phase in which the structures are. for short bouts of exercise, more highly stressed to increase the strength of the injured and associated structures.

TABLE 2: REHABILITATION STRATEGY

1. PROTECTION. During the early phases (post-operative, acute) the adjustable pedal is positioned to reinforce the integrity of and support the injured structures. This is typically achieved by variations in varuslvalgus and/or height adjustments.
2. ACTIVE REHABILITATION. In the next phases of rehabilitation (subacute, chronic) the pedal is positioned to progressively add stress to the structures to increase the strength of the injured tissue, This involves moving the pedal from a protective position to a neutral pedal position.
3. STRENGTHENING. The later phases are designed to continue the strengthening process and involve moving the pedal position to one that applies controlled stresses (micro-stress) to the structures. This involves positioning the pedal beyond the neutral position for short bouts of exercise.

Table 3 presents some of the protocols that have been developed and utilized for foot and ankle injury rehabilitation. Table 4 presents protocols for rehabilitation of knee injuries. The protocols are based upon the strategy of first protecting the structures by placing them in a biomechanical position that reduces stress and then on to active rehabilitation and to the strengthening phase which for short bouts of exercise places the structures in a biomechanical position that provides more stress to the tissues to induce strengthening.

RESULTS and DISCUSSIONS

The stationary bicycle has been used effectively for rehabilitation for many years. It allows for active recovery with gradiation of stress and load application. Unfortunately, many individuals exhibit patho-mechanical variations in their cycling and stroke patterns (Moran, 1988[4]; Francis, 1988[2]) that can limit the effectiveness of the use of cycling for rehabilitation. The introduction of the 3-plane adjustable pedal (Biopedal™) that allows for adjustments in: varuslvalgus, toe-in/toe-out, and pedal height (for limb length shortage) has enhanced the rehabilitation potential of the stationary exercise bike.

The positive clinical results from the utilization of the protocols presented in this paper have demonstrated that in addition to correcting the pathomechanics of a cyclist, the adjustable pedal allows for manipulation of the foot pedal interface in ways that can be utilized to facilitate the rehabilitation process. The ability to adjust the pedal and manipulate the resultant forces on tissue structure can be useful to the researcher and clinician in understanding lower extremity mechanics, devising procedures to alter stresses, and in developing therapeutic modifications.

TABLE 3: REHABILITATION PROTOCOLS - Foot and Ankle

Condition	Biomechanicai Considerations	Protocol Strategy
Achilles Tendonitis	Often related to hypermobility of the foot with greater medial involvement	Mid foot or heel placed on the pedal in a varus position with progression to neutral and slight valgus positions
Ankle sprains (Inversion)	Need significant initial protection to allow early active recovery	Mid foot placed on pedal in a valgus position with progression to neutral and to varus for strengthening
Plantar fasciitis	Often related to more extreme foot types-- hyper mobile or high-arched rigid foot	Mid foot or heel placed on pedal in a varus position with progression to neutral and valgus for strengthening
Posterior tibial shin splints	Often related to excessive pronation	Mid foot or heel pedal position with a varus correction with progression through neutral to valgus for strengthening
Metatarsal stress fractures Ankle fracture	Positional correction as appropriate to protect the injured structure	Typically heel or mid foot position on the pedal with the appropriate varus/valgus correction to minimize stress at the fracture site with progression to neutral and then opposite position for strengthening

TABLE 4: REHABILITATION PROTOCOLS - Knee

Condition	Biomechanical Considerations	Protocol Strategy
Patella Compression Syndrome	Often due to lateral tracking of the patella. Limit internal tibial rotation during symptomatic stages	Mid foot placed on pedal in a varus position with progression to neutral and then to valgus for strengthening of the vastus medialis (VMO)
Medical structure stress Medial collateral ligament (M.C.L.) Strain/tear	Essential to protect these structures during the early phases of rehabilitation	Mid foot or heel pedal position with a varus correction. Progress to neutral and valgus for V.M.O. and M.C.L. strengthening
Lateral structure stress Lateral collateral ligament (L.C.L.) Strain/tear	Essential to protect these structures during the early phases of rehabilitation	Mid foot or heel pedal position with a valgus correction. Progression is to neutral and to slight varus for strengthening
Iliotibial band syndrome	Several causes including limb length shortage and pelvic obliquity with fatigue	Correct limb length difference with height adjustment. Mid foot pedal position with a slight varus to decrease internal rotation. Progress to neutral and slight valgus

CONCLUSIONS

Increasingly, biomechanics is being used in sports and general medicine to assess, analyze, and treat injuries and medical conditions. This paper has presented clinical protocols that have been clinically evaluated and are currently being utilized in rehabilitation in the United States. The results indicate that a three-plane adjustable bicycle pedal can be used to reduce trauma to connective tissue structures. The adjustable pedal can be used in rehabilitation to minimize risk of injury during active recovery and reinforce the integrity of and support injured structures.

REFERENCES

1. Francis, P.R. (1986) Injury prevention for cyclists: A biomechanical approach. In E.R. Burke (Ed.), *Science of cycling* (pp.145-184). Champaign, IL: Human Kinetics.

2. Francis, P.R. (1988) Pathomechanics of the lower extremity in cycling. In E.R. Burke (Ed.), *Medical and scientific aspects of cycling* (pp.3-16). Champaign, IL: Human Kinetics.

3. Hannaford, D.R., G.T. Moran, and H.F. Hlavac (1985), "Video analysis and treatment of overuse knee injury in cycling: A limited clinical study". In Terauds, J. and J. Barham (Eds.), *Biomechanics in Sport II*. Del Mar, CA: Academic Publishers.

4. Moran, G.T. (1988). Biomechanics of cycling: The Role of the foot pedal interface and cycling pathomechanics. In Kreighbaum, E. and A. McNeill (Eds.), *Biomechanics in Sports VI* (pp. 43-49) . Bozeman, MT: International Society of Biomechanics in Sports.

5. Robertson R. and G.T. Moron (1989) A comparison of EMG activity for elite cyclists utilizing an orthopaedically adjustable pedal. In *Proceedings.* American Society of Biomechanics.