BIOMECHANICS OF INJURY: ITS ROLE IN PREVENTION, REHABILITATION AND ORTHOPAEDIC OUTCOMES

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Despite the quality of research that has been published linking mechanical loading and sporting injuries, little has been accomplished in promoting these data to the community from a Public Health perspective. This paper will promote the view that epidemiological and biomechanical data combined with exercise promotion strategies must be coordinated in such a way that injury reduction outcomes are assessed. Only then will the general public and granting agencies value our research contributions. Biomechanists must take a broader view of sport research if our discipline is to survive and grow.

KEY WORDS: biomechanics, injury, exercise promotion

INTRODUCTION: Seldom is a complex question dealing with injury answered by research based in a single science discipline. Previously, the sport biomechanist has been encouraged to combine with the exercise physiologist, the sport psychologist, the motor development specialist, and/or the physician or physiotherapist to structure appropriate research designs. Research into identifying key causal mechanisms associated with injury or rehabilitation processes inevitably requires the combined knowledge and skills of these professions.

van Mechelen et al. (1992) reviewed risk factors involved in sport and suggested a four step prevention process. Researchers must:

1. Base research hypotheses on epidemiological data (nature, extent and severity of injury);
2. Identify the aetiology of the problem;
3. Educate the relevant population as to the dangers inherent in that sport and the techniques needed to avoid these injuries;
4. Evaluate the effectiveness of the preventative measures.

Winston et al. (1996) proposed that biomechanics should be an integral part of what they termed epidemiological research, if injury control mechanics were to be understood (Figure 1). This is essential as most injuries have a mechanically related aetiology (Whiting and Zernicke, 1998).

Therefore sport biomechanists must adopt a team approach for reducing sporting/physical activity based injuries. Epidemiological data on the scope of the injury must clearly establish the “extent of the problem and the need for the research”. Secondly, the aetiology of the injury must clearly be established. This could require collaboration with physicians, physiotherapists and/or radiologists. The choice of research design in studying the aetiology of sporting injuries will greatly influence the outcomes of such research. Only by relating injuries to corresponding populations can an estimate of injury ratio and risk factors be identified. Education and the assessment of the degree of success of the preventative strategies, might then require the assistance of professionals trained in health promotion.

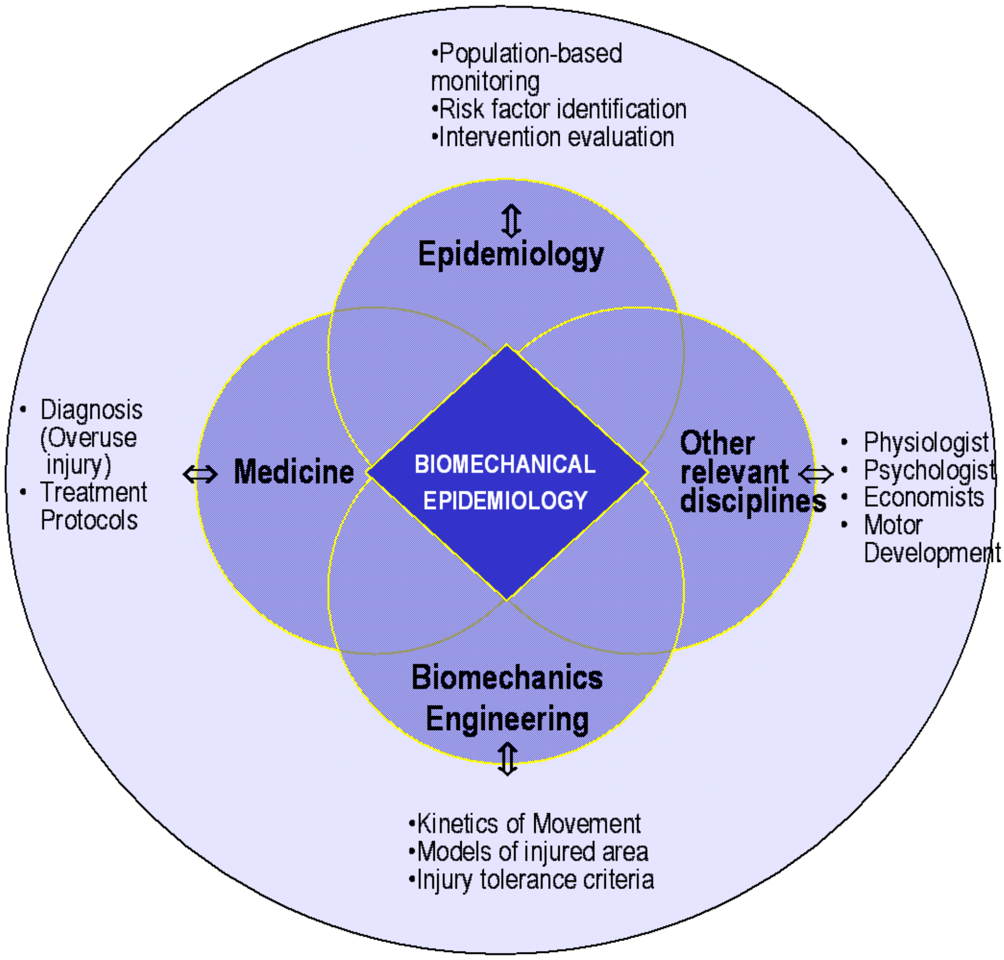

Figure 1 - Biomechanical epidemiology. (modified from Winston et al., 1996)

Research projects discussed in this paper other than the golf case study, are from the biomechanics laboratory at the Department of Human Movement and Exercise Science at the University of Western Australia. These will be used to illustrate the model proposed by van Mechelen et al. (1992) and also to show where deficiencies in design might be improved.

1. The Reduction of Back Injuries During Fast Bowling in Cricket: A Group Approach

a. Epidemiology: In the game of cricket, overuse back injuries to fast bowlers have been extremely common. Elliott et al. (1992) reported the incidence of bony abnormalities (spondylolysis and pedicle sclerosis) was 55%, while the prevalence of inter-vertebral disc abnormalities was 65% in a group of 18-year old high-performance fast bowlers. Furthermore, a group of young bowlers (mean age = 13.6 years) increased their incidence of disc degeneration from 21% to 58% over a 2.5 year period (Burnett et al., 1996).

b. Aetiology: A prospective study of fast bowlers showed that counter-rotation of the shoulder alignment (line joining the two acromion processes) by greater than approximately 0.7 rad (≈ 40°) was related to an increase in spondylolysis and lumbar soft tissue injury over one year (Foster et al., 1989). The incidence of bony abnormalities and disc degeneration in Elliott et al. (1992) and Burnett et al. (1996) were also found to be significantly related to counter-rotation of the shoulder alignment by greater than 0.35 rad (≈20°) in the bowling action. This movement is the key mechanical feature of the “mixed bowling action”.

c. Education: This study examined whether supervised training (4 group sessions per year) reduced the level of shoulder alignment counter-rotation during the bowling action as measured by an overhead camera operating at 50 Hz. Levels of disc degeneration changes were measured from an MRI over a 2 year period. These sessions followed a seminar where all coaches, parents and fast bowlers were told of the dangers inherent in using a "mixed action" and provided with coaching literature to re-enforce "safe techniques".

d. Evaluation: After 2 years, the incidence of "mixed technique", defined as a shoulder counter-rotation of greater than 0.35 rad decreased from 80% to 52% (n = 11 of 21 bowlers). The level of counter-rotation also reduced by 0.16 rad for the entire group. The level of lumbar disc degeneration increased from 17% (1997) to 33% (1999). This was a far better result than that reported by Burnett et al. (1996) over a similar period (21% to 58%) (Figure 2). The 4 bowlers, who showed a progression in degeneration from 1998 to 1999 all used the "mixed action". While these results are pleasing, the education procedures have been modified for the 3rd year of the study to include more video sessions. Hence, each bowler will be treated more as an individual.

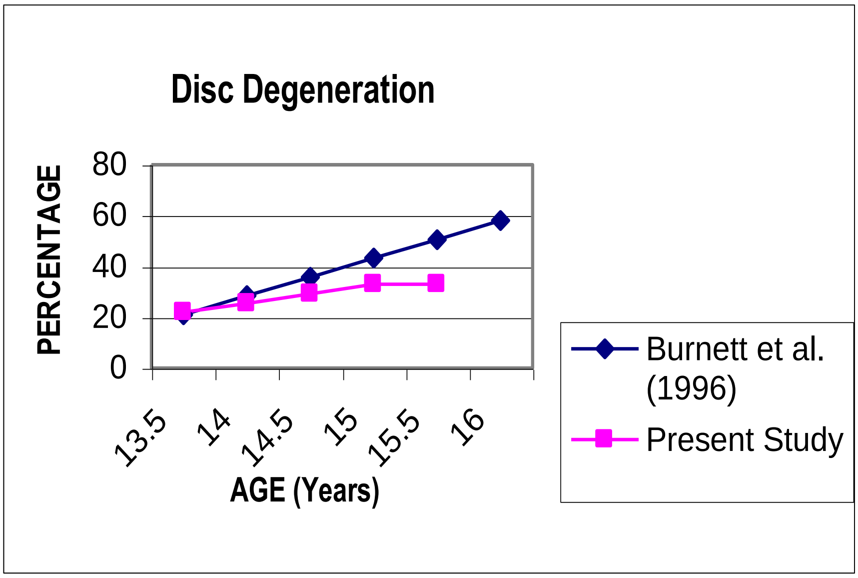

Figure 2 - Disc degeneration of young fast bowlers over a 2-year period.

2. The Reduction in Low Back Pain During Golf: A Case Study Approach

a. Epidemiology: The lower back is the site most commonly injured in both professional and amateur golf (Batt, 1992; McCarroll et al., 1990).

b. Aetiology: Higher levels of torque, and shear and lateral bending forces in the lumbar spine have been identified as being related to these back injuries, particularly if these poor mechanics are linked to overuse (Hosea et al., 1990). Grimshaw and Burden (2000) used 3-D videography of the trunk and para-spinal electromyography, in a case study design, to analyse potential causes of back pain. Their subject was a professional golfer suffering from low back pain. The low back pain was diagnosed by a general practitioner as deterioration of the ligaments and fibrous tissues around the lumbar spine (diagnoses supported by an MRI). The main aim of the education program was to increase hip rotation whilst maintaining approximately the same rotation of the shoulder alignment during the swing (both measured from 3-D videography). This placed less torsional load on the lumbar spine. The level of para-spinal muscle activity was used as a measure of trunk torque.

c. Education: One coaching period per week was undertaken along with para-spinal muscle conditioning (3-4 times daily). This continued for a period of 3 months. The coaching intervention strategy consisted of exercises to reduce lateral hip slide by increasing the hip rotation during the backswing.

d. Evaluation: The re-test results showed that the golfer was standing in a similar position at the address and at impact. The golfer's lumbar movement was modified, particularly the hip to shoulder separation angle. This angle reached a maximum of 93.9^{o} in test 1 (early in downswing) compared with 79.0^{o} in the re-test. The activity level of the para-spinal muscles also was reduced during the swing and the low back pain ceased.

Therefore, technique modification and physical conditioning are potentially critical components in the control and reduction of low back pain in golf. While this case study design does not permit the results to be extended to the broader population it does provide a basic design upon which larger studies could be structured. These findings need to be presented to the broader golfing community and studies developed which evaluate the effectiveness of the program in reducing back pain.

3. A Reduction of Knee Injuries in Sporting Movements

a. Epidemiology: The number of anterior cruciate ligament (ACL) injuries from sport cost Australia $100 million in 1990 (Egger, 1990). A high proportion of ACL injuries in sport are non-contact in nature and occur because of the increase in joint loading brought about by a combination of sudden changes in direction and acceleration of the body (Ryder et al., 1997).

b. Aetiology: Reduced ligament loading is a critical factor in reducing the incidence of ACL injuries. Muscle activity has the potential to reduce ligament loading during extension at the knee (O'Connor, 1993), and during adduction or abduction at the knee (Lloyd and Buchanan, 1996). It also has been shown that muscle activation reduces ligament loading during static tasks (Lloyd and Buchanan, 1996) and preliminary work would indicate that this also is the case for selected dynamic tasks (Besier et al., 1998).

Strength training has become an integral part of training throughout many levels of competition and in an effort to improve performance from enhanced size, strength and/or speed. Most strength training involves movement in one plane only, which is not relevant to the game situation. It is well known that strength training will affect the neural control needed to perform a movement or task. For example, leg flexion/extension strength training reduced the co-contraction of hamstrings and quadriceps, and optimises co-ordination of synergist muscles (Carolan and Cafarelle, 1992). However, this reduced co-contraction also may diminish the activation patterns used to protect the ligaments of the ankle joint (Baratta et al., 1988) and could be viewed as a possible negative outcome of strength training.

Re-training proprioception at the ankle and knee joint by using a wobble board has been an integral part of injury rehabilitation programs for the past decade. However the use of the wobble board as a prophylactic modality is less common. The mechanisms underlying proprioceptive training are not well understood but recent evidence suggests wobble board training can alter the muscle activation patterns at the knee to counter external loads applied to the joint. Caraffa et al. (1996) showed that the incidence of ACL injuries at the knee in elite soccer players was dramatically reduced over two seasons following a wobble board training intervention.

Two questions arise regarding the incidence of knee ligament injuries. 1) Are there training methods that can reduce the incidence rates of knee and ankle joint injuries? 2) Do some of the current training methods increase the risk of knee and ankle injuries?

A randomised controlled field evaluation of 3 different conditioning programs will be conducted over 2 seasons of play to determine the relative effectiveness of these types of program for preventing injuries of the knee. Players will be randomised to one of four study arms: 1) proprioceptive training only, 2) strength training; 3) combined strength and proprioceptive training, and 4) a control group. Ligament loading, pre- and post-training, will be assessed when running and side-stepping at 4 ms^{-1}. A model developed by Besier and Lloyd at the University of Western Australia will be used.

c. Education: A randomised control trial which has been structured by an exercise promotion specialise will be undertaken to investigate the effectiveness of the different training regimes following a season of injury surveillance. Teams of footballers from senior schools and district football teams will be invited to participate in the trial. Teams of players will be chosen as a sampling unit because they provide a natural grouping of players. Randomisation of teams to the above groups will be made such that there is equal representation of each of the footballer codes (Australian rules, rugby) in each group.

d. Re-evaluation: The number of injuries to players for each training condition will be determined through injury surveillance and adjusted for exposure data.

CONCLUSION: Sport biomechanists interested in injury reduction must broaden their approach to research design. This will inevitably mean working with professionals not only from the medical and para-medical professions but also with health promotion professionals. Sport biomechanists must redefine the scope of their research. The ability to define techniques that allow the cricket fast bowler or golfer to remain injury free are clearly within the domain of the sport biomechanist. However, we must broaden the scope of our research to include the understanding of mechanisms involved in gait that will enable athletes of all ages to enjoy running again following knee surgery. We must also take more of an interest in veterans activities so that the differentiation between sport and leisure becomes more closely aligned. Only then will sport biomechanics be able to maintain a valued position within universities and the community, thereby increasing the potential for growth in our profession.

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