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OVERUSE INJURIES IN SPORT: A BIOMECHANICAL APPROACH

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Sporting injuries may be generally divided into those caused by an impact, where there is a sudden increase in the force applied to the body (an inappropriate landing in Australian football or rugby) or those produced through overuse. **Overuse injuries are generally due to overload or repetitive microtrauma of the musculoskeletal system, where a number of repetitive forces each lower than the critical limit of selected tissues produce a combined fatigue effect in that tissue over a period.**

Contributing factors to overuse injuries include: 'poor technique', an excessive number of attempts at an activity, inappropriate conditioning and/or poor body anthropometry or congenital factors that may predispose a person to injury in a particular sport or activity. This paper discusses how a biomechanical understanding of at least some of the causes of the 'overuse injury' will help reduce the incidence of such injuries in sport or activity. Those interested in overuse injuries should also read Nigg (1985), Renström and Johnson (1985) and Dalton (1992).

The causes of overuse injury are generally of two types. The first is associated with a *high number of repetitions of an activity* such as in endurance training where, at each footstrike, ground reaction forces and associated torques must be absorbed by footwear and the body; or in swimming, where the high number of upper limb rotations place stress on the shoulder region. The second type is associated with a lesser *number of repeated performances requiring high levels of skill/technique and power*, such as in gymnastics or in jumping, where much higher internal forces are generated and/or must be absorbed by body tissue than in the first classification.

The potential of a particular activity or technique to cause or limit overuse injuries is best determined by epidemiological or prospective studies. In epidemiological studies for example, changes in injury statistics may be carefully assessed following a change in technique/equipment/playing surface or rules of play. In prospective studies factors such as techniques/physical capacities of athletes are measured prior to the season and the causes of any resulting injuries are then related back to these characteristics (Foster et al., 1989; Brukner et al., 1995). As these studies are difficult to administer when working with high performance athletes and costly to run, biomechanists may use the forces acting on the body during a particular performance as an indicator of the potential for an overuse injury. It must be understood, however, that external forces (usually measured using a force platform) of the same magnitude and direction may produce different internal forces (the reason generally for overuse injuries) when acting with different points of application (the toe as opposed to the heel of the foot) or on structures with different geometry (eg., flat arch versus a high foot arch). The rate and direction of loading must also be taken into account in attempting to objectively measure the influence of force on the body. The following approach, albeit simplistic, gives practitioners a classification guide to better understand the aetiology of overuse injuries.

A. HIGH REPETITION, MODERATE FORCE ACTIVITIES

In this type of overuse injury, frictional forces associated with a high number of repetitions (swimming) or cyclic loading where a high number of exposures of the body to force (running) generally cause an injury to a muscle, tendon, bursa or bone. Examples of these cyclic loading activities include:

(i) Selected movements in aerobic dance: Rates of injury sustained in aerobic classes, particularly to the lower limb, have been reported as high as 76% for instructors and 43% for students (Garrick et al., 1986). One of the major causes of this spate of impact and/or overuse injuries has been attributed to the need for the body to absorb repeated forces (GRF) at each foot contact with the floor (Francis and Francis, 1986). Elliott et al. (1990) compared biomechanically and physiologically two low impact (walking and high intensity walking at 2.14 m s^{-1}) and *two* high impact jogging at 2.14 m s-1 and running at 2.92 m s^{-1}) movements used in aerobic dance classes, in an attempt to find activities that provided sufficient physiological intensity, while reducing the level of GRF at foot contact. While all four movement patterns stressed the cardiorespiratory system above minimum guidelines for training as recommended by the American College of Sports Medicine, differences were apparent in force data. Walking (1.4 SW) and high intensity walking (1.3 SW) produced lower peak vertical GRF's than jogging (2.2 SW) and running (2.4 SW).

The suitability of each of these movements for use in an aerobic dance class or movement routine will depend on the prescribed intensity and impact levels of that class and also the fitness levels of the participants.

- Walking and high intensity walking would both be suitable for use in low impact style classes and jogging and running would be suitable for high impact styles of class. An alternative would be to use a combination of high and low impact activities in the same class such that the sum total of the stress is less than that for a high impact class and yet more than that for a low impact class.
- Classes should also be carried out on 'sprung floors' to help in the reduction of floor impact forces.

The risk of injury, however, from any of these movements seems mainly to arise from excessive repetitions of the activity, insufficient preparation of the participant for the stress of the particular movement pattern, or poor technique in performing these movements rather than the forces generated during any single activity.

(ii) Fast bowling in cricket: Fast bowling is an impact activity in which the bowler experiences a series of minor collisions with the grass surface in the run-up. This is followed by a large collision when landing on the front foot, on hard turf or concrete surfaces during the delivery stride. Peak vertical and horizontal GRFs of approximately 5 times and 2 times the bowlers body weight (SW), respectively have been recorded when the front foot is planted. Stress fractures in the spine (primarily to L4 or L5) are the most serious injury to a fast bowler, although injuries to the body musculature, intervertebral discs and joints, particularly of the lower limb and back are also commonplace. Results from a series of studies over a decade reported in Elliott et al. (1995) showed that anatomical considerations, technique and excessive bowling all predisposed a fast bowler to back injury.

The seriousness of injuries to young fast bowlers is best shown in a study by Surnett et al. (1996). Nineteen male fast bowlers (mean age 13.6 years) underwent MRI scans to detect the presence of intervertebral disc abnormalities and were filmed to assess bowling technique. Bowlers were tested at the beginning and end of a period of 2.7 years. The incidence of thoracolumbar disc degeneration increased from 21 % to 58% and furthermore back pain also increased significantly (1 to 10 cases). The progression of disc degeneration was found to be significantly related to the bowlers who used the mixed bowling action.

In an attempt to reduce the incidence of overuse injuries suffered from fast bowling, in addition to normal warm-up and cool-down exercises players should:

- Bowl with a technique that does NOT include greater than approximately 1 01 of counter-rotation of the shoulder girdle alignment during the delivery stride (Is., a mixed action).
- Follow sensible guidelines on the number of overs bowled in any session.

(iii) Running: Running as a means to maintain general cardiovascular fitness, as a form of aerobic and anaerobic preparation for sport or as part of a sport, has always produced lower back and lower limb injuries. Knee injuries Achilles tendonitis, shin splints and, to a lesser extent, stress fractures are all lower limb injuries common to runners/joggers (Runners World Survey, 1977).

Depending on the direction and point of application, GRF's at each footstrike produce different effects on the body. The level of these GRF's are in part velocity dependent. Maximum vertical and retarding horizontal GRF's of 1.2 BW and 0.2 BW respectively for walking increase to 2.5 BW and 0.5 BW respectively for running and to levels of 3.6 BW and 0.8 BW respectively for sprinting. Unfortunately the internal joint reaction forces can easily be a multiple of the external GRF's and therefore depending on the direction of the acting forces and the geometry of the locomotor system, the stress pattern on the body can be greater than the GRF's would signify (Nigg, 1986).

In an attempt to reduce the incidence of overuse injuries suffered from running in addition to normal warm-up and cool-down exercises, it is necessary to:

- Run on soft surfaces such as grass as much as possible. If running on hard surfaces is necessary then 'quai4' shoes must be used to help absorb GRF's and stabilise the foot.
- Run in shoes that match your gait patterns. That is, if over-pronation occurs when running then shoes that attempt to correct this fault should be purchased (gait abnormalities may necessitate the inclusion of an orthotic).
- Develop a good gait pattern. Any serious abnormalities in pattern should be checked by a suitably qualified person such as a biomechanist.
- Ensure that any increase in training load or change of training environment (hill running; change from aerobic to anaerobic training) is introduced gradually.

(iv) Landing in netball: In a game played primarily on hard surfaces where a player is required to continually accelerate-decelerate, to jump and land in an attempt to receive a pass, it is not surprising that injuries occur, particularly in the lower limb. A study by Hopper (1 986) reported that 5.2% of a total of 3108 players (158 injuries) were injured during one season. The frequency of area injured showed that the ankle (58.2%) and knee joints (15.2%) were the most common sites of injury although those to the knee joint were the most disabling.

A study by Steels and Lafortune (1989) reported that peak vertical GRF's of 5.2 BW (heel landing) and 5.7 BW (forefoot landing) were recorded when landing on one foot after catching a ball propelled 20 cm above their head. Steels and Lafortune (1989) also reported that high performance players generated lower peak braking forces when landing on the forefoot (2.0 BW) when compared to landing on the heel (3.3 BW), which supported the findings of Steels and Milburn (1989). The flmetopeak braking force was however, shorter when landing on the fore foot in comparison to when landing on the heel of the foot, therefore the rate of loading and thus risk of injury associated with this high rate may offset any advantage gained from a lower peak retarding force recorded using this landing technique.

In an attempt to reduce the risk of overuse injuries from jump landings, in addition to normal warm-up and cool-down exercises players should:

- Practise landing skills, while catching a ball, to develop a 'kinesthetic sense' of where their body, particularly their lower limbs, are positioned for ground impact.
- Attempt to train and play on the same type of surface thereby reducing the need for different shoes and the potential for injury.
- Purchase shoes that support the foot on landing, assist in the absorption of GRF's and have a frictional characteristic (slip/grip) related to the surface where training and play most commonly take place.

In basketball, peak vertical GRF's of between 2.3 to 7.1 BW have been recorded on landing following a rebound (Valiant and Cavanagh, 1985). If basketballers were required to train on hard surfaces like netballers and not on 'sprung' gymnasium floors then they too would face similar injury problems.

(v) Swimming: The potential for overuse injuries, particularly in the shoulder region is obvious, as swimmers may rotate each arm 2,500 times while completing 5,000 metres of freestyle (Allegrucci et a]., 1994). Tenosynovitis to the long head of the biceps brachii tendon or to the supraspinatus muscle attachment ('swimmers shoulder') can result from upper limb movement, particularly during freestyle and butterfly swimming. In an attempt to reduce the potential for those injuries coaches and teachers should:

- Adopt a gradual build up in the kilometres swum, particularly when using the freestyle or butterfly strokes.
- Switch the emphasis on muscle groups during training by varying the sections of a session to include full stroking, kicking and pulling (of the four strokes).
- Ensure that shoulder flexibility is sufficient to permit correct stroke technique

(vi) High velocity throwing (baseball pitching): Studies by Adams (1968) and Torg et al. (1972) on young pitchers have clearly shown that overuse injuries are apparent in baseball pitching, the most common being 'elbow' soreness, but separation of the medial epicondylar epiphysis may occur. If a high number of repetitions are combined with poor technique, then an overuse injury is almost inevitable (English et al., 1984).

The underlying mechanism for injury primarily to the elbow region appears to be related to the large forces or torques associated with the forward swing phase of the upper limb during the pitching action. Very high torques are needed to cause the rapid extension of the forearm and support the valgus movement at the elbow joint, characteristics of pitching and high velocity throwing (Gainor et al., 1980). In an attempt to reduce the potential for injury, apart from normal warm-up and cool-down exercises coaches and teachers should:

- Emphasise 'good throwing technique'.
- The number of repeddons must be carefully monitored both in practice and when playing (maximum 1 10). The Australian Baseball Federation have guidelines for number of pitches that may be thrown, however, a sensible approach to the total thrown during the course of a week should also be considered. A pitching schedule may resemble

Saturday	-	pitch
Sunday	-	do not throw but stretching and general activity O.K.
Monday	-	light to moderate pitching
Tuesday	-	rest arm
Wednesday	-	pitch again.

- Any person during a game after throwing a moderate number of pitches should NOT be placed in the field where high velocity throws may be required (such as short stop).

B. MODERATE REPETITION, HIGH FORCE ACTIIATIES

In this category high forces associated with each performance limit the number of repetitions that can be performed if injury, particularly to the musculoskeletal system are to be avoided. With these activities coaches and teachers must develop highly specific lead-up drills that enable athletes to practice selected aspects of the final performance without exposing themselves to the potential for injury related to performance of the full activity. Safety precautions including the use of specialised equipment associated with each of these activities, must be strictly adhered to.

(i) Gymnastics: Take-off and landing forces in gymnastics clearly show the extremely high forces are associated with these activities. Peak single limb vertical GRF's at take-oft for a running forward somersault of 13.6 BW (Miller and Nissenen, 1987) and between 8.8 to 14.4 BW on landing after a double back somersault (Panzer et al., 1988) have been recorded. Bruggermann (1987) recorded peak vertical take-off forces of between 3.4 to 5.6 BW for a back somersault following a round-off, which translated into internal forces approaching 10,000 N in the Achilles tendon. While it has been shown that asymmetrical landings produce higher forces than symmetrical landings, reductions in GRF when landing with a flexed knee joint compared to a competition landing were only minor (Panzer et a[. 1988). Therefore if injuries, particularly those that may disturb normal growth are to be avoided it is imperative that correct equipment, such as an appropriate floor, and good matting be used for teaching gymnastics. Gymnastic coaches and teachers should:

- Ensure that a thorough warm-up and cool down, that includes both flexibility and strength activities, are carried out by all gymnasts prior to and after performance.
- Good technique must be stressed at all levels of performance. This includes lead-up drills where selected aspects of the total skill such as take-off velocity, must be practised, prior to the complete activity (a particular vault) being performed.
- Physically prepare the young gymnast for the activities to be performed.
- Limit the number of repetitions of high load activities, such as rebounding in vaulting and tumbling or in activities requiring weight bearing on the upper body.
- Vary training so that emphasis is placed on different activities throughout each session.

(ii) Jumping activities: Ramey (1970) in a study of the long jump take-oft, recorded peak vertical GRF's of almost 7 BW for a jump of only 4.2 m. These GRF's increased to levels between 7 and 12 BW in the take-offs for the triple jump (Ramey and Williams, 1985). In a high jump of 2.2 to 2.4 m, peak vertical impact forces of between 8.4 to 8,9 BW and peak horizontal retarding impact forces of 5.6 to 6.5 BW (Deporte and Van Gheiuwe, 1989) show the very high forces associated with this activity. It is not, therefore, surprising that athletes involved in jumping activities or students in a physical education class, where jumping is being emphasised, must be very careful to avoid overuse injuries. Jumping coaches and teachers should follow a very similar set of guidelines to those set out above for gymnastics.

(iii) Javelin throwing: A mean peak vertical GRF at front foot impact of 9 BW for javelin throwing (Deporte and Van Gheluwe, 1988) shows that this activity must NOT be constantly repeated if injury to the lower limb or back are to be avoided. The high velocity requirement of the upper limb segments prior to javelin release, also means that high internal forces are acting and thus, as in throwing, repeated maximum efforts should be avoided. In an attempt to reduce the potential for injury, coaches and teachers should:

- Emphasise 'good throwing technique' in all lead-up drills and in the complete performance.
- Ensure that a thorough warm-up and cool-down are employed by all throwers, which must
- include both stretching and strengthening activities,
- The number of repetitions must be carefully monitored at practice.
- The body must be physically trained to withstand the forces associated with throwing.

CONCLUSION

Prevention is the key to all overuse injuries, for in most instances they can be avoided or at least vastly reduced if a sensible approach to performance is adopted. When symptoms of overuse injuries such as pain are reported then the athletes total program must be evaluated. The technique being used must be analysed, the physical preparation evaluated and the intensity of training/play reconsidered. Factors such as the equipment/shoes used and the surfaces played on must also be evaluated. An effective coach/teacher will of course have considered all these aspects of their program prior to the start, and during each season.

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