Risk compensation

Risk compensation, motivation, injuries, and biomechanics in competitive sport

A S McIntosh

There is a need for an integrated perspective on sports injury

Science and medical researchers and practitioners working in the field of sports injury prevention tend to have very tangible objectives and focus on identifying and solving specific injury risks. There is an uncertainty, however, that "solving" one problem may not simply create another. As the field matures, it is worth considering whether theories and models can be developed that have more general application to a range of injury issues. There is a need for an integrated perspective on sports injury that is inclusive of medical, behavioural (psychological, sociological, and organisational), physiological, and biomechanical factors. On the one hand, training and skills development are advocated as the best methods to reduce injury, but injury rates appear only to increase the more competitively a person approaches sport. This leads to the questions: are significant reductions in sports injury risk possible at all—or in only very specific sports, age groups, or competition levels—and only through absolute reductions in exposure, or after reconsideration of injury prevention methods?

A biomechanically focused model of injury causation and prevention has been developed that draws on models by Wismans[1] and Norton.[2] From a biomechanical perspective, injury is "equivalent to the failure of a machine or structure".[3] Injury results from a transfer of energy to the tissue. The mechanical properties of human tissue, such as stiffness (stress–strain relation), ultimate strength, and critical stress, govern how the body responds to physical loads. They differ for each tissue and are dependent on: the nature of the load and its velocity; the magnitude of energy transfer; other intrinsic factors such as age, sex, and physical condition. The latter indicate that positive adaptations occur as the result of physical training, for example. These factors and properties in combination determine the injury outcome of an event. In injury, micro and/or macro failure may occur. The key point to consider with regard to biomechanical injury risk factors is that they must explain how the event either resulted in a mechanical load in excess of that tolerated under normal circumstances or reduced the tolerance levels to a point at which a normal mechanical load cannot be tolerated.

Biomechanically oriented injury interventions focus on modifying the loads applied externally and internally to the human body. Interventions are aimed at controlling injury risks by reducing loading levels below relevant injury tolerance criteria, or improving the body's capacity to tolerate and/or react to patterns of loading. In some situations, there is scope for interventions that increase the body's tolerance through training. Alternatively, interventions could be developed that prevent tolerance levels for specific structures decreasing during prolonged exposure, for example, through time management, training plans, and player rotation. Injury analysis and prevention must explain how energy transfer arises, why it results in injury, and how it can be controlled. What complicates this neat model is the competitive and repetitive nature of sport and the behavioural, physiological, and biomechanical adaptations, in isolation and/or combination, that accompany competition. These concepts form the basis of the following model.

The proposed model incorporates the following inputs: behaviour/attitudes, training, skills, equipment, coaching, other competitors, and the environment. The output is injury risk. Figure 1 is a schematic of the model. The model is intended to account for both single events and repeated events. Using my studies of headgear as an example,[4 5] the model indicates that a player wearing headgear might perceive the severity of a head impact to be softer than without headgear, and decide that in the next event—for example, a tackle—they can hit harder. Their personality, level of competitiveness, knowledge, and coaching will modulate this response. Therefore the end result may be that the player's injury risk remains unchanged. Although young rugby players[6] reported that they felt more confident wearing padded headgear and could tackle harder, it is difficult to measure whether this translates into on field risk taking behaviours. Alternatively, to be most competitive, a tennis or baseball player must deliver or return the ball with as much linear velocity as they can generate and/or with high angular velocities to create movement in the air or off the court. This performance is based on the development of high muscle forces, and related joint forces, combined with large ranges of movement at high velocities. Through strength, fitness, and skill training, the biomechanical inputs into skill execution are developed. But the process may also fulfil both criteria for injury: high loads combined with a potential reduction in tolerance through micro trauma. This may explain why shoulder injury can occur in a tennis player during a serve—that is, decreased tolerance to load, combined with increased kinetic energy and higher forces, coupled with the motivation to serve faster than before. In both examples, time and exposure play important roles.

Norton's[2] assessment of lower limb injury risk factors in Australian football addressed the effect of ground hardness on injury and concluded that it played an indirect role by increasing game speed and thus collision energy. Strength and fitness training and level of competition will also increase game speed. The difference between Norton's model and the model presented here is that there is a greater emphasis on biomechanics, risk perception, and behaviour.

At the heart of the multifactorial model is a biomechanical focus on tissue properties and injury. In this model, the event (players, environment, etc) determines the mechanical load. The mechanical load is quantifiable as velocity, mass, momentum, and energy, for example. Therefore a faster game or "stronger" competitors will result in higher energy impacts. An injury prevention method will influence the biomechanical responses. For example, a helmet will attenuate impact energy, thereby reducing the head impact force, and skills training might enable someone to maintain their balance over the weight bearing knee, thus reducing knee loads, in terms of magnitude and location. The mechanism of injury must be appropriate for the tissue—for example, bone, ligament, cartilage, and brain. At this point, the effects of physical training may also have a positive and/or negative effect on tolerance. Increase in bone or ligament strength may be positive, but decreased "strength" associated with inflammation or micro

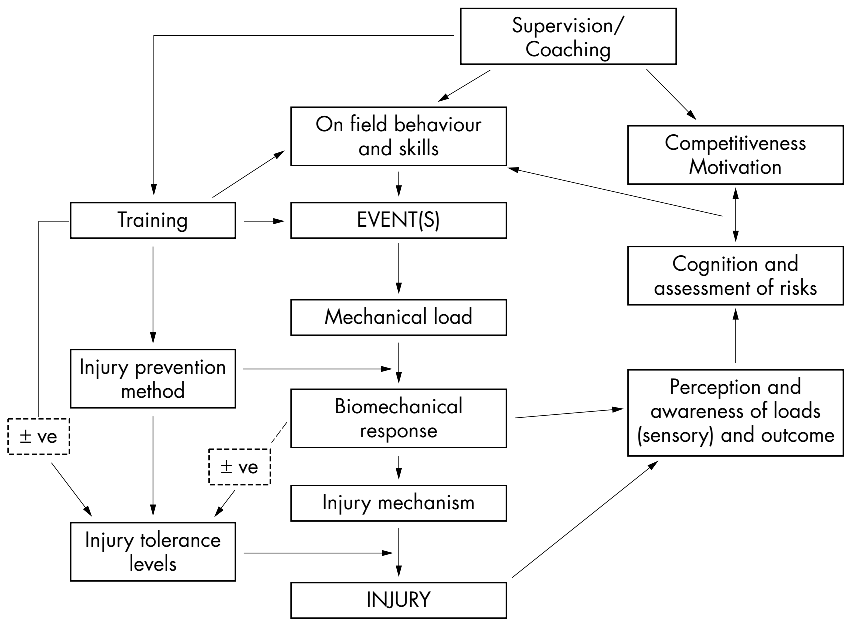

Figure 1 Schematic of injury model. The model would also be coupled to similar models representing other competitors in team sports. The ± symbol indicates that training or a biomechanical response during an event may increase or decrease the injury tolerance level—for example, micro trauma.

trauma would decrease tolerance to load and increase injury risks.

The editorial of Hagel and Meeuwisse[6] on risk compensation addressed a number of relevant issues related to protective equipment, but examined the topic from the perspective of an individual's own assessment of injury risk and response. The model outlined adds a biomechanical basis to the concept and implies that injury risk compensation theories must also consider motivation, and explain how the compensation re-establishes the biomechanical requisites for injury. A great deal of research is required to test the model. However, it is envisaged that consideration of these relations may help to explain why, for example, skills based injury prevention programmes[7] have a high potential for success as they reduce loads without necessarily increasing energy, and lead to further improvements in the success of injury prevention programmes through consideration of a wider range of inter-related factors.

Br J Sports Med 2005;**39**:2–3.
doi: 10.1136/bjsm.2004.016188

Correspondence to: Dr McIntosh, The University of New South Wales, Sydney 2052, Australia; a.mcintosh@unsw.edu.au

Conflict of interest: none declared

REFERENCES

1 **Wismans J**. Injury biomechanics. Eindhoven, Netherlands: Injury biomechanics course, Technical University, PRO 1411-TUe, 2000.
2 **Norton K**. Evidence for the aetiology of injuries in Australian football. *Br J Sports Med* 2001;**35**:418–23.
3 **Fung YC**. *Accidental injury: biomechanics and prevention*. New York: Springer-Verlag, 1993.
4 **McIntosh AS**, McCrory P. Effectiveness of headgear in under 15 rugby union football. *Br J Sports Med* 2001;**35**:167–9.
5 **Finch C**, McIntosh AS, McCrory P. What do under 15 year old schoolboy rugby union players think about protective headgear? *Br J Sports Med* 2001;**35**:89–94.
6 **Hagel B**, Meeuwisse W. Risk compensation: a "side effect" of sport injury prevention. *Clin J Sport Med* 2004;**14**:193–5.
7 **Myklebust G**, Engebretsen L, Braekken IH, *et al*. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sport Med* 2003;**13**:71–8.