Being able to adapt to variable stimuli: the key driver in injury and illness prevention?

Philip Glasgow,[1] Christopher M Bleakley,[2] Nicola Phillips[3]

The capacity of the human body to adapt and flourish in a wide range of environmental conditions is well recognised. Indeed, it is this ability to effectively adapt physiologically, psychologically and genetically that makes us successful as a species. Significant attention has been given to the long-term adaptation to environmental factors, for example, the 'mismatch hypothesis' of evolutionary medicine.[1] Of particular note, however, is the capacity to make rapid changes at neurophysiological and behavioural levels in response to alterations in environmental constraints. The ability to effectively modify responses under a broad spectrum of conditions is central to effective sporting performance and to long-term health outcomes. Simply speaking, the ability of humans to respond to a variety of challenges is what makes us stand out.

The traditional dogma that injury or illness results from the failure to attain a single 'ideal' (specific movement pattern, nutritional status and anatomical alignment) has been challenged.[2] The multifactorial nature of the majority of conditions has resulted in a general acceptance that a reductionist approach is often inadequate to describe the nuanced clinical presentation of many sporting injuries.[3] The dynamic and frequently non-linear relationship between risk factors and injury incidence is, perhaps, better understood in relation to the ability of the individual to adapt to various challenges.

DIFFERENT CONSTRAINTS, DIFFERENT STRATEGIES, SAME OUTCOME

Adaptations are subject to a range of neuromechanical, contextual and emotional factors. It is reasonable to suggest that some adaptations may be beneficial in terms of injury or illness predisposition while other maladaptive responses may increase susceptibility. Referring to the consequences of repeated participation in sports with or without injury, Meeuwisse *et al*[4] noted that 'adaptations occur that alter risk and affect aetiology in a dynamic, recursive fashion'. As such, two individuals under the same environmental constraints may carry out the same functional task using significantly different strategies. Furthermore, the same individual under two different environmental conditions may adopt distinct strategies to achieve the same functional outcome. This phenomenon was demonstrated in a study by Leukel *et al*[5] where the subjects were asked to perform a drop jump under two experimental conditions: condition 1, the subjects had to potentially switch the movement from a drop jump to a landing; condition 2, the subjects were absolutely sure that they had to perform a drop jump. The authors reported that when there was potential for a change in the task, muscular activity was altered in a way that allowed more flexibility in the system to facilitate either a drop jump or a landing. In contrast, when the subjects were certain they were going to carry out a drop jump, they adopted a completely different strategy. These findings highlight that the same task may be programmed differently depending on the situation.

Flexibility in adapting to variable conditions is enhanced by the capacity to fine-tune responses. Nigg[6] described the concept of muscle tuning during running by which selective activation of leg muscles changes coupling between the soft and rigid structures reducing vibrations of the soft tissue. He proposed that impact forces during stance phase act as an input signal that leads to tuning of muscle activity in order to maintain a preferred joint movement path. This concept further emphasises the importance of the adaptability of the locomotor system in maintaining health and effective function.

Expert sportspeople have been shown to use a range of cues to provide information about how best to respond to various tasks. The cricketer may rely on visual cues from their opponent's arm and wrist to predict where their opponent will place the ball and make necessary adjustments in response to their prediction.[7]

In this context, it is possible that a situation where something unpredictable happens (eg, a slip, awkward bounce of a ball or sudden change of direction by an opponent), the individual may not have adaptability in the system to successfully or safely complete the task. Further performance examples include fluctuations of the limb movements of skiers; these movements although chaotic in nature seem to reflect flexibility to adapt for possible perturbations. An interesting observation is that this behaviour seems to degrade with fatigue and is replaced with more random fluctuations.[8]

Figure 1A illustrates a person with low adaptability who then has a very narrow performance zone; when challenged by a range of environmental constraints the balance may easily tip from optimum performance to injury or underperformance. In contrast, figure 1B represents a person with high adaptability who has a wide performance zone and is able to accommodate to environmental constraints while maintaining optimum performance.

VARIABILITY VERSUS STABILITY

Variability has traditionally been defined as noise superimposed upon a signal, with the signal regarded as the intended or optimal movement.[9] There is increasing evidence to support the concept that variability does not mean loss of stability. A trained athlete balancing on an inflated soccer ball without falling has been used as a practical example.[10] Here, the athlete is stable, despite the fact that the athlete's centre-of-pressure measurements under the ball will demonstrate large movement variability. In essence, variability and stability represent different properties within the motor control process.

REDUCING INJURY BY ENHANCING ADAPTABILITY

Injury or illness can compromise the ability of the body to adapt effectively. For example, people with low-back pain alter muscle coordination patterns resulting in decreased variability in the timing of anticipatory postural adjustments, which may impair their ability to adapt to contextual constraints leading to increased tissue load.[11] Similarly, joint injury can have a significant impact on movement variability during gait or other sports-related tasks. For example, anterior cruciate ligament-deficient knees exhibit less divergence in flexion–extension movement trajectories.[12] Lateral ankle sprain can result in longstanding alterations in the activation and recruitment pattern of muscles as well as changes in joint loading. Such alterations may result in a reduction in the number of motor strategies available to the individual to respond to specific

[1]Sports Institute Northern Ireland, University of Ulster, Newtownabbey, UK; [2]Ulster Sports Academy, University of Ulster, Newtownabbey, UK; [3]School of Healthcare Studies, Cardiff University, Cardiff, UK

Correspondence to Dr Philip Glasgow, Sports Institute Northern Ireland, University of Ulster, Jordanstown, Newtownabbey, UK, BT37 0QB; philipglasgow@sini.co.uk

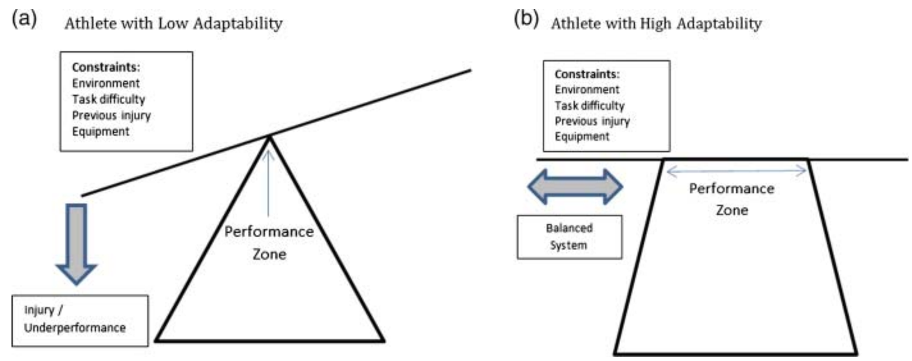

Figure 1 (A) Athelete with low adaptability. (B) Athelete with high adaptability.

challenges such as surface, movement direction, opposition or sport-specific skill.[13] There is evidence that individuals with ankle instability show less variability at the hip and knee during single leg-jump landings, compared with healthy controls.[14] This seems to represent a loss of the optimal state of variability, with the motor system becoming more predictable and rigid. A reduction in movement variability may have long-term implications for joint health; an interesting postulation is that increases in movement or behavioural rigidity cause systematic loading of the same areas on articulating surfaces and subsequently increase the risk of chondral damage and osteoarthritis.

Encouragingly, many interventions appear to increase the ability to adapt to variability. The effectiveness of exercise in the prevention of falls in the elderly has been attributed to improvements in functional plasticity and may be related to enhanced executive functioning.[15] Beyond this, the majority of sports injury prevention programmes are based upon a multifactorial approach that relies on improving neuromuscular control by challenging the system to adapt to various dynamic stimuli.[16 17]

Training and rehabilitation is based on the concept of Specific Adaptation to Imposed Demand, the so-called 'SAID principle'. This principle recognises the specificity of adaptation to a specific training stimulus. Sport and exercise medicine interventions are frequently designed to restore the ideal balance in a given situation. It is suggested that the focus of interventions (whether physical, pharmacological or psychological) should be to prepare the individual for the variable nature of the stresses placed upon them in the sporting environment in a better manner. This goal extends beyond the treatment of the presenting condition and attempts to increase the robustness of the athlete. Strategies to increase adaptability should seek to challenge individuals in a manner that exposes them to physiological stresses or joint control challenges in a relatively safe environment in order to stimulate broadening of their capacity to respond. Motor learning through subsequent success or failure of the response informs future attempts to respond to similar situations leading to a more adaptable and robust system.[18 19]

This approach goes some way in explaining why two individuals who carry out the same programme can have quite distinct responses. A common clinical observation is that some people appear to be more capable of 'soaking up' a wide range of differences in style or equipment without perceptible performance impairment or injury while others appear to be much more finely balanced, picking up injuries when the environmental constraints fall outside the relatively narrow margins. From this perspective, it is necessary to appreciate the complexity of the interaction between physical, physiological and cognitive components to determine which intervention(s) may effectively increase the adaptability of the individual. Given that many sports take place in highly variable environments, the identification of effective strategies to widen the range of conditions under which athletes can safely and effectively execute sport-specific skills should be a priority for clinicians working in sports medicine.

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