Optimal loading: Key variables and mechanisms

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3 authors:

Philip Glasgow
Ulster University

Nicola Phillips
Cardiff University

Chris Bleakley
High Point University

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Optimal loading: key variables and mechanisms

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

OPTIMAL LOADING (POLICE VS PRICE)

The acronym PRICE (protection, rest, ice, compression and elevation) has traditionally been the cornerstone for treating acute soft tissue injury. Recently, its relevance in some cases has been questioned;[1] of particular concern is that protection and rest may correspond with an excessively conservative approach that fails to harness the benefits of progressive tissue loading through exercise.

WHAT IS 'OPTIMAL LOADING'?

Optimal loading may be defined as the load applied to structures that maximises physiological adaptation. Achieving optimal loading is challenging but should be driven by variables such as the tissue type, pathological presentation and the required tissue adaptation for eventual activity. Specific loading goals may include increased tensile strength, collagen reorganisation, increased muscle–tendon unit stiffness or neural reorganisation.

Optimal loading works through various cellular and neural mechanisms to induce a wide range of changes (summarised in figure 1). Manipulation of loading variables can have profound effects on the nature, structure and function of the wider neuromusculoskeletal system.

One variable with the potential to influence outcome is the magnitude of the load. Arampatzis *et al*[2] showed that during cyclical loading of the Achilles tendon complex, magnitude was a strong factor in promoting morphological changes. The authors reported that loads of 90% maximum voluntary contraction (MVC) resulted in an increase in tendon–aponeurosis stiffness and tendon elastic modulus and a region-specific hypertrophy of the Achilles tendon compared with no alteration at 55% MVC. These findings suggest that some tissues have a threshold level of mechanical strain to facilitate adaptation.

Temporal characteristics such as rate of loading also appear to be critical in determining therapeutic effects. Rapid movements such as jumping and running have been show to produce greater stimulus for increased bone density and strength when compared to similar total loads applied more slowly.[3]

VARIABLE LOADING: KEY IN PROMOTING STRUCTURAL AS WELL AS NEUROMUSCULAR ADAPTATIONS

When progressing rehabilitation, attention should be given to facilitating structural and neural adaptations. As tissues adapt to changes in its mechanical properties in response to load, the sensory information provided during movement will also change prompting the central nervous system (CNS) to adapt to these changes. Bayesian theory suggests that we constantly compare predicted with actual movement and make relevant adjustments as we learn an unfamiliar task or relearn a task within a slightly different context.[4] The greater

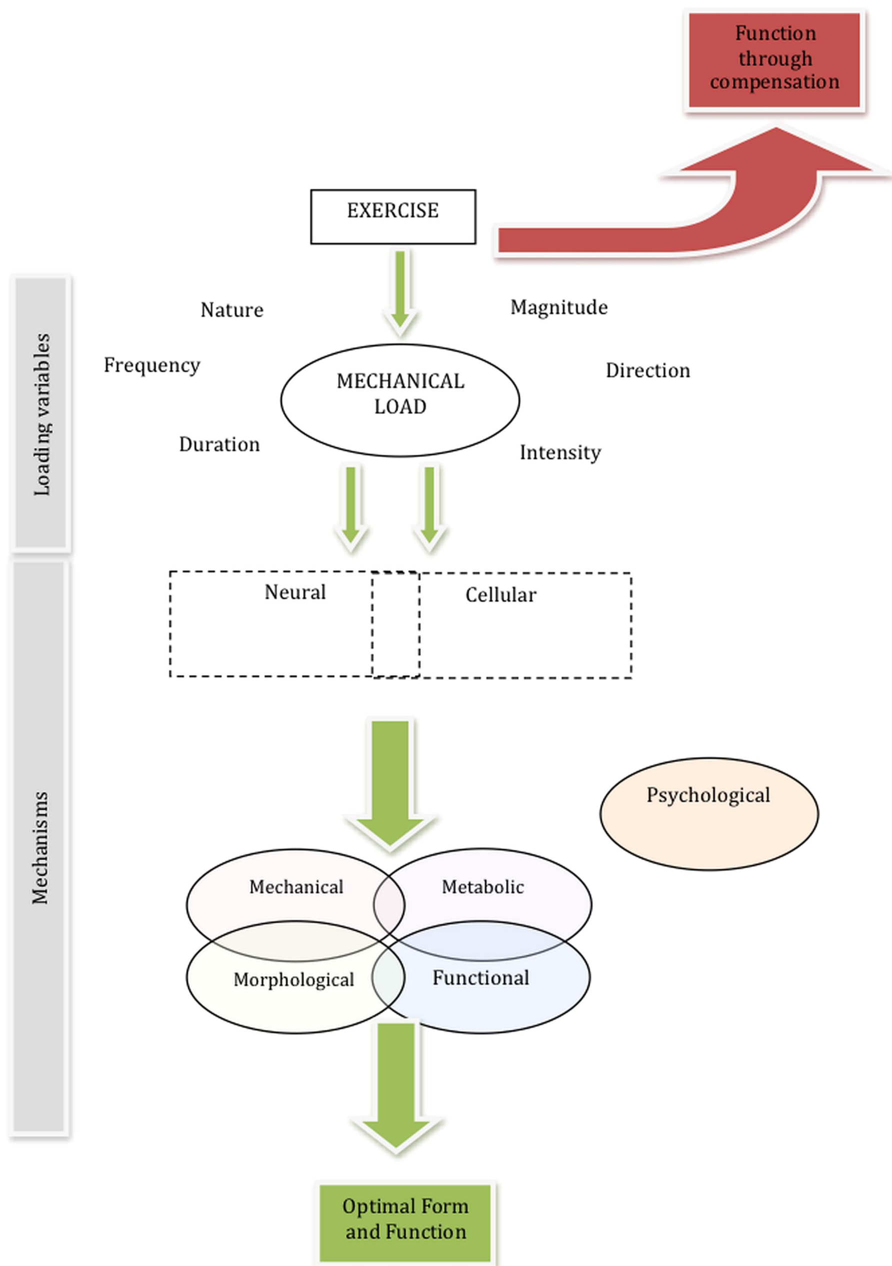

Figure 1 Effects of mechanical loading.

[1]Sports Institute Northern Ireland, University of Ulster, Newtownabbey, UK; [2]School of Healthcare Sciences, Cardiff University, Cardiff, UK; [3]Christopher Bleakley School of Sport, Ulster University, Newtownabbey, UK

Correspondence to Professor Philip Glasgow, Sports Institute Northern Ireland, University of Ulster, Newtownabbey, Co. Antrim, BT37 0QB, UK; philglasgow@sini.co.uk

Table 1 Characteristics of optimal and suboptimal loading

Optimal loading	Suboptimal loading
Directed to appropriate tissues	Non-specific generalised loading
Loading through functional ranges	Loading through limited ranges of movement
Appropriate blend of compressive, tensile and shear loading	Loading exclusively in a single manner
Variability in magnitude, direction, duration and intensity	Constant, unidirectional load
Include neural overload	Minimal neural stimulus
Tailored to individual characteristics	Generic, non-individualised
Functional	Non-functional, isolated segmental loading

the gap between the predicted and actual movement patterns, the more rigid the control. As the movement becomes more familiar the gap reduces and freedom of movement increases, characterised by smooth co-ordinated movement. In light of this, it is not sufficient to isolate our thinking to the progressive increase in magnitude of load as tissue adapts but also consider variation in the rate and direction of that load in order to facilitate motor learning and develop the appropriate co-ordinated tissue interaction required for efficient movement.

Variable loading may be effective in three ways. First, small variations in the magnitude, direction and rate of loading may serve to provide a degree of stress shielding of tissues from repetitive loading. Second, small variations in loading may promote a greater 'mechanotransductive' effect through broader stimulation of mechanoreceptors and prevention of accommodation; the phenomenon of accommodation is well recognised for a range of other stimuli such as temperature, pressure and light. Finally, variable tensile, compressive and torsional forces may promote the creation of stronger biological scaffold that is better able to withstand a range of loading types.

Ligaments respond better to variable loading. Manipulation of loading variables across all joint positions and ranges are required to achieve appropriate stimulation of available mechanoreceptors and subsequent restoration of function.[5] Similarly, muscle-tendon unit (MTU) function is modulated through the precise control of muscle activity relative to tendon stiffness to facilitate efficient, effective storage and release of energy. Evidence suggests that the effectiveness of eccentric exercise for tendinopathy may be related to the variable nature of loading associated with this type of training.[6] MTU function may be further enhanced through manipulation of loading variables such as acceleration/deceleration forces, compressive and tensile loads that facilitate the balance between muscle activity and tendon stiffness. This mediation of muscle activity is a learned motor task and controlled through neural mechanisms.

In summary, optimal loading for specific adaptation should consider integration of the entire neuromusculoskeletal system. For loading to be optimal, it should be directed to the appropriate tissues and gradually progressed in terms of magnitude, direction and rate (table 1). The goal of the clinician is to identify and progress the optimal level of difficulty of a movement that provides significant mechanical and neural stimulus while preventing poor quality, rigid movement or excessive overload.

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