Strength Training and Coordination: An Integrative Approach

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Introduction

Background

Training effects are the result of highly complex processes – so complex that there is now a great need for simplified models in sport-specific training and sports injury rehabilitation. Simplified models have systematically classified the many underlying aspects in a number of separate basic components of the training process. The underlying mechanisms can be evidenced by research and serve as a basis for appropriate practical application. This makes the various components more 'workable'.

The division of training processes into distinct components has led to the emergence of specialists in a number of areas: technique (technical trainers), mental processes (sports psychologists), speed (sprinting coaches), endurance (fitness or conditioning trainers), strength (strength coaches), recovery (recovery trainers and sports physical therapists), and so on. Such specialization is more marked in some sports cultures than in others, and perhaps most of all in the American sports culture, where for example the profession of 'athletic trainer' exists – somewhere between a physical therapist and a fitness trainer. In America, professionalism has become synonymous with the presence of specialists.

Yet there is an opposite tendency in the world of sports preparation: the integrative holistic approach, which sees the whole as more than the sum of the parts. Advocates of this approach are fond of the term 'functionality'. Here the quality of training processes lies in how the various aspects of the training processes affect one another. A highly systematic way of working is considered scarcely possible, and the structure of training theory seems to be constantly collapsing under its own weight and returning to the amorphous clay from which meaningful structures were so hopefully built. In this sense, training theory is a building that is constantly in need of extensive renovation. The vague terminology generated by such a holistic and essentially frustrating perspective is, to the say the least, unsatisfactory.

So training theory is far from complete, and must from time to time be rebuilt from scratch as an exercise in disciplined thinking. It is occasionally useful to review the primary basic elements of thinking about training theory: basic motor properties. Distinctions are made in strength, speed, agility, stamina and coordination. How justified are these distinctions – in other words, to what extent are they grounded in reality? Is there little or even no reason for strength training to take account of other basic elements, since these are more or less independently functioning quantities that each have their own separate significance in training theory?

This book sets out to demonstrate that this is not so, and that the various basic motor properties can hardly exist in isolation. Strength and coordination are thus closely related, and should in fact be treated as a single unit. Strength and coordination are basically one and

the same thing. This notion is a fascinating one, for it implies that various areas of research are brought together in a single systematic approach to strength training. Knowledge about improving coordination (motor control and motor learning) must be applied in strength training. Knowledge of motor learning processes has so far had no little or no impact on strength training. As a result, most literature about strength training is highly mechanical in its approach, and Isaac Newton seems to have contributed more to strength training theory than all the neurophysiologists in history.

This book can be seen, if you will, as an attempt to take the clay of training theory and create a new structure that is more useful in actual practice than previous structures. Instead of approaching strength training in terms of its mechanical manifestation, an attempt is made to produce a model geared to what is known about the underlying processes, particularly in the field of neurophysiology. In this book, sport-specific strength training means coordination training against resistance. This in itself is an admission that the book is inadequate. Knowledge from research is still too limited to allow a clear, consistent translation from theory to practice. Hypothetical models will always be needed. At the same time, this book does not attempt to integrate knowledge of coordination and exercise physiology, for that would be too complex for a workable approach.

Would all this make Newton turn in his grave? Probably not – he wasn't keen on sport.

The route

Chapter 1 describes the organization of complex biological systems. These are characterized by perhaps surprising mutual influence between components such as decentralized control and phase transitions. A 'classic' reductionist approach to systems ignores such influence. Standard training theory is assessed in terms of the special structure of this complex organization. The conclusion is that much of this basic theory, such as the concept of strength as a distinct entity, is inadequate because it is based on reductionist and hence oversimplified models of thinking. This has a major impact on, for example, the design of sports injury rehabilitation protocols, which should focus on the relationship between strength and coordination. Examples are given of protocols that take fuller account of how complex systems function.

Chapter 2 looks more closely at the anatomical and neurophysiological links between strength and coordination. It describes how the production of force is determined by all manner of anatomical details at musculo-tendinous level, by threshold values in the neuromuscular transition, by exciting and inhibiting circuits at spinal cord level and by central nervous-system influences. Production of force turns out to be regulated at various levels at once, and the central nervous-system's contribution can be described as a coordinative influence.

Chapter 3 analyses the structure of complex contextual movements, such as the movement during sporting competition. Using dynamic systems theory, the distinction between open and closed skills is specified in terms of the interplay of attractor and fluctuator components

of the movement. This division between attractors and fluctuators is the basis for the relationship between strength exercises and athletic movement, and is essential for the design of strength training systems based on coordination.

Chapter 4 starts by considering whether strength training should follow a physiological rather than a coordinative track. An approach specifically based on physiological adaptation only makes sense in endurance sports in which coordination is less important. We then look at how non-linear control of overall contextual movements in which coordination plays a key role can limit production of force.

We then look at how non-linear control of movements in which coordination plays a key role, can limit production of force. Since force has a strongly coordinative component and motor control limits production of force, the laws of motor learning are important within strength training. Both motor control and motor learning processes are highly intention-based, and principles of intention-based learning in strength training are described. The importance of variation in the learning process is emphasized, and types of variable learning are described.

Chapter 5 looks at specificity and transfer. Specificity between different types of exercises is a precondition for transfer, since motor control develops through underlying matrices and exercises must conform to the structure of the matrix. The matrix is fine-meshed, and general categories of strength exercises such as maximal strength and generation of power are not subtle enough to cope with this. Strength training must therefore help to improve in performance through carefully described specificity. Six categories of specificity are identified, and their characteristics are described. To guarantee specificity, the design of strength training must meet many conditions – to ensure not only that strength training has a positive impact on athletic performance, but also that it does not have a negative impact.

One example, the function of hamstrings during running, is used to analyse how the specificity requirement is applied in strength training, and a rehabilitation protocol is drawn up on the basis of that analysis. The theory of attractors and fluctuators plays a key role here.

Chapter 6 discusses the counterpart of specificity: overload. Overload and specificity are opposites, and this is reflected in the central/peripheral model. The term 'overload' is highly quantitative, which is not how the learning system responds to training stimuli. The substitute term 'variation' implies a quantitative assessment that is more in keeping with the principles of motor learning. Using a qualitative assessment means that overload is no longer automatically equated with physical load. This means that heavy strength training is not necessarily the same as good training.

To provide meaningful variation in strength training, use is made of the constraints-led approach, involving variation in the task, the environment and the organism. In particular, variation in the organism by targeted use of fatigue is a new and relatively unused concept that may have major potential.

Chapter 7 translates all this into practice. The strength training system is based as much as possible on the contextual coordinative adaptations that will occur. This means abandoning

the standard division of types of strength. Categories such as strength endurance and explosive power are not dismissed as one-dimensional. Of the remaining categories, reflexive strength is not customary, but essential for all sports in which movements must be performed under time pressure.

Finally, the specificity system is applied to the theoretical concept of attractors and fluctuators. A systematic approach to relevant sport-specific strength exercises at the intramuscular level, at the level of elementary intermuscular cooperation and at the level of larger contextual movement patterns is discussed. An example is used to demonstrate how this can be translated into exercises.

The resulting book gives coaches and physical therapists (sports physiotherapists and others) tips for designing a coherent approach based on the laws of coordination. However, that does not mean that coaches and physical therapists no longer need to be creative – this is certainly needed when making the transfer from theory to the design of a tailor-made individual training plan.

Additional knowledge

Although the book is largely the result of thinking models, I have attempted to link up its content with what has been identified by researchers. In doing so, I have frequently made use of types of research that are seldom used when analysing how strength training works. Prior knowledge of these theories makes it easier to understand the text, and here and there it may be useful or even essential to consult other sources. In the context of this book, however, translating the information into practical situations is more important than a full mastery of the underlying theories.

Indeed, this translation to practice is the real challenge for scientific theorizing. However innovative and interesting some of these theories may be, the translation to practice is often rather disappointing, whereas there *are* major implications for practice – translation of theory may result in a substantially different approach to, say, training interventions and rehabilitation.

Chapter 1 describes the implications of dynamic systems theory. This theory is based on – or rather confirmed by – the work of Nikolai Bernstein. The word 'confirmed' is more appropriate here, for dynamic patterns theory had already developed to some extent in the Western world by the time Bernstein's work became known after the fall of the Berlin Wall. His manuscripts focused on the problem of degrees of freedom, including the role of variability, when identifying the structure of motor control. This is entirely in keeping with theorizing on complex biological and other systems, chaos theory and so on, which were being studied by researchers such as Kelso. These theories have a strong mathematical foundation. However, it is not necessary to know the underlying maths in order to understand this book. Understanding a number of exemplary elements of decentralized control, such as the meaning of the attractor-fluctuator landscape, preflexes and phase transitions is sufficient in order

to grasp the implications of these theories for functioning in practice. Readers who want to find out more about the relationship between motor skills and dynamic systems could look more closely at such topics as variability in movement and synergies in movement.

Chapter 3, for instance, provides a practical translation of dynamic patterns theory into analysis of open and closed skills. This analysis is the basis for distinguishing between the incidental and the generic in sporting movements, which in turn is a crucial starting point for positioning sport-specific strength training.

Chapter 2 looks at standard neurophysiology, which can easily be found (for purposes of further study) in numerous textbooks. This is also true (but less so) of knowledge about central pattern generators, about which relatively little is yet known, and knowledge of central governor (and related) theories, which are also in a relatively early stage of development.

Chapter 4 starts by elaborating on the practical implications of the dynamic systems theory discussed in Chapter 1. It then looks at theories on motor control and motor learning. A key basis is the intention-action model, which unfortunately can only found fragmentarily in texts on neurophysiology and motor control. Readers who want to find out more about it have no choice but to plough through the available literature. However, if this somewhat abstract model is translated into motor skills, we find a considerable body of literature on the role of attention in movement, with Gabrielle Wulf as the unmistakable champion of insights into internal and external attention. More detailed specification of the role of intention and attention in theories of feedback again yields a considerable body of literature that provides more in-depth information. However, this body of literature is still far from complete, as witnessed by the speculative additional reasoning in Chapter 4 in the direction of intrinsic feedback, which is result-oriented and for which no terminology is yet available.

To find out more about the role of variation in motor learning, readers are referred in particular to German research. More and more is now known about the role of variation in learning, but insight into the underlying mechanisms again means searching through the literature, partly in neurophysiology (e.g. on the role of chaos in the development of new neural networks) and partly in empirical studies (e.g. on the role of variation in elite athletes).

Chapters 5 and 6 offer alternatives to the standard classifications in training theory. Of course, knowledge of this standard training theory, on which there is substantial literature, makes it easier to read critically and weigh up the various factors – for training theory is not an exact science, but floats somewhere between science and belief.

Chapter 6 examines the constraints-led approach. This theory, founded by Newell, attempts to bring together the existing theories on motor control. After reading the associated literature, we can really only conclude that the theory has greater potential as an aid to translation into practical application than a model for explaining the underlying theoretical principles of motor control. The theory is rather 'linguistic', which may mean it will be unable to fulfil its promises.

The same basically applies to Chapter 7 as to Chapters 5 and 6. It is a translation into practice, which seeks an alternative to what is customary. Additional knowledge of what is customary is therefore extremely useful for a critical study of the potential of practice models.

Frans Bosch, October 2015