Sports Biomechanics
March 2012; 11(1): 120–122

Comment on "Use of deterministic models in sports and exercise biomechanics research" by Chow and Knudson (2011)

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(Received 6 November 2011; accepted 9 December 2011)

Introduction

In a recent issue of *Sports Biomechanics*, Chow and Knudson (2011) provided a comprehensive historical review and an update of the application and utility of deterministic models in both performance- and injury-related sports and exercise biomechanics research. They argued that these models, which were originally introduced and popularised by the late James Hay and his co-workers (e.g. Hay & Reid, 1988), could provide a much-needed theoretical basis for applied sports biomechanics research thereby helping sports biomechanists to *explain*, rather than merely *describe*, mechanical aspects of athletic performance and also limit the number of trivial studies being reported in the sports biomechanics literature. Although Chow and Knudson (2011) made some convincing and robust arguments in favour of the use of deterministic models in sports biomechanics research, there are a number of caveats that we believe need to be considered before adopting this approach.

Need for process-oriented approaches rather than product-oriented approaches

Perhaps the most important issue related to the practical application of deterministic models is that they are models of *performance* and not models of *technique*. That is, they are able to identify factors that are relevant to performance but not necessarily aspects of technique relevant to those factors (Lees, 2002). In other words, deterministic models typically tell us *what* performance parameters are important but not *how* these performance parameters are generated. For example, in the deterministic model of wheelchair discus throwing shown in Figure 3 of Chow and Knudson (2011), the angular velocity of the hand and the linear velocity of the wrist at release were identified as important factors in the generation of release speed. The latter variable was further decomposed into angular and linear velocity components of other more proximal segments and joints in the upper-body kinematic chain at the moment of release, which were, in turn, further sub-divided to describe various

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ISSN 1476-3141 print/ISSN 1752-6116 online © 2012 Taylor & Francis
http://dx.doi.org/10.1080/14763141.2011.650189

movement characteristics of earlier phases of the discus throwing motion. A major limitation of this model is that it does not specify how the body segments should interact to effectively transfer energy and momentum along the kinematic chain to maximise linear and angular velocities of the wrist and hand immediately before release. In principle, a range of different, but equally functional, coordinative movement patterns could be used to produce similar performance parameter values—a phenomenon known in the motor control literature as motor equivalence (Lashley, 1930). Moreover, both the performance parameters and the inter-segmental coupling relationships are, to some extent, influenced by the confluence of interacting constraints impinging on performance (Newell, 1986). It would appear, therefore, that biomechanists must look towards more holistic, process-oriented approaches rather than rely on the reductionist, product-oriented approach of deterministic models to understand more about the underlying coordinative movement patterns.

Use of qualitative analytical techniques

One method of increasing understanding of the coordinative movement patterns that underpin performance parameters is to apply various qualitative analytical techniques. By qualitative, we do not mean the observation and subjective evaluation of movement sequences, as is its traditional meaning in sports biomechanics (Knudson & Morrison, 2002), but rather the study of geometric properties of movement as disclosed, for example, by the application of topological dynamics (McGinnis & Newell, 1982; Newell & Jordan, 2007). Qualitative (topological) techniques have a long tradition in mechanics, dating back to the pioneering work of Henri Poincaré, and they form the basis for many of the coordination measures (e.g. continuous relative phase, vector coding, etc.) that have been developed and applied in human movement science over the past few decades. In our view, sports biomechanists need to explore alternative methodological approaches that are based on these qualitative analytical techniques, such as coordination profiling (Button et al., 2006), and research designs, such as multiple single-participant analyses (James & Bates, 1997), which could assist in establishing formal associations among coordinative movement patterns and performance parameters thereby helping to distinguish between functional and dysfunctional aspects of technique for specific individuals.

An alternative theoretical framework for applied sports biomechanics research

As noted by Chow and Knudson (2011), deterministic models have been used in sports biomechanics research for the past three decades but yet during this period they acknowledge that very little progress has been made in terms of developing a theoretical basis for applied sports biomechanics research. Although deterministic models are putatively based on the well-established principles of mechanics, it could be argued that they may have contributed, at least in part, to this lack of advancement and that sports biomechanists must explore alternative theoretical frameworks that may offer greater explanatory power. Dynamical systems theory has previously been identified as a viable theoretical framework for applied sports biomechanics research (Glazier et al., 2003; Glazier et al., 2006) and could provide a useful adjunct to the more traditional paradigm of deterministic modelling. Whereas deterministic models are able to identify *what* variables are most related to performance, dynamical systems theory, in conjunction with the coordination measures described above, could help explain *how* changes in these variables occur. Dynamical systems theory has already provided meaningful insights into theoretical (e.g. Glazier & Davids, 2009) and applied (e.g. Hamill et al., 1999) issues in sports biomechanics and has also made a significant contribution to the development of the related sub-discipline of sports performance analysis (Glazier, 2010; Glazier & Robins, in press).

Summary

Although deterministic models may provide a useful starting point for sports biomechanists examining the mechanical aspects of athletic performance, they have inherent weaknesses that limit their practical application. Specifically, their inability to provide substantive information about coordinative movement patterns or 'technique' suggests that sports biomechanists must explore alternative paradigms and theoretical frameworks if they are to fulfil their main aims of improving performance and reducing injury risk. We believe that dynamical systems theory and its associated analytical tools can provide a useful adjunct to more traditional paradigms in sport biomechanics, such as deterministic modelling, which have only made a limited contribution to the enhancement of knowledge.

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