MOTOR VARIABILITY AND SKILLS MONITORING IN SPORTS

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The aim of this paper is to present a brief review of the role that movement variability plays in the analysis of sports movement and in the monitoring of the athlete's skills. Motor variability has been traditionally considered an unwanted noise to be reduced, but recent studies have revalued its role and have tried to understand whether it may contain information about the neuro-musculo-skeletal organisation. Issues concerning both views, different approaches to variability, open questions and future perspectives will be discussed.

KEY WORDS: movement variability, motor skills, performance, entropy, coordination.

INTRODUCTION:

The study of movement variability has been gaining increasing interest in the sports biomechanics community. In the last five years at the International Society of Biomechanics in Sport meetings there have been two "Dyson" lectures (Bartlett, 2005; Hamill et al., 2006), several keynote talks (e.g. Bartlett, 2004; Hamill et al., 2005; Wilson, 2009), and an applied session (at ISBS 2009), that have evidenced the importance of motor variability (MV) and coordination variability (CV) in the analysis of sports movements.

Despite the efforts spent by researchers, many issues concerning the variability of human motion are still to be thoroughly addressed and/or are waiting for comprehensive explanations. Among them, for example: the meaning of MV; the information MV may provide; the possible relations between MV and performance or between MV and the acquisition/development of motor skills. Furthermore, variability is fundamental in the definition of the experimental design and may influence the validity of the obtained results.

This paper presents a report about the role that MV and/or CV may have in the process of monitoring the athlete's biomechanical qualities. In particular, attention will be focused on the importance that movement variability has in the attempt of describing motor skills.

MONITORING ATHLETIC SKILLS: THE DUAL NATURE OF MOVEMENT VARIABILITY

Motor skills represent the ability to obtain a predetermined outcome with a high degree of certainty and maximum proficiency (Schmidt & Lee, 2005; Newell & Ranganathan, 2009). Hence, the process of learning or improving sports skills involves the capability of producing a stable performance under different conditions: only repeated motor performance reflects mastery in carrying out a desired task.

According to this definition and thinking of some of the biomechanists' principal aims – e.g. describing the athlete's kinetic and kinematic peculiarities, evaluating the correctness and proficiency of their movement, preventing possible injuries – MV may emerge as an unwanted drawback that should be eliminated or at least reduced. In fact, when trying to capture the biomechanics of individual technique, research should depict the core strategy that governs the movement, regardless of the variations that emerge across repetitions.

Nevertheless, MV always occurs when the same action is repeated and even the elite athlete cannot reproduce identical motor patterns. MV is inherently present throughout the multiple levels of movement organisation. It remarkably manifests not only between but even within individuals and may be associated to the extreme complexity of the neuro-musculo-skeletal system and to the redundancy of its degrees of freedom (e.g. Newell et al., 2006; Bartlett et al., 2007). MV may not correspond only to randomness but also to functional changes whose investigation might unveil information about the system health, about its evolutions, and about its flexibility and adaptability to variable external conditions (Hamill et al., 1999; Bartlett et al., 2007).

Therefore MV possesses a dual connotation. (1) It is an impediment that obstacles a straight description of the actual individual status through standard approaches. Moreover, it hinders the detection of the small inter-individual differences or intra-individual changes that often characterise the sports field. At the same time, (2) it is the reflection of inherent proprieties of the neuromuscular system and may contain important information that should not be neglected.

MOVEMENT VARIABILITY AS NOISE

According to the conventional control theory approach, movement variability is made equal to noise (Equation [1]) that prevents the final output from matching the planned program (Bartlett et al., 2007; Bays et al., 2007). The noise may corrupt the different levels of motor organisation (V_{eb}, i.e. errors in the sensory information and in the motor output commands) and may be caused by the changeable environmental conditions (V_{ee}) or by measuring and data processing procedures (V_{em}).

[1] $$V_e = V_{eb} + V_{ee} + V_{em}$$

This view of MV has important implications for the investigation of sports skills and leads to the need for proper experimental designs and data reduction (Bartlett et al., 2007). MV should be assessed before proceeding with any kind of biomechanical assessment and a full analysis of an individual's motor behaviour should involve the evaluation of an appropriate number of repetitions (e.g. Bates et al., 1992; Rodano & Squadrone, 2002; James et al., 2007; Preatoni, 2007). The selection of a single representative trial may be arbitrary and results derived from analyses of such performances may be misleading (Bates et al., 1992). While several researchers have thoroughly investigated the reliability of normal walking variables, relatively fewer studies have been conducted to assess the variability of kinematics and kinetics in sports movements (Preatoni, 2007). This lack is amplified by the huge variety of motor tasks that are performed by athletes in many different sports disciplines. The effective trial size needed to depict a representative biomechanical behaviour likely depends on the activity, on the subject and on the variable under investigation (e.g. Bates et al., 1992; Rodano & Squadrone, 2002; James et al., 2007; Preatoni, 2007). For example, by studying race walking and vertical jump exercises in a population of high-level athletes, Preatoni (2007) and Rodano & Squadrone (2002) found that 11–16 repetitions were necessary to obtain stable estimates for kinematic and kinetic parameter.
The use of suitable statistics is also necessary to obtain a meaningful summary of the collected parameters or curves, in order to discover the most typical features and to predict whether a pattern is representative for the athlete's skill description or not. Non-parametric estimates of central tendency and spread appear to be more robust to the presence of outliers (Chau et al., 2005; Preatoni, 2007).

MOVEMENT VARIABILITY AS INFORMATION

Recent investigations have supported the idea that inter-trial variability (V_{tot}) does not correspond to noise only, but is a combination (Equation [2]) of random fluctuations (i.e. error, V_e – Equation [1]) and functional changes that may be associated with properties of the neuromotor system (V_{nl}) (e.g. Hamill et al., 1999; Bartlett et al., 2007):

[2] $$V_{tot} = V_e + V_{nl}$$

V_{nl} may be interpreted as the flexibility of the system to explore different strategies to find the most proficient one among many available. This flexibility allows for learning a new movement or adjusting the already known one by gradually selecting the most appropriate pattern for the actual task (e.g. Dingwell et al., 2001; Riley & Turvey, 2002). The subject is thus able to gradually release the degrees of freedom that have been initially frozen to gain a greater control over an unfamiliar situation (e.g. Hamill et al., 2005; Newell et al., 2006). Changes in the contributions of V_e and V_{nl} to the total variability may be related to changes in motor strategies and may thus reveal the effects of adaptations, pathologies and skills learning (e.g. Dingwell et al., 2001; Bartlett et al., 2007).

The conventional approaches to the issue of MV only quantify the overall variability, but are not effective in evaluating the information MV conveys. The use of nonlinear dynamics tools (e.g. entropy measures) or the analysis of coordinative features (e.g. continuous relative phase) represent alternative instruments to explore the nature of motion variability or its relation with performances, skills or injury factors. Only recently and only a few authors have used these methods to investigate MV in sports and in elite athletes in particular.

Preatoni et al. (2007; 2010-under review) studied the nature of MV by measuring sample entropy in kinematic and kinetic variables during race walking. Their results confirmed that MV is not only random noise but also contains information about the neuromuscular organisation. Possible changes in variability across the individual's testing session were also analysed. Results suggested that the structure of variability appears invariant and that no adaptation effects emerge when a proper experimental protocol is followed. Other authors have focused their attention on injury factors (e.g. Hamill et al., 1999; Hamill et al., 2005) or on coordinative patterns (e.g. Seay et al., 2006), by studying the variability in phasing relationships between different elements of the locomotor system (body segments or joints). Fewer works have concentrated their attention on the relation between sports skills and MV/CV, with practical implications for performance monitoring and training purposes. Wilson et al. (2008) studied how coordination variability changes in relation with skills development in the triple jump. Preatoni et al. (2007; 2008; 2010-under review) reported different levels of entropy, in selected variables, between elite and high-level race walkers. Furthermore, Preatoni et al. (2007; 2008; 2010-under-review) and Donà et al. (2009) evidenced how advanced methodologies may be an important means for finely investigating individual peculiarities – e.g. subtle changes over time that may be due to underlying pathologies – when no apparent changes occur at a macroscopic level.

CONCLUSION

Similar performances in sporting events are often the result of different motor strategies, both within and between individuals. These subtle discrepancies are typically less detectable than the ones that emerge in clinical studies, and are often concealed by the presence of variability. Hence, the conventional use of discrete variables or continuous curves may be ineffective, while the study of movement and/or coordination variability may make important neuro-musculo-skeletal features emerge.

This paper has briefly presented the "double" role that motion variability plays in the analysis of sports movement, being concurrently a limitation and a potentiality. Regardless of the point of view from which we look at MV, many efforts are still needed to gain a more thorough insight into this issue. In fact, for example, there is still lack of: (1) reference values and database, that could help in the interpretation of MV/CV in sports; (2) knowledge of the relations between causes (e.g. detrimental behaviours, motor learning) and effects (e.g. changes in the analysed variables or indexes) (Hamill et al., 2005; Bartlett et al., 2007; Preatoni, 2007); (3) integration between the outcomes of the different methods of investigation; (4) ability in translating complex approaches and results into suitable information that may be easily read as feedback and thus applied on the field.

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