APPROACHES FOR OPTIMISING JUMPING PERFORMANCE

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The ability to maximise jumping performance can be a critical factor for success in sport. This paper presents a number of studies which have looked at optimising or enhancing jumping performance. The first of these is a computer simulation study which addresses the need for model constraints when optimising high jumping performance. The second study investigates the role of coordination variability in elite triple jumping performance and the final study investigates the effectiveness of training drills in maximising performance in the triple jump.

KEYWORDS: jumping, performance, optimization

INTRODUCTION: Jumping activities are required in many sporting situations and therefore the ability to optimise jumping performance is a key element in performance enhancement. This paper presents different approaches to studying jumping activities in an attempt to optimise or enhance performance. The areas of simulation modelling, motor control and learning and the application of biomechanical principles to training theory are addressed.

SIMULATION MODELLING: When using simulation models to optimise performance care must be taken to avoid obtaining unrealistic solutions. Specifically, in the optimisation of high jumping performance, simply maximising the peak height reached by the centre of mass may result in a theoretical simulation that is inaccurate since various factors will have been neglected. Wilson et al. (2007) investigated the effects of imposing various constraints on optimisations of high jumping. An eight segment simulation model of the contact phase in running jumps for height was developed (Figure 1). The model was torque driven and contained wobbling masses to represent the soft tissue movement within the human body. Following evaluation, the model was used to maximise the height reached by the centre of mass in a series of optimisations with various constraints imposed. The constraints took into account the technical requirements of the skill, the anatomical range of motion and the robustness or consistency of the performance.

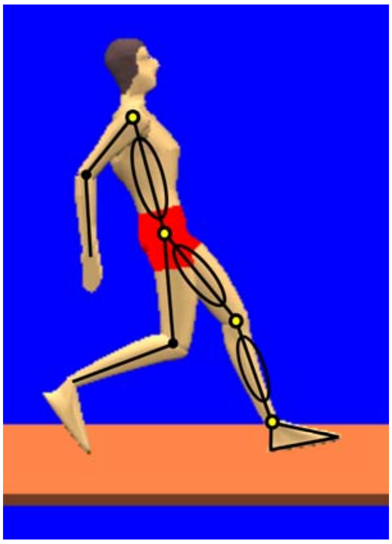

Figure 1. Eight segment model

With no constraints imposed the jump height was unrealistically high when compared to the personal best of the subject to whom the model was specific. By introducing the constraints sequentially, the height reached by the centre of mass was reduced incrementally. The height reached by the centre of mass when all constraints were imposed was very similar to the height achieved in the actual performance against which the model was evaluated. These results highlighted the need for the consideration of (i) technical requirements of the skill, such as the angular momentum at take off, so the performance is representative of an actual performance (ii) the anatomical ranges of movement so the performance is not likely to result in injury and (iii) consistency of performance which is crucial in elite sport. Future work will focus on use the model with constraints to investigate the effect of changes in different parameters or variables on jumping performance.

COORDINATION VARIABILITY AND SKILL DEVELOPMENT: The study of Wilson et al. (2007) highlighted the need for consistency of performance and therefore the need for the system (body) to be able to adapt to small changes or perturbations which may occur during a performance. Coordination is the relationship between the movements of limb segments and the variability of this coordination has been considered to be an essential element to normal healthy function offering flexibility in adapting to perturbations (Hamill et al.,1999). In contrast to this and from a traditional motor learning perspective, variability has been considered to be noise leading to an inconsistent performance. Wilson et al. (2008) investigated how coordination variability changes as a function of skill in the triple jump. Specifically we studied how lower extremity intra-segmental coordination variability in the hop-step transition of the triple jump changes as a function of the skill level in expert performers and how skill level influences the nature of the coordination variability present in the system.

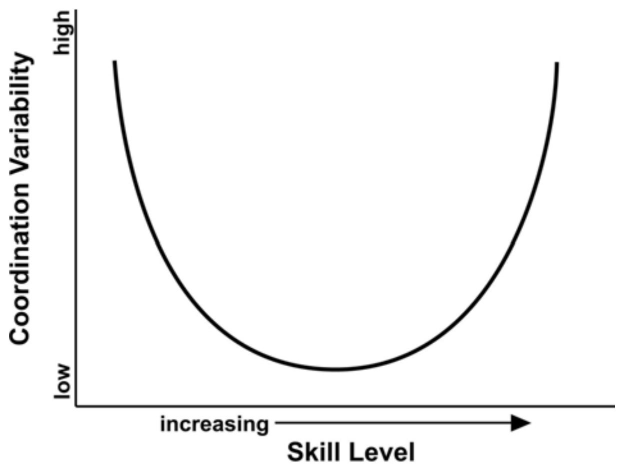

Figure 2. Proposed U-shape profile of coordination variability

The results from this study are consistent with a U-shaped change in the coordination variability, present in a system, as skill increases in expert performers (Figure 2). From a dynamical systems perspective, it has been suggested that the coordination variability in a system allows the flexibility to adapt to perturbations and this can be used to explain the higher coordination variability in the participants with the highest skill. The higher coordination variability found in the participant with the lowest skill compared to the participants with intermediate skill can be explained from a traditional motor learning perspective. This higher level of coordination variability found in the participant with the lowest skill may be surprising considering all the participants are classed as expert and likely to be in the third stage of learning according to Newell's (1985) hierarchy of the stages of learning. It may, however, be the case that even apparently high level performers go through a U-shaped change in coordination variability as skill develops. One such explanation for this is the complexity of the movement being developed. The ability of participants to integrate the three phases of the triple jump into a coordinated process may be similar to that when learning a new movement. The ability to access functional variability that allows the athlete to cope with perturbations, which could be present due to environmental or task constraints, may be indicative of a highly skilled jumper. The reduced level of variability displayed by the intermediate performers may be an indication of the ability to produce a consistent performance without necessarily being able to adapt to perturbations. Differences in coordination variability could be due to individual coordination strategies.

SPECIFICITY OF TRAINING PRINCIPLE: As intimated by Wilson et al. (2008), the study of the individual coordination strategies, in addition to the coordination variability, may provide a more holistic analysis of jumping performance. The use of training drills have previously been used in the development of complex movements, whereby coaches use the concept of specificity to encourage performance-related adaptations (Irwin, Hanton & Kerwin, 2004). As well as developing a complex movement, training drills may also be used to develop and improve movements when the full skill places very high loads on the body and where repetitions should be limited. Quantifying the similarity between a skill such as the triple jump and training practices or drills in terms of coordination patterns rather than single joint kinematics may provide a better overall assessment of their effectiveness as a training drill (Irwin & Kerwin, 2007). The ground contacts preceding the hop, step and jump phases in the triple jump largely determine the flight distance within each phase and it has been suggested that the transition, or contact, between the hop and step phase is the most critical element in successful triple jump performance (Jurgens, 1998). The demands placed on the body during the triple jump are very high with vertical forces of around 18 body weights experienced during the contact between the hop and step phases (Perttunen, 2000). Activities with such high demands might therefore have implications for injury and coaches should ensure that the number of repetitions are limited. The purpose of the study by Wilson et al. (2009) was to examine the differences between the triple jump and four plyometric drills (2 static and 2 dynamic), that are employed in training, in terms of the coordination strategies adopted by the lower extremities during the hop-step transition phase. The similarity between the drills the triple jump was assed using coupling angles quantified through the use of vector coding. Three coupling angles were investigated; ankle flexion/ext – knee flex/ext (stance), knee flex/ext – hip flex/ext (stance) and knee flex/ext – hip flex/ext (swing). For each coupling, a two-way repeated measures analysis of variance (ANOVA) was employed (trial main effect; phase main effect; trial – phase interaction effect) to investigate any differences in movement coordination patterns between jump and drill trials.

Table 1. Interaction effects from an ANOVA for differences in coupling angles (C1-C3) between the phases of the triple jump and drills (D1-D4)

	Coupling 1 ankle flex/ext – knee flex/ext (stance) [º]	**Coupling 2** knee flex/ext – hip flex/ext (stance) [º]	**Coupling 3** knee flex/ext – hip flex/ext (swing) [º]
Drill 1 static hop-step	p = 0.282	**p = 0.046***	**p = 0.032***
Drill 2 dynamic hop-step	p = 0.465	p = 0.499	P = 0.055
Drill 3 static raised hop-step	p = 0.871	p = 0.159	**p = 0.032***
Drill 4 dynamic raised hop-step	p = 0.996	p = 0.289	p = 0.200

*Significant interaction effects are displayed in bold.

The results of this study show that the dynamic drills are more similar to the triple jump than static drills and that replication of the coordination strategies adopted in the stance leg are better than in the swing leg. Therefore, if the primary purpose of the training drills, as suggested by coaches, is to replicate the movement patterns used in the triple jump then coaches should encourage the use of the dynamic drills. In addition, more attention should be given to the swing leg given previous studies have highlighted the importance of free limbs in jumping activities (Yu & Andrews, 1998).

DISCUSSION: The studies presented have all sought to optimize or enhance jumping performance. They have highlighted key components of jumping activities which may contribute to performance enhancement as well as important considerations for future studies.

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