

CHANGES IN COORDINATION VARIABILITY WITH SKILL DEVELOPMENT IN EXPERT PERFORMERS

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The purpose of this study was to investigate the influence of skill level, in triple jumping, on the coordination variability of lower extremity intra-segmental couplings. Relative motion plots and a modified vector coding technique were utilised to quantify the coordination variability across the trials. The results suggest that coordination variability in expert performers follows a U-shape curve as skill level increases. Higher levels of coordination variability were observed in the most and least experienced performers with relatively lower levels observed in the subjects with moderate levels of experience. This study has highlighted the need for addressing the learning effect when analysing coordination variability from a dynamical systems perspective.

KEYWORDS: joint coupling, triple jump, performance

INTRODUCTION:

Coordination emerges from constraints imposed on the DOF of the system associated with the individual, the task and the environmental dynamics (Newell, 1986). In order to produce coordinated movement patterns the characteristics that define these patterns need to be acquired. From a motor learning perspective, whilst in the early stages of learning or developing a movement the search for the appropriate characteristics may result in an inconsistent performance with high coordination variability whereas once a skilled performance has been achieved the ability to optimally refine these characteristics will likely result in a consistent performance with low coordination variability. From a dynamical systems perspective variability, which has traditionally (and from a motor learning perspective) been considered to be noise and detrimental to normal function, is considered to be an essential element to normal, healthy function thus offering flexibility in adapting to perturbations (Hamill et al., 1999). Variability in movement is particularly important in many sport skills in which the adaptability of complex motor patterns is necessary within dynamic performance environments (Button et al., 2006). The triple jump is a complex sporting movement consisting of three separate, yet integrated phases and it has been suggested that the transition between the hop and step phase is the most critical element in successful triple jump performance (Jurgens, 1998). As each phase is affected by the preceding phases, it might be expected that the ability of the coordinative units to adapt to perturbations is crucial if the performer is to consistently achieve successful performances. The purpose of this study was, therefore, to determine 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.

METHOD:

Five competitive triple jumpers (three males and two females) with experience levels ranging from one year to seven years were recruited as subjects for this study. All of the subjects were members of the same training group and had the same coach. Using a 12-camera Vicon™ MX13 motion analysis system, three-dimensional kinematic data were collected during the hop-step transition phase of triple jump performances. Simultaneously, ground reaction force data were sampled at 1000 Hz using a Kistler force platform. Thirty-nine retro-reflective spherical markers of 14 mm diameter were attached to specific anatomical landmarks on the subject for use with the Plug-In-Gait model (Vicon™, Oxford Metrics Ltd.,

Oxford, UK). Each subject performed a total of 10 trials. Coordinates for each of the 39 reflective markers were reconstructed using Workstation software (version 5.2.4, Oxford Metrics Ltd., Oxford, UK). Lower extremity joint angles were subsequently calculated. The frames associated with touchdown and toe-off of the hop-step transition phase for each trial were established using the ground reaction force data and a force threshold of 20 N. The angle data between touchdown and toe-off were then interpolated using a cubic spline with touchdown at 0% and toe-off at 100%. Relative motion (angle-angle) profiles and a modified version of the vector coding technique were used to quantify the joint coordination patterns (Heiderscheit et al., 2002). Intra-limb couplings were created for ankle flexion–knee flexion (coupling 1) and knee flexion–hip flexion (coupling 2) of the stance leg and knee flexion–hip flexion of the swing leg (coupling 3). These couplings were chosen on the basis of the importance of knee flexion–extension of the support limb and the use of the free limb during triple jump performances. Relative motion plots were created for each coupling with the abscissa and ordinate comprising the proximal and distal segments respectively. Coupling angles were calculated using the orientation of the resultant vector to the right horizontal between two adjacent points on the relative motion plots. Following conversion from radians to degrees, the resulting range of values for the coupling angles was between 0° and 180°. The standard deviation of coupling angles across trials was calculated for each percent of the stance phase, providing a measure of between trial and within subject coordination variability. This procedure was repeated for each intra-limb coupling. The mean standard deviation between trials across the whole of the stance phase was determined for each subject for coupling 1, coupling 2 and coupling 3.

RESULTS:

The personal best (PB) performance of each subject was calculated as a percentage of the respective world record (WR). The correlation between the level of ability and experience level was $r^2 = 0.97$. This supports the definition of skill level used in this study. The mean coordination variability across the whole of the stance phase for each subject for coupling 1 (C1), coupling 2 (C2) and coupling 3 (C3) are presented in Figure 1.

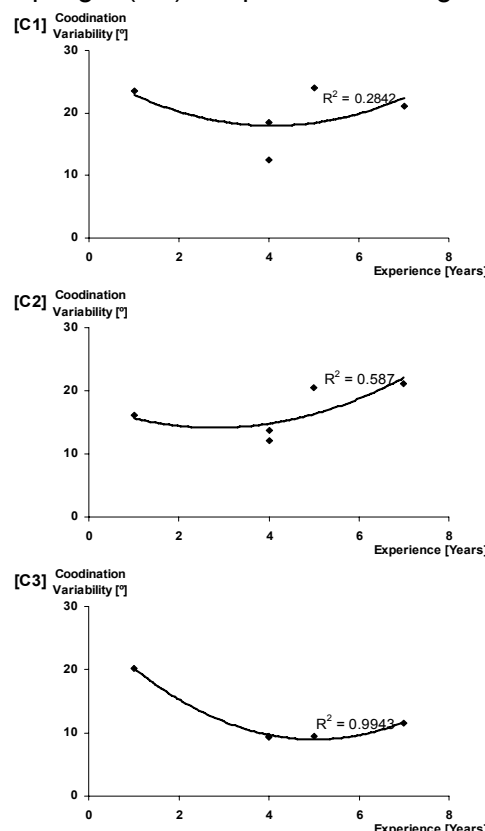


Figure 1. Mean coordination variability across trials for each subject in each of couplings, C1, C2, C3.

For all three couplings, the two subjects with moderate experience (four years experience) displayed the least coordination variability. In coupling 1 (ankle flexion-knee flexion of the stance leg), the subjects with the least and most experience (e.g. one, five and seven years experience) all displayed similar levels of coordination variability. In coupling 2 (knee flexion-hip flexion of the stance leg) the subjects with most experience showed the highest levels of coordination variability whereas in coupling 3 (knee flexion-hip flexion of the swing leg) the subject with least experience showed the highest levels of coordination variability.

DISCUSSION:

From a dynamical systems perspective, it has been suggested that the coordination variability in a system allows the flexibility to adapt to perturbations (Hamill et al., 1999) and this can be used to explain the higher levels of coordination variability in the subjects with the highest level of experience. The higher level of coordination variability in the subject with least experience compared to the subjects with moderate experience does not support this hypothesis. The lack of support for the hypothesis can be explained from a motor learning perspective. A requirement in the early stages of motor learning is the acquisition of the appropriate characteristics that define coordination (Newell, 1985). This may suggest that individuals at this stage of learning are searching for the appropriate coupling characteristics on an almost trial and error basis which may explain the higher levels of coordination variability observed in this study. The lower coordination variability displayed by the subjects with moderate experience may also be a result of the stage of developing the movement. From Newell's (1985) hierarchy of the stages of learning, after acquiring the appropriate characteristics that define coordination, further practice will lead to the refined scaling of these characteristics. At this intermediate stage of skill development, the refinement process may lead to only small changes in these coordination characteristics and therefore perhaps a more consistent performance. From a dynamical systems perspective, the coordination variability present in the system allowing flexibility may not yet have been accessed. In coupling 3, the coordination variability was highest for the subject with least experience whereas, for the subjects with most experience, the coordination variability levels were only slightly higher than for the subjects with moderate experience. Whilst the explanation for the high levels of coordination variability for the subject with least experience remains the same, one explanation for the lower coordination variability for the two most experienced jumpers is that the flexibility needed in the system is much lower for the swing leg than the stance leg. The perturbations which occur in the swing leg may be expected to be lower and, therefore, a more consistent movement coordination pattern can be adopted as high flexibility of the system is unnecessary. With the stance leg however, the two most experienced subjects may have been able to access the functional variability needed to cope with the perturbations which will occur due to the impact and transitional phases experienced. The results from this study suggest that during skill development in expert performers the coordination variability present in a system follows a U-shape profile. In the early stages of skill development coordination variability is high and this decreases as the movement is refined. As the performer becomes more skilled, movement coordination variability increases accordingly (Figure 2). This profile aids in the explanation of the role of coordination variability in movement which is crucial if a better understanding of coordination variability is to be gained. During the initial stages of developing the movement, the high coordination variability present may be detrimental resulting in an inconsistent performance. As the movement is refined this negative coordination variability is reduced coinciding with a more consistent or regulated performance. The results of this study suggest that the increases in coordination variability in subjects with higher levels of skill may be associated with increases in functional variability. Thus coordination variability in more skilled performers behaves as a beneficial adaptive mechanism that responds to perturbations to produce a robust solution (Hamill et al., 2006; Wilson et al., submitted).

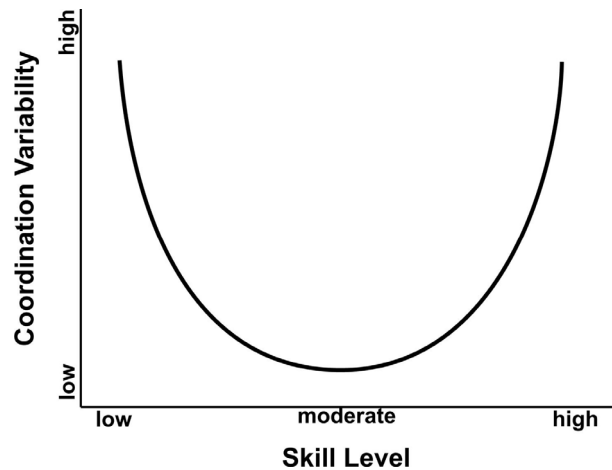


Figure 2. Proposed U-shape profile of coordination variability

CONCLUSION:

This study has proposed a relationship between coordination variability and skill level in expert performers whilst attempting to examine the role of coordination variability within the process of skill development. This study has highlighted the need for addressing the learning effect when analysing coordination variability from a dynamical systems perspective

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