WITHIN SUBJECT VARIABILITY ANALYSIS REVEALS A TRANSITION POINT FOR THE LONGSWING ACROSS AGE GROUPS

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This research aimed to observe changes in the within subject variability of the longswing performance and coordination across age groups in gymnasts divided by their competition level, from younger (group 1) to experts (group 5). Data were collected by two video cameras. Performance and coordinative within subject variability were calculated by the standard deviation (inter-trial variability) and the deviation phase (intra-trial variability). Results only showed significant group differences for within subject variability (inter- and intra-trial) in the SD P3H-P3S. In addition, group 4 (14.78±0.57 yrs) showed both large inter-trial variability in the upswing shoulder flexion (P3) and large intra-trial variability during hip and shoulder extension (P2) and P3. Such large variability in group 4 suggests a transition point towards the experts´ performance and coordination (19.96±3.37 yrs).

KEYWORDS: motor learning, performance, coordination, gymnastics.

INTRODUCTION: An effective motor strategy (performance and coordination) should to be discovered during the process of skill acquisition. Coordination has been defined as the stable spatial-temporal relationship among limb segments or joints to achieve the task's goal (Irwin & Kerwin, 2007). Discovering new modes of coordination may involve undergoing a transition from one stable form of coordination to another (Handford et al., 1997). High within subject variability is characteristic of a system in transition (Clark & Phillips, 1993). It was suggested that within subject variability conforms to a U-shaped graph as a function of skill progression (Wilson et al., 2008), because high within subject variability were observed in beginners as well as experts. Sport skills represent an ideal situation to assess changes in performance, coordination, and within subject variability at different levels of expertise. The 'regular' longswing on high bar in gymnastics was selected as the focus of our research because this skill is identified as a fundamental basic skill (Irwin & Kerwin, 2007). The principal aim of this study was to assess changes in the within subject variability of the longswing performance and coordination across different competition age groups. Additionally, the U-shaped fit of the within subject variability across the groups was analyzed.

METHOD: Five competition age groups: group 1 (8.92±0.85 years); group 2 (11.08±0.67 years); group 3 (12.88±0.50 years); group 4 (14.78±0.57 years), and group 5 (19.96±3.37 years) were used to classify participants (113 male gymnasts). All participants gave informed consent. The study was approved by the local ethics committee.

We defined 3 events independently for hip (H) and shoulder (S) angle joints (Figure 1): the smallest angle during downswing (P1H, P1S); the largest angle after P1 (P2H, P2S); and the smaller angle during upswing (P3H, P3S). We focused our study in P2 and P3 given that functional phases of the longswing are defined by these events (Arampatzis & Brüggemann, 1999). The total maximum elevation of the center of mass on the downswing, initial position (Pi), and the maximum elevation on the upswing, final position (Pf), were used to infer the total path of the swing and defined as swing amplitude (Figure 1). Participants were asked to perform ten consecutive swings from a quiet starting swing position under the bar. They were filmed with two digital video cameras located on the participant's right side and in front of them describing a 90 degrees angle between their optical axes. The best three consecutive swings, selected qualitatively by an expert coach, were analyzed for each participant. The videotaped images captured at 50 Hz were manually digitized (Kwon3D, Young-Hoo Kwon & Visol, Inc). Flexion-extension angular displacement and velocities for the hip and shoulder in the sagittal plane were computed. Body position angle was defined as the angle formed by the line connecting the center of mass with the middle of the grasping hand and the vertical (z-axis) (Arampatzis & Bruggemann, 1999) (Figure 1). We calculated the location of the center of mass differently depending on the gymnast age (Jensen & Nassas, 1988; Jensen, 1989; De Leva, 1996).

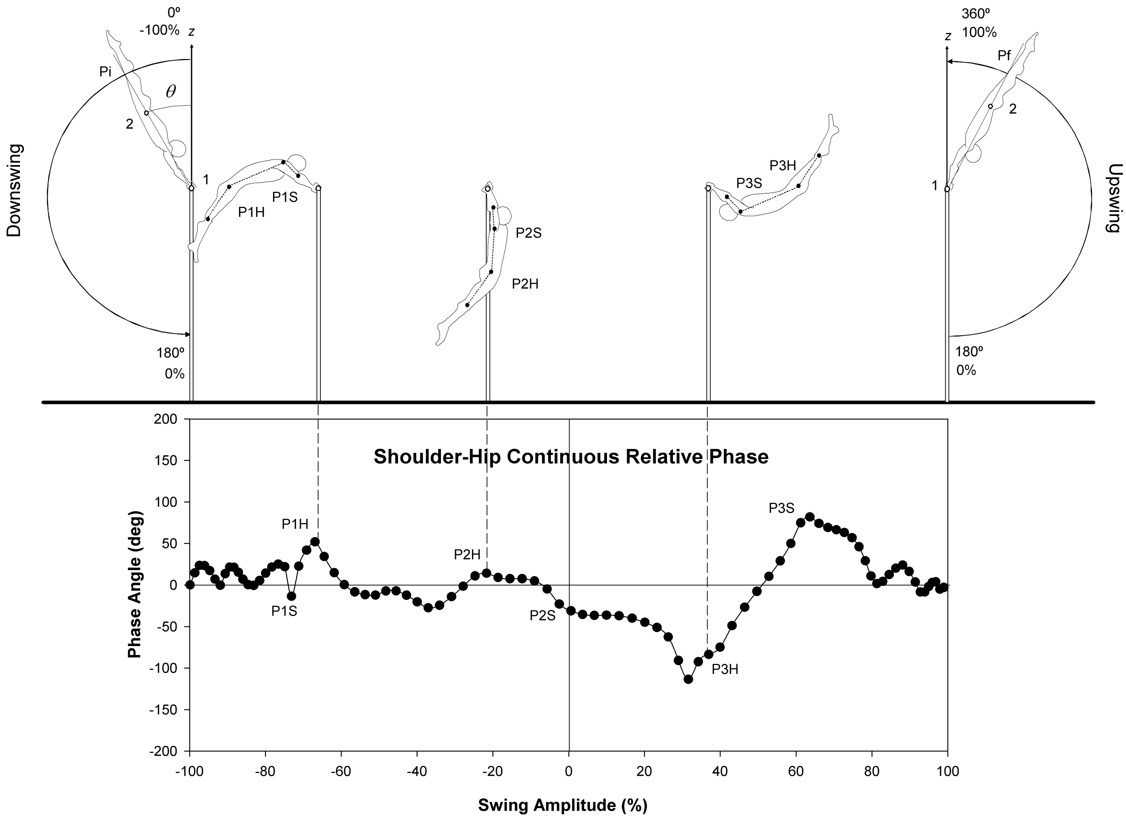

Figure 1. In the upper section, swing amplitude defined in reference of the body position angle (θ) delimited by z axis, middle grasping hand landmark (1) and the center of mass (2). Additionally, we illustrated the initial position (Pi), final position (Pf) and swing events (P1, P2, and P3) from the hip (H) and shoulder (S) joints. In the lower section, the continuous relative phase between the hip and shoulder joints during a longswing of an expert gymnast (group 5) is represented. For simplicity, H and S events have been represented at the same instant of time for P1-P3 in the upper section.

Performance was described by swing amplitude and events, while coordination was assessed using the inter-joint reversal points (P1H-P1S, P2H-P2S, and P3H-P3S) and the absolute difference in the continuous relative phase between contiguous events of the two joints. Each continuous relative phase was obtained by subtracting the phase angle of the distal joint (hip) from that of the proximal (shoulder) (Clark & Phillips, 1993; Hamill et al., 1999). In turn, the phase angle (φ_i) was calculated from the normalized angular displacement (θ) and angular velocity (ω) using $\varphi = \tan^{-1}(\omega / \theta)$. In Figure 1 (lower section), the continuous relative phase of an expert gymnast was depicted for a longswing in high bar. Relative phase around -20% was close to 0º indicating that the hip and shoulder moved in synchrony or they did not move remaining with the same angle values. This in-phase relationship became clearly out-of-phase led by hip flexion around 30%. Around this point in the upswing, the hip achieved the maximum flexion (P3H). Subsequently, the coordination changed faster to a positive out-of phase mode led by the shoulder's flexion while the hip initiated slower its extension. Performance and coordination within subject variabilities were assessed in two different ways: inter-trial variability (standard deviation between the trials of the participants, SD) and intra-trial variability (coordination changes within the trial described by the deviation phase, DP).

One-way ANOVAs were used to examine differences across the competition age groups in standard deviation and deviation phase. Tukey post-hoc comparisons between groups were conducted when appropriate. Statistical significance was set at $p<.050$ level; however, p values between .050 and .100 were also discussed. When normal distribution (Kolgomorov-Smirnov test) and homogeneity of variance (Levene test) were verified, parametric statistics were used; else non-parametric test were used. All tests were performed with Systat 11.0 and SigmaStat 3.1 (Systat Software, Inc., San José, CA, USA).

RESULTS: Results of this study found group differences in the SD P3H-P3S ($H=9.47$, $p=.050$). Despite pair comparisons not yielding significance, it's important to notice that group 2 and group 3 had more consistency than the other groups. The intra-trial variability variables (DP P2H-P2S and DP P3HP3S) did not show significant differences between the competition age groups; however, both variables showed a tendency to differ between groups (DP P2HP2S: $H=9.26$, $p=.055$; and DP P3H-P3S: $F_{4,334}=2.15$, $p=.074$). Compared to group 1-group3, deviation phase in P2 was larger for group 4 and smaller for group 5 (Figure 2e), while deviation phase in P3 was higher for the group 4 and group 5 (Figure 2j). As seen in Figure 2, group means of the inter-trial variability in P2 had a better U-shape fit than in P3 variables. Interestingly, group 4 showed the largest within subject variability in all P3 variables except SD P3H compared to the rest of the groups.

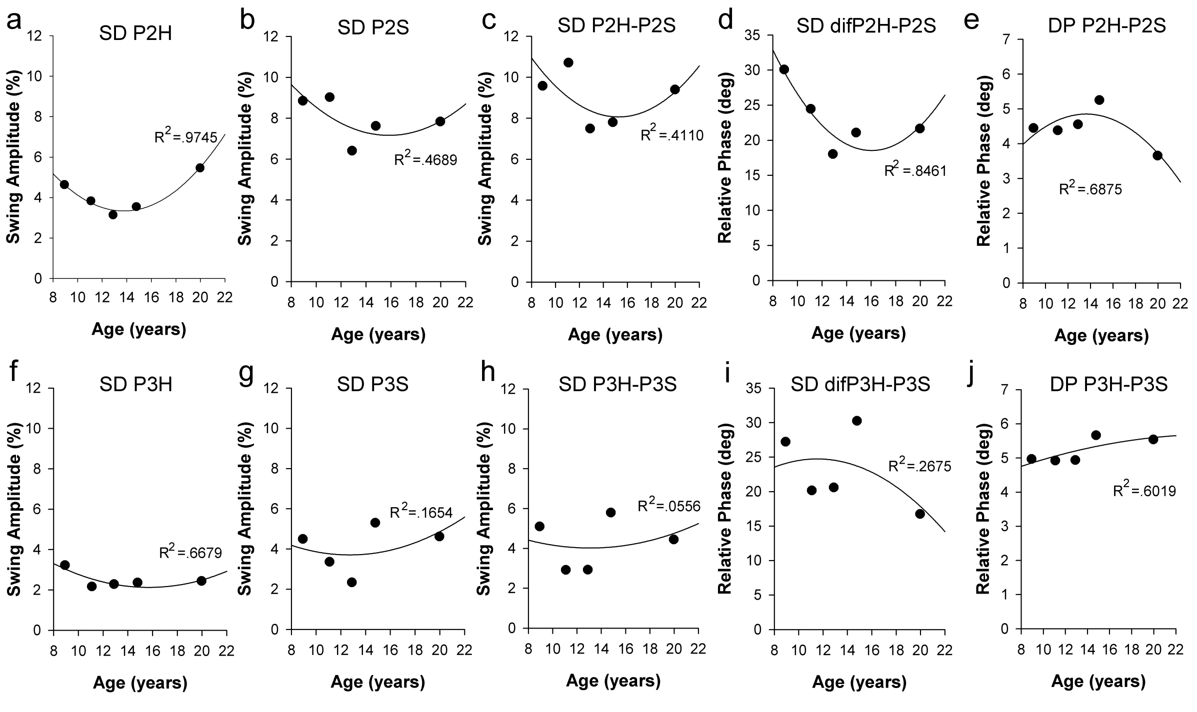

Figure 2. Graphs illustrate group means of the inter-trial variability of performance (a, b, f, and g) and coordination (c, d, h, and i), and intra-trial variability of coordination (e and j). P2 variables are depicted in the upper section and P3 variables in the lower section. Quadratic curve fit for data points and R^2 are also included.

DISCUSSION: Two distinct patterns were observed: a U-shaped fit, and a large deviation for group 4. A better U-shaped fit was found in graphs obtained from P2 inter-trial variability variables supporting the results presented by Wilson et al. (2008). In contrast, large group 4 deviations were found in graphs of the inter-trial variability for the P3 variables and the intra-trial variability variables. It could be suggested that group 4 represents a transition point in the process to achieve the expert coordination mode of group 5. In agreement with these results, three of these variables (SD P3H-P3S, DP P2H-P2S, and DP P3H-P3S) also showed a tendency for group 4 to have increased variability suggesting again a transition point. These results could be interpreted on the basis of previous research (Teulier et al., 2006) proposing that when the initial behavior does no longer improve the task, the performer needs to change motor strategies. However, the swing amplitude between group 4 and group 5 were not statistically different. Therefore an alternative explanation is provided: the transition phase in group 4 could be due to increased demands of the sport. Sport demands at the age range of the group 4 drastically change by including flight elements and dismounts learning.

CONCLUSION: Large increases in within subject variability in P3 and intra-trial variability for the group 4 indicated a transition point towards the expert coordination mode of group 5. Two different arguments are proposed to explain this transition point occurrence: (1) motor strategies adopted until group 4 did not improve anymore the skill level (Teulier et al., 2006); and (2) the increased demands of the sport incorporate the longswing into more complex tasks.

REFERENCES:

Arampatzis, A., & Bruggemann, G.P. (1999). Mechanical energetic processes during the giant swing exercise before dismounts and flight elements on the high bar and the uneven parallel bars. *Journal of Biomechanics,* 32, 811-20.

Clark, J.E., & Phillips, S.J. (1993). A longitudinal study of intralimb coordination in the first year of independent walking: a dynamical systems analysis. *Child Development,* 64, 1143-57.

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29,* 1223-30.

Hamill, J., van Emmerik, R.E., Heiderscheit, B.C., and Li, L. (1999). A dynamical systems approach to lower extremity running injuries. *Clinical Biomechanics , 14*, 297-308.

Handford, C., Davids, K., Bennett, S., & Button, C. (1997). Skill acquisition in sport: some applications of an evolving practice ecology. *Journal of Sports Sciences,* 15, 621-40.

Irwin, G., & Kerwin, D.G. (2007). Inter-segmental coordination in progressions for the longswing on high bar. *Sports Biomechanics*, 6, 131-44.

Jensen, R.K. (1989). Changes in segment inertia proportions between 4 and 20 years. *Journal of Biomechanics, 22,* 529-36.

Jensen, R.K., & Nassas, G. (1988). Growth of segment principal moments of inertia between four and twenty years. *Medicine and Science in Sports and Exercise, 20,* 594-604.

Teulier, C., Nourrit, D. & Delignières, D. (2006). The evolution of oscillatory behavior during learning on a ski simulator. *Research Quarterly for Exercise and Sport,* 77, 464-75.

Wilson, C., Simpson, S.E., van Emmerik, R.E.A., & Hamill, J. (2008). Coordination variability and skill development in expert triple jumpers. *Sports Biomechanics,* 7, 2-9.

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