BALANCE VARIABILITY DURING THE PYRAMID EXECUTION IN ACROBATIC GYMNASTICS

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The objective of this study was to analyse the relationship between intra-trial variability in balance scores obtained via a force platform and acrobatic gymnasts' pyramid scores provided by a qualified and experienced judge. Twelve acrobatic gymnasts grouped in pairs performed five successful straddle lever pyramids on two force platforms with one foot on each platform. The variability of path length of the centre of pressure of each foot was examined to analyse the balance of the pyramid. The variability of path length was negatively correlated with pyramid score in both legs, non-preferred (rho = -0.706 [very large]) and preferred leg (rho = -0.530 [large]). The results suggest a relationship between intra-trial variability and pyramid performance.

KEY WORDS: centre of pressure, trial-to-trial, performance.

INTRODUCTION: In acrobatic gymnastics various balance formations or pyramids are part of the competition routines (Figure 1). A pyramid is formed by at least one gymnast in the base of the formation who supports his/her partner(s) on the top while maintaining static equilibrium for a minimum of three seconds (Fédération Internationale de Gymnastique, 2013). Continuous postural control by the gymnasts is required to avoid premature dismount and achieve success. Due to the strength, flexibility and balance demands, a pyramid is a complex task and some variability between trials is expected. However, the amount of this variability between trials remains unknown but it may be related to performance. A high level of variability could be indicative of a flexible movement control strategy which would enable the gymnasts to cope any perturbations during task execution. Alternatively, high variability may be indicative of reduced performance stability and an inability to maintain balance (Emmerik & Wegen, 2002). The objective of this study was to analyse the relationship between intra-trials variability in balance scores obtained via a force platform and pyramid scores provided by a qualified and experienced judge.

METHODS: Twelve (n = 12) female acrobatic gymnasts, grouped in pairs, were recruited for this study. Each pair consisted of a base and a top gymnast. The base gymnasts were aged 13.5 ± 0.9 years (mean ± SD), with a mass of 46.8 ± 5.8 kg and a height of 1.51 ± 0.07 m. The top gymnasts were aged 10.0 ± 1.1 years, with a mass of 27.1 ± 2.7 kg and a height of 1.31 ± 0.05 m. No participants had any past history of nervous system or muscular dysfunction. The study had obtained ethical approval from the University Research Ethics Committee and all parents/guardians of participants signed informed consent forms before participating in the study.
Before the test, the leg preference was determined by asking the gymnasts to perform a cartwheel. The leg used to lead the side lunge at start of a cartwheel was determined as the non-preferred leg. The participants completed their general and normal pyramid warm-up under the supervision of their coach before data was recorded. Since all participants regularly performed different kinds of pyramids in their daily training, a short familiarization session with the force platform was sufficient to ensure the participants could complete the tasks to a satisfactory level. Each pair was instructed to perform a "straddle lever" pyramid (Straddle, Figure 1), on the regular surface of two force platforms (Dinascan 600M, Biomechanical Institute of Valencia, Spain) maintaining the position for 7 s. In the Straddle pyramid, the top gymnast had her hips flexed at approximately 45º and knees extended in a

straddle position. During the performance of the pyramids, the base gymnast stood with one foot on each platform to facilitate recording of the variations in the centre of pressure at a frequency of 200 Hz. Five successful trials were recorded for each pair, with at least 2-3 minutes rest allowed between trials.

Figure 1: Straddle lever pyramid.

Balance and performance measures were defined as follows. Performance of each trial was judged live by a certified international judge with five years international experience who determined the technical penalties of the pyramid performance. All trials were videotaped (Sony NEX-5T, New York, NY) so the judge could review the score given. All scores were consistent with the Code of Points, Acrobatic Gymnastics (Fédération Internationale de Gymnastique, 2013): amplitude, body shape, angle, line, hesitations, steps and instability. The validity of judge score was tested by assessing the correlation coefficient and typical error of the estimate (Hopkins, 2000). These were calculated form average score of three judges who scored the pyramids from recorded video. Near perfect correlation ($r = 0.988$) and low typical error of estimate (0.17 points with 95% confidence limits of ± 0.03) demonstrated the validity of the judge scored. The balance measure was the path length of centre of pressure which was calculated separately for each foot. The centre of pressure path length was calculated by summing the Euclidian distance between successive data points over the sampling period.
Statistical analyses were conducted using SPSS version 18.0 (IBM, Armonk, NY, USA). Non-parametric statistics were used based on: the research design of the study; the limited number of expert participants available; and the fact that deductions assigned by the judge were an ordinal variable. Medians, median absolute deviations, inter-quartile range and range of each pair were computed for all the measured variables. Spearman rank order correlations were performed to assess the degree of association between median absolute deviation and the median score of all trials of the same pair.

RESULTS: The intra-trials variability in balance for each pair of gymnasts is presented in Figure 2. These box-and-whisker plots show the median of path length of centre of pressure for the median judge score over 5 trials for each pair. The box and whisker plots show that reductions in trial-to-trial balance variability during the pyramid execution were associated with improved performance (i.e. smaller range in box plots with higher scores). This negative relationship was observed in both legs; non-preferred (*rho* = -0.706 [very large]) and preferred leg (*rho* = -0.530 [large]). The median score in the gymnastic pairs across the five trials ranged from 1 to 3.5 points. In the non-preferred leg, the centre of pressure path length variability (median absolute deviation) ranged from 9 to 166 mm, while in the preferred leg ranged from 22 to 114 mm. Outcome balance variability was generally lower in preferred leg in comparison to the non-preferred leg.

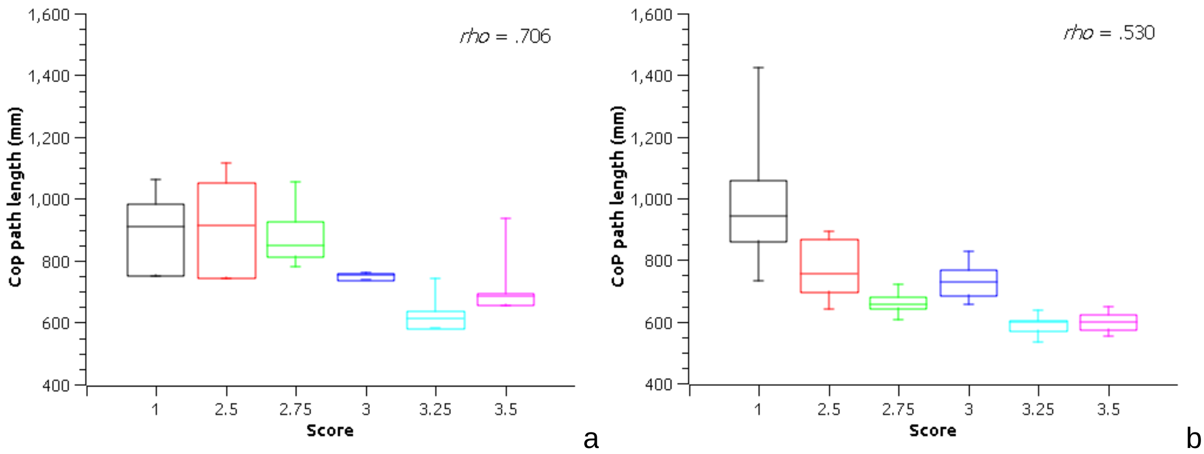

Figure 2: Relationship between values of balance parameters of each leg (a: non-preferred leg; b: preferred leg) and median pyramid score of 5 trials for each pair. Data presented as box-plots-line in centre of box represents the median value; the box represents the inter-quartile range, and the whiskers represent the range.

DISCUSSION: This study described the relationship between the judge score and variability of balance parameters during pyramid execution in acrobatic gymnastics. The results of this study indicated those pairs of gymnasts who are able to achieve a lower trial to trial variability were highly scored by the judges and therefore achieved higher performance. This correlation of low variability in biomechanical parameters with performance has been observed in other gymnastic disciplines. Hiley et al. (2013) observed that elite gymnasts were very consistent in their swinging movements during execution of high bar giant circles. The authors suggested that lower temporal movement variability in important aspects of technique could be an advantageous trait. Although the present study has shown an inverse relationship between variability and skill level, some previous research has found quite different relationships. Bradshaw et al. (2007) observed high biological movement variability in top sprinters. The authors indicated that improvements in sprint performance were associated with an increase in the variability of this movement. Bradshaw et al. (2007) suggested that the higher variability allowed the athletes adapt their movement patterns to a wider set of circumstances which they typically encounter during the competition. These conflicting results could suggest that the relationship between performance and variability is task dependent. Therefore, when the task requires precision, the movement variability should decrease with increasing performance and when the task requires adaptability to unexpected perturbations, the variability should increase.

In this study the behaviour of each foot was analysed separately. Although the trajectory of the centre of pressure of each foot showed an association with the score of the judge, the magnitude of this relationship was different in each task. The path of centre of pressure of non-preferred leg showed a higher correlation than the preferred leg. This could suggest the existence of different roles for each foot in maintaining balance in the pyramid. This would be consistent with previous studies, which found a specialised role for each leg in tasks that require maintaining balance (Haddad et al. 2011; Sadeghi et al. 2000). Further studies with more participants and with different pyramids are needed to provide a more detailed analysis of the relationship between performance and balance variability.

CONCLUSION: The present study revealed a relationship between variability and performance in balance tasks. The acrobatic gymnasts who registered lower intra-trial variability in the path length of centre of mass during the pyramid execution achieved higher scores. The results of this study demonstrate the usefulness of force platform as a tool to assess the gymnastic performances of pyramid balance tasks. Moreover, the variability of the path of the centre of pressure can be used as quantitative parameter to evaluate the pyramid performance.

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