Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

THE INFLUENCE OF EXPERIENCE ON KINETIC CHARACTERISTICS OF THE LOOPED LONGSWING

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The aim of this study was to increase understanding of the strategies performers use to complete the looped longswing (LLS) in order to provide useful information for the development of this skill. For an elite gymnast and two novice performers, kinematic and kinetic data were collected during 5 series of three LLS (CODA motion analysis system, 200 Hz; instrumented high bar, 1 kHz). Inverse dynamics were employed to determine joint kinetics during the second LLS in each trial for each performer. The elite gymnast performed positive work at the hips during the downswing resulting in hip flexion, which facilitated the control of proceeding functional phase actions. Peak shoulder power values were highest for the elite gymnast and lowest for the least experienced novice participant.

KEY WORDS: technique, skill development, gymnastics.

INTRODUCTION: In men's gymnastics the longswing consists of a rotation about the horizontal bar axis in the vertical plane. The biomechanics of the longswing performed by elite gymnasts is well understood. Explanations of the skill have established the importance of Functional Phase (FP) actions, characterised by rapid hyper extension to flexion of the hips and flexion to extension of the shoulders as the performer passes under the bar (Arampatzis & Brüggemann 2001; Yeadon & Hiley, 2000; Irwin & Kerwin, 2007b). Recently, Williams et al. (2010) investigated the changes in the hip and shoulder kinematics of novices as they learnt the looped longswing (LLS) over an 8 week period. Particularly, analysis focussed on the FP actions of the skill. Based on a single subject design, the findings of this study established individualised developmental strategies, with a range of techniques employed. Interestingly, successful performers ranged from those with FP techniques similar to ones reported for elite gymnasts, to others that had developed their own strategies. Set against the theoretical framework of Newell (1985), and building on the findings of Williams et al. (2010), an inverse dynamics approach was adopted to quantify joint kinetics. The aim was to increase understanding of the strategies performers use to complete the LLS in order to provide useful information for the development of this skill.

METHOD: Prior to the onset of the study, approval was gained from the University's Ethics committee. Three male participants, 1 elite international GB Squad gymnast, participant A; and 2 novices, B and C, (mean age 22 ± 1 years, mass 69 ± 2 kg, height 1.74 ± 0.08 m), gave voluntary informed consent to take part in this study. Novice performers had previously learnt the LLS during 8 weekly training sessions led by a National level gymnastics coach (Williams et al., 2010). Novice B was able to perform the LLS after 3 weeks training, novice C was able to perform the LLS after 7 weeks training. Anthropometric data were obtained using the digital image technique reported by Gittoes et al. (2009), facilitating the calculation of individual-specific body segment inertia parameters. Each participant performed 5 series of 3 LLSs. Unilateral kinematic data were collected using an automated 3D motion capture system (CODA) sampling at 200 Hz. Two CX1 CODA scanners (Charnwood Dynamics Ltd, UK) provided a field of view exceeding 2.5 m around the centre of the bar. Active markers were placed on the lateral aspect of each participant's right side at the estimated centre of rotation of the shoulder and the elbow, at the mid forearm, greater trochanter femoral condyle, lateral malleolus, fifth metatarsophalageal and the centre of the underside of the bar. Reaction forces at the bar were recorded using strain gauges bonded in pairs to the bar's surface, sampling at 1 kHz. Bar calibration was performed by loading (up to 4 kN) and unloading the bar in the vertical with known loads and recording the average voltage output for each loading condition. The horizontal stiffness of the high bar used in this study was previously shown to be 15 % lower than the calculated vertical stiffness (Kerwin and Irwin, 2006). Vertical (K_z) and horizontal (K_y) bar stiffness were used in a linear regression equation to predict vertical (F_z) and horizontal (F_y) bar forces from voltage outputs.

Data Processing: Swing two in each trial was analysed and used to generate a participant mean (±SD) based on 5 trials. 2D coordinate data were processed with the kernel smooth function (MathCad14™) with the smoothing parameter set to s = 0.10. Circle angle was defined by the mass centre to bar vector with respect to the horizontal, where a circle angle of 90° and 450° saw the CM of the performer above the bar (in handstand). Hip angle was defined by lines joining the shoulder centre, greater trochanter and femoral condyle markers. Shoulder angle was defi ned by the lines joining elbow, shoulder and greater trochanter markers. Differentiation of linear and angular quantities was achieved using a variation of Ridder's divided difference method (Press et al., 1992) to generate angular velocity. The human performer was modelled as a pin-jointed, 4 link system comprising arms, torso, thighs and shanks. Joint moments (JM) were determined through the application of Newton's 2nd law of motion. To minimise the propagation of error, the closest known forces were used to calculate internal joint forces, ('bar down' approach for the shoulders, 'toe up' approach for the knees, and an average of bar down and toe up for the hips). Joint powers (JP) were calculated as the product of JM and angular velocity (ω) for each joint. Joint work (JW) was calculated from the time integral of JP profiles and presented as percentages of the sum of work done by each joint. JMs were normalised to each performer's body weight and height according to Hof (1996) and JP were normalised according to a modified version of Hof's (1996) scaling procedure. Data were interpolated in 1° increments of rotation about the bar. The analysis is presented in four quadrants (Q1 – Q4) of the swing. Within these quadrants the functional phases have been identified (Irwin and Kerwin, 2007b).

RESULTS: For all participants the knee played a minimal role, with knee contributions ranging from -2 – 6% of the total work done (Figure 1). The hips and shoulders dominated the JW, where the ratio of hip and shoulder contribution changed between participants (Figure 1). For example, novice C showed the highest overall contribution for the hips (78%). Figure 2 shows joint angle, JM and JP profiles of the hips and shoulders during the longswing performed by each participant. **Q1: θ_C 90-180°**: For performer A, a small positive JM slightly closed his hip and shoulder joint angles. Conversely, novices B and C produced positive JMs to open their hip and shoulder joints (negative work). **Q2: θ_C 180-270°:** Gymnasts A performed a negative hip JM and positive JP to rapidly hyper-extended then begin to flex his hips, while a positive JM and negative JP flexed then extended his shoulders. Novice C produced a positive JM and JP, rapidly closing his hip angle through positive work. Novice B showed continued hip flexion and shoulder extension with an increased JM. **Q3: θ_C 270-360°:** For all performers, peak JM occurred just after the lower vertical, during rapid flexion of the hips and extension of the shoulders. The magnitude of the peak hip JM was double for novices B and C compared to performer A. Novice B's peak shoulder JM was approximately 33% more than the other two participants. However, maximum shoulder JP were highest for performer A and lowest for novice C. Interestingly the contribution for JP from the hips and shoulders was different for performer A compared to novice B and C. For performer A, peak JP at the shoulders is greater than JP at the hips, the opposite is true for novices B and C. **Q4: θ_C 360-450°:** For performer A and novice C, positive JM and JP peaks resulted in extension of the hips and flexion of the shoulders in order to return to the handstand position. Novice B decreased hip and shoulder JM until the handstand position was reached.

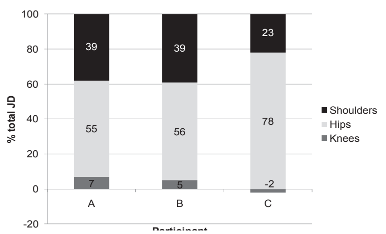

Figure 1: Joint work as a percentage of total work at the knees, hips and shoulders during the looped bar longswing for an elite gymnast (A) and 2 novices (B and C).

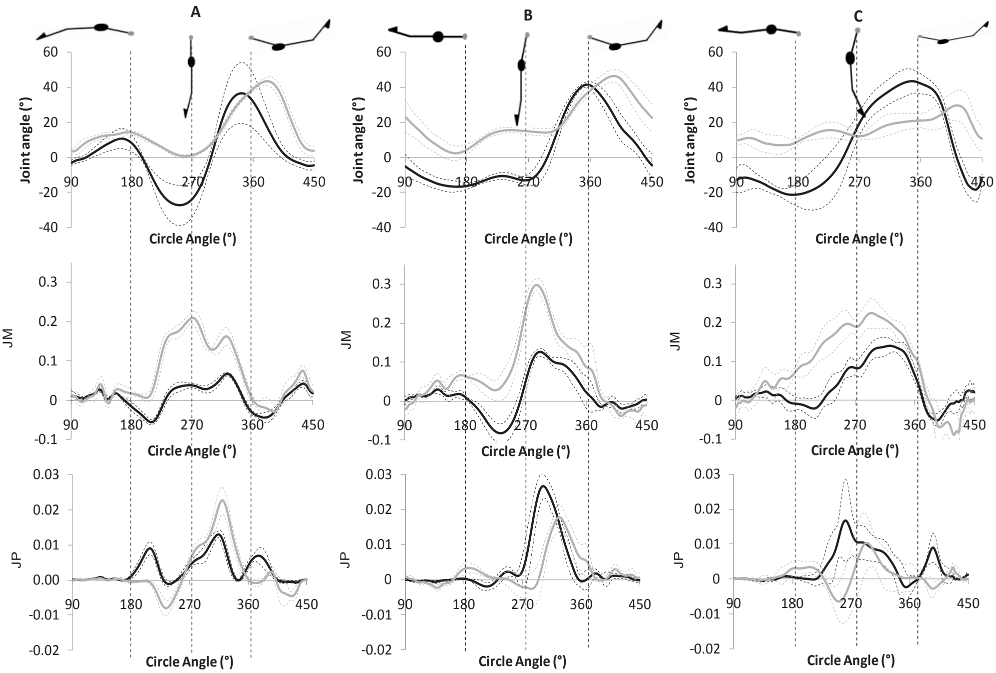

Figure 2: Mean (± SD) joint angles, normalised joint moments and powers of the hips (black line) and shoulders (grey line) for elite performer A, and novices B and C during 5 looped bar longswings.

DISCUSSION: Utilising an inverse dynamics approach to profile joint moments, powers and work at the hips and shoulders, the aim of this study was to examine the individual musculoskeletal strategies of performers of different experience levels during the LLS. Building on previous work (Williams et al., 2010), the purpose of this study was to further our understanding of novice LLS technique in order to obtain useful information for the development of novice performers. A single subject design provided an in depth insight into each performer’s technique, avoiding averaging across subjects. JW was calculated at the knees, hips and shoulders, and expressed as a percentage of the total work done by each participant. The hips were seen to play a dominant role across all performance levels (Figure 1). In contrast, Irwin and Kerwin (2007b) found approximately 55% of total JW at the shoulders during elite LLSs. JW contribution at the hips was similar for elite performer A and novice B. However, JP profiles identified the distribution of JW throughout the entire skill, highlighting differences in the contributions of the hips and shoulders during the four quadrants for each performer. Specifically, performer A incorporated 3 distinctive positive inputs of hip work in quadrants 2, 3 and 4. In contrast novice B produced one major input of positive hip work during quadrant 3 (Figure 2). The three inputs of hip power performed by A can be explained though the coaching literature which highlights the two key shapes between handstand positions; hollow to dished (Readhead, 1997). These shapes are referred to within biomechanics research as the FP actions, characterised by rapid hyper extension to flexion of the hips and flexion to extension of the shoulders as the performer passes under the bar (Irwin & Kerwin, 2007b). Building on the findings of these authors, this study has shown that for the elite gymnasts a powerful action is also used to obtain hip hyper-extension of the hip, while negative work is done to obtain flexion of the shoulder preceding the FP. These actions may play a key role in facilitating the initial contribution of positive work from the hips within the FP. The three inputs of positive hip power produced by the elite performer may be considered the finer control strategy during this skill, distributing the joint work requirements during the skill. Therefore, these findings suggest that in order for these novices to match the technique of the elite gymnast, performing similar positive hip powers profile is possible through a sequence of hip actions preceding the FP actions, initiated by a closing of the hip and shoulders during the downswing to facilitate powerful hip hyper extension and shoulder flexion.

Common actions for participants A, B and C were a rapid flexion of the hips and extension of the shoulders, during which maximum JM and JP were produced. These actions have been identified as the key functional actions during the longswing (Irwin and Kerwin, 2007b). In accordance, maximum JM and JP for participants A and novice B occurred during Q3, whereas maximum values for C were performed earlier in the circle. Coaching literature has identified a closing of the hips and shoulders during the downswing as preventing early functional actions (Readhead, 1997) emphasising that the key FP action is facilitated by a preceding hip flexion and shoulder extension during Q1.

The relative magnitude of maximum hip and shoulder JP varied between participants. Elite performer A increased maximum JP at the shoulder beyond that of the hips. Conversely, novices B and C performed higher hip JP than they were able to perform at the shoulder. Moreover, performer A's maximum shoulder JP was highest and novice C's maximum JP the smallest. Therefore, it is suggested that the ability to produce a powerful extension action at the shoulder could be an influential factor that distinguishes more and less successful novices.

CONCLUSION: Building on the findings of Williams et al. (2010) this study has shown that joint kinetics play a vital role in understanding LLS technique. Specifically, the study has identified that a series of actions at the hips and shoulders preceding the FPs may be key to enable a novice to match the kinetic profile of an elite LLS, which comprised three inputs of concentric work by the hips. In addition an increase in JP at the shoulders could be a key factor for the development of novice performers.

An applied Sports Biomechanics has the ability to provide scientifically grounded, quantitative information to enhance performance in a sports training environment, often enhancing information available to a coach. Kinetic analysis provides an insight into the musculoskeletal contribution of the athlete while performing skills, bridging the gap between the coach's external view of performance and the athlete's internal sensory perceptions of kinetic information. Thus, future work aims to evaluate such kinetic information as meaningful and effective feedback to a performer.

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