MECHANICAL SIMILARITIES OF HIGH BAR PROGRESSIONS

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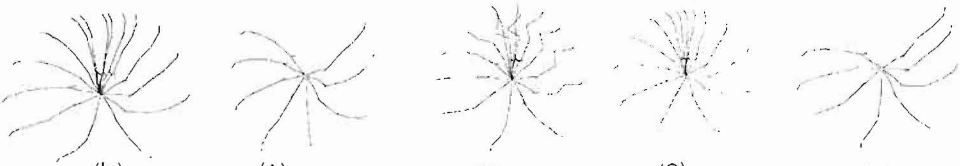
The purpose of this study was to develop a method to rank selected progressions for learning the longswing on high bar. Video recordings of four male international gymnasts performing the longswing and four associated progressions were quantified using 2D DLT techniques. Root mean square differences (RMSD) for hip and shoulder angular displacements and velocities facilitated grouping of the progressions based on overall level of agreement. The progression that was most similar to the 'target' skill was the 'chalked bar pendulum swing', whilst the least similar was the same skill without hip and shoulder 'action'. The method provided a useful means to quantify and rank progressions based on kinematic similarity to the longswing.

KEY WORDS: biomechanics; specificity; coaching; high bar; longswing; progressions.

INTRODUCTION: As gymnasts are already close to physiological maxima, coaches are continually seeking TRAINING methods to develop elite performers in a safe and effective fashion. One of these approaches is through the identification of skill pathways that allow high levels of performance to be achieved. The longswing on high bar has been identified as a key basic skill due to its association with the development of more complex movements (Readhead, 1997). Biomechanists have paid a great deal of attention to analysing the longswing and have experimentally and theoretically identified the functional characteristics of the longswing to be a rapid hyper extension to flexion of the hip and hyper flexion to extension of the shoulder joint, as the gymnast passes underneath the bar (Yeadon and Hiley, 2000). Progressions form the focal point of most gymnastics skill development programmes allowing the safe and effective acquisition of key skills and subsequently more complex movements (Readhead, 1997). In general, to learn motor skills it has also been reported that the fundamental principles of training are adhered to (Dick, 1980). A qualitative investigation identified that elite gymnastic coaches use the concept of specificity in the development of progressions for the longswing on high bar (Irwin et al., 2002). The appropriateness of progressions based on the biomechanical similarities to the target skill has been recognised as an important component in skill development (Olbrecht and Clarys, 1983). In gymnastics, Elliott and Mitchell (1991) and Kolar et al. (2002) have used kinematic and kinetic profiles of a complex vault and parallel bar skill respectively, to identify progressions, which they regarded as more valid. Modifications to the less similar progressions were recommended in order to make skill development more effective (Elliott and Mitchell, 1991). Kolar et al. (2002) suggested that progressions should be based on pedagogical principles and should simulate the movement pattern of the target skill. Underpinned by the specificity of training and based on biomechanical analysis, the purpose of this study was to develop a method to rank selected progressions for learning the longswing on high bar.

METHODS: Data Collection: Four members of the Men's National Gymnastics Squad participated in this study (age = 22 4 yrs mass = 69 2 kg and stature = 1.69 0.05m). Each participant gave informed consent and ethical approval was gained from the University Ethics Committee. Anthropometric data were collected for use with a geometric inertia model (Yeadon, 1990). Movement in the sagittal plane was recorded using a digital camcorder (Sony DSR-PD1100AP, 3-CCD, Japan) placed approximately 40 m from the centre of the activity at a height of 5 m with its optical axis at 80 to the plane of motion. The camera was operated at 50 fields per second with the electronic shutter set to 1/300 s. Calibration of the performance area was achieved by placing a single calibration pole of height of 5.176 m, containing four 0.10 m spherical markers, at three pre marked locations to form a plane of approximately 5 m x 5 m. Each participant randomly performed three series of five longswings and four progressions with appropriate rest. The progressions were derived from interview data gathered from sixteen National level coaches and included (a) chalked bar pendulum swing with no action; (b) chalked bar bent kneed long swing; (c) loop bar long swing with no action; and (d) chalked bar pendulum swing (Figure 1). All testing was performed in a gymnastic arena on a standard competition high bar. A national level coach and qualified judge, following the criteria of the FIG (2000) ascertained success of each element.

Data Processing: The images of the calibration object and the gymnast were digitised using the high resolution TARGET motion analysis system (Kerwin, 1995). Images of the calibration structure were digitised ten times. Camera calibration was achieved using an 8 parameter direct linear transformation (DLT) algorithm (Kwon, 1999). Checks for accuracy and reliability were achieved through repeated digitisations of six independent spherical markers (0.10 m in diameter) located within the calibrated area. These points were digitised 1, 5, 10, 15 and 20 times on different days. In each video field the centre of the bar, the centre of the gymnast's head and his right wrist, elbow, shoulder, hip, knee, ankle and toe were digitised. The shoulder angle (S) was defined by lines joining the right hip, shoulder and wrist. Lines joining the right shoulder, hip and knee defined the hip angle (H). Hip and shoulder angular displacements (S, H) and velocities (S, H) were determined using CODA motion analysis software (Charnwood, Dynamics LTD, Leics, UK). A digital filter with a cut off frequency of 5 Hz was implemented for random noise removal (Challis et al., 1997). Locations of each gymnast's mass centre (CM) were determined using a geometric model, (Yeadon, 1990). Digitising accuracy and reliability were ascertained by determining the RMSD between measured and mean locations of the six independent markers. Based on previous research and a theoretical analysis the 'functional' phases of the skill were considered to occur around maximum hip extension to flexion and maximum shoulder flexion to extension. In order to compare within and between gymnasts all digitised data were interpolated using a cubic spline function, (Mathcad, 2001, MathSoft Engineering & Education, Inc. Surrey, UK). For each progression and the longswing S, H, S, and H were plotted against the angular position of the gymnast's mass centre as he rotated anticlockwise around the bar. The maximum height of the mass centre on the downswing and upswing phases of each skill defined the beginning and end points respectively. The RMSD between the shoulder and hip angles (RMSD S RMSD H) and angular velocities (RMSD S and RMSD H) for each progression and the longswing during the two functional phases were calculated. Each RMSD was represented as a percentage of the range of each corresponding variable during the functional phase of the longswing. An overall RMSD based on the average of the four separate root mean squared differences was also calculated providing a ranked list of progressions based on their similarity with the target skill (where a high score represents a lack of similarity between the progression and the target skill).



(ls) (A) (B) (C) (D)

Figure 1: Four associated progression for the long swing (ls). (A) Chalked bar pendulum swing with no action; (B) chalked bar bent kneed long swing; (C) loop bar long swing with no action; and (D) chalked bar pendulum swing.

RESULTS & DISCUSSION: The average reconstruction accuracy based on the locations of six independent markers was found to be less than the 0.1% recommended by Challis et al. (1997). An increase in the number of digitisations showed no increase in reconstruction accuracy and therefore, each sequence was digitised once. The group average angular position of the gymnasts at the beginning and end of the functional phases of the longswing were found to be (162 20 and 272 6) for the shoulder and (159 5 and 248 10) for the hip. The difference in the angular position of the gymnast during the occurrence of the hip and shoulder functional phases is characteristic of the longswing (Okamoto et al., 1987).

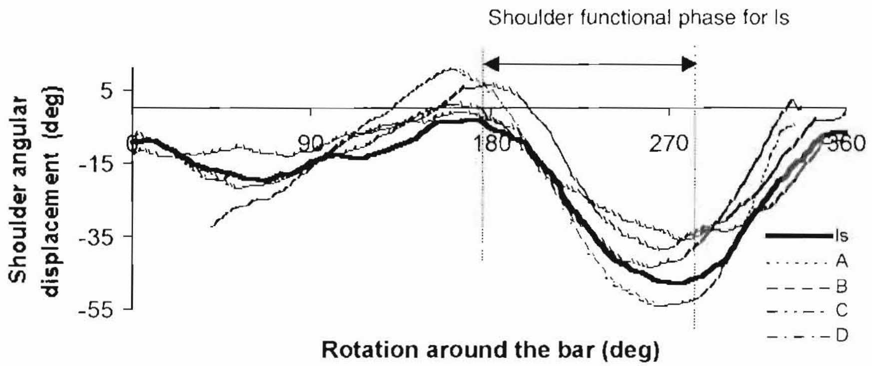


Figure 2: Graph illustrating the shoulder angular displacement (deg) for one gymnast performing a chalk long swing (ls) and four associated progressions (A-D).

Figure 2 shows that the angular position of the gymnast around the bar at the start and stop of the functional phase of the longswing, for the shoulder joint, occurred at 172 and 274 compared to 179 and 265 for the bent kneed longswing respectively. Therefore, the gymnast started the functional phase of the longswing 7 earlier and performed 16 more rotation. Additionally the shoulder joint underwent 10 more flexion during the longswing. Previous research has suggested specific kinematic modifications to progressions in an attempt to make them more similar to the target skill and therefore more effective for skill learning (Elliot and Mitchell, 1991). Table 1.0 details the group average RMSD and RSMD as a percentage of the range for each of the key kinematic variables (S, H, S, H) between the functional phases of the longswing and the corresponding phases of the progressions. Overall similarity is provided as the average (sd) score represented as a percentage of the range. All progressions showed some level of difference with the target skill. The chalked bar pendulum swing was the most similar progression with an overall score of 15% with a particularly close match to the hip kinematics of the target skill.

Table 1 The group average RMSD and (RMSD expressed as a % of the range) for hip and shoulder angular displacement (H, S), velocity (H, S), between the functional phases of the longswing and the corresponding phase of four associated progressions (a-d).

	A	C	B	D
RMSD S (rad.s-1)	0.97(26)	0.67(18)	0.75(20)	0.72(19)
RMSD S ( )	8.6(18)	5.1(10)	6.4 (13)	5.9(12)
RMSD H (rad.s-1)	1.4(44)	1.7(51)	1.3(38)	0.67(20)
RMSD H ( )	10.7(22)	9.7(20)	11.6(24)	4.6(9)
(sd) % RMSD	27(12)	25(18)	24(11)	15(5)

The group average difference between all four progressions and the longswing was 0.6rad.s-1 greater for H compared to S and 2.6 greater for H compared to S. The loop bar longswing 'no action' highlights the influence of the greater difference in the hip kinematics, this progression has the lowest RMSD for S compared to the highest H. The chalked bar bent kneed longswing shows the largest average difference for H (11.6) due to the fact that this skill demands the gymnasts' perform hip and knee flexion during the ascending phase. The group average maximum hip flexion was 13 greater for this progression compared to the longswing. Previous studies have suggested that progressions, which are biomechanically more similar to the target skill, may be more effective in the development of that skill (Elliott and Mitchell, 1991; Kolar et al., 2002). Therefore, the ranked list of progressions (Table 1) may serve as a method, which identifies the most effective progressions for the development of the longswing, a factor that is primary to the coaching process (Readhead, 1997).

CONCLUSIONS: Based on the principles of biomechanics and underpinned by the specificity of training the progressions that were most similar to the target skill were 'chalked bar pendulum swing' and 'looped bar longswing with no action'. Angular hip joint kinematics accounted for most of the differences for all the progressions. These findings support the use of this method to rank the progressions based on their kinematic similarity to the final skill and may therefore serve as a mechanism to identify the most effective progressions. Future to this study, there is the need for an experimental investigation to determine whether biomechanically related progressions are more effective in the learning of the longswing.

REFERENCES:

Dick, F.W. (1980). Sports Training Principles. London: Lepus Books.

Challis, J.H., Bartlett, R.M. & Yeadon, M.R. (1997). Image Based motion analysis. In Biomechanical Analysis of Movement in Sport and Exercise (edited by R.M. Bartlett), pp.7-31. The British Association of Sports and Exercise Sciences, Leeds.

Elliott, B., & Mitchell, J. (1991). A biomechanical comparison of the Yurchenko vault and two associated teaching drills. International Journal of Sport Biomechanics, 7, 91-107.

Federation International de Gymnastique (2000). Code of Points, artistic gymnastic for men. Switzerland.

Hiley, M.J., Yeadon, M.R. and Kerwin, D.G. (1999). Optimisation of rotation from the backward giant circle, Proceedings of the VIIth International Symposium on Computer Simulation in Biomechanics, University of Calgary, pp 38-41.

Irwin, G., Hanton, S., Kerwin, D. (2002). A model of the development of gymnastic skills. Journal of sports sciences, 20, 65

Kerwin D.G. (1995). Apex/Target high resolution video digitising system. In Proceedings of the Sports Biomechanics section of the British Association of Sports and Exercise Sciences (Edited by J. Watkins), 20:1-4. Leeds: BASES

Kolar, E., Kolar, K, A., Stuhec, S. (2002). Comparative Analysis of Selected Biomechanical Characteristics between a Support Backward Swing and Support Swing for the 1¼ Straddle-Piked Forward Salto on the Parallel Bars. Sports Biomechanics. 1(1) 69 -78.

Kwon, Y,H. (1999). 2D Object plane deformation due to refraction in two-dimensional underwater motion analysis, Journal of Applied Biomechanics, 15(4), 396-403.

Lauder, M., and Payton, C. (1995). Handle paddle in swimming - A specific form of resistance training. Swimming Times, 72, (12), 25-27.

Okamoto, A., Sakurai, S., Ikegami, Y. & Yabe, K. (1987). The changes in mechanical energy during the giant swing backward on the horizontal bar. Biomechanics XIB, International Series on Biomechanics pp. 338-345

Olbrecht, J and Clarys, J, P. (1983). EMG of specific strength training exercises for the front crawl. Biomechanics and medicine in swimming: International symposium, Amsterdam, 1982. (pp 136-141). Champaign, Ill., Human Kinetics.

Readhead, L. (1997). Men's Gymnastics Coaching Manual. Huddersfield: Crowood Press.

Yeadon, M, R and Hiley, M, J. (2000). The mechanics of the backward giant circle on the high bar. Human movement sciences,19(2), 153-173

Yeadon, M.R. (1990). The simulation of aerial movement. Part II: A mathematical inertia model of the human body. Journal of Biomechanics, 23, 67-74.