HIP AND SHOULDER COORDINATION DURING THE HANDSPRING FRONT SOMERSAULT ON THE VAULTING "HORSE" AND "TABLE"

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The purpose of this study was to establish inter-segmental co-ordination (ISC) during a handspring front somersault performed on the old vaulting horse and new table. Four male international level gymnasts were filmed in 3D performing five trials on separate occasions. ISC of the hip and shoulder joint in three phases (board contact; flight; vault contact) was assessed using continuous relative phase (CRP). CRP variability (CRPsd) and root mean square difference (RMSD) between the old and new vault CRP profiles were also calculated. Small differences existed at key moments (e.g. both board touch downs=155), but the RMSD in the CRP profiles were large (e.g. board contact phase= 27). Larger variability on the table than the horse (e.g. CRPsd during vault contact 26% greater) suggests a less stable co-ordination pattern requiring further investigations into devising learning drills for the table.

KEY WORDS: continuous relative phase, gymnastics, inter-segmental.

INTRODUCTION: Following the Sydney 2000 Olympics, vaulting in gymnastics underwent an historic change with the introduction of the new style of vaulting table approved for use in the subsequent 2001 World Championships. The changes in the width and length support area ratios, and a more elastic contact surface were introduced (Knoll and Krug, 2001) that were designed to increase safety during contact and facilitate the performance of more complex vaults. Biomechanists have paid a great deal of attention to analysing the vaulting horse (e.g. Elliot and Mitchell, 1991) and specifically the handspring front somersault (e.g. Takei, 1991) as it is a key basic vault in the development of elite gymnasts owing to its association with the acquisition of more complex vaults (Readhead, 1997). In general, studies have considered the mass centre velocity, body angles and hip and shoulder angular kinematics as fundamental to the successful execution of this vault. These studies have formed the basis for coaching recommendations (e.g. Takei, 1991) suggesting that gymnasts should use a large shoulder range during horse contact. Currently, a lack of information exists regarding the influence of the vaulting table on these variables and the subsequent effect on current coaching recommendations. Previous studies have primarily used discrete values or patterns over time, although to obtain a full understanding of the movement, Sparrow (1992) has suggested that an accurate assessment of inter- and intra-limb co-ordination is required. This is supported by Tepavac and Field-Fote (2001) who suggest that co-ordinations between and within segments distinguish motor behaviours. The decision regarding the method of quantifying co-ordination is pivotal to the accurate and reliable assessment of segmental movement and has been recommended to be based on the activity under assessment, the ease of interpretation and primarily the question that is being asked concerning the movement (Hamill et al., 2000).
Continuous relative phase (CRP) has been used to identify segmental co-ordination and spatial organisation in a variety of activities (e.g. Kurz and Stergiou, 2002). CRP describes the spatial and temporal relationship between segments as the calculation of the phase angle uses a combination of the angular velocity and angular displacement. As such, CRP provides an appropriate measure of inter-segmental co-ordination with the standard deviation of CRP quantifying variability (e.g. Mullineaux and Wheat, 2002). During the handspring front somersault vault the interaction of the hips and shoulders define the spatial and temporal relationship required for the successful execution of this skill. Based on the above theoretical concepts the aim of this study was to establish the differences in the inter-segmental co-ordination during a handspring front somersault vault on the old horse and new table.

METHOD: Four members of the Men's UK Gymnastics Squad participated in this study

(age=21 1.5 years; mass=63 5 kg; stature=1.66 0.07 m). Each participant provided informed consent and ethical approval was granted from the University Ethics Committee. Each gymnast randomly performed five handspring front somersault vaults over the old vaulting horse and new table; appropriate rest intervals were taken between each performance. Movement was recorded at 50 Hz using two digital camcorders (Sony DSR-PD1100AP, 3-CCD, Japan) placed 16 m away from the performance at approximately 45 to the right and left of the plane of motion. A single calibration pole of height 5.176 m containing four 0.10 m spherical markers was moved through 6 pre-marked locations to form a three-dimensional (3D) calibration volume of 1.5 m x 4.0 m x 5.176 m. All testing was performed in a gymnastic arena on a standard competition vaulting horse and table.
The images of the calibration object and the gymnast from each camera view were digitised using the TARGET motion analysis system (Loughborough University of Technology, Leics, UK). The gymnasts' left and right fingers, wrists, elbows, shoulders, hips, knees, ankles and toes and the head were digitised. A 3D DLT algorithm was used to reconstruct the co-ordinates in the object-space and were time synchronised to less than 1 ms. Both hip and shoulder angular displacements (S, H) and velocities (S, H) were determined using CODA motion analysis software (Charnwood Dynamics Ltd, Leics, UK). All angles were defined as 0 to 180 from full extension to full flexion with maximum hyperextension of -180 . Touch down and take off angles were determined between the horizontal and a line passing through the mass centre to a point midway between the right and left ankles or hands contacting the board or vault, respectively. To compare within and between gymnasts all digitised data were interpolated to 101 points using a cubic spline (MATLAB, MathWorks Inc., Natick, MA, USA). Inter-segmental co-ordination was quantified using CRP where, first, the phase-plane portraits of both the knee and hip were normalised to -1 and +1 of the angle range over the trial (hence 0 on the x-axis reflects the angle at half the range) and to +1 or -1 of the maximum absolute angular velocity over the trial (hence 0 on the y-axis reflects 0?.s-1). The component phase angles (?) of each segment, that is the arctangent of the angular velocity over the angle for each of the 101 data points, were calculated with the range 0? ? 180?. The difference between the knee and hip phase angles provided the CRP. The vault was separated into three functional phases (i.e. board contact; flight; vault contact) and the mean (CRPmean) and standard deviation (CRPsd) of the CRP calculated for each subject and the group. The RMSD between the phases was also calculated for the CRPmean and CRPsd.

RESULTS AND DISCUSSION: Table 1 shows the minimum and maximum hip and shoulder angular displacements during the three phases of the vault. The standard deviations indicate a high level of inter-subject variability, particularly during the flight phase for H on the table (max=-27 24 ; min=-6 29). Average hip angle range showed the greatest difference between the vault and table during the flight and vault contact phases. Average shoulder angle range showed the smallest difference during vault contact suggesting little technique change between the horse and table. Previously the change in shoulder angle was suggested to be a key requirement to the successful execution of this vault (Takei, 1991).

Table 1 Maximum and minimum shoulder angular displacement during each phase for the vaulting horse and table. Values are Mean (SD).

	Board contact phase		Flight phase		Vault contact phase	
	Max	Min	Max	Min	Max	Min
Horse S ( )	138 (11)	118 (25)	144 (11)	134 (11)	155 (5)	143 (5)
Table S ( )	145 (9)	127 (18)	140 (13)	131 (11)	155 (7)	141 (10)
Horse H ( )	65 (8)	40 (7)	-34 (12)	-20 (21)	-42 (7)	-29 (11)
Table H ( )	68 (7)	44 (5)	-27 (24)	-6 (29)	-37 (12)	-14 (21)

Table 2 shows small differences between the average touch down and take off angles of the gymnasts during board and vault contact. In comparison to Takei (1991), for the same vault on on the horse, average angles of the gymnast at board touch down (57 2.3) and take off (106 3.8) and vault touch down (28 4.1) and take off (89 6.7) were found for elite gymnasts. Differences to this study can be attributed to Takei (1991) using a different angle definition (centre of mass of the segment contacting the surface instead of the mid-point between the two distal segments), more elite gymnasts (11 top scorers at the 1988 Olympic games), and that the gymnasts' competitive vault was analysed and was therefore well practised. The standard deviations of the touch down and take off profiles in Takei's study, however, show a similar level of consistency with this study. Differences in average hand width were found between the horse (0.24 0.02m) and the table (0.38 0.05m). Despite the greater surface area that may increase the safety of vaulting, these had a small effect on the angles at touch down and take off between the horse and table (Table 2).

Table 2 Mean (SD) touch down and take off angles of the body.

Apparatus	Board touch down		Vault touch down	
	Touch down	Take off	Touch down	Take off
Horse	77 (4)	99 (5)	50 (4)	79 (3)
Table	75 (4)	98 (4)	48 (7)	77 (6)

The average duration of the whole vault showed little difference between the horse (0.45 0.02s) and table (0.43 0.03s), but the average duration for each phase of the vault differed. Table 3 shows the greatest difference between the horse and table was found for the contact phase (35% less contact time for the horse). The greater amount of time spent in contact with the new table may be due to the changes in the resonance and spring characteristics (Readhead, 2001).

Table 3 Duration, CRPmean and CRPsd for each phase for the vaulting horse and table Values are Mean (SD).

Variable	Apparatus	Board contact phase	Flight phase	Vault contact phase
Duration (s)	Horse	0.07 (0.01)	0.27 (0.02)	0.09 (0.02)
	Table	0.07 (0.02)	0.24 (0.02)	0.14 (0.04)
CRPmean (*)	Horse	-79 (27)	22 (29)	96 (43)
	Table	-62 (29)	6 (18)	67 (23)
CRPsd (*)	Horse	25 (12)	26 (6)	26 (10)
	Table	31 (16)	25 (2)	35 (7)

Inter-segmental coordination is illustrated by the mean CRP curves plotted for both the horse and table (Figure 1). The over all RMSD between the old and the new vault was 17 . When considering the individual phases the RSMD between the old and the new vault was found to be greatest for the flight phase (27), followed by board contact (24) and smallest for the vault contact (11). These differences are as a result of the shoulder and hip interaction being specific for each of the two vaults. The results of this study may highlight a common co-ordination pattern specific to the type of vault used (e.g. Temprado et al., 1997). The CRPsd (Table 3) provides a measure of the variability in the CRP profile where a smaller value indicates greater inter-segmental co-ordination. The CRPsd was found to be greater for both board and vault contact on the table (31 16 and 35 7) than the horse (25 12 and 26 10), suggesting less inter-segmental co-ordination on the table during these phases. The lower CRPsd for the horse may suggest that the inter-segmental co-ordination profile is more stable probably due to the fact that the horse has been used more by the gymnasts than the recently introduced table. Based on the specificity of training principle (Dick, 1980) the progressions used to develop the handspring front on the vaulting table need to simulate the movement pattern of the vault on the table. The importance of biomechanical specificity between progressions and the target skill has previously been emphasised (e.g. Elliott and Mitchell, 1991).

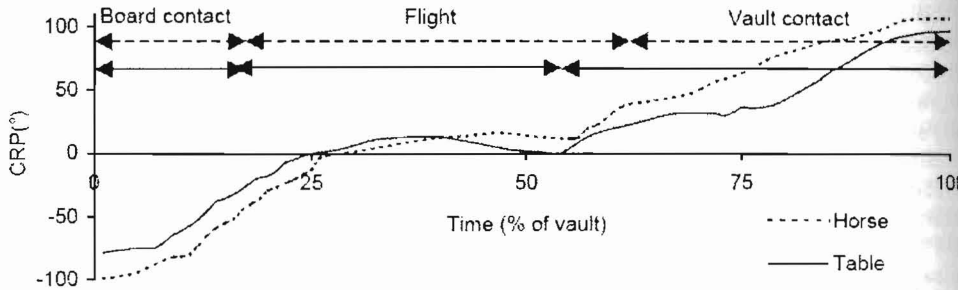

Figure 1: CRP between the hip and shoulder during the handspring front somersault vault on the old vaulting horse and the new vaulting table.

CONCLUSION: Small differences in touch down and take off angles highlighted similarities in technique between the vault on the horse and table. Temporal differences were identified between the table and horse, particularly during vault contact (table 35% longer). CRP showed differences in the inter-segmental coordination between these two vaults, and was largest for the flight (27) and board contact (24) phases. CRPsd indicated larger variability for the table compared to the horse suggesting a less stable co-ordination pattern that may be due to the recent introduction of this apparatus. This study provides a platform for further investigations into establishing developmental pathways for inter-segmental co-ordination for learning to vault on the table.

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