KINEMATIC CHANGES DURING LEARNING THE LONGSWING ON HIGH BAR

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Understanding technique development during complex skill learning provides information that can be used to influence feedback and skill development. The purpose of this study was to investigate changes in longswing technique during an 8 week period of learning. Fourteen male participants with no previous high bar experience took part in the training study. Data were collected using a CODA motion analysis system (200 Hz) during weekly testing sessions. There was a significant increase in swing amplitude for the group between week 1 and all subsequent weeks ($p < .05$). Based on initial swing amplitude three patterns of learning were displayed; each having distinctive functional phase characteristics. This study highlights the importance of quantifying changes in technique throughout learning on an intra-individual basis, to understand how technique changes.

KEYWORDS: Technique, skill acquisition, functional phase

INTRODUCTION: Previous literature has reported differences between novice and expert technique during gross complex motor skills (Delignières *et al.,* 1998), however, few have considered the nature of how novices' technique changes during a period of learning. Understanding how technique develops during learning provides precise information that can be used to influence feedback.

In men's gymnastics the longswing on high bar is a key skill which underpins the development of more complex skills. The biomechanics of performing successful longswings are well understood. Research has emphasised the importance of movements at the hip and shoulders, specifically, a hyper-extension to flexion action of the hips and hyper flexion to extension action of the shoulders occurring beneath the lower vertical (Arampatzis & Brüggemann, 1999; Yeadon & Hiley, 2000; Irwin & Kerwin, 2005). Irwin & Kerwin (2007) termed these movements Functional Phases (FP) since 70% of the gymnast's musculoskeletal work was found to occur during this part of the skill. Knowledge of the biomechanics of successful longswings, specifically the FPs, provides a theoretical underpinning to address more applied issues associated with learning longswing technique. Initial insights into kinematics associated with learning the longswing have been provided by Busquets *et al.* (2009) who described changes in coordination between the hip and shoulder for a novice cohort after a two month practice period in comparison to that of experienced gymnasts, and Williams *et al.* (2009) who provided a comparison of FP characteristics between performers at different stages of learning. However, the specifics of how longswing technique changes during a period of learning are not known. The purpose of the current study was to investigate the position of FPs of the 'looped bar longswing' performed by novices over a period of learning, in order to identify key kinematics of technique associated with learning.

METHOD: 14 male participants with no prior high bar experience (age 20 ± 3 years, mass 73 ± 7 kg, height 1.76 ± 0.06 m), volunteered to take part in this study. The participants consented to learn the 'looped bar longswing' (LLS), a mechanically similar but safer variant of the traditional 'chalked bar longswing' (Irwin & Kerwin, 2005). The longitudinal study comprised an initial testing session in which participants were shown videos and received an explanation of the aims of the LLS before attempting the skill. Testing sessions required each participant to perform 5 trials of 3 swings with the ongoing aim of increasing swing amplitude. A gymnastics coach provided support to assist each participant in gaining initial angular momentum. Data were collected during each trial for each performer. The testing sessions were interspersed with training sessions throughout the study. During training sessions, longswing specific skills and conditioning exercises reflective of those used in contemporary coaching environment were performed in a gymnasium.

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, mid forearm, greater trochanter femoral condyle, lateral malleolus, fifth metatarsophalageal and the centre of the underside of the bar. For individuals, measures of height and mass were obtained, digital images facilitated the calculation of all other anthropometric data for use with a geometric inertia model (Yeadon, 1990) to obtain individual-specific body segment inertia parameters.
Swing 2 in each trial was analysed, ensuring a full independent attempt was being performed. Circle angle (θ_C) was defined by the mass centre to bar vector with respect to the horizontal. In order to provide inter-performer comparisons of swings, data were interpolated in 1 degree increments of rotation about the bar. Lines joining the shoulder centre, greater trochanter and femoral condyle markers defined the hip angle (θ_H). Shoulder angle (θ_S) was defined by the lines joining elbow, shoulder and greater trochanter markers. Hip and shoulder angles (θ_H; θ_S) were differentiated to create angular velocity (ω_H; ω_S) profiles. 2D coordinate data were processed with the kernel smooth function (MathCad14™) with the smoothing parameter set to s = 0.10.
The performance measure; Swing amplitude (θ_{CA}), was defined as the circle angle between maximum height of the mass centre on the downswing to maximum height on the upswing. FP analysis of the hips was described by the position of maximum hyper-extension (θ_{CH1}) to flexion (θ_{CH2}) in θ_C, and shoulders by maximum hyper flexion (θ_{CS1}) to extension (θ_{CS2}) in θ_C. Differences across testing sessions were quantified using repeated measures ANOVA. Statistical significance was set at $p < .05$. Maulchy's test was used to determine the sphericity assumption within the data; where sphericity was violated probability was corrected according to the Greenhouse-Geisser procedure. Post hoc comparisons were made on the resultant data. Bonferroni corrections were applied for multiple comparisons.

RESULTS: Group mean θ_{CA} showed significant increases between session 1 (178 ± 42°) and session 8 (322 ± 41°), $p < .05$. The most rapid improvements occurred between the first and second testing sessions $p < .05$ (Fig. 1.).

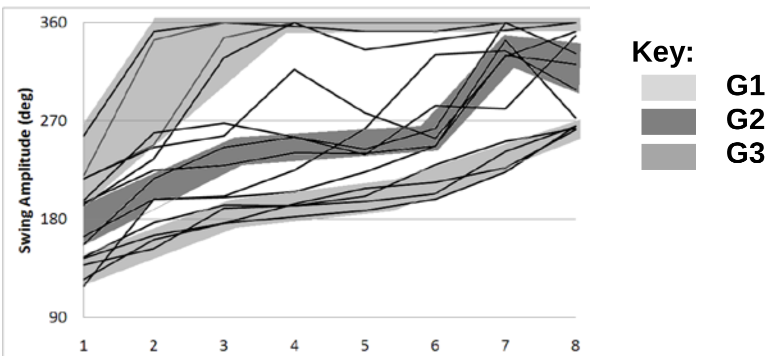

Figure 1. Mean swing amplitude over practice sessions.

Increases in θ_{CA} followed there distinct trends (Fig. 1). Based on these trends, three groups were defined; G1, G2, G3 as follows:
G1 ***High learning rate*** (n=4): participants were able to perform the skill by session 3. Largest amplitude swings were demonstrated by these participants. (Fig. 1). FP analysis identified that θ_{CH1} became progressively later during the learning period ($p < .05$). During successful LLS in sessions 3-8, θ_{CS1} occurred earlier and θ_{CS2} later than in sessions 1 and 2 (Table 1, Fig. 2).
G2 ***Variable learning rate*** (n = 5): demonstrated an initial increase in θ_{CA} between weeks 1 and 3, plateaued within the middle weeks before increasing during the penultimate week (Fig. 1). There were significant changes in hip FP variables θ_{CH1} and θ_{CH2} ($p < .05$), but not in the corresponding shoulder variables, θ_{CS1} and θ_{CS2}.

G3 ***Low learning rate*** (n = 4): participants began and ended with the smallest swing amplitude but demonstrated a steady increase over the 8 sessions (Fig. 1). No significant differences occurred in θ_{CH1} during the 8 weeks, but θ_{CH2} advanced between sessions 1 and 8 (*p*< .05). After session 2, the onset of the shoulder FP (θ_{CS1}) did not change (Fig. 2).

Table 1. Session mean results for representative participants from G1, G2, G3 of the onset and termination of functional phase of the hips (θ_{CH1}, θ_{CH2}) and shoulders (θ_{CS1}, θ_{CS2})

	G1				G2				G3			
Session	θ_{CH1}	θ_{CH2}	θ_{CS1}	θ_{CS2}	θ_{CH1}	θ_{CH2}	θ_{CS1}	θ_{CS2}	θ_{CH1}	θ_{CH2}	θ_{CS1}	θ_{CS2}
1	185	290	186	368	230	325	241	346	202	288	285	320
	(8)	(17)	(10)	(12)	(12)	(11)	(16)	(15)	(10)	(12)	(9)	(4)
2	177	278	182	355	214	332	206	371	209	288	209	322
	(10)	(12)	(6)	(22)	(3)	(13)	(11)	(14)	(3)	(4)	(10)	(20)
3	222	338	150	381	191	313	181	385	204	297	202	335
	(60)	(23)	(8)	(8)	(4)	(18)	(11)	(10)	(4)	(5)	(4)	(14)
4	236	345	151	384	192	321	194	343	211	304	209	358
	(38)	(4)	(11)	(7)	(6)	(23)	(31)	(56)	(6)	(10)	(6)	(8)
5	251	350	163	392	191	298	175	346	206	296	202	354
	(9)	(4)	(10)	(8)	(9)	(22)	(13)	(56)	(4)	(7)	(4)	(8)
6	260	348	149	387	192	335	171	393	200	300	197	352
	(12)	(9)	(3)	(8)	(7)	(23)	(17)	(10)	(18)	(8)	(18)	(8)
7	260	356	166	398	156	349	227	403	190	308	202	361
	(11)	(5)	(4)	(7)	(31)	(20)	(68)	(17)	(16)	(17)	(33)	(8)
8	250	351	150	392	203	346	211	330	207	335	200	371
	(13)	(1)	(13)	(14)	(11)	(18)	(44)	(55)	(5)	(8)	(31)	(9)

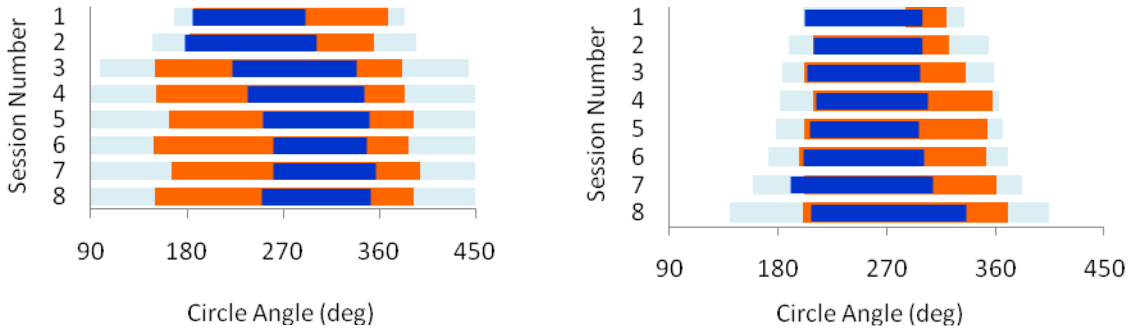

Figure 2. Mean functional phases (FP) of the hips (blue line) and shoulder (orange line) during the circle angle (light blue) for G1 (left) and G3 (right)

DISCUSSION: The aim of this study was to describe changes in the position of FPs of the LLS performed by a group of novices during a period of learning. Swing amplitude (θ_{CA}) significantly increased during the 8 week learning period. Three patterns of change in θ_{CA} (Group 1-3) were evident based on 2 criteria; the initial θ_{CA} and subsequent pattern change. Specifically, those participants who obtained the greatest θ_{CA} during session 1 were able to successfully perform the LLS by session 3 (G1). Four participants who had a mid-range θ_{CA} showed inconsistent increases in θ_{CA} over sessions (G2). Those who began with the smallest θ_{CA} in session 1 had the smallest θ_{CA} during session 8, sustaining a steady increase in θ_{CA} over sessions (G3). Therefore, the nature of improvement in the current skill appears to be closely related to skill level during initial attempts. Evidence from contemporary motor learning literature indicates that learning rate is individual and task specific even when a persistent change is apparent across subjects (Newell *et al.*, 2001). During learning a lateral swinging task on a suspended platform, Teulier & Delignières (2007) found between participant differences in initial coordination pattern complexity, however during subsequent trials it was reported that technique evolved in a similar manner. Though, during this study initial θ_{CA} appears to be a good predictor of final success of the LLS. For similar tasks (Teulier & Delignières, 2007) it has been suggested that, based on Newell's (1986) categories of 'individual-specific organismic constraints' differences in initial skill levels can be related to organismic factors, as task and environmental constraints were constant for all participants.

FP analysis revealed individual specific changes throughout the learning period; analysis of a representative performer from G1, G2 and G3 were presented. Results showed differences in the ability to adjust the placement of the FP within the θ_C across sessions. Specifically, G1, appeared able to significantly change the onset and termination of the hip and shoulder FP throughout learning. G3 appeared to adjust hip FP, but not shoulder FP. In contrast, G2, were unable to significantly change the onset of the FP after session 2. Newell *et al.* (1989) suggested that variability in movement patterns permits the exploration of a motor-perceptual workspace, and was therefore an inherent characteristic of functional dynamical systems when learning a given motor task. For example, the more successful participants appear to be able to alter placement of both the hip and shoulder FPs in order to create a movement pattern that enabled them to increase θ_{CA}, however it appeared that less successful participants were unable to alter these aspects of FPs in order to improve performance. Based on theories of motor learning, these findings have potential implications for the types of training intervention provided to a novice performer learning the LLS. For example, it could be interpreted that differences in initial θ_{CA} are related to organismic constraints of the system, where it is the ability to vary the onset and termination of the hip and shoulder FP which enable a progression to successful LLS. As such, it could be suggested that for a less successful performer (G3), skill progressions which promote actions temporally similar to that of the LLS for which firstly the hips (as per G2), and then the hips and shoulder actions (as per G1) would aid a performer in changing from an initially inadequate motor behaviour (Newell *et al.,* 2001).

CONCLUSION: This study highlights the importance of quantifying changes in technique throughout learning, and on an intra-individual basis when seeking to investigate the nature of technique modifications. These experimental findings could provide key information which is required when considering motor learning in a sports context, in order provide the most effective feedback to a performer during skill acquisition. Additional work is required to explore if a relationship exists between the placement of the FP and θ_{CA} via kinetics analysis.

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