MANIPULATION OF THE KINEMATIC CHAIN USING VISUAL BIOFEEDBACK

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Feedback has been shown to be an influential component in skill development, yet this has not been assessed in movements involving an explosive proximal to distal sequencing pattern. Novices (n=14) were introduced to a lunge touch task. Visual biofeedback were given on the timing and magnitude of rear leg kinematics. Results showed that those who received feedback adapted their movement patterns by developing extension velocity magnitudes in a summative pattern (pre v post, mean ± SD peak ankle angular velocity: biofeedback; 479 ± 181 v 689 ± 117, control; 466 ± 106 v 477 ± 84 deg·s^{-1}), resulting in greater horizontal impulse (mean ± SD: biofeedback; 1.17 ± 0.60 v 1.7 ± 0.89, control; 1.33 ± 0.33 v 1.49 ± 0.33 N·s·kg^{-1}). The changes were retained after six weeks. These results demonstrate that knowledge of performance based biofeedback interventions alone are effective in developing whole limb contributions in an explosive task.

KEY WORDS: knowledge of performance, feedback, angular velocity.

INTRODUCTION: Feedback (Fb) provides direction to skill exploration, helping to refine muscle coordination and identify efficient movement patterns during motor task learning. External Fb can either be knowledge of results (KR) or knowledge of performance (KP). KP is information on movement characteristics toward a desired goal (Ericksson et al., 2011). While KR provides useful information on task success, KP directs toward a model of desired technique. Confidence in the application of previous KP research to complex motor skills remains ambiguous for two main reasons; it has 1) neglected to isolate the effectiveness of KP without providing additional KR (Mononen et al., 2003), or 2) predominantly focused on simple skills involving single or limited degrees of freedom. In reality, the human musculoskeletal system is a combination of mono-articular and biarticular muscles. Therefore the application of KP should allow for multi-joint interaction for it to be more meaningful in an applied setting.
The kinematics of the lower limb can be modelled as a kinematic chain, through identifying magnitudes and timings of joint angular velocities. The lower limb can be used in a proximal to distal sequence, allowing for utilization of velocities generated in the preceding segment. Proximal to distal lower limb kinematic sequencing has been linked with successful performance in jumping (Gregoire et al., 1984) and sprinting (Jacobs et al., 1996). Furthermore, mathematical modelling has identified the effectiveness of the lower limb rigid body chain in turning joint segment angular velocity into effective linear centre of mass velocity (Bobbert & van Soest, 2001). The aim of this research was twofold: 1) to determine whether KP alone can be used to develop the kinematic chain in a novel, explosive gross motor skill, and; 2) whether development of the sequential kinematic chain leads to greater propulsive ability. These findings would be useful to inform Fb provision toward complex skills, particularly coaches looking to develop whole limb, multi-joint contributions in explosive tasks.

METHODS: Fourteen participants (mean ± SD; age: 22 ± 3 yrs, height: 1.70 ± 0.09 m, mass: 67.3 ± 11.1 kg), after providing written informed consent, were randomly grouped into either biofeedback (BFb; n=7) or control (C; n=7). Participants visited the laboratory on three occasions evenly spaced over one week. During session one (S1) participants were introduced to a novel explosive lunge and touch task. In each session participants completed blocks of practice of six lunges. Following the intervention week, participants returned after 6 weeks for a retention session (Figure 1a).

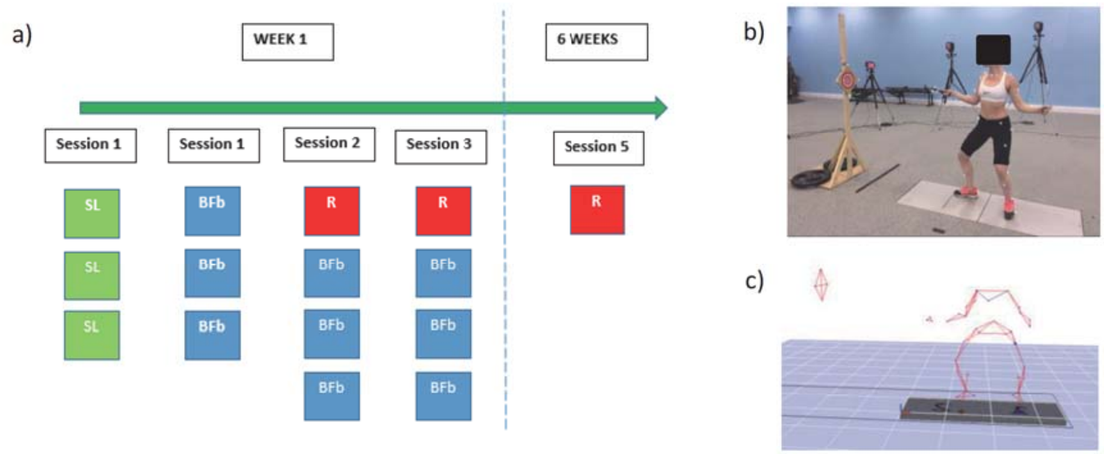

Figure 1: a) Schematic representation of the longitudinal data collection protocol. Each square represents 1 block of 6 lunges. SL = self-learning, where no BFb was provided; BFb = 100% BFb (or no BFb for controls) and R = a retention block. b) Image depicting the start position c) Marker set.

The aim of the lunge task was to strike a 15 x 15 cm target which was placed 1.5 leg lengths away from the front foot in the lunge start position, with a customized 20 cm long pointer held in the leading hand. During the first three blocks of S1, participants practiced ‘self-learning’ lunges following instruction on the required start position before each lunge. This position simulated an “en-guarde” stance adapted from fencing, with each foot on an individual force plate. The front foot was pointed toward the target, with the rear foot perpendicular to the target. Elbows were tucked in, with the participant crouching to 130° of flexion at the rear knee (Figure 1b).

Participants were instructed to propel themselves forward as quickly as possible and strike the target centre. Following completion of each lunge the BFb group received visual Fb on the magnitude and timing of rear leg hip, knee and ankle maximal angular extension velocity. These data were displayed as a bar-chart with a colour system used to identify joint sequencing (green signifying correct proximo-distal sequencing; red identifying joints that were out of sequence). Following the intervention week, participants returned at 6 weeks for a retention session.

Kinematic data were collected using 12 Raptor cameras sampling at 150 Hz and Cortex v5.3 software (Motion Analysis Corporation, Santa Rosa, CA), Kinetic data were sampled at 1500 Hz through two Kistler force plates (Kistler, Switzerland). Thirty 12.5 mm retro reflective markers were placed on lateral anatomical landmarks of the whole body (Figure 1b and 1c). Four additional markers were placed on the target, with three on the pointer. The 3D joint angles were calculated for the rear hip, knee and ankle. The start of stance phase was identified as the onset of rear leg vertical force (>20 N) and the end as take-off (<20 N). The data were interpolated to 126 data points with the first 101 representing stance and the remaining 25 representing early flight phase. Local maxima were identified for rear hip and knee flexion, and ankle plantarflexion. The timing that these occurred was calculated as a percentage relative to time. The integral of both horizontal and vertical rear leg force was calculated using the trapezoidal method, and normalized to body mass.

Means and standard deviations were calculated for the last self-learning block of S1, last block of session 3 and session 4 for pre, post and retention time points. A two by three (group x time) mixed model ANOVA was used to test for significant interaction for joint angular velocities and impulse. Paired t-tests were used to compare means between sessions to identify where significant interaction occurred. Statistical analysis was completed in SPSS (v.22, IBM, Armonk, NY) with an alpha level of 0.05.

RESULTS: A significant interaction effect was found between group and time for knee (p=0.015) and ankle angular velocity (p=0.02) over time. Hip angular velocity increased in both groups, however there was no significant interaction effect (p=0.548) between group and time for hip angular velocity. Figure 2 shows the mean joint interactions.

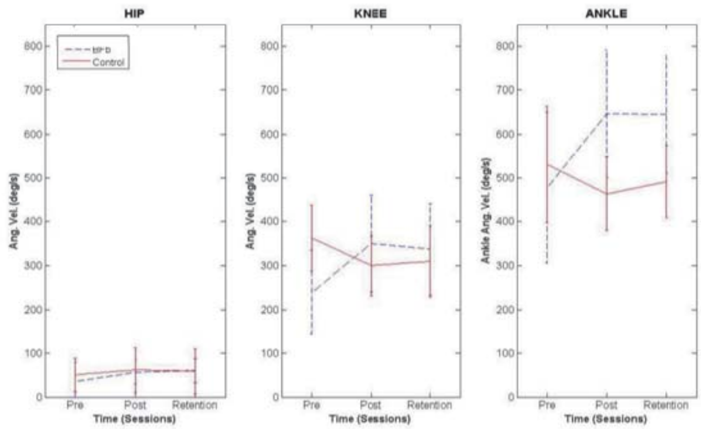

Figure 2: Means and SD of joint angular velocities at pre, post and retention session. The full line represents the control group, with the dotted line representing BFb.

Ankle and knee angular velocity significantly increased from pre to post in the BFb group (ankle: Δ210 deg·s^{-1}, p=0.04; knee Δ135 deg·s^{-1}, p=0.02) following the KP intervention (Table I). Timings did not significantly change. Normalised vertical impulse did not significantly differ between groups or sessions, however normalized horizontal impulse did significantly increase with BFb from the pre – post sessions, and was retained after 6 weeks (Table II).

Table 1. Mean (±SD) maximum angular velocities and timings for rear leg during a lunge task at pre, post and retention following 1-week for both Biofeedback and Control groups.

		Ang. Vel. Magnitudes (deg·s^{-1})		Ang. Vel. Timing (%)	
		Control	**Biofeedback**	**Control**	**Biofeedback**
Pre	**Hip**	58 (± 36)	48 (± 44)	70 (± 30)	69 (± 19)
	Knee	389 (± 81)	264 (± 93)*	100 (± 2)	97 (± 3)
	Ankle	566 (± 106)	479 (± 181)*	101 (± 1)	101 (± 3)
Post	**Hip**	69 (± 52)	66 (± 25)	69 (± 19)	65 (± 19)
	Knee	308 (± 69)	399 (± 72)*	97 (± 3)	98 (± 5)
	Ankle	477 (± 84)	689 (± 117)*	101 (± 3)	103 (± 1)
Ret.	**Hip**	70 (± 22)	70 (± 22)	70 (± 24)	76 (± 17)
	Knee	319 (± 80)	387 (± 44)	99 (± 3)	98 (± 7)
	Ankle	500 (± 84)	696 (± 108)	101 (±2)	103 (± 2)

** denotes p < 0.05 between pre and post intervention sessions*

Table 2. Normalised vertical and horizontal impulse for the rear leg during a lunge task at pre, post and retention time-periods following 1-week for both Biofeedback and Control groups.

	Vertical Impulse (N·s·kg⁻¹)		Horizontal Impulse (N·s·kg⁻¹)	
	Control	**Biofeedback**	**Control**	**Biofeedback**
Pre	2.27 (± 0.39)	2.19 (± 0.57)	1.33 (± 0.38)	1.17 (± 0.60)*
Post	2.48(± 0.74)	2.42 (± 0.30)	1.49 (± 0.30)	1.7 (± 0.89)*
Ret.	2.72 (± 0.88)	2.42 (± 0.12)	1.71 (± 0.64)	1.6 (± 0.33)

** denotes p > 0.05 between pre and post intervention sessions*

DISCUSSION: The findings of this research demonstrate that KP alone elicited a development in the lower limb kinematic chain in an explosive movement. Significantly greater extension velocities of the more distal joints in the BFb group (mean knee; 264 to 399 deg·s⁻¹, ankle; 479 to 689 deg·s⁻¹) highlight a distal summation of joint angular velocity. These changes were retained over 6 weeks in the BFb group (696 deg·s⁻¹) therefore, according to motor learning principles, it is likely that these changes were relatively learnt (Schmidt & Lee, 2005). The development of the sequential kinematic chain resulted in significantly greater horizontal impulse in the BFb group compared to the control group, with no significant changes in vertical impulse. This shows that not only were the kinematics developed, the resulting external kinetics of this technique were more effective in a forward propulsion task.

The increases in the more distal joint angular velocity lend support to theoretical principles that the accumulation of angular velocity is achieved through optimal kinematic sequencing that capitalize on the biarticular design of the lower limb (Jacobs et al., 1996). Interestingly, the lack of temporal changes suggest that individuals had already identified their optimal kinematic sequence timing, although future work should seek to manipulate this in addition to joint angular velocity magnitudes. Additionally, future work needs to be carried out on the isolation of KP Fb delivery, to optimize approaches for particular skills and individualized delivery, as not all participants responded to the Fb in the same way.

CONCLUSION: Visual KP was found to increase rear leg ankle and knee extension velocities in an explosive lunge task. These increases, facilitated the use of the kinematic chain, resulted in greater horizontal impulse. These findings are useful for informing Fb provision for complex skills, in particular for coaches looking to develop whole limb, multi-joint strategies in explosive tasks.

REFERENCES:

Bobbert, M. F., & van Soest, A. J. (2001). Why do people jump the way they do? *Exercise and Sport Sciences Reviews, 29*(3), 95-102.

Eriksson, M., Halvorsen, K. A., & Gullstrand, L. (2011). Immediate effect of visual and auditory feedback to control the running mechanics of well-trained athletes. *Journal of Sports Sciences, 29*(3), 253-262.

Gregoire, L., Veeger, H.E., Huijing, P.A., & van Ingen Schenau, G. J. (1984). Role of mono and biarticular muscles in explosive movements. *International Journal of Sports Medicine*, 5(6), 301-305.

Jacobs, R., Bobbert, M.F., & van Ingen Schenau, G.J. (1996). Mechanicaloutput from individual muscles during explosive let extensions; the role of biarticular muscles. *Journal of Biomechanics*, 29(4), 513-523.

Mononen, K., Viitasalo, J. T., Konttinen, N., & Era, P. (2003). The effects of augmented kinematic feedback on motor skill learning in rifle shooting. *Journal of Sports Sciences, 21*(10), 867-876.

Schmidt, R.A. & Lee, T.D. (2005) *Motor Control and Learning. A Behavioural Emphasis.* 4th edition. Champaign, IL: Human Kinetics.