LONGITUDINAL MANIPULATUION OF THE KINEMATIC CHAIN USING A REDUCING BIOFEEDBACK SCHEDULE

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Feedback has been shown to be an influential component in skill development, yet this has not been assessed longitudinally in a complex motor skill. Novices (n=32) 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 (40.0%, 24.8% and 28.9% increases for the hip, knee and ankle respectively). The changes were retained across 26 weeks, with a reducing visit schedule of feedback. These results demonstrate that knowledge of performance based biofeedback interventions alone are effective in developing whole limb contributions in an explosive task, and that a reducing visit schedule negates dependence on feedback.

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

INTRODUCTION: Feedback is implicit to motor learning and skill development. Research paradigms have established the effectiveness of knowledge of results (KR; Konttinen *et al.,* 2004) and knowledge of performance (KP; Mononen *et al*., 2003) in discrete skills, and subsequent short term retention. Concurrent research has identified differences with traditional feedback paradigms emerging from simple, single degree of freedom tasks in comparison to more complex, sporting skills (Sigrist *et al*; 2013). However to the authors' knowledge, the majority of this body of research has not investigated long term skill development, and subsequent retention, beyond 4-6 weeks, with a paucity extending beyond 12 weeks (Rice *et al*, 2009). The guidance hypothesis dictates that feedback must be provided with an extracting schedule, reducing contact time, to avoid participant dependence on feedback (Schmidt, 1991), however this has not been tested longitudinally. The aim of this research was twofold; 1) Can KP feedback develop a complex skill in a propulsive, coordinated gross motor skill over 26 weeks, and; 2) Can these changes be retained with a reducing feedback schedule.

METHODS: Thirty-two participants, after providing written informed consent, were randomly grouped into two equal groups, either biofeedback (mean ± SD; BFb; age: 26 ± 5 yrs, height: 1.71 ± 0.08 m, mass: 67.4 ± 10.8 kg, leg length: 0.91 ± 0.04 m) or control (C; age: 24 ± 4 yrs, height: 1.71 ± 0.10 m, mass: 70.1 ± 14.9 kg, leg length: 0.92 ± 0.06 m). Participants visited the laboratory on 7 occasions spaced over a six month period. During session one (S1) participants were introduced to a novel explosive lunge and touch task. In each subsequent session participants completed four blocks of practice of six lunges. In each session following S1, the BFb group completed one block of retention lunges without feedback, and three blocks with KP feedback, with a retention block at week 26. Following the intervention week, participants returned at 4-6 (S4), 12 (S5) and 26 (S6) weeks. The control group matched all lunges without feedback (Figure 1a).
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 (S1a), participants practiced 'self-learning' lunges following instruction on the 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).

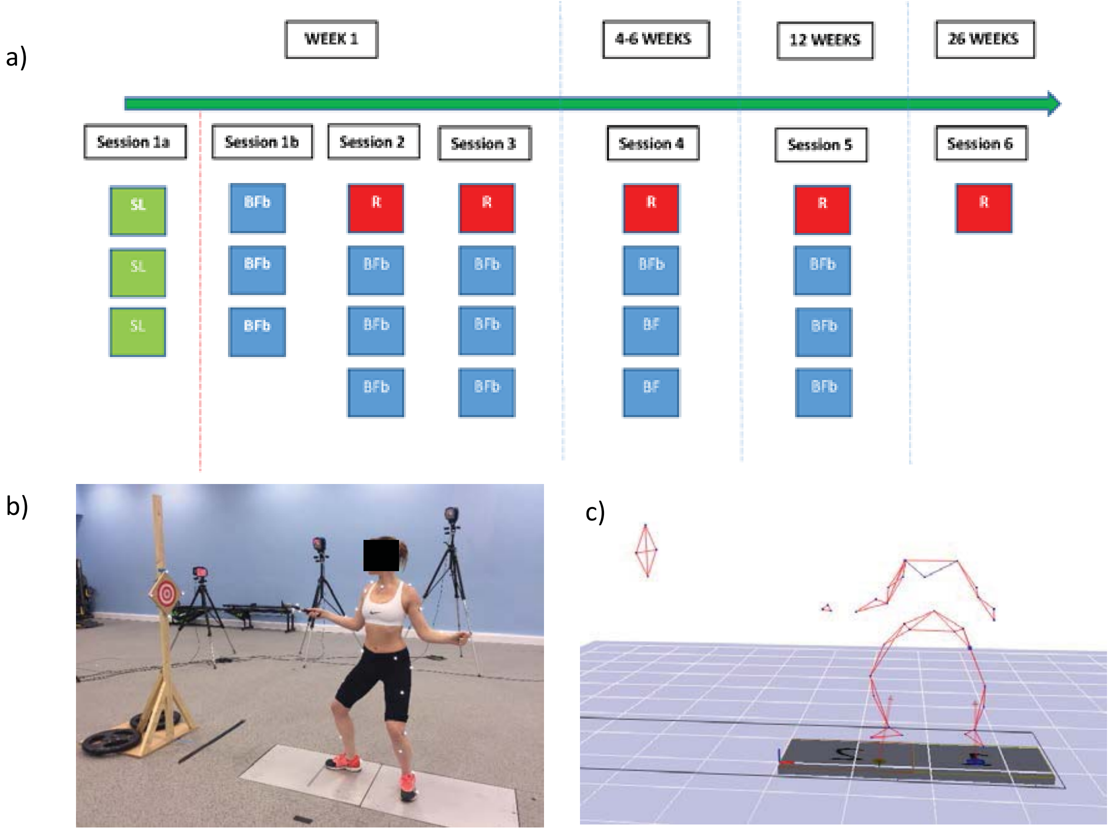

Figure 1: a) Schematic representation of the longitudinal data collection protocol. Each square represents 1 block of 6 lunges. SL = self-learning, where no BFb was provided; BFb = 100% BFb (or no BFb for controls) and R = a retention block. b) Image depicting the start position c) Marker set.

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 for repeat sessions, once at 4-6 weeks and at 13 weeks. Each sessions consisted of one retention block followed by 3 BFb blocks. Participants concluded the investigation by returning for a final retention session at 26 weeks.
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. Local maxima were identified for rear hip and knee flexion, and ankle plantarflexion. Means and standard deviations were calculated for each block, for hip, knee and ankle respectively for both groups. These blocks were normalised and

presented as a percentage relative to Block 3 for both groups, as the end of the "directed self-learning" session.
Paired t-tests were used to compare means between blocks to identify significant differences between pre, post and subsequent retention sessions throughout the 26 week period. Statistical analysis was completed in SPSS (v.22, IBM, Armonk, NY) with an alpha level of 0.05.

RESULTS: Participants of the BFb group significantly increased hip (40.0%), knee (24.8%) and ankle (28.9%), angular velocities after the BFb intervention from pre (block 3; 0%) to post (block 14). These changes indicate that by attending to the BFb augmented a change in the kinematic chain of the rear leg. Over the same period, the control group showed no significant changes in any joint angular velocities.
After a period of 4-6 weeks, these changes were retained across all rear leg joints as exemplified by no significant differences between the retention block (e.g. 15) and the previous block (e.g. 14). There were no further significant increases at any time point across any later blocks. An average for each block is presented below (figure 2).

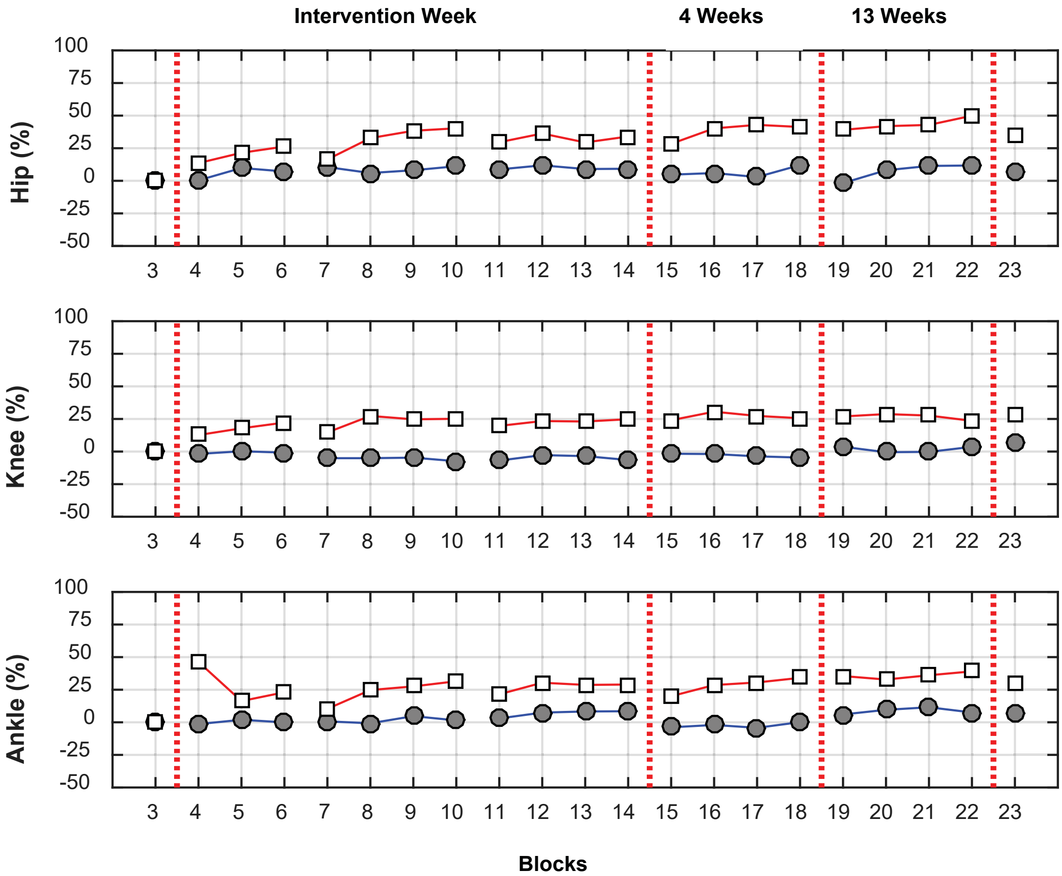

Figure 2: Mean percentage change of joint angular velocities. Each shape represents one block. The squares represent BFb, while the circles represent the control group. The red dotted lines separate between sessions (Self learning, Intervention, 4 Weeks, 13 Weeks and 26 Weeks). Note, only block 3 (the last block of self learning session 1a) was included. B23 is 26 Week retention.

DISCUSSION: The BFb group demonstrated significant increases in joint angular extension velocity percentages ($p<0.05$) in the hip, knee and ankle of the rear leg in a propulsive lunge

task following a one week BFb intervention. This shows that the BFb intervention was effective in altering kinematics of a complex gross motor skill, further adding to evidence for the use of biofeedback in discrete complex skill development (Mononen *et al*., 2003).
These changes were retained at 4-6 weeks, with no significant differences (p>0.05) demonstrated from post (block 14) to the first retention time point (block 15). This demonstrates maintenance of the kinematic changes induced by the BFb conditions. This pattern was continued for the subsequent 13 weeks and 26 week retention time points showing no significant drop in performance, suggested that these changes were relatively permanent (Schmidt and Lee, 2005). These findings are in line with previous KP research demonstrating retention in kinematic parameters of up to 3 months (Rice *et al,* 2009), however this invetigation adds new insight into retention beyond this time frame. The control group demonstrated that self-directed learning did not lead to significant changes in lunge kinematics in the hip, knee or ankle joint of the rear leg in a propulsive lunge task. Despite continued self-learning, across the 26 weeks the kinematics did not change. This suggests that the BFb intervention was more effective in increasing joint extension velocity in a complex, explosive lunge task, than practice alone.
Traditional paradigms of motor learning indicate that following skill development, there is a subsequent drop off with retention (Rice et al., 2009). The lack of significant differences between block 14 and subsequent retention 4-6 weeks following this show that this paradigm may not be applicable to explosive complex motor skills in a sporting context. Furthermore, the provision of ‘top up’ BFb with an extracting visit schedule over 26 weeks, as demonstrated in this study, appears to be an effective approach to reduce this negative response, and perhaps aids long term retention (i.e. learning). These findings are useful in guiding applied approaches to skill development and working with athletes in longitudinal development cycles. This has implications for the effective integration of BFb into technique training regimes in sport.

CONCLUSION: Visual KP was found to increase rear leg ankle and knee extension velocities in a complex skill, in the form of an explosive lunge task. These changes were retained over a total period of 26 weeks, with intermittent return visits with increasingly larger time periods in between.

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