EFFECTS OF NON-INSTRUCTED PRACTICE ON A NOVEL ROWING TASK

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Information feedback has been shown to be an important part of the learning process, yet changes have not been assessed within sporting applications. Non-rowers (n=7) performed a 10-minute novel rowing task, and joint and rowing ergometer kinematics recorded. Following four non-instructed practice rowing sessions, their techniques were reassessed. Results showed that the ergometer handle trajectory became more elliptical throughout the stroke and that the knees were more flexed at catch (11°) and more extended at the finish (13°). Changes in the shape of the handle trajectory caused changes in the lengths of the pull and recovery phases and implied changes in the timing of joint motions. This study is a step towards understanding the motor learning of novices.

KEY WORDS: biofeedback, feedback, learning, motor, novice

INTRODUCTION: The performance of motor skills is an essential part of expert performance. When learning a complex motor skill, practice difficulty can be manipulated so that task requirements are introduced abruptly and maintained throughout the practice. This approach has been shown to result in large movement errors (Schmidt & Lee, 2005). Detection of these errors and their correction is thought to drive the adaptation of movement strategies and subsequent motor learning (Tseng *et al.*, 2007), thus modifying the internal representation of the interaction between the limb and the environment (Wolpert & Ghahramani, 2000). Alongside practice difficulty, feedback is another important component when learning a motor skill (Salmoni *et al.*, 1984). Feedback can be intrinsic or extrinsic, and the latter can take a number of forms including knowledge of performance, where this provides information about how an action itself was completed (Newell & Walter, 1981), information which could be given through biofeedback of biomechanical parameters (e.g. Fothergill, 2010).

When learning a motor skill, it has been proposed that the main concern for a beginner is to master the multiple and redundant degrees of freedom (DOF) that could potentially be involved (Bernstein, 1967). The control of this complexity could be achieved by "freezing" a number of joints to reduce the number of active DOF, and the progressive freeing of these DOF then happens in concordance with improvements in skill (Vereijken & Bongaardt, 1999). Little research, however, has measured what biomechanical changes occur during the learning of a novel complex motor skill whilst receiving no augmented biomechanical biofeedback. The aim of this study was to determine the biomechanical changes over time of complete novice performers learning a motor skill for the first time whilst receiving no biomechanical feedback. Using rowing as a model task, as it is relatively controlled and cyclical, this information could be used to aid in the development of motor learning theories or to identify task specific variables for rowing biofeedback interventions.

METHODS: Seven females were recruited for this study (mean±SD, age 19.7±1.4years, height 167.2±4.7cm, mass 63.6±4.5kg) and provided informed consent. The inclusion criteria were that they were physically active and free from injury, and had no experience of rowing or sculling, ergometer rowing, or any other rowing motion. The subjects visited the laboratory on six occasions, each separated by one day. During each visit the subjects performed a non-rowing related warm up and then rowed continuously for 10 minutes on a Dynamic ergometer (Concept2, Morrisville, VT). Throughout the study no rowing instructions or biomechanical feedback were provided. To standardise the intensity, subjects rowed at a heart rate between 130-150 bpm (Mackenzie *et al.*, 2009) provided through a FT1 monitor and T31 coded transmitter (Polar Electro, Kempele, Finland). During the first (pre) and last (post) visit, data were captured from the start of the first rowing stroke performed on the ergometer.

Kinematic data were obtained from 16 passive, spherical, retro-reflective markers, of 12mm diameter, affixed to anatomical landmarks of the ankle, knee, elbow and wrist joints, and 12 markers affixed to the hip and shoulder joints, pelvis and spine. On the ergometer 15 markers were placed on the handle, foot stretcher, and frame. The ergometer was orientated so that the length of the slider ran along the X-axis, towards the feet of the subject, the Z-axis was vertically up and the Y-axis was the cross-product of Z and X (pointing left). Three-dimensional kinematics of the markers were recorded at a rate of 150Hz using eight Raptor-E and three Raptor-4 Digital Cameras (Motion Analysis Corporation, Santa Rosa, CA).
All marker identification was completed using Cortex v4.0.1 (Motion Analysis Corporation) and data analysed using MATLAB (R2013b; MathWorks, Natick, MA). Data were smoothed using a zero lag 4th order Butterworth low-pass filter with a cut-off frequency of 7Hz. Two key events were defined as the instants at which the velocity of the centre of the ergometer handle in the X-axis changed from positive to negative (catch), and from negative to positive (finish). These were used to define the ‘pull’ (catch to finish) and ‘recovery’ (finish to catch) phases, and the combination of one pull and the following recovery constituted one stroke. The first ten and the last ten strokes of the pre and post-practice sessions were analysed. Kinematics were analysed further in the sagittal (XZ) plane only. Angles were defined for the knee (where 180° was full extension), spine (where >0° was flexion and <0° was extension) and pelvis (where <0° was anterior pelvic tilt and >0° was posterior pelvic tilt). Ergometer handle displacement was defined as the straight-line distance from the position at the catch to the finish, and the pull and recovery lengths were defined as the distances over which the ergometer handle centre moved during each phase, respectively. The stroke length was the sum of one pull length and the following recovery length. Data were presented as means and standard deviations, and pre to post values were compared using paired t-tests at an alpha level of 0.05 (SPSS v.21 (IBM)).

RESULTS: Between the two sessions all subjects exhibited changes in the kinematics of their rowing technique, most notably in the trajectory of the handle and the knee motion. The handle trajectory in the post-practice session was more elliptical than in the pre-practice session (Figure 1), indicating a move towards more skilled performance (Černe, 2013). Furthermore, the change in trajectory shape had the effect of increasing the stroke length by 4cm, which also had the effect of increasing the pull length and the recovery length (Table 1). During the pre-practice session the timing of knee joint motion was such that the knees began to move into flexion immediately after the finish, in such a pattern that the knees were interfering with the desired path of the handle. Subjects accommodated for this by changing the path of the handle so that it moved over the flexing knees, creating a curve in the recovery path, having the effect of moving the trajectory away from a straight line (Figure 1). Moreover, possibly due to this, the variability of handle trajectory during the pull increased, as did the position of the finish.

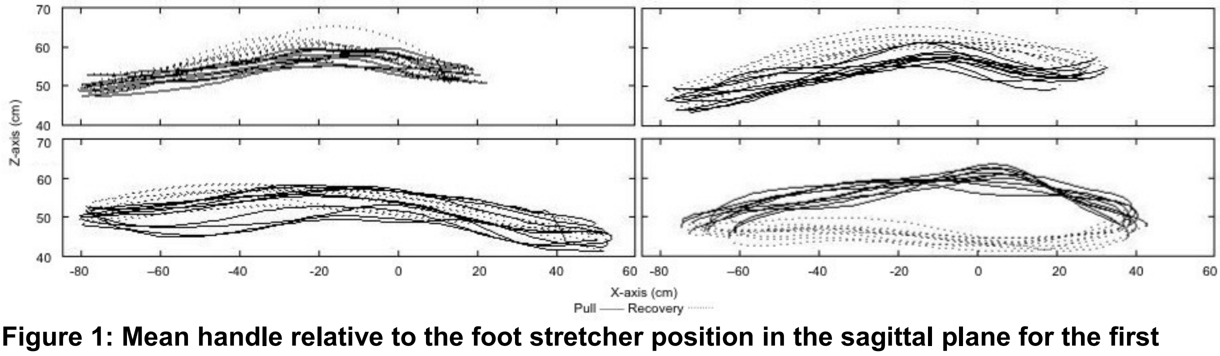

Figure 1: Mean handle relative to the foot stretcher position in the sagittal plane for the first ten (left) and last ten (right) strokes for pre (top) and post-practice (bottom) sessions. Each line shows the mean of each of the ten strokes across all seven subjects.

Stroke length over the course of both sessions decreased, yet remained seven centimetres longer during the last ten strokes of the post-practice session than during the last ten strokes of the pre-practice session. As a result of this, both the lengths of the pull and recovery demonstrated similar changes (Table 1). Knee range of motion (ROM) decreased over the course of the post-practice session, yet moved 11° more into flexion at the catch and extended 13° more at the finish when compared to the start of pre-practice. Changing both the ROM and timings of the knee motion allowed subjects to move the ergometer handle past their feet, changing the shape of the handle trajectory during the end of the recovery and the beginning of the pull in the post-practice session. Lumbar spine and pelvic ROM decreased over both sessions.

Table 1: Handle and joint kinematics in the sagittal plane pre and post-practice. Data is the mean±SD for the first ten and last ten strokes.

		Handle path: length (cm)			C to F disp. (cm)		Angle (°)		
		Stroke	Pull	Rec.			Knee	Spine	Pelvis
Pre	First	145±16	73±10	72±7	66±6	C	91±16*	5±9	12±5*
						F	151±29*	-32±60*	38±6*
	Last	133±16	67±10	66±7	61±5	C	66±43	-16±11	29±12
						F	142±24	-34±5	37±16
Post	First	145±25	72±14	72±11	65±15	C	63±41	9±5	4±4
						F	168±16	-18±7	26±5
	Last	140±11	71±6	69±6	63±6	C	80±77*	2±3	21±10*
						F	164±70*	-21±6*	31±7*

Rec.=Recovery; disp.=displacement; C=Catch; F=Finish. *Significant change between the first ten strokes of pre-practice and the last ten strokes of post-practice.

DISCUSSION: Throughout the pre-practice session, subjects displayed large movement errors, characterised by more vertically inclined handle motion at the start of the pull phases, greater movement variability of handle motion during the pull phase and a recovery path which was not comparable to that of more skilled rowers (Černe *et al.*, 2013). As all biomechanical feedback was withheld, changes in joint ROM and movement patterns during practice were guided by the subjects' self-discovery of the task and their interaction with the kinetic and kinematic demands of the rowing motion. This induced handle trajectory changes that imply a move towards more skilled performance. Kinematic differences between the last strokes of the pre-practice session and the first strokes of the post-practice session suggest that over the self-discovery practice sessions there was some retention of the changes in the kinematics of the technique employed.

The trajectory of the handle motion, stroke length and body posture have all been previously identified as biomechanical parameters which characterised ergometer rowing technique (Černe *et al.*, 2013). All subjects in this study exhibited considerable change in the trajectory of their handle motion. These non-rowers demonstrated a greater handle movement away from horizontal during the start of the pull phase (Figure 1). The loop at catch developed into the post-practice session would possibly make the transition between pull and recovery easier and more efficient. It has been shown that, compared to non-rowers, the handle motion trajectory of more elite performers follows a more elliptical shape and that, especially during the pull, the handle motion is closer to horizontal (Černe *et al.*, 2013).

The drop in vertical movement at the beginning of recovery seen here shows that handle moves 'under' the trajectory of the pull in the post-practice session, possibly reflecting a change in the timing of knee joint motion to accommodate this. After the non-instructed practice sessions, the knees remained in an extended position after the finish, allowing the handle to move into the recovery before the knees started to move into flexion. This consequently lengthened the duration of the recovery at the end of post-practice compared to pre-practice and increased the ratio between the two phases at this point, traits also seen in more skilled rowers (Černe *et al.*, 2013). Demonstrating similar results to Černe *et al.* (2013), a shorter stroke length compared to more skilled rowers is a consequence of a lack of knee flexion at catch and a lack of knee extension at finish. The post-practice decrease of lumbar spine ROM shows that subjects used an increased knee ROM more than spinal flexion and hyperextension to maintain stroke length. The increased pre-practice lumbar spine ROM indicates that more novice subjects move their hands further in the positive X direction by leaning their upper body forward rather than by flexing their knees during the recovery. The larger vertical change in handle motion across the start of the pull phases of the pre-practice session indicates an early initiation of trunk and spinal movement. Delayed spinal motion could have accounted for the post-practice decrease in the vertical ROM of the handle trajectory during the pull. A delayed spine movement supports the notion that, through knee extension, the lower limbs initiate the pull phase of the rowing motion before being followed sequentially by trunk movement (Nelson and Widule, 1983). Furthermore, Kleshnev and Kleshnev (1998) reported that consecutive segment movement produced increased power when compared to synchronous segment movement.

CONCLUSIONS: This study has demonstrated the changes in technique brought about as a consequence of self-discovery of a novel rowing task. Over the course of the practice sessions, novices decrease spinal ROM whilst increasing knee joint ROM. Moreover, the timing of these joint motions has the effect of moving the position of the catch to beyond the feet, flattening the pull trajectory and changing the path of the recovery. These observed changes indicate a move towards a more ‘skilled’ handle trajectory. As some specific kinematic motions are altered, related joint motions potentially adjust to accommodate this change with the aim of maintaining performance output. By providing a greater understanding of the changes employed by novices and the ways in which these changes are brought about, these findings will help to inform studies in which, through the use of biofeedback, attempts are made to control multiple kinematic variables at the same time.

REFERENCES:

Černe, T., Kamnik, R., Vesnicer, B., Gros, J.Z. & Munih, M. (2013). Differences between elite, junior and non-rowers in kinematic and kinetic parameters during ergometer rowing. *Human Movement Science*, 32, 691-707.

Fothergill, S. (2010). Examining the effect of real-time biofeedback on the quality of rowing technique. *Procedia Engineering*, 2, 3083-3088.

Kleshnev, V. & Kleshnev, I. (1998). Dependence of rowing performance and efficiency on motor coordination of the main body segments. *Journal of Sports Sciences*, 16, 418-419.

Mackenzie, H.A.M, Bull, A.M.J. & McGregor, A.H. (2008). Changes in rowing technique over a routine one hour low intensity high volume training session. *Journal of Sports Science and Medicine*, 7, 486-491.

Nelson, W.N. & Widule, C.J. (1983). Kinematic analysis and efficiency estimate of intercollegiate female rowers. *Medicine and Science in Sport and Exercise,* 15, 535-541.

Newell, K.M. & Walter, C.B. (1981). Kinematic and kinetic parameters as information feedback in motor skill acquisition. *Journal of Human Movement Studies*, 7, 235-254.

Salmoni, A.W., Schmidt, R.A. & Walter, C.B. (1984). Knowledge of results and motor learning: a review and critical reappraisal. *Psychological Bulletin*, 95, 355-386.

Schmidt, R.A. & Lee, D.L. (2005). *Motor control and learning: A behavioral emphasis*. Champaign: Human Kinetics.

Tseng, Y.W., Diedrichsen, J., Krakauer, J.W., Shadmehr, R. & Bastian, A.J. (2007). Sensory prediction errors drive cerebellum-dependent adaptation of reaching. *Journal of Neurophysiology*, 98, 54-62.

Wolpert, D.M. & Ghahramani, Z. (2000). Computational principles of movement neuroscience. *Nature Neuroscience* (suppl. 3), 1212-1217.