ACCELEROMETRY BASED IPSATIVE BIOFEEDBACK TO IMPROVE KINEMATIC CONSISTENCY AND PERFORMANCE IN ROWING

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The training and competition regimen of elite athletes demands rapid feedback regarding their performance. The aim of this study was to determine if real time, visual feedback of instantaneous kinematic consistency can improve rowing performance and overall kinematic consistency. Prototypical accelerometry based kinematic patterns representing the upper and lower body were determined for thirteen rowers. Percentage time outside these kinematic patterns (kinematic consistency) and performance indicators were recorded for all rowers for three 2000m time trials with different visual feedback interventions. Significant improvements were found for kinematic consistency for visual feedback. No improvements were found for performance related parameters.

KEY WORDS: rowing, biofeedback, consistency, technique optimisation.

INTRODUCTION: Despite the physiological demands of sport it is very often the biomechanics (both kinematics and kinetics) that can determine the more successful of two physiologically identical athletes (Nelson & Widule, 1994). Kinematic biomechanical analysis has confirmed that the rowing stroke is a highly complex movement and a high level of consistency and efficiency must be obtained throughout the race distance if the oarsperson is to be successful (Klavora, 1980). A consistent power/stroke output is mathematically more efficient in rowing than varying power/stroke values over a set distance. To obtain a constant repeatable power/stroke output it is essential that the kinematic patterns of the athlete are initially optimised and these patterns are then reproducible throughout the whole race time. The co-ordination and technical proficiency of each oarsperson has also been deemed to be a crucial factor in overall crew harmonization and thus the speed of the boat (Nelson & Widule, 1994). Therefore, the training and competition regimen of elite athletes demands immediate feedback regarding their kinematic consistency. By enabling the athlete to view kinematic patterns in real-time, early deviations from their optimal patterns can be detected. Using this information the athlete can make immediate alterations to their kinematics or begin to focus on particular aspects of the kinematic pattern. A portable accelerometer-based ipsative (comparison to oneself) kinematic biofeedback system has been developed using LabVIEW Version 6.0 software and a DAQCard-AI-16E-4 data acquisition card (National Instruments, Texas, USA), in conjunction with IC-based ADXL202 accelerometers (Analog Devices, Massachusetts, USA – Analog, 2002). Accelerometer based motion analysis has been shown previously to be effective for comparing kinematic patterns (Anderson *et al.*, 2001). The biofeedback system is based on an 800MHz Pentium III laptop computer running Windows 2000 (Microsoft, Washington, USA); a laptop computer is used to ensure electrical isolation between the mains power supply and the sensors attached to the athletes. This approach provides a high degree of portability, and also offers a higher degree of flexibility than more expensive optical isolation solutions. The sampling rate of each channel (16 in total) can be independently controlled by the software. The data is buffered using the system RAM prior to writing it to the hard drive to ensure the hardware controlled sampling frequency is maintained accurately. The data flow is approximately 50MB per hour for one sensor operating at 250Hz. Figure one shows a schematic diagram of the biofeedback system, illustrating the different components of the system. This study tested the effectiveness of the biofeedback system in improving performance and kinematic consistency over standard distance (2000m) time trials. Two types of feedback were utilised within the study; the first displays actual kinematic data during the stroke and the second displays summarised results after the completion of the stroke; comparisons will be made with a non-feedback control condition.

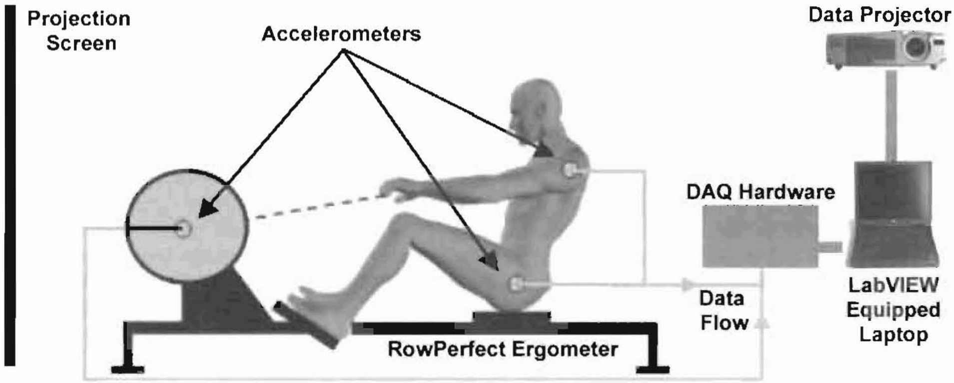
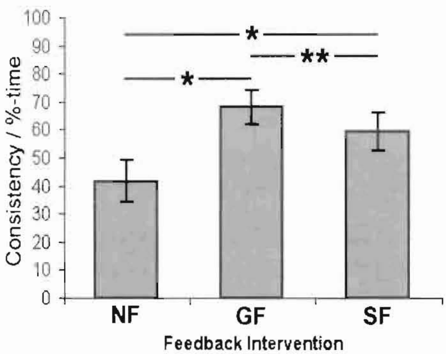


Figure 1. Schematic of the portable accelerometer based kinematic biofeedback system.

METHODS: Thirteen male rowers took part in the study (mean age: 17.95±4.05yrs; mean mass: 73.56±5.7kg). All were actively involved in competitive rowing at the time of the study under the supervision of one coach. The subjects (or if <18yrs – the subjects legal guardians) gave informed written consent prior to participating in the study as required by the University Research Ethics Committee. Prior to experimental trials all thirteen subjects underwent four 15-minute familiarisation sessions over a two-week period. These sessions were essential, as none of the subjects had any experience with a RowPerfect ergometer (Care RowPerfect, Hardenberg, The Netherlands); previous studies have indicated significant differences in kinematics and performance for the same rower on different ergometers (Stuble *et al.*, 1980). Each subject was asked to perform three 2000m time-trials, separated by a period of approximately two weeks, on a RowPerfect ergometer; which is known to simulate the kinematics of on-water rowing (Rekers, 1993). The damper setting of the ergometer was standardised and the parameters of the RowPerfect software were set to simulate a single scull. For each of the three 2000m time-trials a different type of feedback intervention was displayed to the rower; no feedback (NF), summarised feedback (SF), and graphical feedback (GF). The order of the feedback was randomised to remove any temporal interference from the study. The distance remaining and stroke rate was also displayed during the 2000m. All feedback was based on a measure of kinematic consistency of the horizontal acceleration of the shoulder in relation to the ergometer flywheel (HAS) and the horizontal acceleration of the hip in relation to the ergometer flywheel (HAH). Consistency of these two parameters has previously been shown to be a significant performance predictor in rowing (Anderson *et al.*, 2001). As technique varies on an individual basis there are no optimal parameters that all rowers should exhibit (Lamb, 1989). To obtain an individuals prototypical pattern HAS and HAH data for each subject were collected for a two-minute period (prior to the 2000m time-trail) while rowing at a constant stroke rate of 25 strokes per minute. The data was collected using the previously described biofeedback system; HAS and HAH were derived from accelerometer data sampled at 250Hz, event indicators (used to identify each stroke) were obtained from monitoring the chain direction at 250Hz. During this period the subjects were asked to concentrate solely on their technique, no information regarding performance or kinematics were revealed to the rower. From these 50 strokes, the data from strokes 25 – 40 was extracted, ensuring the rower had settled into a reproducible technique (Korner, 1993). The HAH and HAS data for these strokes were normalised to percentage time using a MatLab (The Mathworks, Massachusetts, USA) based cubic spline algorithm, allowing for minor inconsistencies in stroke rate to be accounted for. The mean and standard deviation was then calculated for the HAH and HAS data for each 0.5% time interval. The prototypical stroke patterns (or consistency bands) for HAH and HAS were derived prior to each 2000m trial using a mean ± 2SD calculation for each 0.5% interval. Any data existing outwith these limits was assumed to be sub-optimal and indicates the level of kinematic consistency throughout the stroke. The HAH and HAS kinematic consistency data can be reduced to the percentage time the rower spends within these consistency bands, a score of 100% indicated a high level of kinematic consistency and 0% no kinematic consistency. The SF intervention was based solely on these percentage figures; a projected image was used to display a bright green colour at 100% and a bright red at 0% (between these extremes 255 other colours, ramped from green to red, were displayed) in conjunction with the percentage time spent within the bands for both HAH and HAS consistency. The GF intervention displayed the consistency bands and the rowers actual HAS and HAH data, this enables the rower to make immediate mid-stroke alterations to their kinematics. Data for the previous stroke is also displayed highlighting the sections of the stroke where the rower was outwith the consistency bands. The NF intervention acted as a control trial where no kinematic consistency feedback information was given, the only information available to the rower during the NF intervention is the total distance remaining and the stroke rate. The subjects were allowed to warm-up using their customary routine and data collection was not started until each subject was comfortable with the experimental conditions. For all three 2000m trials the kinematic consistency feedback (NF, SF, & GF) was continuously projected on a 5m screen directly in front of the rower, darkened conditions were used to eliminate any distractions from the rower's viewpoint. Data was collected for both kinematic consistency indicators (total percentage time outside consistency bands over 2000m for HAS (*%HAS*) and HAH (*%HAH*)) and for performance indicators (2000m time (*2KT*), average power per stroke (*AP*), and total work done on the ergometer by the rower (*WD*)). The consistency and performance data were analysed separately using full factorial repeated measures general linear model ANOVAs. Mauchly's test of sphericity was used to determine the homogeneity of variance within the data, and where this test was significant a Greenhouse-Geisser correction was used. Pairwise comparisons were resultantly made on the data; a Bonferroni correction was applied for multiple comparisons.

RESULTS AND DISCUSSION: All performance related parameters were deemed spherical in nature. The ANOVA revealed no significant main effects when analysing the performance related variables *2KT* (p=0.452), *AP* (p=0.439), & *WD* (p=0.942) with the type of feedback intervention. For the kinematic consistency parameters *%HAS* had to be corrected using a Greenhouse-Giesser due to the non-homogeneity of variance of this data; *%HAH* was deemed spherical. The ANOVA revealed significant main effects when analysing the kinematic consistency related variables *%HAS* (p=0.000) and *%HAH* (p=0.001) between feedback interventions. Further analysis by pairwise comparisons indicate that the three feedback interventions are significantly different for both *%HAS* and *%HAH* (see figure 2).



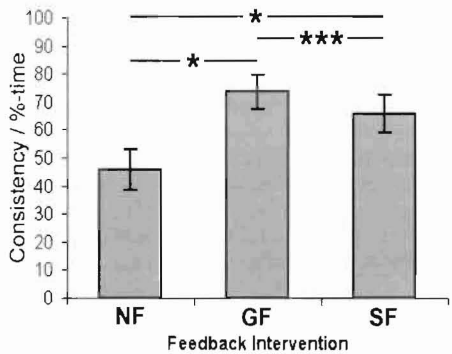


Figure 2. Results of pairwise comparisons for all three feedback interventions (NF, GF, & SF) for %HAS (left) and %HAH (right) [* = p<0.001, ** = p<0.01, *** - P<0.05].

Intervention GF is deemed to significantly enhance kinematic consistency to a higher level than both NF (p=0.000 – *%HAS*: p=0.003 – *%HAH*) and SF (p=008 – *%HAS*: p=0.046 – *%HAH*) interventions, although SF was shown to enhance kinematic consistency to a higher level than NF (p=0.000 – *%HAS*: p=0.009 – *%HAH*). It can be shown that both types of kinematic feedback enhance kinematic consistency significantly. The more complex feedback type (GF) was significantly the better of the two feedback types, this may be due to the feedback intervention offering the capability for the rower to alter their kinematics mid-stroke, and to obtain information regarding the location of kinematic inconsistencies within each individual stroke.

CONCLUSIONS: The accelerometer-based ipsative kinematic biofeedback system has been shown to significantly improve the kinematic consistency of simulated rowing. The graphical feedback intervention (GF) has been found to be significantly better than the summarised feedback intervention (SF) in improving kinematic consistency. Performance related parameters were not affected by either feedback intervention; a significant improvement in performance may be an unreasonable expectation during the timescale of the study. Further investigation regarding the effect of the biofeedback on rowing performance is thus required. The system does, however, promote consistent kinematics during rowing. This consistency enables the rower to become more efficient, may improve crew harmonization, and improve the speed of the boat (Schwanitz, 1991). Other, non-hypothesised, benefits reported by the subjects include an improved desire to train on ergometers (when using the biofeedback), increased concentration levels during training, a heightened awareness of their technique and the techniques of other (possibly better) rowers. The system described here enables the coach and athlete to obtain an immediate measure of kinematic consistency during training, and possibly with telemetry, during a competitive event. Other possible uses of the system are the tracking of developmental patterns in non-elite athletes, kinematic fault finding in elite athletes, enhancement of athlete consistency, and augmented training regiments for the sole participant. The ability for rowers to train using a biofeedback system that can provide immediate information regarding their kinematic consistency is a stimulating prospect.

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