BODY ACCELERATIONS AS PREDICTORS OF POWER OUTPUT ON A ROWPERFECT BOAT SIMULATOR

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The training and competition regimen of athletes at the elite level is highly intensive and demands rapid feedback regarding their performance. The aim of this study was to determine the kinematic parameters which correlate with power output per stroke on a RowPerfect boat simulator. Optimal movement patterns for each kinematic parameter were determined for ten elite lightweight rowers. A measure of time/area away from this optimal movement pattern was used to show consistency of movement. A stepwise regression indicated that shoulder and hip acceleration were correlated with power output per stroke ($R=0.7$, $p<0.01$). These results illustrate the viability of a training regimen utilising accelerometry based real-time biofeedback.

KEY WORDS: RowPerfect, rowing, ergometer, regression, accelerometry, motion analysis

INTRODUCTION: Despite the physiological demands of rowing it is the rowing biomechanics that can determine the more successful oarsperson of two physiologically identical athletes (Nelson & Widule, 1994). Kinematic analysis has confirmed that the stroke is a highly complex movement and a high level of consistency and efficiency must be obtained throughout the racing distance if the oarsperson is to be successful (Klavora, 1979). The co-ordination and technical proficiency of each sequence has been deemed as crucial to the smooth movement and thus the speed of the boat (Nelson & Widule, 1994). Thus, the training and competition regimen of athletes at the elite level is highly intensive and demands rapid feedback regarding their performance. To provide detailed kinematic data instantaneously to any athlete is difficult without relatively expensive equipment that may also require highly labour intensive techniques. These techniques are based mainly upon either 2D or 3D video analysis of the athlete. The fact that kinematic data is both cost and labour demanding has hindered the use of it as a daily tool of the sport scientist, athlete or coach.

Techniques where rapid availability of kinematic data can be obtained without the use of a video based system, for example the use of accelerometry rather than video images, may offer an alternative solution. The same movement patterns available from video based motion analysis can be obtained from an accelerometry based motion analysis. These movement patterns, based on the acceleration of specific body markers, may be vital in providing useful biofeedback to the athletes. If the movement patterns are known for the optimal technique of an athlete at varying effort levels, deviations from this optimal technique can be quantified.

Although it is the biomechanics that can determine the success of an athlete (Nelson & Widule, 1994) the effect of specific kinematics in relation to performance needs to be investigated. Firstly, it must be determined to which movement pattern the power output on the ergometer is related to, secondly it would be unwise to show the athlete all possible kinematic information during a training session. Thus this initial study focuses on differentiating between the important and the non-important kinematic characteristics (movement patterns) of the rowing stroke. To do this an outcome measures power per stroke (PS) will be used and the significant effect between power and various kinematic parameters will be investigated.

METHODS: Ten international lightweight rowers took part in the study; all males aged between 18 and 34 yrs (mean age: 23.65 ± 5.1yrs; mean mass: 74.6 ± 3.7kg). All were actively involved in competitive rowing at the time of the study under the supervision of one coach. The subjects were familiarised with the experimental procedure and all possible risks before providing written consent to participate as approved by the University Research Ethics Committee. Each subject was asked to perform 210 strokes ($\approx$ strokes during a 2000m race) at a rate and effort equivalent to a regular training session (including intervals of increased effort) on a RowPerfect Boat Simulator (Care RowPerfect, Hardenberg, The Netherlands): this ergometer is known to simulate the kinematics of on-water rowing (Rekers, 1993). The damper setting of the ergometer was standardised and the subjects were asked to maintain a stroke rate between 20 and 30 strokes/minute to emulate training conditions. The parameters of the RowPerfect were set to simulate a single scull. All subjects were experienced with the rowing ergometer. The joint centres of interest for each subject, and the ergometer handle, were marked using retro-reflective markers; markers were also placed at two fixed points on the ergometer for calibration purposes (Figure 1).

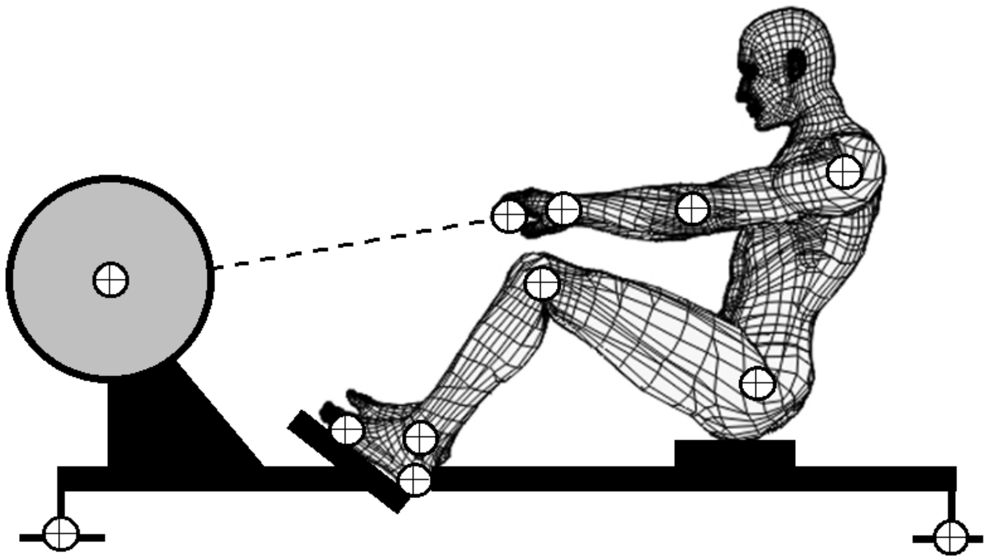

Figure 1 – Schematic of the rower and RowPerfect indicating the joint centres, ergometer handle and reference markers.

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. All 210 strokes for each subject were continuously captured on videotape in the sagittal plane using a 50Hz S-VHS camera (Panasonic AGDP800, Matsushita Electric Industrial, Japan), every tenth stroke was marked using an electronic synchronisation event recorded on the videotape. The first ten strokes rowed by each subject were discarded, at this point the oarsperson has been reported to have settled into a repeatable technique (Korner, 1993). From the remaining 2000 strokes (10 x 200) 100 were randomly selected using a LabVIEW (National Instruments, Texas, USA) based routine for further analysis. These strokes were extracted from the recording post-trial using Peak Motus 2000 (Peak Technologies, Colorado, USA) and subsequently digitised in two dimensions according to the seven-point segmental model (Figure 1). The horizontal accelerations of the following points were calculated w.r.t. the centre of the ergometer flywheel - shoulder (a_{sX}), hip (a_{hX}), knee (a_{kX}), ankle (a_{aX}), elbow (a_{eX}), wrist (a_{wX}), and the ergometer handle (a_{hdX}), the Y acceleration of the knee (a_{kY}) was also calculated w.r.t. the ground. Additionally, the following data was acquired from the RowPerfect boat simulator software for each stroke: power/stroke (PS), stroke rate (SR), stroke length (SL), and estimated 500m time (T_{500}). All acceleration data were normalised to percentage time using a MatLab (The Mathworks, Massachusetts, USA) based cubic spline algorithm, allowing for inconsistencies in stroke rate to be accounted for. From these 100 strokes 10 were selected, the stroke with the highest PS value for each of the 10 subjects. The mean and SD of a_{sX}, a_{hX}, a_{kX}, a_{aX}, a_{eX}, a_{wX}, a_{hdX}, and a_{kY} were calculated at each percent-point of the stroke cycle. These data were classified as the optimal movement pattern for each parameter, with the SD being the upper and lower limits, outside of which the movement pattern was assumed to be sub-optimal. Figure 2 illustrates the mean horizontal shoulder acceleration with the upper and lower limits, a typical shoulder acceleration (a_{sX}) has been included, and from this illustration the points of sub-optimal technique become apparent.

RESULTS & DISCUSSION: Initial results indicated a strong positive relationship between Ta_{hdX} & PS and Ta_{wX} & PS, due to the kinetic link between the chain of the RowPerfect and the handle, wrist and elbow. The RowPerfect calculates PS by accounting for the rotational acceleration of the flywheel, this is directly related to the linear acceleration of the chain, and thus directly related to a_{hdX} and a_{wX}. a_{aX} and a_{eX} are related to PS in a similar way. Due to this multicollinearity the following variables were removed from the regression: Ta_{aX} Ta_{eX}, Ta_{wX}, Ta_{hdX} Aa_{aX}, Aa_{eX}, Aa_{wX}, Aa_{hdX}, resulting in a 12.5:1 S/IV ratio. A second stepwise regression, with these variables excluded, gave the results outlined in Table 1.

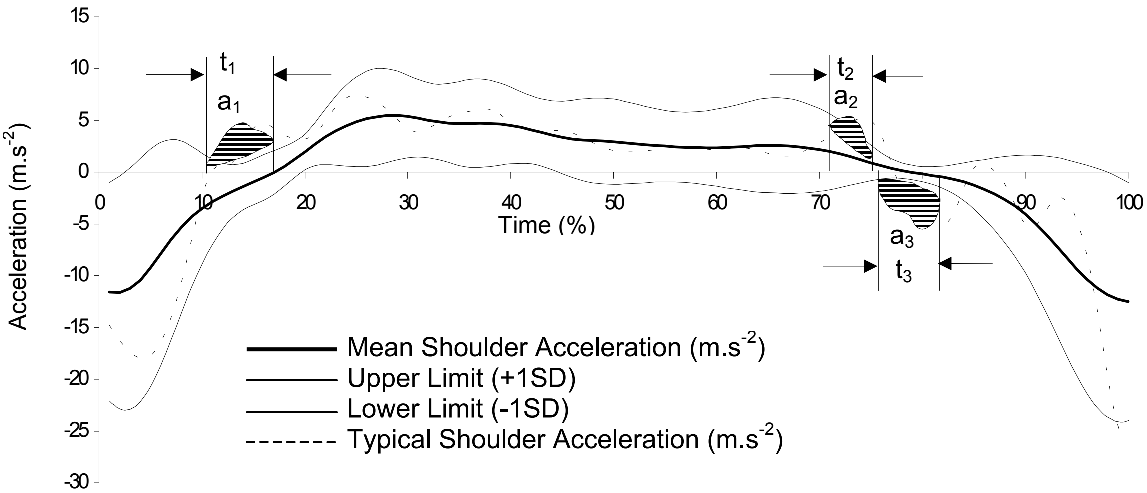

Figure 2 – The technique used for the calculation of T (time outside limits) and A (area outside limits).

The results indicate that Ta_{sX}, Aa_{hX}, Aa_{sX} were the only predictors that add significantly to the regression equation (Table 1), thus all other predictors were discarded. The study is not attempting to quantify PS from the predictors, only the magnitude of their relationship. The resulting R value of 0.70 was significant ($p < 0.01$). The negative correlation between Aa_{sX} and PS is an interesting result, as the movement pattern becomes more variable (i.e. Aa_{sX} for the oarsperson is outside the given limits) PS decreases. From this we can conclude that higher consistency in shoulder acceleration results in higher power output per stroke. The positive correlation between both Ta_{sX} and Aa_{hX} may be due to the limits set on the movement patterns. The rowers were asked to row at a training pace, to reduce the effect of both fatigue and stroke rate on the stroke kinematics (Anderson & O'Donovan, 2000), thus the movement pattern, upper and lower limits may not have been indicative of peak power. A rower may have the same movement pattern as described here when producing peak power but the pattern may be offset. Several examples of the data were investigated qualitatively and this appears to be the case. The correlations between Ta_{sX} and Aa_{hX} and PS indicate there is a relationship between these predictors and PS and warrants further investigation.

Table 1 – Results for Stepwise Regression (Dependant variable – PS)

MODEL SUMMARY

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.70	0.49	0.47	48.32

Predictors: (Constant), Ta_{sX}, Aa_{hX}, Aa_{sX}

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	215664.14	3	71888.04	30.78	<0.001
Residual	224172.45	96	2335.13		
Total	439836.59	99			

Predictors: (Constant), Ta_{sX}, Aa_{hX}, Aa_{sX}
Dependent Variable: PS

COEFFICIENTS

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	274.50	6.27		43.74	<0.001
Aa_{hX}	22.72	7.15	0.322	3.17	0.002
Aa_{sX}	-4.35	1.82	-0.275	-2.39	0.019
Ta_{sX}	2.56	0.61	0.598	4.16	<0.001

Dependent Variable: PS

CONCLUSIONS: The three variables Ta_{sX}, Aa_{hX}, Aa_{sX} correlate with the PS on the RowPerfect ergometer (R=0.7, p<0.01). These predictors represent both the gross upper and lower body movement patterns throughout the rowing stroke. This illustrates that a high level of movement pattern consistency is required to retain a consistent PS value. Consistent PS throughout a rowing session is more efficient than using a range of PS values throughout a race. The ability to train on a boat simulator that can assess movement patterns and stroke consistency in real-time, indicating to the rower whether they are outwith specific limits is an exciting prospect. Future research will concentrate on using biofeedback to improve technique and/or movement pattern consistency within elite and novice rowers.

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