INFLUENCE OF TECHNICAL PARAMETERS ON ROWING ERGOMETER PERFORMANCE

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The purpose of this study was to evaluate the influence of technical parameters on rowing ergometer performance defined as mean power handle. Twenty high levels rowers (14 men and 6 women) were evaluated at their competitive stroke rate on RowPerfect 3. Mean power handle is influenced by the power produced of legs, trunk and arms on the drive phase, the latter being the most important according to the one SD change value. The movements of these segments are linked, and the power produced by one influence the next. The ability to produce the highest relative maximal power throughout the drive phase, is important to improve segments powers. Trunk power is enhanced by an earlier peak power of the trunk, and higher trunk and pelvis ranges of motion. Accordingly, increasing simultaneity of trunk and leg movements seems important to optimise the transfer of power from the legs to the arms and so performance.

KEYWORDS: ergometer rowing, power, kinetic chain, trunk, prediction

INTRODUCTION: Mean power output at the handle has been reported to be a relevant performance parameter in ergometer rowing (Bourdin et al., 2004). It's an important variable to be monitored and/or controlled both during training and competitive events (Hofmijster et al., 2018). Indeed, measurements of an athlete's power in rowing are commonly used as the main tool to identify the rower's energy production and technique efficiency (Kleshnev, 2000). These latter are dependent on the ability to produce large forces in their lower limbs and to efficiently transmit these forces via the trunk to the upper limbs.

Each body segment participates in power generation during the drive phase. The power of the legs (P_{legs}) accounts for about 45% of the final power output measured at the handle in ergometer rowing (P_{handle}). Moreover, powers of the trunk (P_{trunk}) and arms (P_{arms}) contribute 29% and 25% respectively to the power output (Kleshnev, 2000). Different technical styles with specific movement sequences have been observed and can influence this distribution (Kleshnev, 2016). For instance, work of the legs and trunk can be simultaneous or sequential and with more or less emphasis of one of these segments, therefore having a different impact on power generation.

Beside power, other parameters might be useful to analyze the technical performance. Time to peak power from the catch, mean to peak power ratio of the legs, trunk and arms are for instance influenced by the stroke rate (Kleshnev, 1996). Also, asymmetries in legs forces have been studied in relation to stroke rate or different boat equipment configurations (Buckeridge et al., 2014; 2016). Finally, studies have focused on trunk and pelvis kinematics to further understand forces transmission from lower to upper limbs. For instance, it has been found that trunk motion with respect to pelvis is increased at higher stroke rate (Buckeridge et al., 2016), but the possible link between power production and trunk movements remains unclear.

Accordingly, it seems interesting to analyse the links between each of these variables and their influence on performance. For this purpose, linear-mixed model analyses have been carried out in previous research. For instance, velocity efficiency has been found to be related to the movement execution (Hofmijster et al., 2008). Moreover, other variables like time to peak force or mean to peak force ratio have recently been associated with rowing performance (Holt et al., 2020). However, no study has precisely analysed the link between technical parameters of each segment (i.e. legs, trunk, arms) and rowing ergometer performance. The purpose of this study was therefore to analyse the influence of the technical parameters of the legs, trunk and arms, on the power output at the handle level during ergometer rowing. The goal was to find out which relevant technical parameters, such as mean segment power, time to peak power, mean to peak power ratio, legs asymmetry, or trunk and pelvis range of motion, would predict the power output, i.e. the ergometer rowing performance.

METHODS: Twenty healthy and voluntary high-level rowers (14 men and 6 women, 20.2 ± 2.1 years old; 1.82 ± 0.05m; 76.1 ± 4.4kg), from the Elite, U23 and University categories of the French Rowing Federation were recruited for this study. After a free warm-up of 10 minutes, each rower performed 15 strokes with maximal intensity at their typical stroke rate during a competition. Participants were rowing on a mobile rowing ergometer (RP3®, Care RowPerfect BV, Hardenberg, The Netherlands) that was equipped with BioRow Catch Training System (BioRow Tech, London, United Kingdom) registering force data, at the handle, right and left foot stretcher (consisting of two plates with two load cells for toe and heel in between them, attached to the stretcher), and positions of the seat, trunk and handle. All these parameters were measured at 25Hz.

In addition, 3D trunk and pelvic kinematics were measured at 100Hz, using two inertial measurements units (iSen, STT Systems, Spain) placed on the rower's back between the two scapulas (trunk) and between the two posterior superior iliac spines (pelvis).

P_{handle} was defined as the performance parameter, while the others operationalized the technical performance. The power at each level was determined as follows (Kleshnev, 2000), where handle, seat and trunk velocities were derived from their measured position:

P_{handle} (W) = handle force * handle speed.
P_{legs} (W) = Legs force* seat speed.
P_{trunk} (W) = handle force * (trunk speed - seat speed).
P_{arms} (W) = handle force * (handle speed - (trunk speed - seat speed)).

Mean to peak power ratio (M2P) and time to peak power from the catch (T2P) were calculated for these segments. Legs asymmetry was calculated with left and right foot sensors (Buckeridge et al., 2014). Trunk and pelvis range of motions (ROM) in the sagittal plane were calculated. All data were analyzed during the drive phase, determined according to the handle position; the beginning of this phase, the catch, was defined by the minimum handle position, and the finish by the maximum handle position. Mean values and standard deviations (SD) were computed over 12 consecutives cycles. Multiple linear regression analysis models using the predictors of the technical parameters to determine ergometer performance were used to verify the main hypothesis of a relationship existing between technical and rowing performance of the rowers. Standardized effects of each predictor were computed by multiplying the predictor standard deviation with its estimate. Estimate values were coefficients of independent variables in a linear mixed model. Standardized effects were expressed with respect to the mean of the dependent variable, i.e., the one SD change of the dependent variable when all other predictors were set to their average value (Staynor et al., 2020). In our model, the values of estimates and one SD change were high for predictors with a mean close to 0 (e.g.,M2P). However, only statistical significance and not specific value were considered for analysis. The alpha significance level will be set at 0.05.

RESULTS: Mean (SD) values for performance (P_{handle} mean) as well as for technical parameters illustrating the technical performance are reported in Table 1. During the rowing bout, the mean stroke rate was 38.9 (3.1) strokes per minute.

Table 1: Performance and technical parameter values during the drive phase

Parameter	Mean	SD	Parameter	Mean	SD
P_{handle} mean (W)	700	134	M2P handle	0.48	0.02
P_{legs} mean (W)	214	35	M2P legs	0.38	0.03
P_{trunk} mean (W)	262	57	M2P trunk	0.32	0.02
P_{arms} mean (W)	184	39	M2P arms	0.38	0.02

T2P handle (%drive)	51.3	2.6	Legs asymmetry (%)	6.93	5.29
T2P legs (%drive)	38.2	4.1	Trunk ROM (°)	74	5.2
T2P trunk (%drive)	56.7	2.4	Pelvis ROM (°)	44.4	6.1
T2P arms (%drive)	74.5	2.1			

The first prediction model reported all segments powers (with P_{arms} being the most important according to the one SD change value) to predict the mean power at the handle level (Table 2). However, this variable could be predicted by technical parameters specifically related to the handle (model 2; Table 2). The other models (3 to 5) determined which parameters predicted significantly each segment power production (Table 2).

Table 2: Multiple linear regression models using technical parameters to predict the power produced at the different segment levels.

Model	Variable predicted	Predictor	Estimate	One SD change (%)
1	P_{handle} mean (W)	P_{arms} mean (W) *	1.03	26.2
		P_{trunk} mean (W) *	0.99	24.9
		P_{legs} mean (W) *	0.80	15.9
2	P_{handle} mean (W)	M2P handle	1354	4502
		T2P handle	Not significant	
3	P_{legs} mean (W)	M2P legs *	493	3996
		Legs asymmetry (%)	Not significant	
		T2P legs (%drive)	Not significant	
4	P_{trunk} mean (W)	Pelvis ROM *	2.15	29.6
		Trunk ROM *	1.59	11.1
		T2P trunk (%drive) *	-1.26	5.40
		P_{legs} mean (W) *	0.63	10.4
		M2P trunk	Not significant	
5	P_{arms} mean (W)	M2P arms *	124	1306
		P_{legs} mean (W) *	0.35	5.84
		P_{trunk} mean (W) *	0.22	4.85
		T2P arms (% drive)	Not significant	

*Significant predictor ($p < 0.05$).
An increase of the predicted variable is associated with a higher predictor value. No statistically significant estimate indicates that there is no predictive link.

DISCUSSION: P_{handle} mean was positively associated with the mean power to each segment measured. This relationship is consistent with previous results showing enhanced P_{handle} mean together with higher P_{legs} and P_{trunk} when stroke rate increased (Kleshnev, 1996). The present segments power distribution was different from the one reported by Kleshnev (2000), showing greater P_{legs} than P_{trunk}, possibly because of different conditions (on-water rowing) and different technical styles (Kleshnev, 2016). Moreover, each of these segment powers was predicted by the power generation at the previous level as can be explained by the kinetic chain from legs to arms. This probably highlights the importance of carrying out the movement with an optimal technique.

Indeed, at the legs level, only M2P predicted significantly higher legs power mean. This indicates that the highest relative maximal power should be produced throughout the leg extension. However, although leg asymmetry is an important variable in rowing biomechanics (Buckeridge et al, 2014), this parameter could not predict the power produced by the lower limbs.

At the trunk level, higher range of motion of the pelvis and trunk segments were related to greater trunk power production. Such kinematics changes have already been reported by Buckeridge (2016), when stroke rate was manipulated. These authors hypothesized that L5/S1 ROM was related to greater seat forces. This could serve as good basis for higher trunk power production. In addition, earlier trunk time to peak power induced higher P_{trunk}.

At the arms level, as well as the handle level, M2P was a predictor of power produced at the end of the kinetic chain. Therefore, together with the significant M2P predictor for legs power, this parameter shows the importance of the ability to produce the highest relative maximal power throughout the drive phase. Accordingly, a style close to DDR or Adam rowing style (Kleshnev, 2016), as these include simultaneous movements of the legs and the trunk at the catch, would be the most suitable for high performance production. These rowing styles could also reduce fluctuations in boat speed, limit drag factors and thus limit power losses (Soper & Hume, 2004).

However, T2P appears to be a less key variable, as only the trunk power got predicted by this technical parameter. It seems important to perform the trunk movement simultaneously with the leg movement rather than consecutively, to optimise the transfer of power from the legs to the arms.

CONCLUSION: This study shows first that P_{arms} predict the most P_{handle}, followed by P_{trunk} and P_{legs}. Moreover, technical performance parameters of the legs, trunk, and arms play an important role on rowing performance. It seems important to train to reduce i) the mean to peak segments power production, and ii) the time to peak power of the trunk. This alteration would enhance segments power production as well as performance during ergometer rowing. Given the dynamic aspect of RP3 ergometer, we might considerer transferring these results to on-water rowing, i.e. skiff.

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