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Original Article

Physical and strength variables as a predictor of 2000m rowing ergometer performance in elite rowers

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Abstract:
Aim of this study was to identify the physical and strength profile of Indian elite rowers categorically and finding relation of those variables with rowing performance. The study also aimed to develop rowing performance predicting different regression models to specify their essential performance limiting elements that could be used to maximize performance. To fulfill the research purpose, 139 light weight category and 60 open category elite male rowers with more than five years of rowing experience were evaluated. Height, weight, skin caliper, sliding caliper and strength dynamometer, respectively. Body fat percentage was calculated with Siri's equation and somatotype using Heath-Carter formula. A 2000m rowing test was conducted on a rowing ergometer. Results showed higher body weight (10.3%,$p<0.0001$), height (1.9%,$p<0.0001$), age (8.2%,$p<0.01$), body fat percentage (18.2%,$p<0.0001$), endomorph (30.3%,$p<0.0001$), mesomorph (17.8%,$p<0.0001$), back strength (8.9%,$p<0.0001$), right hand grip strength (5.8%,$p<0.001$), left hand grip strength (6.5%,$p<0.001$), less ectomorph (14.1%,$p<0.001$) and less time to finish 2000m (2.2%,$p<0.0001$) in open category rowers than light weight category. The 2000m rowing time was significantly ($p<0.001$) correlated with age ($r=-0.459$), height ($r=-0.340$), weight ($r=-0.506$), back strength ($r=-0.458$), right hand grip strength ($r=-0.311$) and left hand grip strength ($r=-0.333$). Body fat percentage ($r = 0.191$) and mesomorphic somatotype ($r=-0.223$) were correlated significantly ($p<0.05$) with performance. Multiple regression analysis identifies age, height, weight and body fat percentage as strong predictors of 2000m rowing ergometer performance ($R=0.730$). Combining strength components with the above is also a good predictor of 2000m rowing time ($R=0.704$). 2000m time(s)=519.211–0.480x age+0.111x height–1.836x weight+1.503x body fat%+0.010x back strength–0.099x right hand grip strength–0.075x left hand grip strength. In this context, these decisive physical and strength variables can be used to predict performance, improving training capability and identifying talents.
Key words: body fat percentage, somatotype, strength, correlation, stepwise multiple regression.

Introduction

Olympic rowing is more popular than the traditional rowing. The Olympic rowing is conducted over a 2000-meter course, lasting for about 320 to 460 seconds, depending on the type of boat, a number of rowers, sculling or sweep rowing. It is regarded as a typical strength/power-endurance type of sport (Shaharudin et al., 2014; Arazi et al., 2011) where physique, strength, rowing technique and tactics play an important role in becoming a successful rower.

To obtain optimum performance from a rower, it is mandatory to select talent appropriately. Anthropometric length or breadth measurements are almost exclusively genetically determined and can hardly be changed within the context of a training periodization (Mikulić P, 2008). Numerous studies have tried to establish an association between physiological variables and 2000-meter rowing performances i.e., body mass (Secher NH, 1993; Cosgrove et al., 1999), VO_{2max} (Secher NH, 1993; Cosgrove et al., 1999; Kramer et al., 1994), percentage of slow twitch fibers (Roth et al., 1983) or power output at a blood lactate concentration of 4 mmol/l (Roth et al., 1983) showed strong correlation and were different predictors of performances. Ingham et al. (2002) on 41 elite rowers (23 men and 18 women) showed that powers at maximal oxygen consumption, maximal force and maximal power production were the strongest correlation to measure performances. Apart from the physiological variables, Choszcz et al. (2012) showed relationships between selected anthropometric parameters and the time taken to cover the 500-meter distance on a rowing ergometer.

Rowing is a sport where physical traits are essentially linked with performance. So the present study is taken up to identify physical, strength and 2000m performance level of Indian elite rowers, relation of this selected parameters with rowing performance to specify performance limiting elements and to develop rowing performance predicting regression equations that could be used to maximize performance.

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Material & methods

Participants

139 light weight category and 60 open category elite male rowers having more than five years of rowing experience were included in the study. All the rowers were residing in same geographical region, same climate condition and obtained similar training and nutrition. Institutional review board approved the project and the written informed consent was taken from the participants before testing.

Parameters Studied

Physical and strength parameters along with performance of elite men rowers were evaluated to fulfill the aim. Participants were advised not to engage in any strenuous activities from one week before this test and not to exercise on the day of the test. Verbal encouragement was provided during the testing procedure.

Measurement of physical parameters

Height and weight were measured using anthropometric rod and portable weighing machine, respectively. Skin fold thickness of biceps, triceps, sub-scapula, supra-spinale and calf was measured by Harpenden skinfold caliper, forearm circumference and calf circumference were measured by anthropometric tape and sliding caliper were used to measure and knee and elbow diameters. Body fat% was calculated from the Siri's equation (Siri WE, 1961). Heath - Carter method was used for somatotype rating (Carter et al., 1990).

Measurement of strength

Digital back strength dynamometer and hand grip dynamometer were used to assess the back strength and hand grip strength, respectively. Grip strength was measured at the angle of 90°. Two trials were performed with three minute rest after each trial and the best result was recorded.

Performance evaluation

On-water Olympic rowing performance is not only depends on physiological characteristics but also on mechanicals or external factors i.e. environmental conditions. So, rowing ergometer has improved training and provided a controllable and repeatable tool to use in the assessment of rowing performance (Urichianu et al., 2010). The standard error of estimate of on-water 2000meter time predicted by 2000meter ergometer performance is 2.6% and 7.2% (Smith et al., 2012) which is widely accepted by coaches and scientists. 2000m rowing test was conducted on Concept II model D (USA) rowing ergometer and total time taken to complete 2000m was noted and considered for further calculations.

Statistical analysis

The Statistical Package for Social Sciences (SPSS v14.0) was used for all statistical analysis. Pearson correlation coefficient (r) was used to check interdependency of variables. Stepwise multiple regression analysis was used to determine predictors of 2000m rowing performance where dependent variable was 2000m time on rowing ergometer and independent variables were age, height, weight, body fat%, somatotype, back strength and grip strength (right hand and left hand). The independent variables correlates most significantly with 2000m rowing performance were considered into regression analysis. The value of $p<0.05$ was considered to be statistically significant.

Results

Physical characteristics and performance of Indian elite male lightweight rowers, open category rowers and combination of all are presented in Table 1. Open category rowers showed higher body weight (10.3%, $p<0.0001$), height (1.9%, $p<0.0001$), age (8.2%, $p<0.01$), body fat% (18.2%, $p<0.0001$), endomorph (30.3%, $p<0.0001$), mesomorph (17.8%, $p<0.0001$), back strength (8.9%, $p<0.0001$), right hand grip strength (5.8%, $p<0.001$), left hand grip strength (6.5%, $p<0.001$), less ectomorph (14.1%, $p<0.001$) and less time in 2000m test (2.2%, $p<0.0001$) than light weight category rowers.

Table 1 Morphology, strength and rowing ergometer performance of elite male rowers

Variables		Light weight category (n=139)	Open category (n=60)	Combined group (n=199)
Age (years)		22.57 ± 0.322	24.43 ± 0.453 **	23.13 ± 0.269
Height (cm)		181.74 ± 0.316	185.29 ± 0.551 #	182.81 ± 0.299
Weight (kg)		69.84 ± 0.176	77.05 ± 0.440 #	72.01 ± 0.296
BMI (kg/m^2)		21.16 ± 0.066	22.45 ± 0.132 #	21.55 ± 0.074
Body fat%		10.46 ± 0.217	12.37 ± 0.325 #	11.09 ± 0.192
Somatotype	Endomorph	1.59 ± 0.072	2.08 ± 0.086 #	1.84 ± 0.062
	Mesomorph	3.45 ± 0.084	4.07 ± 0.104 #	3.76 ± 0.075
	Ectomorph	3.75 ± 0.098	3.22 ± 0.091 $	3.48 ± 0.073
Back strength (kg)		157.34 ± 1.534	171.41 ± 2.884 #	161.95 ± 1.480
Grip Strength (kg)	Right hand	53.8 ± 0.521	56.93 ± 0.730 $	54.82 ± 0.437
	Left hand	52.12 ± 0.551	55.53 ± 0.768 $	53.34 ± 0.469
2K total time (sec)		406.37 ± 1.123	397.45 ± 1.209 #	403.68 ± 0.911

*Data is represented as mean ± SEM. n = Number of subjects. ** = p<0.01; $ = p<0.001; # = p<0.0001 compared to light weight category.*

Table 2 presents correlation coefficient (r) for all measured variables and 2000m rowing ergometer performance. Significant correlation was observed for a number of parameters. 2000m rowing ergometer time was significantly correlated ($p<0.001$) with age (r = -0.459), height (r = -0.340), weight (r = -0.506), back strength (r = -0.458), right hand grip strength (r = -0.311) and left hand grip strength (r = -0.333). Significant correlation ($p<0.05$) of body fat% (r = 0.191) and mesomorphic somatotype (r = -0.223) were also observed with performance. No significant correlation of endomorph and ectomorph were observed with 2000m performance.

Significant correlation between other variables of rowers was also found. All strength components were significantly correlated with age, weight and mesomorph. Significant association of height, weight, body fat%, ectomorph, back strength, right hand grip strength and left hand grip strength with mesomorph was found. Significant correlation was also observed between endomorph and body fat%.

Table 2 Pearson correlation matrix of age, physical parameters, strength parameters and 2000m rowing performance

	Age (years)	Height (cm)	Weight (kg)	Body fat%	Endo-morph	Meso-morph	Ecto-morph	Back Strength (kg)	Right hand grip st. (kg)	Left hand grip st.(kg)	2000m total time (s)
Age (years)	-	0.196**	0.324 #	-0.349 #	-0.102	0.176	-0.271*	0.433 #	0.309 #	0.312 #	-0.459 #
Height (cm)	-	-	0.574 #	0.051	0.064	-0.300**	0.500 #	0.308 #	0.059	0.008	-0.340 #
Weight (kg)	-	-	-	0.308 #	0.408 #	0.456 #	-0.395 #	0.473 #	0.260 #	0.354 #	-0.506 #
Body fat %	-	-	-	-	0.974 #	0.362**	-0.315**	-0.173*	0.004	0.000	0.191*
Endomorph	-	-	-	-	-	0.391 #	-0.361**	-0.078	0.213	0.063	0.035
Mesomorph	-	-	-	-	-	-	-0.834 #	0.320**	0.330**	0.359**	-0.223*
Ectomorph	-	-	-	-	-	-	-	-0.228*	-0.266*	-0.319**	0.166
Back st. (kg)	-	-	-	-	-	-	-	-	0.520 #	0.648 #	-0.458 #
Right hand grip st. (kg)	-	-	-	-	-	-	-	-	-	0.661 #	-0.311 #
Left hand grip st.(kg)	-	-	-	-	-	-	-	-	-	-	-0.333 #
2000m total time (s)	-	-	-	-	-	-	-	-	-	-	-

** = p<0.05; ** = p<0.01; # = p<0.001.*

The rowing ergometer performance prediction models using significantly correlated ($p<0.001$) single variables and different categories of variables are presented in Figure 1 and Table 3, respectively. Stepwise multiple regression analysis identifies, considering age, height, weight and body fat% could be a strong predictor of 2000m rowing ergometer performance (R = 0.730). Combination of age, height, weight, body fat% and strength components also a good predictor of rowing performance (R = 0.704).

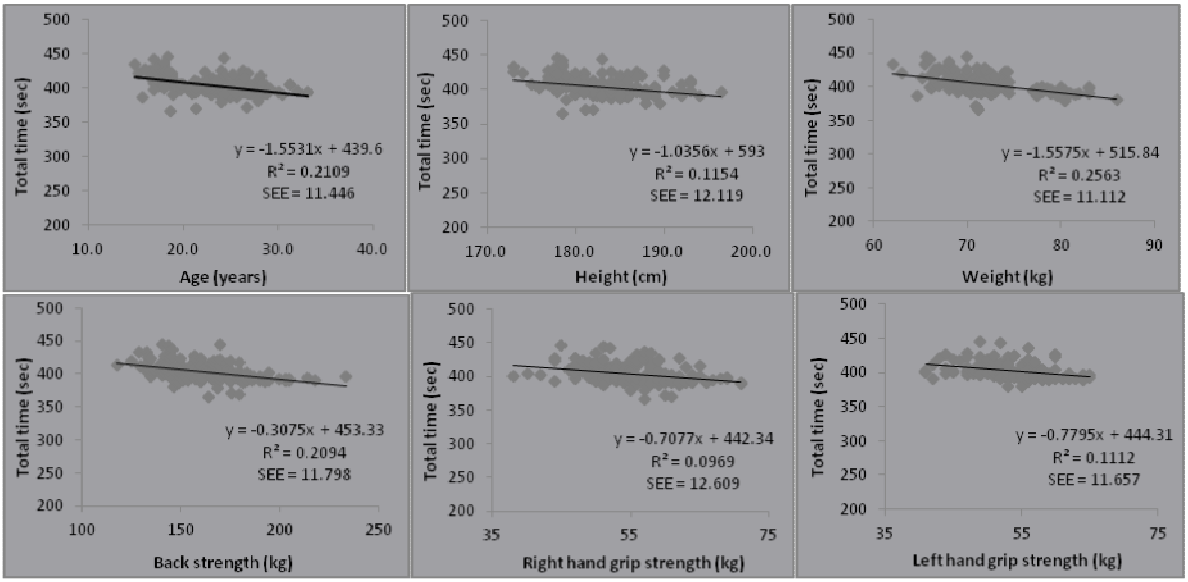

Fig.1 The relationship of 2000m rowing ergometer performance with age, height, weight, back strength, right hand grip strength and left hand grip strength of elite male rowers.

Table 3 Regression equations predicting 2000m rowing performance

Categories	Multiple Regression equation	R	R^2	SEE
Physical	2000m time (s) = 547.229 - 1.112 x age - 0.208 x height - 1.109 x weight	0.597	0.357	10.388
	2000m time (s) = 534.105 - 0.653 x age - 0.013 x height - 1.779 x weight + 1.481 x body fat%	0.730	0.533	8.406
	2000m time (s) = 563.552 - 0.730 x age - 0.547 x height - 0.553 x weight - 1.691 x mesomorph	0.595	0.354	7.566
	2000m time (s) = 550.692 - 0.476 x age - 0.437 x height - 0.853 x weight + 0.902 x body fat % - 2.020 x mesomorph	0.635	0.403	7.321
Strength	2000m time (s) = 456.252 - 0.219 x back strength - 0.224 x right hand grip strength - 0.098 x left hand grip strength	0.444	0.198	11.166
Combined	2000m time (s) = 519.211 - 0.480 x age + 0.111x height - 1.836 x weight + 1.503x body fat% +0.010x back strength -0.099 x right hand grip strength - 0.075 x left hand grip strength	0.704	0.495	9.004
	2000m time (s) = 572.400 - 0.659 x age - 0.575 x height - 0.465 x weight - 1.472x mesomorph + 0.042 x back strength - 0.035 x right hand grip strength - 0.332 x left hand grip strength	0.610	0.373	7.610
	2000m time (s) = 568.247 - 0.363x age - 0.503 x height - 0.848 x weight + 1.166x body fat% - 2.253 x mesomorph + 0.117 x back strength - 0.222 x right hand grip strength - 0.336 x left hand grip strength	0.662	0.438	7.255

R = Correlation coefficient; SEE = Standard Error of the Estimate

Discussion

Game specific physique is an important factor in any sport performance besides other physiological variables and skills. Rowing is a sport where physical traits are undoubtedly performance related factor (Bourgois et al., 2000; Bourgois et al., 2001). Finalist can be distinguished from non-finalists by physical characteristics i.e. height, weight and circumferences (Bourgois et al., 2000; Kaloupsis et al., 2008). In this study, it was observed that open category elite rowers are characterized by higher body weight (10.3%), height (1.9%), body fat% (18.2%), endomorph (30.3%), mesomorph (17.8%) and less ectomorph (14.1%) compared with light weight rowers. Significant correlation was also found between rowing performance and rower's height. This finding is consistent with other previous study which reported that gold medal winners were taller than national champions in the single scull (Hirata K, 1979) and Bourgois et al. (2001) found that during the 1997 International World Junior Rowing Championship, finalists were taller than non-finalists. The elite rowers were usually taller and heavier (Bourgois et al., 2000; Secher et al., 1983) and possess a shorter sitting height (relative to stature) but longer extremities (Mikulić P, 2008; Bourgois et al., 2000). Longer limbs are an advantage due to the catch and drive action involving all four extremities giving a biomechanical advantage to create more force during rowing followed by longer stroke (Secher et al., 1983). Long stroke lengths are closely identified with high-level rowing performance (Ingham et al., 2002). Malina (1994) observed that within childhood promising rowers were already taller compared to the general population and they retained their relative advantage during adolescent. It was also suggested that there was no effect of regular training on statural growth and rowers were already taller than average with longer limbs during childhood, maintaining their position relative to reference data during childhood and adolescence, this point may be important to use this information for talent identification in rowing. So if one can identify rowing talent at childhood and after a proper nurturing can produce a good rower.

Body weight is supported by the sliding seat in the boat therefore they can afford to carry a greater body weight and possess an advantage. Owen et al. (2002) demonstrated that heavyweight rowers were able to produce more force and power compare to light weight rowers. In this study weight was significantly correlated with performance (r = -0.506). Open category rowers took less time to complete 2000m rowing than light weight rowers. Literature suggests that elite rowers were heavier than the less successful rowers (Secher et al., 1983). In addition, it seems that the current average height (185.29cm) and weight (77.05kg) of these elite rowers were lower than reported in other study with International level Olympic rowers i.e. 191.3 to 193cm and 90 to 96kg respectively (Ingham et al., 2007).

For rowing talent identification as well as for training periodization, somatotyping is an important criterion and plays an important role (Adhikari et al., 2015). Rowing demands high force production as well as strength and endurance where muscularity of the rower plays a significant role. Thus identifying mesomorph

component which represents the muscularity is an important factor. In this study, open category rowers were more mesomorphic than lightweight category rowers. Significant correlation was also found between mesomorph and performance indicates more muscularity is advantageous for rowing to produce more force and power followed by better performance. Research suggests that rowing engages most of the principal muscle groups and larger fraction of total muscle mass of the upper and lower body is recruited during rowing (30kg muscle mass in a 70kg male) (Roberts et al., 2005).

In this study positive correlation was found between rowing performance and body fat percentage. It is well established that high body fat% adversely affects 2000m rowing ergometer performance (Ingham et al., 2002). Therefore low body fat% can be an advantage for success in rowing. A certain amount of fat is required for maintenance of body metabolism but excess adiposity has a negative influence in performance. Manore et al. (2000) showed that body fat% varies depending on the athlete's sex and the sport itself. Studies on male international rowers had noted that the range of body fat% values was from 6% to 10% (Hagerman et al., 1997). Mean fat percentage for the rowers in this study is close to these cited ranges. It is interesting to note that the body fat% seems to have been decreasing in recent years in elite rowers (Mikulić P., 2008).

Another performance related parameter in rowing is strength. Strength improvement has an influence on speed and power, also provides the basis for strength endurance (Maestu et al., 2005). Several studies have emphasized the important role of factors such as maximal strength and muscle power output in Olympic rowing performance. As a typical power-endurance sport, rowers need physical strength to achieve high power per stroke during the oar cycle, endurance to sustain this power, as well as specific motor and tactical skills (Secher NH, 1993; Steinacker et al., 1986). Successful elite rowers produce about 75–80% of their power with their legs and 20–25% with their arms during the rowing stroke (Cosgrove et al., 1999). Fiskerstrand et al. (2004) considered that strength training in rowers have increased approximately 20% in the last few years, suggesting that greater intensity in training may be more influential in performance.

Conclusions

The result of this study on elite male rowers revealed that rowers with more height, weight, muscle mass, strength and less body fat percentage are at an advantage in rowing performance. Except for height, other variables can be improved through systematic training and nutrition to translate into rowing performances. Information of these decisive physical and strength components can be effectively utilized for rowing talent identification and induction of rowers in higher level of competitions. Rowing performance predicting regression equation can be used to specify essential performance limiting elements that can be particularly trained to maximize performance.

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