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Original Article

Morpho-physiological profile and 2K performance of Indian elite rowers

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Abstract:

Purpose: The present study was carried out to determine anthropometric, physiological and performance profile of Indian elite rowers categorically at the base preparation of periodized training cycle. Methods: 15 lightweight category (LWC) and 12 open category (OC) elite male rowers attending National camp were evaluated to fulfill this purpose. Anthropometric parameters were measured using standard anthropometric kit, physiological parameters i.e. oxygen uptake ($\dot{V}O2$), minute ventilation ($\dot{V}E$), respiratory exchange ratio (RER) during 2K rowing were measured breath-by-breath using metabolic gas analyzer, heart rate (HR) by heart rate monitor and post-exercise blood lactate by using portable lactate scout. Results: Performance determining anthropometric parameters discriminates OC rowers from LWC. Height (1.6%, $p<0.05$), arm span (3.3%, $p<0.01$), leg length (4%, $p<0.05$), elbow diameter (4.8%, $p<0.01$), knee diameter (3.1%, $p<0.01$), upper-arm circumference (9.5%, $p<0.001$) and body fat percentage (24.4%, $p<0.001$) were higher in OC rowers. Back strength (10.6%, $p<0.01$), grip strength (9.9%, $p<0.01$) and mesomorphy (22%, $p<0.01$) also showed the same trend. No significant difference ($p>0.05$) was observed in peak absolute $\dot{V}O2$, RER, HR and post-exercise lactate. But, peak relative $\dot{V}O2$ of OC rowers was 8.9% ($p<0.01$) less, $\dot{V}E$ and power output were 10.6% ($p<0.01$) and 5.1% ($p<0.05$) more in OC compare to LWC, respectively. It was also observed that OC rowers had taken significantly ($p<0.05$) less time (2.1%) to finish 2K all-out rowing than LWC rowers. Conclusions: This data provides unique anthropometric and physiological information of elite Indian rowers which can be used to set normative value of these performance determining variables categorically and also as a benchmark for Indian rowers at base preparation phase.
Key words: open category, lightweight category, strength, power, peak HR, peak $\dot{V}O2$.

Introduction

Olympic rowing is a typical strength/power-endurance type of sport and several factors such as aerobic capacity, anaerobic power, physical strength, rowing technique and tactics required for a successful rowing performance. In rowing, 70-80% is aerobic and 20-30% is anaerobic (Ingham et al., 2002). This anaerobic energy system needed most at critical periods of the race: at the start to break the inertia of the boat and again during the sprint at the finish. Various physical and physiological characteristics have been found to be closely related to successful performance in rowing and they need to be assessed. The power produced by the rower at the handle is a decisive factor in performance (Baudouin et al., 2002). Ingham et al. (2002) determined that maximal force and maximal power production strongly correlated with the measured performance. Therefore, several potential qualities need to be identified and developed in a rower to become successful.

The ability to obtain and to use precise information regarding the physical and physiological status of rowers is a fundamental issue mainly for two reasons - a detailed insight is required to design an effective training program and to select talent appropriately, because some characteristics (e.g., anthropometric measurements) are almost exclusively genetically determined and can hardly change by a training program. Therefore, for enhancing rower's ability, it is necessary to understand a rower's physique, strength and changes occur in the physiological system during rowing, categorically before recommending any specific training. So, a valid testing battery for rowers should include parameters that are highly related to rowing performance. Several studies have reported different physical and physiological parameters to evaluate a rower. But studies on rowers' specifically on elite rowers are limited in India. To unwrap this domain 15 lightweight category and 12 open category Indian elite male rowers have been selected from National camp and evaluated at the base-preparation phase of the training periodization to understand anthropometric, strength and physiological profile of Indian elite male rowers. It is also tried to find the magnitude of variation in morpho-physiological profile among the groups.

Material & methods

Participants

15 lightweight category (LWC) (mean age: 23.95±2.48years) and 12 open category (OC) (mean age: 25.91±1.60years) elite male rowers having more than 4 years of training experience, attending National camp at

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Hyderabad, India, for participating in the International competition were included in the study. All of them were at the beginning of base preparation of the training preriodization. The institutional ethical committee approved this study and written informed consent was taken from participants before testing.

Measurement of anthropometric parameters

Height and weight were measured using an anthropometric rod and portable weighing machine, respectively. Skinfold thickness of biceps, triceps, sub-scapula, supra-spinale and calf was measured by Harpenden skinfold caliper. Arm span, sitting height and circumferences were measured by anthropometric tape and bone diameters by sliding caliper. Leg length was calculated by subtracting sitting height from height. A minimum of two measurements were made at each site. Body fat percentage was calculated from the Siri's equation (Siri WE., 1993). Heath - Carter formulas were used for somatotype rating (Carter et al., 1990).

Measurement of strength

Digital back strength dynamometer and handgrip 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 in between and the best result was recorded. Average grip strength was calculated from the data.

Measurement of physiological parameters

Changes in weather and water conditions make it difficult to compare data in rowing and drawing valid conclusions. The ability to perform a rowing movement in a controlled environment made the rowing ergometer an attractive tool for assessing physiological variables. 2K rowing test was conducted on Concept II model D (USA) rowing ergometer. Pulmonary gas exchange was determined breath-by-breath by portable metabolic gas analyzer (Metamax 3B, Cortex, Germany) and heart rate (HR) by HR monitor (Polar Wearlink®, Finland). Value of peak oxygen uptake ($\dot{V}O_2$), minute ventilation ($\dot{V}E$), respiratory exchange ratio (RER), HR and power along with 2K rowing timing was recorded. Verbal encouragement was given during testing. Blood lactate after three-minute of 2K rowing was measured by lactate scout.

Statistical analysis

Lightweight category and open category were compared to each other by doing Student t-test using SPSS 15.0 statistical software. Data is presented as mean ± standard deviation (SD). The value of $p<0.05$ was considered to be statistically significant.

Results

Results showed that height (1.6%) and body fat percentage (24.4%) were significantly high in OC rowers compared to LWC. Arm span (3.3%), leg length (4%), elbow (4.8%) and knee (3.1%) diameters and upper arm circumference (9.5%) were also shown the same trend. No significant difference was observed in sitting height and calf circumference. Endomorphy (28.4%) and mesomorphy (22%) were significantly high, whereas ectomorphy (18.5%) was significantly less in OC rowers than LWC (table 1). It was observed that back strength (10.6%) and average grip strength (9.9%) were significantly high in OC compare to LWC (fig. 1).

Table 1 Anthropometric and strength characteristic of Indian elite lightweight and open category rowers

Parameter		Lightweight category (n=15)	Open category (n=12)
Height (cm)		182.73 ± 3.59	185.58 ± 3.37 *
Weight (kg)		70.72 ± 1.20	79.13 ± 2.54 $
Arm span (cm)		190.30 ± 4.43	196.52 ± 2.99 #
Sitting height (cm)		92.59 ± 2.00	93.83 ± 2.16
Leg length (cm)		88.09 ± 3.61	91.58 ± 2.50 *
Upper arm circumference (cm)		29.33 ± 0.91	32.13 ± 1.51 $
Calf circumference (cm)		35.81 ± 0.93	36.79 ± 1.58
Elbow diameter (cm)		6.96 ± 0.27	7.29 ± 0.31 #
Knee diameter (cm)		9.55 ± 0.23	9.84 ± 0.28 #
Body fat percentage		9.17 ± 1.12	11.40 ± 1.99 $
Somatotype	Endomorphy	1.47 ± 0.21	1.88 ± 0.36 #
	Mesomorphy	3.39 ± 0.51	4.14 ± 0.65 #
	Ectomorphy	3.76 ± 0.61	3.06 ± 0.50 #
Back strength (kg)		157.93 ± 12.50	174.67 ± 14.01 #
Avg. grip strength (kg)		51.13 ± 3.85	56.21 ± 4.54 #

Values are expressed as mean ± SD. p<0.05 was considered to be statistically significant. * = p<0.05; # = p<0.01; $ = p<0.001.

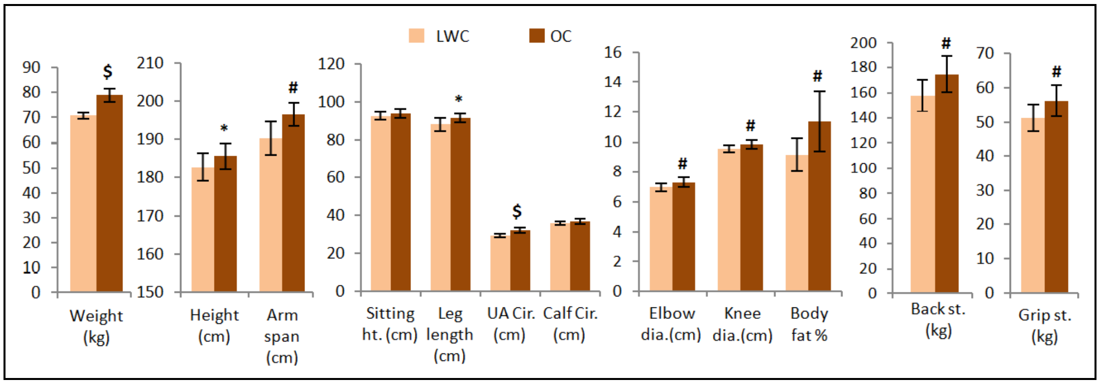

Fig. 1 Anthropometric and strength profile of Indian lightweight category (LWC) and open category (OC) rowers. (Data is represented as mean ± SD; * = p<0.05; # = p<0.01; $ = p<0.001).

Table 2 Cardio-respiratory response and performance in 2K rowing

Parameter	Lightweight category (n=15)	Open category (n=12)
Peak HR (bpm)	189.33 ± 7.39	194.25 ± 8.75
Peak $\dot{V}O_2$ (l/min)	4.82 ± 0.34	4.91 ± 0.46
Peak $\dot{V}O_2$ (ml/kg/min)	68.40 ± 4.87	62.33 ± 6.41 #
Peak $\dot{V}E$ (l/min)	167.09 ± 12.02	185.85 ± 14.70 #
Peak RER	1.20 ± 0.19	1.21 ± 0.05
Power (watt)	352.45 ± 11.50	370.36 ± 5.70 *
Peak lactate (mmol/l)	16.25 ± 2.55	16.61 ± 1.92
2K timing (sec)	401.67 ± 12.83	393.17 ± 3.35 *

Values are expressed as mean ± SD. p<0.05 was considered to be statistically significant. * = p<0.05; # = p<0.01.

Cardio-respiratory response and 2K timing of LWC and OC rowers are presented in table 2. Results showed that there was no significant difference in peak HR, absolute peak $\dot{V}O_2$ and RER at 2K rowing among the groups. But OC rowers reached 2.6% higher HR, 1.8% higher $\dot{V}O_2$ and 0.9% more RER than LWC rowers. Significant difference was found in relative peak $\dot{V}O_2$ and $\dot{V}E$. Relative $\dot{V}O_2$ was 8.9% less and $\dot{V}E$ was 10.6% more in OC rowers than LWC. Average power was 5.1% high in open OC than LWC. It was also observed that OC rowers are 2.1% faster compare to LWC rowers. No significant difference was observed in peak lactate after 2K rowing.

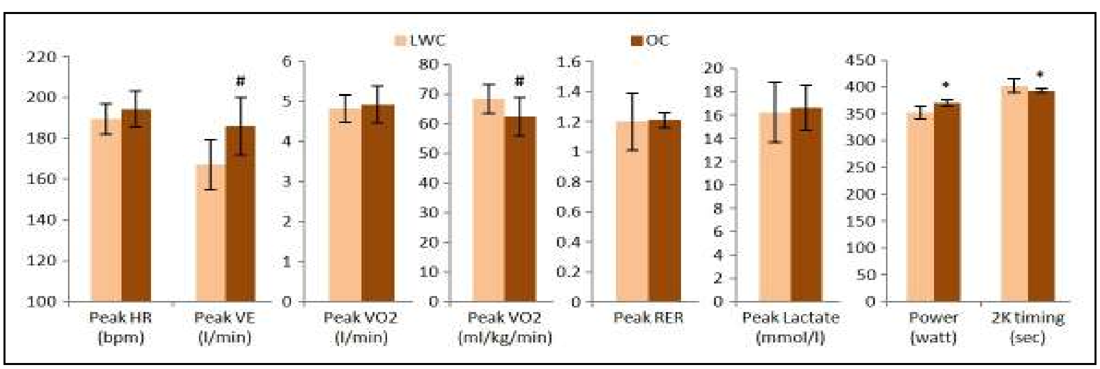

Fig. 2 Effect of 2K all-out rowing on cardio-respiratory parameters of light weight category (LWC) and open category (OC) rowers. (Data is represented as mean ± SD; * = p<0.05; # = p<0.01).

Discussion

Anthropometric characteristics are undoubtedly performance related factors, especially in rowing. The elite rowers were usually taller and heavier and possess a shorter sitting height compare to stature but longer extremities (Bourgois et al., 2000; Mikulic P., 2008). Indian open category rowers are significantly taller with greater arm span and leg length than lightweight category rowers. Long legs increase the drive phase of the rowing stroke (Bourgois et al., 2000) thus providing the rowers with long legs has a biomechanical advantage to create more force during rowing (Claessens et al., 2005; Arazi et al., 2011). Longer limbs are an advantage in catch and drive action closely identified with high-level rowing performance (Ingham et al., 2002). In this study, open category rowers have taken significantly less time to complete 2K than lightweight category supports the same.

Body weight is typically supported by the sliding seat in the boat, therefore, they can afford to carry a greater mass and possess an advantage. Average weight of Indian open category rowers is much lesser than their other counterpart participated in 2000 Sydney Olympic (94.3±5.9 kg) (Kerr et al., 2007), US Olympic team (88.1 kg) (Hagerman et al., 1979), FISA champions (94kg) (Secher NH, 1990) and Iranian rowers (80.6±3.9 kg) (Arazi et al., 2011) whereas in lightweight category no such difference was observed (Kerr et al., 2007; Shephard RJ., 1998).

Body fat percentage has a significant role in sports performance. To maintain body metabolism, a certain amount of fat is required but excess adiposity has a negative influence on performance (Majumdar et al., 2017). It is interesting to note that the body fat percentage in elite rowers seems to have been decreasing in recent years (Mikulic P, 2008). Studies have reported that high body fat percentage adversely affects 2K rowing ergometer performance (Ingham et al., 2002; Majumdar et al., 2017; Secher NH, 1983). In this study, body fat percentage was significantly lower in the lightweight category than open category. The average body fat percentage of both groups in the present study was slightly higher or almost similar revealed in other studies (Arazi et al., 2011; Cosgrove et al., 1999; Izquierdo-Gabarren et al., 2009).

Significant difference was observed in somatotype. Open category Indian rowers were more endomorphic and mesomorphic and less ectomorphic than lightweight rowers. This pattern is similar to the somatotype of 2000 Sydney Olympic rowers (open category: 1.9-5.0-2.5; lightweight: 1.4-4.4-3.4) (Kerr et al., 2007). But mesomorphy of Indian rowers were less than the rowers at the Sydney Olympic (Open: 4.2 vs 5.0; lightweight: 3.4 vs 4.4) or 1976 Montreal Olympic (5.0) (Kerr et al., 2007; Carter et al., 1982). Rowing involves a large body muscle mass approximately 70% because all extremities and the trunk participate in a complete stroke. Thus, muscle mass has a significant role as the sport requires strength, power and endurance. Majumdar et al. (2017) found that rowers with higher mesomorphy took less time to complete 2K rowing. Thus, identifying the mesomorphic component which represents muscularity is important for the evaluation of a rower.

Previous research suggested that, during a rowing stroke, successful elite rowers produce about 75–80% of power with their legs and 20–25% with their arms (Cosgrove et al., 1999). Thus improvement of strength has an influence on speed and power, provides the basis for strength/power endurance and an advantage to sustain a more powerful stroke during the oar cycle (Maestu J., 2005). In the present study, back strength and grip strength is higher in open category rowers may be influenced by their body weight and more muscle mass than lightweight rowers. It is reported that strength training in rowers has increased in recent years and to elicit optimal adaptations and rowing performance, the prescription of strength training for rowers requires careful implementation and monitoring as high volume strength training can lead to the development of 'residual fatigue' (Majumdar et al., 2017; Izquierdo-Gabarren et al., 2010).

Competitive 2K rowing is regarded as an endurance sport and researchers found strong relationship between rowers' aerobic capacity and rowing performance (Cosgrove et al., 1999; Izquierdo-Gabarren et al., 2009). For selecting elite rowers, East German sports scientists were emphasized assessing absolute $\dot{V}O_{2max}$ for rower's maximal aerobic capacity as body weight is supported by the boat (Hagerman et al., 1979). $\dot{V}O_{2max}$ is increased over the years from approximately 3.4 l/min to 6 l/min and may approach an average of 6.4 to 6.6 l/min for men in open category (Clark et al., 1983; Hagerman et al., 1978). These values reflect a gradual increase in $\dot{V}O_{2max}$ during a rowing career from 3.7 l/min in untrained individuals to 4.3 l/min in beginners, 4.9 l/min after 3 to 4 years of rowing and 5.5 l/min in national competitive oarsmen (Grujic N., 1989). Absolute $\dot{V}O_2$ of Indian LWC and OC rowers at the base preparation of the training periodization revealed no significant difference. In other studies, higher absolute $\dot{V}O_2$ value was reported in open category which was an expression of higher body size (Secher NH, 1990; Shephard RJ., 1998; Hagerman et al., 1978). The inconsistency in absolute $\dot{V}O_2$ data between Indian open category rowers and other International rowers may be due to differences in subjects' body weight and muscle mass. In this study, relative peak $\dot{V}O_2$ was 8.9% higher in LWC than OC maybe favored by less body weight and mesomorphy of lightweight rowers.

Research suggests that ventilation greater than approximately 70 l/min is achieved through increases in breathing frequency and not by further increase in tidal volume (Steinacker et al., 1993). Varying observations were reported for changes in $\dot{V}E$. It has been reported that pulmonary ventilation is impaired in rowers because of cramped body position with both knees and hips flexed at the catch of a rowing stroke. Increased intra-abdominal pressure in this position may impair downward excursion of the diaphragm and therefore inspiration (Cunningham et al., 1975). But Hagerman et al. (1978, 1979) and Clark et al. (1983) found no such impairment. In this study, $\dot{V}E$ was 10.6% more in OC than LWC followed by 5.1% more power generation and taking 2.1% less time in 2K rowing.

HR in rowing is the only means to monitor intensity of training or to identify exhaustion. Different studies on Olympic rowers, elite and highly trained rowers have reported that peak HR reached 185-200bpm during 2K rowing (Hagerman et al., 1978; Ingham et al., 2007; Jurimae et al., 2000). Greater body size and muscularity of the rowers and fulfilling higher O_2 demand of exercising muscles may be the reason of this. Peak

HR of Indian rowers in 2K rowing is within this range. Peak HR and blood lactate in 2K rowing showed no significant difference between the groups.

Rowing performance is dependent upon 21–30% of energy derived from anaerobic metabolism (Secher NH, 1993). Owen et al. (2002) demonstrated that OC rowers were able to produce greater maximal power and maximal force compared to LWC rowers. Result of this study also supports the same. Average power (watt) in 2K rowing was 5.1% high in OC than LWC. This may be due to involvement of larger active muscle mass of OC rowers. Maximum power output involving anaerobic energy system is needed most at the start with a tremendous burst of effort to break the inertia of the boat and again during the sprint at the finish (Gee et al., 2013).

Conclusions

This is the first study carried out to identify anthropometric and physiological profile of Indian elite rowers at the beginning of a training plan. This data provides detailed insight into elite rowers' anthropometry and physiology that are important for the coaches, sports scientists and rowers. Having good aerobic capacity, body strength and anaerobic power are the most important factors needed to achieve good results in rowing competitions. The primary finding of this study indicates that Indian open category rowers are in better position compare to the lightweight group as performance determining factors in rowing such as arm span, leg length, upper arm circumference, body fat percentage, mesomorphy, strength, power, $\dot{V}O_2$ values were comparatively high in open category and close to International counterpart. So, this information can be used to create reference range categorically, setting a benchmark for Indian rowers at the base preparation phase and also to find strength and weaknesses of the rowers compare to other International counterparts.

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Conflicts of interest - The authors declare no conflicts of interest.

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