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Effect of training on Motor Ability Parameters and Rowing Ergometer Performance of Indian Junior Female Rowers

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ABSTRACT

The physical, physiological and motor ability parameters are important determining factors for success in rowing, and hence the present study was aimed not only to evaluate selective physical, physiological and motor ability profiles of Indian female rowers but also to enumerate the effects of systematic training on these parameters to correlate them with their rowing performance. Eleven Indian junior female rowers (15.7 ±0.4 years) were selected for this study. Height, body weight, 800m run, 100m sprint, 6×10m shuttle run, push-up, sit-up, standing broad jump, vertical jump, sit and reach test, bench pull and squat tests were done by the standard procedures. Performance time, power output, stroke rate was evaluated by rowing ergometer (concept II). Four sets of tests were conducted, maintaining three months interval between each set of test. The average body height and body weight of Indian junior female rowers was 163.7 ±3.6 cm and 52.6 ±2.7 kg respectively. Body height was found to be significantly and negatively correlated with performance time (r = -0.98) and positively with total power output (r = 0.97). All the motor ability parameters were progressively increased after systematic training was applied on them. On the other hand, per-

Key Words: *Rowing, Concept II ergometer, Training effect, Physical & Physiological parameters.*

formance time, power output and stroke rate was progressively improved through systematic training which is desirable for better performance. The present rowers were found to be shorter and lighter as compared to their international counterparts. They also took more time to complete 2000m distance as compared with their international counterparts. Systematic training improves the various physical, physiological and motor ability parameters which are responsible for rowers to excel in rowing. The present data could be used as further reference standard for comparison in rowing.

INTRODUCTION

Rowing imposes a challenge to the human body involving nearly 70% of the skeletal muscle tissue in the rower's body during a single stroke cycle (31). The rowing stroke is supported by the sliding seat of the boat so that the drive phase is sequentially performed by extension of the legs and trunk with simultaneous flexion of the arms. The rower has to attain a combination of high stroke force and optimal stroke length to produce an effective stroke (16, 28). Rowing demands 70-80% aerobic and 20-30% anaerobic capacities for successful performance and also depends on number of oarsmen in the boat, skill level, race distance, and race duration (14).

Strength testing and training appears relatively ingrained as part of the physical preparation plans of rowers (9). Large testing actions are needed to form a group of rowers with potential for practicing high performance rowing. The rowing ergometer has become an important tool for training and physiological monitoring of rowers since it has facilitated not only environmentally controlled training and monitoring of rowers, but more critically, the establishment of important physiological determinants of 2000m on-water performance (17,25,26).

A strength enhancement program provides the basis for components of strength and endurance along with influence on speed and power in addition to the applicative motor training; the rowers develop motor skill. Izquierdo-Gabarren et al. (15) indicated the advantages of moderate volume of high-intensity stimuli on the performance gains resulting from resistance training protocols. Laursen (19) reviewed intense exercise performance, such as rowing; rely on near maximal energy delivery, both aerobic and anaerobic, over a sustained period of time and discussed the importance of combining different modes of training to form a successful program. Good anaerobic and aerobic capacity, strength, power and agility are the most important factors which needed to achieve success in rowing competitions (21). Ideally, a successful training program is one, which provides a peak level of performance at the appropriate time (23) i.e. at the time of competition. However, an

overwhelming majority of these studies have focussed on the use of male rowers as subjects. Literature addressing the effects of training in female rowers is extremely limited. As per literature, no such study was conducted on the effect of training on rowing performance & its relationship with various physiological & motor ability parameters especially in case of Indian female rowers. So the objectives of the present study were to evaluate:

i. various Physical, Physiological & Motor ability profiles and 2000m off water rowing ergometer performance of Indian national level junior female rowers.

ii. the effect of systemic training on 2000m off water rowing performance and on above mentioned profiles.

iii. to establish the relationship among rowing performance, physical and physiological parameters & motor ability variables.

MATERIAL AND METHODS

Participants

The present study was carried out on 11 Indian national junior female rowers (mean age 15.7 ±0.4 years). They were undergoing training at SAG centre (Special Area Game scheme, of Sports Authority of India) Jagatpur, Orissa. All the girls were inducted in the scheme from various parts of costal Orissa, the eastern region of India. They belonged to almost similar socio-economic status having similar dietary habits. They were residing in same geographical region and climatic condition and obtained similar kind of physical training. Hence, the subjects were considered to be homogeneous. All the girls had undergone investigations for their physical, physiological and motor ability profiles at SAI, SAG centre, Jagatpur. Four sets of tests were conducted, maintaining three months interval between each set. Before the test, all the players were clinically examined by the doctors of SAI, specialized in sports medicine. Prior to the initial testing, a complete explanation of the purpose, procedures and the potential risk and benefits of the tests were given to all the players and written consents were obtained from all the subjects. The players, who were found to be clinically fit, healthy and with no history of any hereditary and cardiorespiratory diseases were finally selected for the present study.

Training regimen

The subjects of the present study were having at least 4-5 years of prior formal training. The formulation and implementation of training program was made by the

qualified coaches/trainers of SAI. The training regimen was applied 24 to 30 hours a week (six days/week). The training schedule comprised of different training on the land, Ergometer and as well as on boats along with their specific skill training in respective events. The land training schedule included different strength, speed, and endurance training programs along with flexibility exercises. Strength and endurance training was also applied according to their event specific requirement. The training schedule also consisted of prior warming up and post cooling down session. The training protocol was made keeping the scheduled competitions throughout the season under consideration. Besides the technical and tactical training, the players were also provided with psychological or mental training session.

Measures

The physical characteristics of the subjects including age (yr), height (cm), weight (kg) were measured by anthropometric rod and digital weighing machine respectively following standard procedure (32). The decimal age of the players was calculated from their date of birth recorded from original birth certificate at the time of testing. All the tests were conducted at a temperature varying from 24 to 27 degree centigrade with relative humidity varying between 55- 70%.

Procedures

Motor ability test*:* Motor ability parameters were measured by means of standard tests (7) to assess the level of different motor qualities. The tests which were conducted to asses motor qualities were speed ability (100m run), explosive power of lower limbs (Standing Broad Jump and Vertical Jump) Bench pull, Squat and agility (6×10 m shuttle run).Trunk flexibility was measured by Lafayette Flexometer (Model No. 01285, Lafayette, Indiana, USA). Bench pull test was also measured by a standard procedure (1).

Maximal one minute Ergometry test

One minute Ergometry test was conducted on the Concept II rowing ergometer (made in Vermont, USA, model D) for each subject. Subjects performed a warm-up session for 10 minutes prior to the actual ergometer test. After the warm-up session, the ergometer was programmed for a 60 sec trial and the damper was set to provide a “drag factor” of 140. Because dust, worn parts and other factors can affect the amount of resistance provided by each stop in the resistance control dial, the “drag factor” is the method used on the Concept II ergometer for standardizing the resistance setting between ergometer.

Participants performed an all-out 60 sec. effort on rowing ergometer with verbal

encouragement. Participants were asked to row full strokes on each stroke of the test rather than use the partial strokes that are often incorporated at the start of a race. Power output (Watt) for every stroke was calculated and displayed on the Concept II computer and was recorded. Peak power is the highest power obtained on any individual stroke. Mean power is the average of the individual stroke powers over the 60s trial as calculated by the Concept II computer.

Ergometer Test

The subjects were rested and fully hydrated for at least two hours postprandial and having avoided strenuous exercise in the 24 hours preceding the test session. All exercise tests were performed on an air-braked rowing ergometer (concept II) with a drag factor of 140. Ergometer was set to perform the 2000-meters rowing to find out the split timing, power output, and stroke rate during exercise. After the exercise 3 minute recovery heart rate was also recorded by polar heart rate monitor and the 3rd min heart rate was recorded.

Statistical Analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS, version 21.0). Mean and standard deviation was obtained for all variables followed by one-way ANOVA which was conducted to examine the differences (if any) among the groups. Pearson product - moment correlation coefficient (r) was calculated to establish the relationship between various motor ability parameters and rowing performance parameters. Graphical representations were also made by the regression line between rowing performance and motor ability parameters along with simple linear curve between rowing performance & test phase to show the improvement (if any).

RESULTS

Table 1 depicted the descriptive statistics (mean & standard deviation) of Indian (Jr.) female rowers of four different test phases (Test I, Test II, Test III and Test IV) and the level of significance of successive three month interval (effect of training) for each and every parameter. The table further revealed that the changes in all the motor ability variables were found to be statistically insignificant except push up (per min) which was found to be significant when compared among the tests. The performance times of 800m run and shuttle run were found to decrease progressively from 184.2 ±11.0 sec to 175.3 ±14.7 sec and from 17.2 ±0.5 sec to 16.8 ±0.4 sec respectively after four

successive tests were conducted. However, no such significant changes were found in both the parameters when compared between them. On the other hand, trunk flexibility was increased from 16.9 ±4.9 cm to 20.1 ±7.5 cm after four successive tests were conducted. By and large, almost all the motor ability variables were found to improve after training i.e. at the end of test-IV as compared to test-I.

Table 1.

Mean, standard deviation, and level of significance of various motor ability parameters of Indian female rowers at four different test phase

Variables	Test – I (n=11)	Test – II (n=11)	Test – III (n=11)	Test – IV (n=11)	F value
Age (yrs)	15.3 ±1.72	15.6 ±1.71	15.9 ±1.64	16.1 ±1.72	0.48 (ns)
Height (cm)	163.5 ±3.53	163.7 ±3.74	163.7 ±3.74	163.7 ±3.57	0.00 (ns)
Weight (kg)	51.8 ±3.72	52.6 ±2.60	53.2 ±2.63	52.6 ±2.67	0.41 (ns)
800m (sec)	184.2 ±11.02	181.5 ±13.72	181.3 ±17.90	175.3 ±14.67	0.75 (ns)
100 m run (sec)	17.1 ±0.84	16.9 ±0.79	17.0 ±0.91	16.4 ±1.06	1.30 (ns)
6×10m shuttle run (sec)	17.2 ±0.46	17.2 ±0.46	16.9 ±0.31	16.8 ±0.37	2.17 (ns)
Push-up (per min)	28.8 ±8.99	33.7 ±10.56	42.8 ±0.09	40.6 ±7.41	5.51*
Sit-up (per min)	39.2 ±8.80	44.3 ±5.00	46.5 ±4.48	45.5 ±4.78	3.19 (ns)
Standing Broad Jump (cm)	188.8 ±14.56	194.3 ±12.61	183.8 ±30.68	199.1 ±12.39	1.32 (ns)
Vertical Jump (cm)	37.0 ±5.83	37.5 ±5.13	39.8 ±4.47	38.5 ±5.39	0.63 (ns)
Sit and reach test (cm)	16.9 ±4.90	17.9 ±6.58	16.1 ±7.13	20.1 ±7.45	0.76 (ns)
Bench pull (kg)	73.7 ±14.64	80.5 ±15.49	85.3 ±11.44	85.0 ±11.41	1.78 (ns)
Squat (kg)	96.1 ±15.36	106.8 ±18.85	97.8 ±16.06	109.8 ±22.43	1.47 (ns)

Values are (mean ± sd); *, $p<0.05$; ns, not significant

Table 2 comprises the parameters of one minute ergometry test of rowers i.e., distance covered, power output**,** total number of strokes & maximum heart rate. All the parameters were found to be statistically insignificant when compared among the tests. This table also showed that the distance covered, power output**,** total number of strokes in one min (ergometer test) were found to be progressively increased (from 258.4 ±9.7 m to 267.8 ±5.8 m; from 225.5 ±25.9 watt to 251.1 ±17.8 watt; and from 40.3 ±7.3 sec to 43.5 ±2.1 sec respectively) in four successive tests. Maximum heart rate and 3 min recovery heart rate was also increased after training.

Table 2.

Mean, standard deviation, and level of significance of various parameters of 1 minute ergometry test of Indian female rowers at four different test phase

Variables	Test – I (n=11)	Test – II (n=11)	Test – III (n=11)	Test – IV (n=11)	F value
Distance covered (m)	258.4 ±9.69	266.9 ±5.54	267.8 ±5.79	264.9 ±10.56	2.97 (ns)
Power Output (watts)	225.5 ±25.89	246.8 ±15.71	251.1 ±17.84	244.3 ±28.24	2.76 (ns)
Number of stroke	40.3 ±7.32	42.5 ±3.67	43.5 ±2.11	42.3 ±2.53	1.02 (ns)
Max. Heart Rate (beats/min)	181.5 ±5.73	186.6 ±4.18	182.5 ±5.87	182.5 ±4.93	2.08 (ns)
Recovery Heart Rate (beats/min after 3 min)	119.3 ±9.83	124.0 ±13.60	122.5 ±13.31	121.5 ±10.05	0.31 (ns)

Values are (mean ± sd); ns, not significant

Table 3 demonstrated the mean, standard deviation and level of significance of various split time for 2000 m rowing performance (500 m, 1000 m, 1500 m, 2000 m, total time and average time) and were found to be statistically significant when compared among the tests at the level of $p<0.01$. The average time indicated the mean time of each 500 m distance. Total time and average time were found to be progressively decreased (from 555.5 ±24.5 sec to 516.2 ±8.5 sec & from 138.6 ±6.4 sec to 129.0 ±2.1 sec) when compared among four successive tests.

Table 3.
Mean, standard deviation, and level of significance of various split time (on ergometer) of Indian female rowers at four different test phase

Variables	Test – I (n=11)	Test – II (n=11)	Test – III (n=11)	Test – IV (n=11)	F value
500 m (sec)	135.8 ±6.40	127.2 ±1.72	124.0 ±1.85	126.8 ±2.69	20.93**
1000 m (sec)	139.4 ±6.46	131.6 ±2.05	129.0 ±1.86	130.9 ±3.19	15.69**
1500 m (sec)	140.8 ±6.97	134.2 ±3.38	131.9 ±3.11	131.9 ±4.68	8.57**
2000 m (sec)	139.6 ±5.34	132.2 ±3.33	131.4 ±4.93	130.1 ±3.56	10.52**
Total Time (sec)	555.5 ±24.46	524.7 ±9.24	516.2 ±8.47	519.5 ±12.43	15.73**
Average Time (sec)	138.6 ±6.36	131.3 ±2.33	129.0 ±2.12	129.8 ±3.12	14.05**

Values are (mean ± sd); **, P<0.01;

Table 4 indicated the mean, standard deviation and level of significance of power output (in 500 m, 1000 m, 1500 m, 2000 m, total and average power output) of Indian junior female rowers and were found to be statistically significant (p<0.01) when compared among four successive tests. This table also depicted the total power output and average power output and were also found to be increased progressively and significantly (from 528 ±65.8 watt to 655.4 ±30.4 watt and from 132.5 ±16.8 watt to 162.3 ±8.8 watt) when compared among the tests.

Table 4.
Mean, standard deviation, and level of significance of power output of different distance of Indian female rowers at four different test phase

Variables	Test – I (n=11)	Test – II (n=11)	Test – III (n=11)	Test – IV (n=11)	F value
500 m (watt)	141.5 ±18.59	170.5 ±7.09	183.8 ±8.53	171.9 ±10.84	24.31**
1000 m (watt)	129.7 ±16.84	153.9 ±7.06	163.3 ±6.93	156.6 ±11.12	18.68**
1500 m (watt)	126.9 ±18.47	145.3 ±10.94	153.7 ±11.64	153.3 ±16.53	7.96**
2000 m (watt)	129.9 ±14.52	151.8 ±11.25	154.5 ±16.03	159.7 ±13.13	9.92**
Total Watt	528 ±65.80	621.5 ±32.13	655.4 ±30.37	641.5 ±45.12	17.45**
Average (watt)	132.5 ±16.77	154.8 ±8.15	162.3 ±8.83	159.4 ±11.50	14.45**

Values are (mean ± sd); **, P<0.01

The mean, standard deviation and level of significance of stroke rate, maximum heart rate and recovery heart rate (after 3min) of female rowers at different distance of 500m, 1000m, 1500m, 2000m were depicted in Table 5. All the above parameters were found to be statistically insignificant when compared among the tests. However, total number of strokes and average stroke rates were increased progressively from 108.6 ±3.3 to 113.6 ±5.3 and from 27.6 ±1.0 to 28.1 ±1.4 respectively in every 500m distance when compared among the tests. It was interestingly noted that all the above parameters including performance time and power output in previous table also were found to be reduced in test phase- IV as the trends were seen in test phase I-III respectively.

Table 5.

Mean, standard deviation, and level of significance of various stroke rate (/min.) of Indian female rowers at four different test phase

Variables	Test – I (n=11)	Test – II (n=11)	Test – III (n=11)	Test – IV (n=11)	F value
500 m	26.6 ±1.63	26.9 ±1.58	28.7 ±1.56	26.8 ±2.40	3.15 (NS)
1000 m	26.4 ±1.12	26.3 ±2.15	27.5 ±1.57	25.6 ±1.36	2.46 (NS)
1500 m	27.1 ±1.22	26.5 ±1.69	27.6 ±1.86	26.4 ±1.36	1.61 (NS)
2000 m	28.5 ±1.13	30.4 ±2.73	29.8 ±2.27	29.5 ±1.29	1.65 (NS)
Number of Stroke	108.6 ±3.32	110.0 ±7.09	113.6 ±5.28	108.3 ±4.38	2.44 (NS)
Ave. Stroke (per 500m)	27.6 ±1.03	27.2 ±1.89	28.1 ±1.38	26.7 ±1.01	2.01 (NS)
Max. Heart Rate (beats/min)	196.1 ±7.71	197.5 ±5.43	197.7 ±6.45	196.0 ±7.94	0.19 (NS)
Recovery Heart Rate (beats/min after 3 min)	132.4 ±11.04	141.2 ±6.69	135.3 ±10.21	133.4 ±6.65	2.18 (NS)

Values are (mean ± sd); ns, not significant

Table 6 represented the Scheffe's f-test for multiple comparisons of selected motor ability and rowing performance ability parameters of Indian junior national female rowers. The table depicted that all the parameters were found to be statistically significant at $p<0.01$ & $p<0.05$ respectively when test I was compared to test II, test

III and test IV respectively except push up which was significant in case of test I vs. test II only. However, no such parameters were found to be statistically significant when test II was compared with test III and test IV respectively. Further, when test III was compared with test IV, only split time (500 m) was found to be significant at the level of $p<0.01$.

Table 6.

Scheffe's f test for multiple comparisons of selected motor ability and rowing parameters of Indian female rowers at four different test phases

Variables	Test I Vs Test II	Test I Vs Test III	Test I Vs Test IV	Test II Vs Test III	Test II Vs Test IV	Test III Vs Test IV
Push up(/min)	4.91(ns)	14.00**	11.82*	9.01(ns)	6.91(ns)	2.18(ns)
Split Time 500 m (sec)	8.61**	11.76**	9.00**	3.16(ns)	0.39(ns)	11.76**
Split Time 1000 m (sec)	7.82**	10.46**	8.56**	2.64(ns)	0.74(ns)	1.90(ns)
Split Time 1500 m (sec)	6.58*	8.90**	8.96**	2.32(ns)	2.38(ns)	0.06(ns)
Split Time 2000 m (sec)	7.38**	8.23**	9.52**	0.85(ns)	2.14(ns)	1.29(ns)
Split Total Time (sec)	30.85**	39.34**	35.97**	8.49(ns)	5.13(ns)	3.36(ns)
Split Average Time (sec)	7.33**	9.60**	8.76**	2.27(ns)	1.43(ns)	0.85(ns)
500 m (watt)	29.00**	42.36**	30.46**	13.36(ns)	1.46(ns)	11.91(ns)
1000 m (watt)	24.18**	33.55**	26.91**	9.36(ns)	2.73(ns)	6.64(ns)
1500 m (watt)	18.36*	26.82**	26.36**	8.46(ns)	8.00(ns)	0.46(ns)
2000 m (watt)	21.91**	24.64**	29.82**	2.73(ns)	7.91(ns)	5.18(ns)
Total Power output (watt)	93.46**	127.36**	113.55**	33.91(ns)	20.09(ns)	13.82(ns)
Average Power output (watt)	22.36**	29.82**	26.91**	7.46(ns)	4.55(ns)	2.91(ns)

Values are (mean ± sd); **, $P<0.01$; *, $P<0.05$; ns, not significant

Table 7 demonstrated the coefficient of correlation of various motor ability parameters and physiological variables with 2000m off water rowing performance parameters of Indian junior national female rowers. Height was found to be significantly and negatively correlated to the total 2000m rowing performance time, and positively correlated to the total power output at the level of $p<0.05$. Similarly, sit up and bench pull were also found to be significantly and negatively correlated to total 2000m rowing performance time, and positively with total power output at the level of $p<0.01$ and $p< 0.05$ respectively. Total power output was negatively correlated to the total 2000m off water rowing performance time ($p<0.01$). Standing broad jump and trunk flexibility were also found to be significantly and positively related to the average stroke rate (every 500m rowing) at the level of $p<0.01$. This table also indicated the recovery heart rate and was found to be positively and significantly related with number of strokes (last lag of 500m) at the level of $p<0.01$.

Table 7.

Coefficients of Correlation of different variables with performance time, total power output and stroke rate of Indian junior female rowers

Variables	Performance Time	Total Power Output	Avg. Stroke Rate (/500m)	No. of Strokes (last 500m)
Height (cm)	-0.981*	0.970*	–	–
Sit Up (/min)	-0.996**	0.999**	–	–
Bench Pull (kg)	-0.971*	0.979*	–	–
Stroke Power (watt)	-0.999**	–	–	–
Standing Broad Jump (cm)	–	–	0.786**	–
Sit & Reach (cm)	–	–	0.749**	–
3 min Recovery HR (beats/min)	–	–	–	0.998**

Values are **, $P<0.01$; *, $P<0.05$

Figures 1, 2 and 3 represented the effects of training on performance time, total power output and total number of stroke of Indian junior female rowers. Figure 4 to 6 represented the relation of performance time with sit ups, bench pull and total power output respectively. Figures 7 & 8 represented the relation of stroke rate with standing broad jump and trunk flexibility of Indian female rowers. The figures

revealed that the performance time decreased and the total power output and total number of strokes increased gradually with training (test 1 to 3), but in all the cases the performances were decreased slightly in test phase 4.

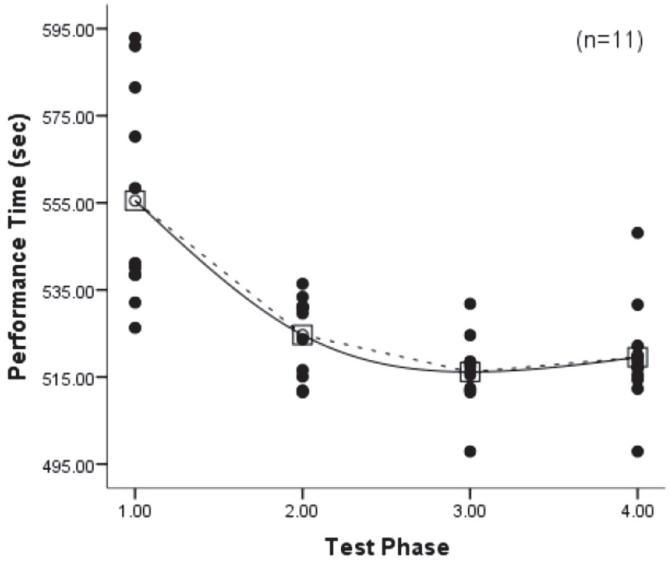

Fig.1. *Effects of training on Performance Time of Indian Junior Female Rowers.*

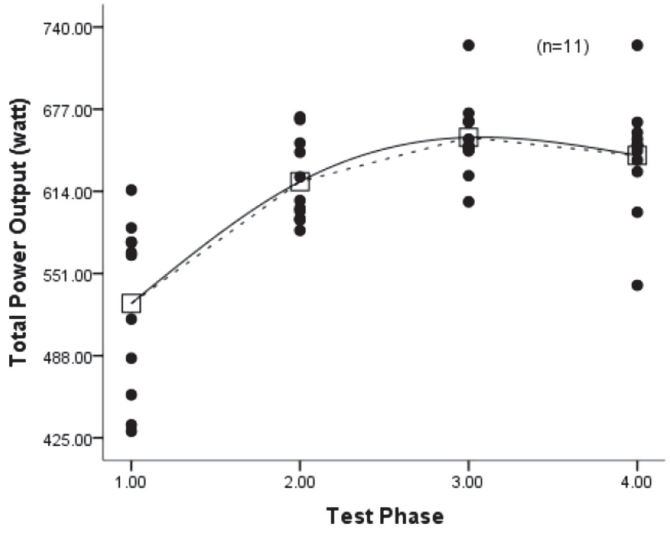

Fig. 2. *Effects of training on Total Power outpur of Indian Junior Female Rowers.*

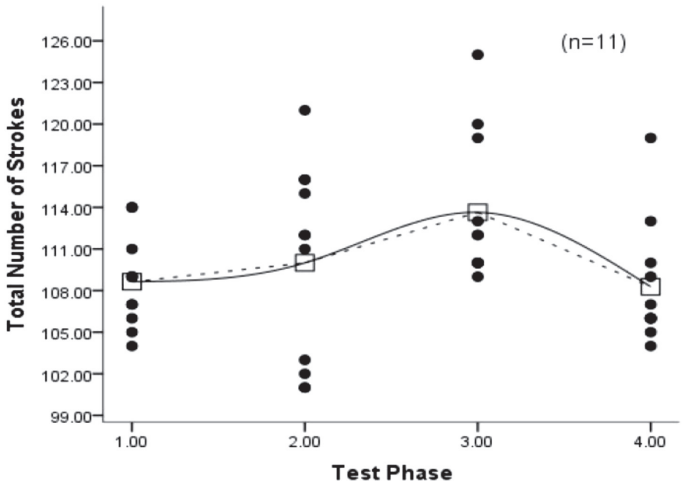

Fig. 3. *Effects of training on Total No. of Strokes of Indian Junior Female Rowers.*

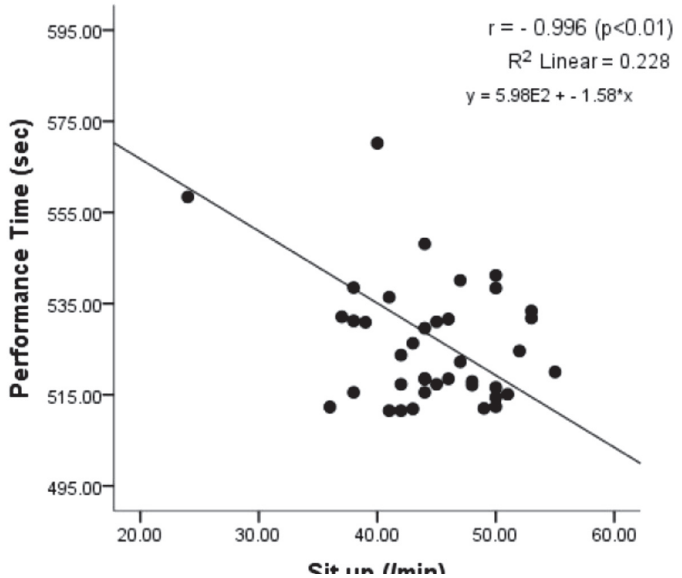

Fig. 4. *Relationship between Performance time and sit up for Indian female rower.*

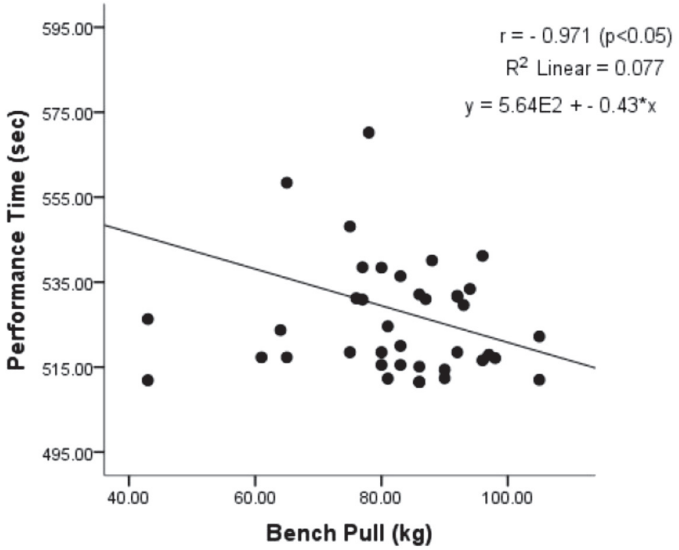

Fig. 5. *Relationship between Performance time and Bench pull for Indian Junior Female rower.*

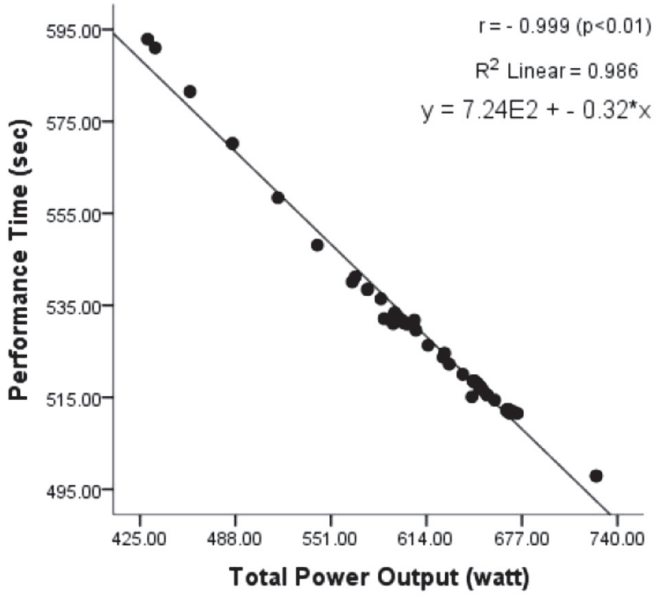

Fig. 6. *Relationship between Performance time and Total Power outpur for Indian Female rower.*

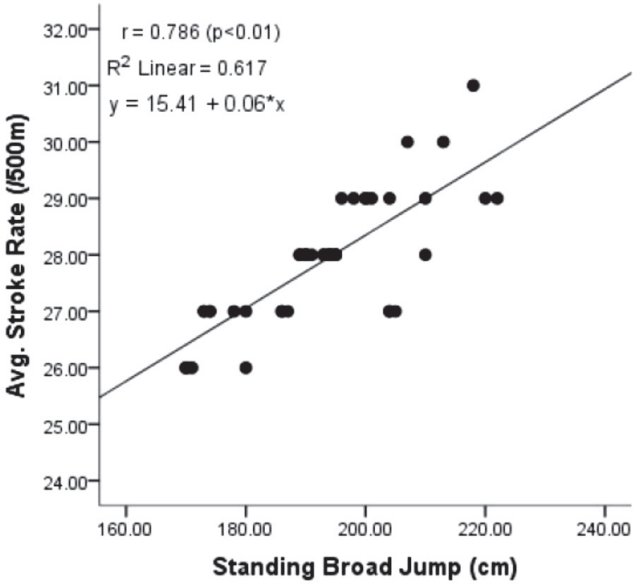

Fig. 7. *Relationship between Avg. Stroke Rate and Standing Broad Jup for Indian Female rower.*

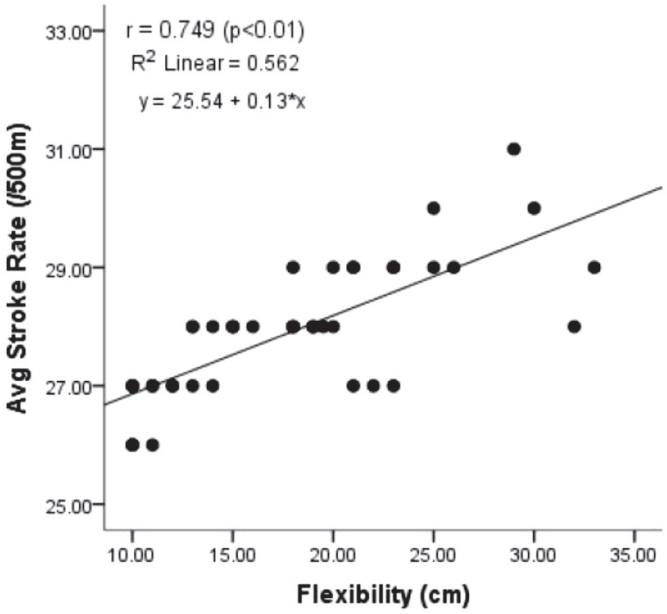

Fig. 8. *Relationship between Avg. Stroke Rate and Flexibility for Indian Junior Female rower.*

DISCUSSION

The present study was conducted to assess various anthropometric, motor ability and physiological characteristics of a homogeneous group of Indian elite junior female rowers to identify the effect of training and also to identify the relationship of these characteristics with performance in the 2000m distance on rowing ergometer.

Physique is an important factor that contributes to success in rowing (30) and evidences indicated that anthropometric characteristics have influence on rowing performance (2). Various studies on anthropometric parameters have showed that elite rowers are usually taller and heavier than athletes of other sports discipline (24,3). Tall rowers are able to make long rowing strokes and long stroke lengths are closely identified with high level rowing performance (29, 14).

In competitive rowing, body weight is another important parameter because it is typically supported by a sliding seat in the boat where they can afford to carry a greater mass and possess an advantage in rowing performance (28). Average weight of the present Indian female rowers was 52.5 kg which is more than their sedentary counterparts (51.0 kg) but less than their international counterparts. Training has an influence on body composition and the importance of low body fat enhance success in rowing (20).

The average body height and weight of the Iranian junior female rowers were 170.3 cm and 70.1 kg respectively as reported by Faraji (8). Since the average body height and weight of the present rowers were 163.5 cm and 52.5 kg which were far behind as compared to their Iranian counterparts. The smaller sizes of the present Indian female rowers as compared to their Iranian counterpart were probably due to the genetical reason. However, it is well established that ethnic and racial factors also affects the average body size, for example the North African and the Korean teams playing World cup final matches tends to be smaller than their European and South American rivals. Japanese team in the 1964 Olympic Games was described as especially smaller and lighter for playing at that level (12). The result of the present study also revealed that the height has an important role to excel better performance on rowing ergometer. The body height was also found to be significantly correlated to the performance time of 2000m distance. Several authors have also reported that long legs increase the drive phase of the rowing stroke, thus providing the rowers with long legs a biomechanical advantage (4). Further, it has been reported that there was no effect of regular training for rowing on statural growth and rowers were already taller than average during childhood, maintaining their position relative to reference data during childhood and adolescence (22). The height of the present rowers was found to be more as compared to their sedentary counterparts and other sports discipline except volleyball and

basketball players who were slightly taller as compare to the present subjects. However, this observation also corroborated with the information reported by other scientists as mentioned above.

The high levels of maximal strength, muscular endurance and muscle power in the elite rowers provided an advantage to sustain a more powerful stroke during the oar cycle (21). Ziffren (34) has reported that rowers have long limbs and especially long upper arm length. Successful elite rowers produce about 75-80% of their power with their legs and 20-25% with their arms during the rowing stroke (5). Rowers can be considered moderately stressful aerobic sports with the element of anaerobic energy involvement. Since the construction of training programme should be based on accurate knowledge of the demand of the game and therefore, training for these sports should include activities promoting endurance abilities as well as those that develop explosive power of lower limbs, agility and speed ability.

To complete 100m distance the average time (16.85 sec) was taken by the present female rowers were much higher as compared with the sprinters. The purpose of the 100 m run test was to determine acceleration, maximum running speed and speed endurance, depending on the distance run. On the other hand the aim of 800m run test was to evaluate the endurance capacity of the rowers and the shuttle run was used to determine agility of the rowers.

The present study showed that push-up was significantly improved with training. According to Golding et al. (10), the value of push-up per minute is >35 belonged to excellent category and the average value of push-up per minute of the present subjects was found to be 36.5. So the power of upper body particularly the shoulder area was high and which was effective for rowing stroke. Push-up is a common calisthenics exercise performed in a prone position by raising and lowering the body using the arms. On the other hand the sit-up is an abdominal strength training exercise commonly performed to strengthen the abdominal muscles. The average value of sit-up per minute of Indian junior female rowers was found to be 44. Sit-up is negatively related with performance time and positively related with total power output ($r = -0.996$ and 0.999 respectively). Hence abdominal strength is also an important prerequisite which is necessary for success in rowing. Figure-4 indicated similar trend as well.

It is well known that strength improvement has an influence on speed and power and which ultimately affect the rowing performance (21). Standing broad jump is an excellent way to measure the development of explosive strength of the leg. The average value of standing broad jump of the present Indian female rowers was 191.5 cm which was excellent as compared their sedentary counterparts but the values of standing broad jump of runners and cyclists were reported to be higher than the present subjects. The present study further demonstrated that standing broad jump was significantly and positively correlated to average stroke rate which indicated that the explosive power of lower limbs got direct positive

influence on rowing performance (r =0.786). Figure-7 also showed the relation of average stroke rate with standing broad jump since average stroke rate increased with the performance of standing broad jump.

Vertical jumping height is one of the basic characteristics of physical performance which is trained by the rowers. In these tests the results were determined among other things by the explosive force production in the extensor musculature of lower extremities and trunk, coordination of swing movements of the upper extremities and ability to reach (27). The present study showed that vertical jump was progressively improved in the present rowers due to training. In addition, single and multiple vertical jumps were also sometimes used to assess muscular strength of lower extremities and anaerobic power in athletes. Development of muscular strength of lower extremities and anaerobic power was very important for rowers. Yoshiga and Higuchi (33) examined 332 young rowers (age 21 ±2 yrs) in bilateral leg extension power on a 2000-m rowing ergometer and have emphasized that rowing involved the most of the muscles in the body, and the bilateral leg extension power was very important during rowing performance. Huang et al. (13) have demonstrated that the mean value of vertical Jump of USA club level rowers (15-18 yrs of age) was 49.5 ±7.1 but the mean height of vertical Jump of present rowers were only 38.1 cm which was much lower. So, the lower value may be due to their shorter body height than their foreign counterpart and also probably due to the difference in genetical factors.

The rowing stroke is supported by the sliding seat of the boat so that the drive phase is sequentially performed by extension of the leg and extension of the trunk with simultaneous flexions of the arms (16, 28). The average value of flexibility of the present subjects was about 18 cm. According to Davis et al. (6), this value belonged to excellent category. The present study also corroborated with the above findings because significant positive correlation between average stroke rate and flexibility (r = 0.763) had been demonstrated in the present study. However, the objective of the flexibility test was to evaluate and monitor the development of the athlete's flexibility in abdominal region. Figure 8 showed that the average stroke rate was positively correlated with flexibility since average stroke rate increased with flexibility.

Hagerman (11) reported that the maximal heart rate of rowers was 190-200 beats per minute. The mean maximal heart rate of present rowers was also found to be 196 beats per minute and which was almost similar to the above finding. But well trained oarsmen have lower values which were often seen around 185 ± 3.0 beats per minute (29). The maximal heart rate of present rowers was slightly higher than well trained rowers because of their lower training age or may be their training duration and intensities were less as compare to well trained rowers. The average time required to complete 2000m rowing distance for USA club level female rowers was 521.4 sec (mean age; 17.3 years) as reported by Huang et al. (13), whereas

the present Indian junior female rowers needed 528.9 sec which was slightly more as compared to their International counterpart. This higher time was needed may be due to their less body height and body weight as compared to USA club level rowers or may be due to genetical factors.

Klusiewicz and Faff (18) have reported that 234 watt average power output was utilized by Poland national team female rowers (Age - 19.4 years) to cover 2000m distance. In case of Indian junior female rowers average power output (2000m rowing) was only 152 watt which was far behind as compared to their international counterparts. This lesser value was may be due to their morphological differences, training regimen which was applied to them or may be due to some genetic factors and hence the present Indian rowers took longer time to complete 2000m distance as compared with their International counterpart.

CONCLUSION

From the above discussion it may be concluded that the systematic training has got a direct impact on rowing performance. The difference in various parameters of the present rowers as compared to their international counterparts may be due to the difference in their genetical traits. Further, these data can be the tool for future reference and comparison.

REFERENCES

1. Akca F, Muniroglu S. Anthropometric-Somatotype and Strength Profiles and On-Water Performance in Turkish Elite Kayakers. Int J Appl Sports Sci 20: 22-34, 2008.
2. Bachev V, Blazevich AJ, Diafas V, Dimakopoulou E, Kaloupsis SV. Prediction of stroking characteristics of elite rowers from anthropometric variables. Serb J Sports Sci 1(3): 89-96, 2007.
3. Bourgois J, Claessens AL, Janssens M, Renterghem BV, Loos R, Thomis M, et al. Anthropometric characteristics of elite female junior rowers. J Sports Sci 19: 195-202, 2001.
4. Claessens AL, Bourgois J, Aken VK, Auwera VR, Philippaerts R, Thomis M, et al. Body proportions of elite male junior rowers in relation to competition level, rowing style and boat type. Kinesiol 37: 123-132, 2005.
5. Cosgrove MJ, Wilson WD, Grant SF. The relationship between selected physiological variables of rowers and rowing performance as determinedly 2000m ergometer test. J Sports Sci 17: 845-852, 1999.

6. Davis B. Physical Education and the Study of Sport. UK: Harcourt Publishers Ltd, 2000.
7. Dey SK, Sinha SK. Effects of training on some physical and physiological profiles of young female Volleyball players. Indian J Physiol Allied Sci 48(2): 69-77, 1994.
8. Faraji H, Arazi H, Mohammadi SH. Anthropometric and Physiological Profiles of Elite Iranian Junior Rowers. Middle-East J Sci Res 9(2): 162-166, 2011.
9. Gee T, Olsen P, Berger N, Golby J, Thompson K. Strength and conditioning practices in rowing. J Strength Cond Res 25(3): 668-682, 2011.
10. Golding LA. Y's way to physical fitness: the complete guide to fitness testing and instruction. 3rd edition, USA: Human Kinetics, 1986.
11. Hagerman FC, Staron RS. Seasonal variations among physiological variables in elite oarsmen. Can J Appl Sports Sci 8: 143-148, 1983.
12. Hirata K. Physique and age of Tokyo Olympic champions. J Sports Med Phys Fitness 6: 207-222, 1966.
13. Huang CH, Nesser TW, Edwards JE. Strength and power determinants of rowing performance. J Exerc Physiol 10: 43-50, 2007.
14. Ingham SA, Whyte GP, Jones K, Nevill AM. Determinants of 2,000 m rowing ergometer performance in elite rowers. Eur J Appl Physiol 88: 243-246, 2002.
15. Izquierdo - Gabarren M, Gonzalez de Txabarri Exposito R, Garcia-Pallares J, Sanchez-Medina L, de Villareal ESS, Izquierdo M. Concurrent endurance and strength training not to failure optimizes performance gains. Med Sci Sports Exerc 42(6): 1191-1199, 2010.
16. Jurimae T, Perez-Turpin JA, Cortell-Tormo JM, Chinchilla-Mi IJ, Cejuela-Anta R, Maestu J, Purge P, et al. Relationship between rowing ergometer performance and physiological responses to upper and lower body exercises in rowers. J Sci Med Sport 13: 434–437, 2010.
17. Kendall KL, Smith AE, Fukuda DH, Dwyer TR, Stout JR. Critical velocity: A predictor of 2000-m rowing ergometer performance in NCAA D1 female collegiate rowers. J Sports Sci 29(9): 945-950, 2011.
18. Klusiewicz A, Faff J. Indirect methods of estimating maximal oxygen uptake on the rowing ergometer, Biol Sport 20 (3): 181-194, 2003.
19. Laursen PB. Training for intense exercise performance: high-intensity or high training volume? Scand J Med Sci Sports 20: 1-10, 2010.
20. Maestu J, Jurimae J. Anthropometrical and physiological factors of rowing performance: A review. Acta Kinesiol Univ Tartuensis 5: 130-150, 2000.
21. Maestu J, Jurimae T, Jurimae M. Monitoring of performance and training in rowing. J Sports Med 35: 597-617, 2005.
22. Malina RM. Physical activity and training: effects on stature and the adolescent growth spurt. J Med Sci Sports Exerc 26: 759-766, 1994.

23. Martin DE, Coe PN. Training distance runners. Champaign, IL: Human Kinetics, 1991.
24. Mikuliae P. Anthropometric and physiological profiles of rowers of varying ages and ranks. Kinesiol 40(1): 80-88, 2008.
25. Mikulic P. Anthropometric and metabolic determinants of 6,000-m rowing ergometer performance in internationally competitive rowers. J Strength Cond Res 23(6): 1851-1857, 2009.
26. Nevill AM, Allen SV, Ingham SA. Modeling the determinants of 2000m rowing ergometer performance: a proportional, curvilinear allometric approach. Scand J Med Sci Sports 21: 73-78, 2011.
27. Reilly T, Secher N, Snell P, William, C. Physiology of Sports. Champion and Hall India, Madras, 1st Edition, 1990, p 427.
28. Secher NH. Rowing. In R.J. Shepherd and P.O. Astrand, (Eds.). Endurance in sport. Oxford: Blackwell Science, 2000.
29. Secher NH. The physiology of rowing. J Sports Sci 1: 23-53, 1983.
30. Shepherd RJ. Science and medicine of rowing: a review. J Sports Sci 16: 603-620, 1998.
31. Steinacker JM. Physiological aspects of training in rowing. FISA Coach 5: 3, 1994.
32. Weiner JS, Lourie JA. Human Biology: A Guide to Field Methods. 1BP No. 9, Blackwell, London, 1969.
33. Yoshiga C, Higuchi M. Bilateral leg extension power and fat-free mass in young oarsmen. J Sports Sci 21(11): 905-909, 2003.
34. Ziffren P. Olympic Record. Los Angeles Olympic Organizing Committee, Los Angeles, 1984.

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