

# A Glimpse into the Future of Rowing in Sri Lanka Through Cardiopulmonary Exercise Testing (CPET)

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## ABSTRACT

Rowing requires high physiological demand with metabolic contribution from both aerobic and anaerobic energy pathways. Hence  $\text{VO}_2 \text{ Max}$  measurement is the most important physiological factor affecting rowing performance. The purpose of this study was to evaluate the cardiopulmonary fitness states of National rowers, National youth rowers, and rowers from General Sir John Kotelawala Defence University (KDU), Sri Lanka who are at three different age categories and thereby to get a glimpse into the prospects of rowing in Sri Lanka. Twenty male and twenty-seven female rowers from the three groups were recruited and all the subjects performed incremental exercise tests on a Concept II rowing ergometer. All three groups achieved a heart rate of more than 90% of predicted. The best oxygen pulse ( $\text{VO}_2/\text{HR}$ ) was achieved by male youth rowers (15.52 L/min) followed by KDU rowers (14.53 L/min) and national rowers (11.48 L/min). Youth male rowers had the best delivery of oxygen which is 97.6% predicted. The highest average  $\text{VO}_2 \text{ Max}$  value obtained by male youth rowers was 43.84 ml/min/kg (87.5 % of the prediction of  $\text{VO}_2$ ). KDU male rowers achieved a  $\text{VO}_2 \text{ Max}$  of 40.33 ml/min/kg which is higher, than the national rowers with a  $\text{VO}_2 \text{ Max}$  of 36.23 ml/min/kg. The highest mean  $\text{VO}_2 \text{ Max}$  among females was 30.43 ml/min/kg (76% of the predicted) achieved by national rowers. Female KDU rowers achieved the lowest  $\text{VO}_2 \text{ Max}$  at 27.03 ml/min/kg (69% of the predicted) and female youth rowers achieved a  $\text{VO}_2 \text{ Max}$  value of 29.1 ml/min/kg. KDU male rowers had the lowest  $\text{VO}_2$  at anaerobic threshold (AT) indicating capacity to improve (27.34 ml/min/kg). The highest  $\text{VO}_2$  at AT among females, (21.65 ml/min/kg) was achieved by youth rowers. National female rowers also showed a  $\text{VO}_2$  AT of 21.02 ml/min/kg and The KDU female rowers achieved 19.49 ml/min/kg, indicating the need for improvement. Considering the age of national youth rowers and their respective  $\text{VO}_2 \text{ Max}$  and  $\text{VO}_2$  AT values, our finding suggests the national rowing federation of Sri Lanka should focus more on youth rowers to improve the future chances to bring international victories to Sri Lanka.

**Keywords:** Cardiopulmonary Exercise Testing, CPET, Rowing, Sri Lanka.

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## I. INTRODUCTION

Rowing is a physically demanding sport that requires a combination of physiological and physical characteristics for optimal performance. The sport of rowing involves a repetitive motion of the upper and lower extremities, requiring both muscular strength and endurance, as well as aerobic and anaerobic fitness. Physiological characteristics, such as maximal oxygen uptake ( $\text{VO}_2 \text{ Max}$ ) and lactate threshold is highly important for rowing performance (Volianitis *et al.*, 2009). High levels of aerobic fitness, as measured by  $\text{VO}_2 \text{ Max}$ , are strongly associated with high performance, as they allow rowers to maintain a high level of intensity over long periods of time. The lactate threshold, which is the point at which lactic acid begins to accumulate in the blood, is also a key predictor of success in rowing, as it allows rowers to maintain a high level of intensity without accumulating excessive levels of lactic acid (Hofmijster *et al.*, 2015). Overall, the relationship between physical and physiological characteristics and rowing performance is complex.

However, by studying the physiological fitness of rowers, coaches and athletes can develop more effective bespoke training programs to improve performance. Rowing is a famous sport in Sri Lanka, with a growing number of athletes and teams participating in local and international competitions and is recognized as a popular sport.

Rowing has been practiced in Sri Lanka since the early 20th century and has since become a national sport in the country. Despite this very little research is done on cardiopulmonary fitness among national-level rowers. To fill this gap in the literature, a study was done previously by the same research team of this study on cardiopulmonary fitness among national rowers in Sri Lanka using CPET and found the average  $\text{VO}_2 \text{ Max}$  to be 36.23 ml/min/kg for males and 30.43 ml/min/kg for females (Senanayake *et al.*, 2023). The demographic information from that study indicated that the average age of national rowers in Sri Lanka is 25yrs with some of the best rowers in their 30s, indicating that they are at the end of their peak age-related to performance.

With this background, it is important to investigate the fitness states of the 2<sup>nd</sup> and 3<sup>rd</sup> line of rowers who are at the national level (University level rowers and national youth rowers) to shed some light into the future trajectory of rowing Sri Lanka. With this background, the aim of this study is to investigate the cardiopulmonary fitness of National rowers, National youth rowers, and rowers from General Sir John Kotelawala Defence University, Sri Lanka.

## II. METHODOLOGY

### A. Inclusion and Exclusion Criteria

All players who volunteered to be part of the study from General Sir John Kotelawala Defence University, National Youth, and the National rowing team, were included in the study. Participants with upper or lower limb musculoskeletal, neurological, and other injuries within the last 2 weeks as confirmed by a diagnosis card, participants who have undergone any surgeries within the previous 6 months, or rowers under medical advice not to participate in vigorous or any other physical activity, players with known cardiorespiratory condition (Exercise-induced asthma, Asthmatic attacks) were excluded from the study. A total of 47 rowers (female n=20, male n=27) took part in the study (Table I). Ethical clearance to conduct the study was obtained by the ethical board of General Sir John Kotelawala Defence University.

### B. Data Collection Procedure

Before the CPET began, the researchers gathered anthropometrical data, including height, weight, and BMI, from all participants. They then conducted an incremental exercise test on a Concept II rowing ergometer, gradually increasing the resistance by 50 W/min until the participants could no longer continue. The participants were encouraged to exercise for as long as possible to get the most accurate measurement of their  $\text{VO}_2 \text{ Max}$ .

Throughout the test, participants were asked to breathe through a facemask that continuously sampled the inspired and expired air using a bidirectional pi tube flow sensor (BLT, Cardiopoint, USA). During the exercise heart rate (HR) was continuously monitored. Aerobic threshold (AT) was identified using a combination of the two methods used by Castro *et al.* (2010).

Firstly, using the point of upward inflexion of the  $\dot{V} \text{ CO}_2$  vs  $\text{VO}_2$  curve and secondly, using the onset of a consistent increase in ventilatory equivalent for oxygen ( $\text{Ve}/\dot{V} \text{ O}_2$ ) occurred with no increase in the ventilatory equivalent for carbon dioxide ( $\text{Ve}/\dot{V} \text{ CO}_2$ ) by an experienced exercise physiologist and a sports physician.

## III. RESULTS

The anthropometrical data obtained for both male and female rowers are given in Table I below. Total sample size was 47 with males (n=27) and females (n=20).

	KDU		National youth		National	
	Male (n= 12)	Female (n= 7)	Male (n = 5)	Female (n = 2)	Male (n=10)	Female (n=11)
Age	21.42 ± 1.08	21.57 ±1.40	15.4 ±1.52	14.5 ±0.71	25.2 ±5.77	24.36 ±3.83
Height	176.5 ±5.81	164 ±9.61	177.8 ±5.03	167.5 ±8.49	174.9 ±11.88	168 ±5.55
Weight	65.17 ±8.35	57.43 ±4.58	65.4 ±2.95	60 ±7.78	66.2 ±15.50	61.55 ±6.64
BMI	20.94 ±1.69	21.25 ±2.61	20.67 ±1.20	21.32 ±1.04	21.41 ±3.54	21.78 ±1.92

Mean physiological parameters at peak exercise and values of university-level rowers at the Anaerobic threshold (AT) are given in Table II below.

TABLE II: PHYSIOLOGICAL PARAMETERS OBTAINED FOR CPET

	Male			Female		
	Maximum	Achieved % of the predicted	Anaerobic threshold	Maximum	Achieved % of the predicted	Anaerobic threshold
VO <sub>2</sub> (ml/min)	2610.50 ±379.96	76.75 ±10.60	1755.42 ±1639.65	1526.86 ±214.91	69.43 ±9.07	1017 ±646.88
VO <sub>2</sub> (ml/min/kg)	40.33 ±6.75	76.75 ±10.60	27.34 ±1639.65	27.03 ±4.33	69.43 ±9.07	19.49 ±5.98
VO <sub>2</sub> / HR (l/min)	14.53 ±2.02	84.50 ±9.49	12.06 ±3.47	12.79 ±7.61	113.57 ±63.01	7.04 ±0.98
VCO <sub>2</sub> (ml/min/kg)	2075.92 ±318.91	47.00 ±7.42	1278.33 ±535.08	1156.43 ±505.10	45.57 ±6.37	822.71 ±182.07
VE (l/min)	124.52 ±10.97	79.50 ±6.92	1278.33 ±29.15	78.66 ±8.36	67.14 ±7.03	42.84 ±14.28
HR (Beats/min)	187.92 ±10.00	93.75 ±5.75	146.33 ±39.34	190 ±6.76	95.86 ±3.67	151.71 ±27.71
RER	0.85 ±0.13	NA	0.74 ±0.09	0.87 ±0.03	NA	0.76 ±0.06

Mean physiological parameters at peak exercise and values of National level youth rowers at the Anaerobic threshold (AT) are given in Table III below.

TABLE III: PHYSIOLOGICAL PARAMETERS OBTAINED FOR CPET

	Male			Female		
	Maximum	Achieved % of the predicted	Anaerobic threshold	Maximum	Achieved % of the predicted	Anaerobic threshold
VO <sub>2</sub> (ml/min)	2863.6 ±277.92	87.4 ±6.99	2202.6 ±585.99	1729.5 ±10.61	80 ±4.24	914 ±144.25
VO <sub>2</sub> (ml/min/kg)	43.84 ±3.21	87.4 ±6.99	35.22 ±6.77	29.1 ±3.96	80 ±4.24	21.65 ±3.75
VO <sub>2</sub> / HR (l/min)	15.52 ±1.74	97.6 ±7.13	13.62 ±2.94	9.25 ±0.07	88.5 ±6.36	42.55 ±48.72
VCO <sub>2</sub> (ml/min/kg)	2251.8 ±219.44	53.2 ±4.27	1608.4 ±481.78	1417.5 ±129.4	51 ±7.07	917 ±144.25
VE (l/min)	141.74 ±19.10	130 ±17.51	89.9 ±38.72	94.7 ±1.56	100 ±9.90	51.45 ±0.64
HR (Beats/min)	195.8 ±195.8	95.8 ±9.86	170.8 ±4.82	191 ±1.41	93 0	163.5 ±10.61
RER	0.95 ±0.12	NA	0.69 ±0.08	0.86 ±0.04	NA	0.72 ±0.09

Mean physiological parameters at peak exercise and values of National level rowers at the Anaerobic threshold (AT) are given in Table IV below.

TABLE IV: PHYSIOLOGICAL PARAMETERS OBTAINED FOR CPET

	Male			Female		
	Maximum	Achieved % of the predicted	Anaerobic threshold	Maximum	Achieved % of the predicted	Anaerobic threshold
VO <sub>2</sub> (ml/min)	2226.3 ± 648.62	76.70 ± 13.45	1528.40 ± 574.87	1902 ± 550	87.55 ± 25.10	1312.55 ± 539.69
VO <sub>2</sub> (ml/min/kg)	36.23 ± 13.10	76.70 ± 13.45	31.22 ± 9.13	30.43 ± 8.73	87.55 ± 25.10	21.02 ± 7.68
VO <sub>2</sub> / HR (l/min)	11.48 ± 3.74	85.00 ± 13.17	12.45 ± 3.31	10.55 ± 2.81	95.45 ± 27.77	9.05 ± 2.72
VCO <sub>2</sub> (ml/min/kg)	2179.60 ± 582.88	61.27 ± 19.74	1578.7 ± 576.28	1696.2 ± 521.73	53.50 ± 19.74	1042.3 ± 466.81
VE (l/min)	127.1 ± 21.88	85.70 ± 12.28	80.23 ± 27.52	98.28 ± 28.44	81.36 ± 19.29	54.24 ± 26.85
HR (Beats/min)	187.50 ± 9.77	96.30 ± 3.29	163.30 ± 26.18	185.91 ± 6.76	95.09 ± 3.40	150.64 ± 22.55
RER	0.96 ± 0.19	NA	0.78 ± 0.10	0.84 ± 0.28	NA	0.78 ± 0.10

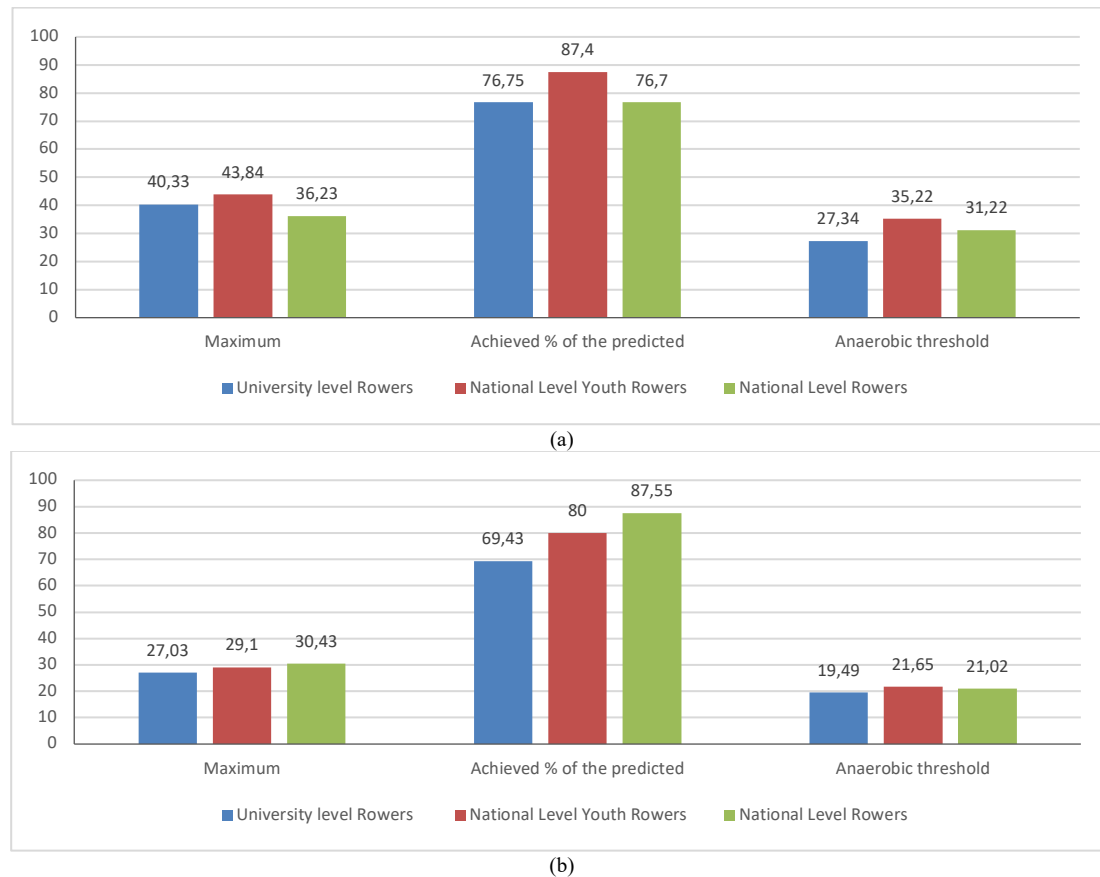


Fig. 1.  $\text{VO}_2$  (ml/min/kg) of university level, national level youth and national level rowers: a) Male; b) Female.

A One-way ANOVA test was conducted to compare the maximum  $\text{VO}_2$  in KDU, National youth and National rowing team. The test revealed that there was not a statistically significant difference in maximum  $\text{VO}_2$  between groups ( $p > 0.05$ ). [maximum  $\text{VO}_2$  - male:  $p$ -value = 0.5904,  $F$ -value=0.5382; Female:  $p$ -value = 0.3772,  $F$ -value=1.0331]. Similarly,  $\text{VO}_2$  at AT in three groups was not significantly different. ( $p > 0.05$ ) [ $\text{VO}_2$  at AT -Male:  $p$ -value = 0.1690,  $F$ -value=1.9291, Female:  $p$ -value = 0.4465,  $F$ -value=0.6481].

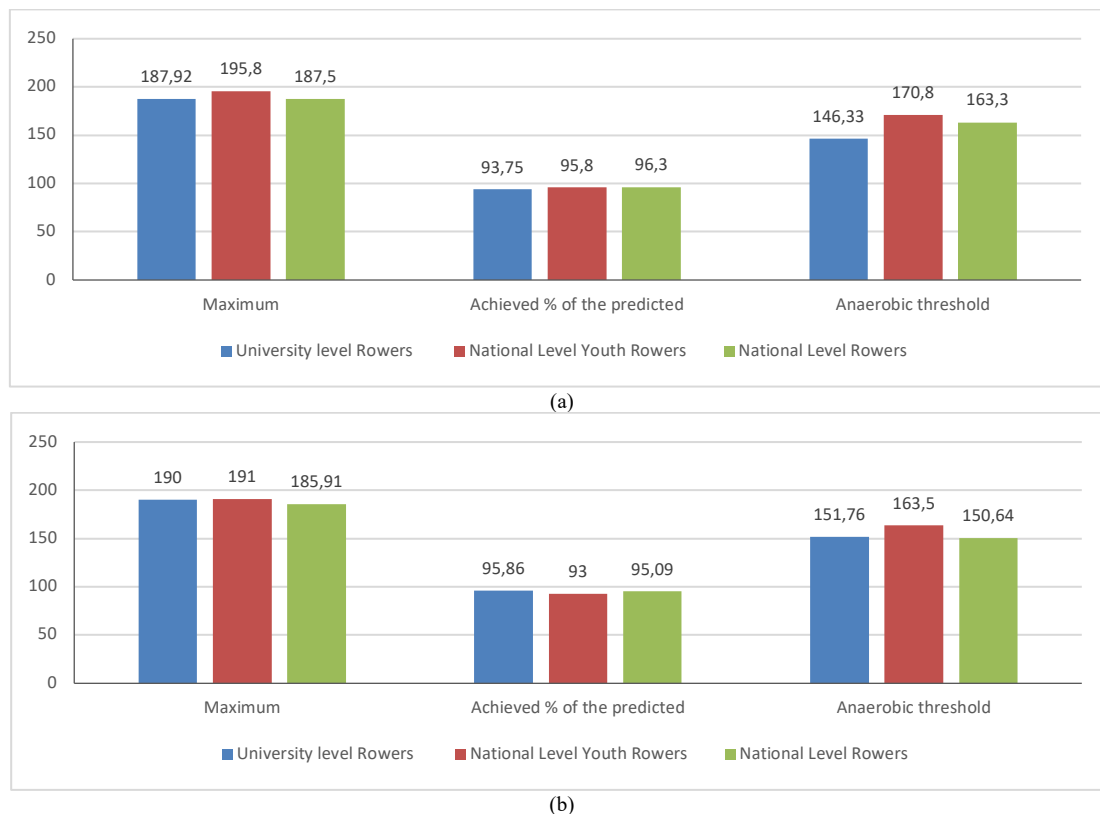


Fig. 2. Heart rate (Beats/min) of university level, national level youth and national level rowers: a) Male; b) Female.

One way ANOVA test revealed that there was not a statistically significant difference in maximum heart rate in t three groups( $p>0.05$ ). [ Male;  $p$ -value = 0.2672,  $F$ -value=1.3918, Female;  $p$ -value = 0.3599,  $F$ -value=1.0806]. Similarly, we found that the heart rate at AT in the three groups was not statistically significantly different( $p>0.05$ ) [Male;  $p$ -value = 0.4722,  $F$ -value=0.7742 /female;  $p$ -value=0.3221,  $f$ -value=1.2170].

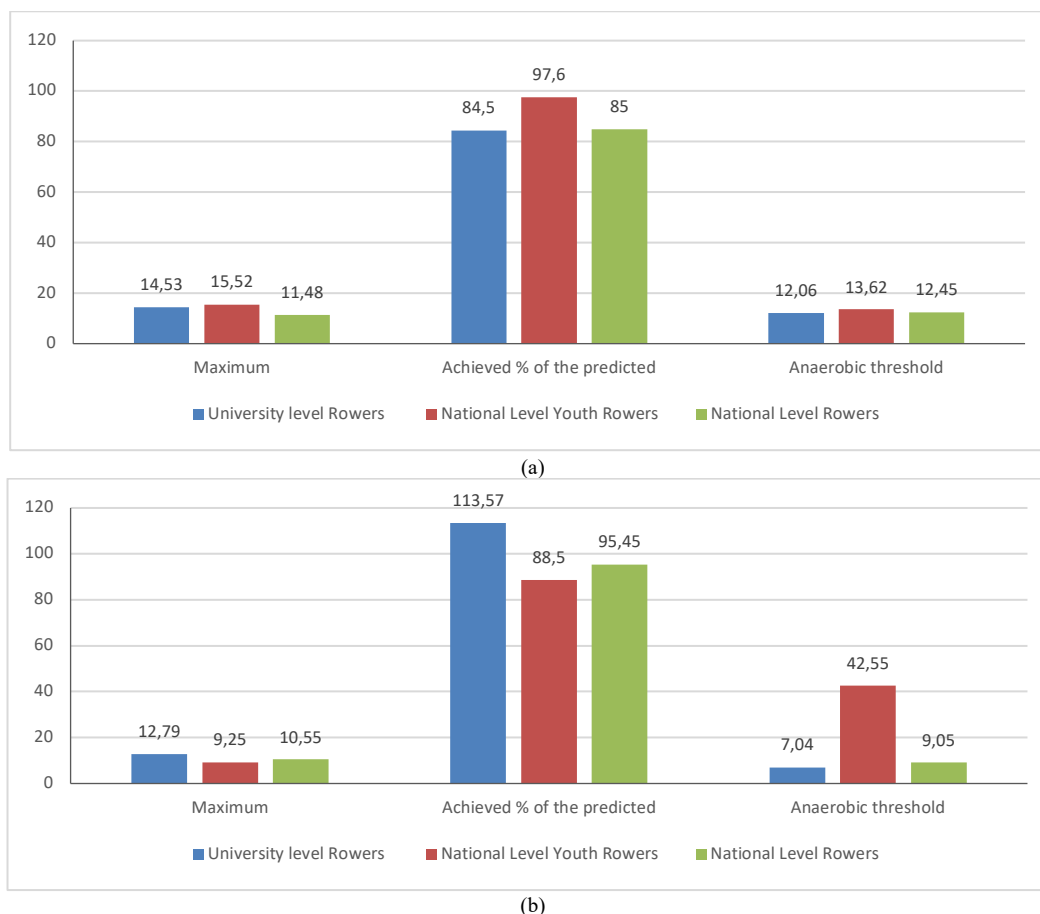


Fig. 3.  $VO_2/HR$  (L/min) of university level, national level youth and national level rowers: a) Male; b) Female.

A one-way ANOVA test revealed that there was not a statistically significant difference in mean values of maximum  $VO_2/HR$  in the three groups( $p>0.05$ ) [ $VO_2/HR$ - Male;  $p$ -value = 0.6007,  $F$ -value=0.5202, Female;  $p$ -value = 0.0881,  $F$ -value=2.8683].

#### IV. DISCUSSION

The purpose of the study was to assess the cardiovascular fitness among Sri Lankan national rowers, national youth rowers, and rowers from General Sir John Kotelawala Defence University who are at three age categories to get a glimpse into the future of rowing in Sri Lanka.

All three groups achieved a heart rate of more than 90% of the predicted (Fig. 2). This maximum effort during the test indicates good reliability and quality of the collected data.  $VO_2/HR$  is the oxygen pulse or the delivery of oxygen to muscle tissues, which was best among male youth rowers (15.52 L/min) followed by KDU rowers (14.53 L/min) and national rowers (11.48 L/min). Youth male rowers have the best delivery of oxygen which is 97.6% of predicted indicating better delivery of oxygen to working muscle leading to better fitness compared to KDU rowers whose oxygen pulse was only 84.5% of the predicted indicating a large room for improvement. Mean BMI values of the three different groups were not significantly different.

Numerous studies have shown that age affects the  $VO_{2\text{ Max}}$  of athletes (Messonnier *et al.*, 1998), (Legaz Arrese *et al.*, 2005), Lacour *et al.* (2009), Murase *et al.* (1981), Ingjer (1992). In the present study, national youth, KDU, and National rowers belong to three different age categories. The mean age of national youth rowers was 15 years, KDU rowers were 21 years, and national rowers were 25 and higher, making them more than 10 years older than the youth rowers (Table I). Croatian quadruple school rowers showed the greatest improvement in  $VO_{2\text{ Max}}$  at the age of 19.2-20.2 years. According to Messonnier *et al.* (1998) top rowers'  $VO_{2\text{ Max}}$  peaked at the age of 23 and subsequently gradually grew until the age of 28 years. The rower's  $VO_{2\text{ Max}}$  and lactate threshold were taken into consideration.  $VO_{2\text{ Max}}$  has been considered the main physiological criterion for evaluating cardio-pulmonary fitness and potential for success in endurance sports

(Hue *et al.*, 2000; Klusiewicz *et al.*, 1999; Legaz-Arrese *et al.*, 2007) A study conducted by Klusiewicz *et al.*, 2014 on Polish rowers of different ages shows that the peak oxygen uptake was significantly lower in male rowers who are older than 19 years with a  $\text{VO}_2 \text{ Max}$  value of 64.1 ml/min/kg for males and 49.1 ml/min/kg for females.

Rowing has a high physiological demand with a metabolic contribution of aerobic (70.8-88%) and anaerobic (12-30%) energy pathways (Pripstein *et al.*, 1999) (Ingham *et al.*, 2002). Due to the important involvement of the aerobic system, direct  $\text{VO}_2 \text{ max}$  measurement was found to be significantly correlated with actual rowing performance (Ingham *et al.*, 2007). Also, it is the most important physiological factor affecting rowing performance. (Nevill *et al.*, 2011) (Secher *et al.*, 1983). High-performing international rowers have shown a peak  $\text{VO}_2$  value of 60 ml/min/kg for males and 53 ml/min/kg for females (Klusiewicz *et al.*, 2014). In our study, although statistically not significant the highest average  $\text{VO}_2 \text{ Max}$  value was obtained by male youth rowers which was 43.84 ml/min/kg (87.5 % of the prediction of  $\text{VO}_2$ ). KDU male rowers achieved a  $\text{VO}_2 \text{ Max}$  of 40.33 ml/min/kg which is the higher, than the national rowers with a  $\text{VO}_2 \text{ Max}$  of 36.23 ml/min/kg. The low  $\text{VO}_2 \text{ Max}$  value obtained by national rowers could be due to their higher age despite their experience (Fig. 1a). The highest mean  $\text{VO}_2 \text{ Max}$  among females was 30.43 ml/min/kg (76% of the predicted) which was achieved by national rowers. Female KDU rowers achieved the lowest  $\text{VO}_2 \text{ Max}$  at 27.03 ml/min/kg (69% of the predicted) and female youth rowers achieved a  $\text{VO}_2 \text{ Max}$  value of 29.1 ml/min/kg. (Fig. 1b).

A high  $\text{VO}_2$  at anaerobic threshold (AT) indicates the ability to exercise at a higher intensity without the exponential buildup of lactic acid allowing the rower to compete for a longer duration with higher intensity.  $\text{VO}_2 \text{ AT}$  was highest among male youth rowers (35.22 ml/min/kg) indicating higher fitness due to high oxygen consumption at AT. National male rowers (31.22 ml/min/kg) are also in a similarly good state due to their good overall fitness. KDU male rowers have the lowest  $\text{VO}_2$  at AT indicating capacity to improve (27.34 ml/min/kg). (Fig. 1a). Following the same pattern with male rowers the highest  $\text{VO}_2$  at AT among females, (21.65 ml/min/kg) was achieved by youth rowers. National female rowers also showed a  $\text{VO}_2 \text{ AT}$  of 21.02 ml/min/kg. The KDU female rowers  $\text{VO}_2 \text{ AT}$  was 19.49 ml/min/kg, indicating the need for improvement (Fig. 1b).

## V. CONCLUSION

The highest average  $\text{VO}_2 \text{ Max}$  among males was observed in national youth rowers followed by university rowers and national rowers of Sri Lanka. This higher  $\text{VO}_2 \text{ Max}$  among national youth rowers is reflected by their present age of prediction they achieved for  $\text{VO}_2 \text{ Max}$  (87%). University and national level male rowers archived 76.75% and 76.67% of predicted  $\text{VO}_2 \text{ Max}$  value respectively. Indicating room for improvement. Highest  $\text{VO}_2 \text{ Max}$  for females was achieved by national level rowers followed by national youth and university level rowers. Considering the age of national youth rowers and their respective  $\text{VO}_2 \text{ Max}$  and  $\text{VO}_2 \text{ AT}$  values, our finding suggests the national rowing federation of Sri Lanka should focus more on youth rowers to improve the chances of achieving international victories for Sri Lanka.

## CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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