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COMPARISON OF TRAINING LOADS AND PHYSIOLOGICAL RESPONSES IN ATHLETES: CONSIDERATION OF BODY WEIGHT IMPLICATIONS

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ABSTRACT

COMPARISON OF TRAINING LOADS AND PHYSIOLOGICAL RESPONSES IN ATHLETES: CONSIDERATION OF BODY WEIGHT IMPLICATIONS. **Venkata Ramana Y, Surya Kumari Mvl, Sudhakar Rao S, Balakrishna N**. **JEP**online 2004;7(3):134-139. In order to assess the influence of body weight on training load, and in turn its relationship to physiological responses, twelve national level male athletes were subjected to two types of ergometry (Treadmill and Bicycle Ergometer). Anthropometry and body composition variables were measured at rest, and physiological variables were measured during and in recovery from graded exercise tests (GXT). The quantification of training load was done by the time-allocation pattern (TAP), combined with heart rate and oxygen consumption. Results indicated that there was a 1.3 fold of higher work rate with increased oxygen consumption and heart rate, and slower rate of recovery from treadmill exercise compared to cycle ergometry. Moreover, it was also observed that subjects with higher body weight were receiving higher workloads on the treadmill than their lean counterpart. Similar results were observed in the training schedules through TAP, where the athletes with lower body weight were receiving 23% lower training load resulting in lowered physiological and work intensities as compared to their heavier counterparts, despite undergoing the same training protocol. Therefore, this study clearly suggests that consideration of body weight component in the formulation of training program is essential to achieve optimal sports performance.

Key Words: Ergometry, Running, VO_2max, Work Rate.

INTRODUCTION

A multi-stage exercise test on treadmill or bicycle ergometer will provide a measurement of the rate of work an individual is able to tolerate without symptoms of fatigue and ECG abnormalities (1). The work rate is dependent on the subject's body weight in treadmill exercise (TE) and independent on cycle ergometry (CE). The energy output per kilogram and km/hr is more variable in TE as it changes with the speed of walking and running, than it is at a given work load during CE. The energy output on the bicycle ergometer is independent of body weight. Therefore, usage of both treadmill and bicycle ergometer is essential to study the influence of body weight on energy output and work performance (2). Every type of exercises a unique situation. However, all forms of muscular activity increases metabolic rate, therefore, it is of interest to be able to analyze oxygen consumption, transporting systems and other related physiological changes (3,4). It is evident that the variations in physiological demands are caused by the workload intensities.

As it is known that in most training situations, athletes of the same event and age are receiving similar type of training schedules, especially in the Indian context. This leads to variation in training load received by the athletes, because the athletes with higher body weights receive higher workload than athletes with lower body weights, as their body weight adds to the training workload. Therefore, for a given training workout, the load received by the athletes with lower body weight may not be sufficient to meet the physiological demands of the competition.

The purpose of this study was to assess the maximal work performance of athletes with and without the influence of body weight and corresponding physiological variations by testing them on treadmill and bicycle ergometer separately. Such studies would help to understand how far body weight causes additional demand on energy expenditure and other physiological mechanisms. It also indicates the variations in quantum of load received by the athletes with different body weights. This would help coaches to modify training intensity and duration to give optimal load to every athlete.

METHODS

This study was conducted on all the available (n=12) national level healthy male long distance runners from Sports Authority of Andhra Pradesh who were aged between 18 and 22 years. The Anthropometric measurements such as height nearest to 0.1 cm (Anthropometric Rod, SECA, Germany), weight with minimum clothing, nearest to 0.1 kg (SECA balance) and BMI were recorded using standard procedures. The body composition was assessed from skin-fold thickness taken at four sites, namely, biceps, triceps, sub-scapular and supra-iliac regions using Holtain Calipers (Holtain Co., UK) with ±0.2 mm accuracy. The fat-free mass (FFM) and fat mass were derived from the sum of the skin-fold thickness using age and sex matched equations of Durnin and Womersley (1974)(5). The basal metabolic rate (BMR), energy cost of different loads of ergometry (Treadmill and Bicycle Ergometer) along with recovery phases was measured by open-circuit indirect calorimetry using Douglas bag method (6). The minute ventilation (VE) was measured by dry gas meter (Morgan, UK), expired oxygen (FEO_2) was analyzed by a paramagnetic oxygen analyzer (Taylor Servomex, model 720, USA), while the expired carbon dioxide ($FECO_2$) was analyzed by an infrared analyzer (Beckman Medical Gas Analyzer LB-2 model, USA). Heart rate (HR) was measured by using online heart rate monitor (PE-3000, Finland) during field activities.

The standard continuous graded exercise test (GXT) protocol was given on treadmill (Venky, India) and bicycle ergometer (Venky, India) separately with a gap of 10 days to evaluate their maximal work performance. During cycling on bicycle ergometer an increment of 50 watts was given up to 150 watts, followed by 25 watts increment for the rest of the protocol, while Bruce Protocol was given to each subject on the treadmill (7). In both tests the protocol was continued till the subject expressed his inability to continue further or attainment of the predicted maximal heart rate, whichever was earlier. During these test protocols three minutes acclimatization was followed by one minute's collection of expired air at each load to measure physiological variables such as minute ventilation, oxygen consumption, carbon dioxide production, and the respiratory exchange ratio (RER). Online heart rates were recorded using PE-3000 heart rate monitor during these tests. After termination of the test protocol, the recovery phase was continued for 20 minutes. The energy cost and work rate of the field activities were estimated from both actual measurement (8,9) using the KM meter (Max Planck Institute, Germany) and heart rate monitoring methods using PE-3000. The measurement of energy cost and work rate of the training activities were derived from the regression lines developed individually using heart rate - oxygen consumption combined with heart rate – work rate relationships (10,11) using dual exercise protocol (DXT) (treadmill for ambulatory activities and bicycle ergometer for non-ambulatory activities, Figure 1). The subjects were divided into three groups based on their body weights as 60 kgs above (group-1), 55-59 kgs (group-2) and 50-54 kgs (group-3) to test the influence of body weight on training load / training intensity.

Statistical Analyses

The data was analyzed using SPSS 10.0 version statistical package. The values were expressed in terms of mean±SD. For comparison of two types of ergometry tests (treadmill vs. bicycle ergometer) paired t-test was used and the significance levels were noted.

RESULTS

The mean anthropometric and body composition profiles such as age, height, weight, BMI, BSA, WHR, FFM, % body fat and hemoglobin values are given in Table 1. The current nutritional status of these athletes based on the BMI had revealed that they were normally nourished. Assessment of body composition showed that the fat percentage of these athletes was found to be well within the normal range.

Table 1: Anthropometry and Body Composition Profile (n=12)

Age (Yrs)	*Height (cm)*	*Weight (kg)*	*BMI (kg/m^2)*	*BSA (m^2)*	*WHR*	*FFM (kg)*	*FAT (%)*	*Hb (g/dL)*
20.2 ±2.01	172.0±5.48	58.0±5.44	19.4±1.65	1.68 ±0.09	0.8±0.02	51.5±4.73	10.3±2.89	14.8±0.63

Values are means ± S.D

The 24-hour basal metabolic rate (BMR) was found to be 1393±101.0 Kcal; when this was expressed in terms of unit body weight and unit FFM, the values were 23.9±1.96 Kcal and 27.1±1.59Kcal respectively (Table 2).

Table 2: Basal Metabolic Rates of the Athletes (n=12)

Kcal/min	*MV$_E$ (L/min)*	*HR (beats/min)*	*RER*	*Kcal/day*	*Kcal/kg Body wt*	*Kcal/kg FFM*	*Kcal/ m^2/hr*
0.968 ± 0.07	4.7 ± 0.76	57 ± 4.2	0.92 ± 0.07	1393 ± 101.0	23.9 ± 1.96	27.1 ± 1.59	34.1 ± 1.95

Values are means ± S.D.

The athletes could receive a significantly ($p<0.001$) higher workload (1.3 fold) on treadmill than on bicycle ergometer (1977 V 1530 kpm/min). This might be due to the fact that their own body weight was added on during work performance on the treadmill. The higher maximal work performance in turn resulted in significantly higher oxygen consumption (16.9%), also 8% increase in ventilation (67 vs. 62 L/min), 6.8% increase in heart rates (188 vs. 176 beats/min) and 13% higher oxygen pulse. The maximum oxygen consumption when expressed in terms of unit body weight and FFM, significantly higher values were found ($p<0.001$) on treadmill than on the bicycle ergometer (Table 3).

Table 3. Physiological Profile during Maximal Work Performance. (n=12)

Variable	*TM*	*BE*
VO_2 (mL/min)	3005.4 ± 453.1***	2570.8 ± 274.2
Kcal/min	15.5 ± 2.27***	12.9 ± 1.4
VE (L/min)	67.7** ± 13.07**	62.7 ± 11.1
HR (beats/min)	188 ± 13.3**	176 ± 0.05
RER	1.02 ± 0.07**	1.09 ± 0.05
O_2 Pulse (mL/beat)	16.5 ± 2.5***	14.6 ± 1.7
Power (kpm/min)	1977 ± 194.2***	1530 ± 30.6
VO_2 (mL/kg/min)	53.8 ± 4.5***	44.5 ± 4.6
VO_2 (mL/kg FFM/min)	60.2 ± 5.6***	49.9 ± 4.4

TM=Treadmill, CE=Bicycle Ergometer.Values are means ± S.D.
*** $p<0.001$; **$p<0.01$

Table 4. Quantification of Training Intensity (n=12)

Group	*n*	*Body Weight (Kg)*	*Duration (min)*	*Work Load (kpm/min)*
1	4	63.9 ± 4.18	95 ±10.01	931 ± 19.98
2	4	57.8 ± 1.21	95 ±4.04	831 ± 47.57
3	4	51.8 ± 1.69	95 ±3.79	722 ± 89.31
Significance Levels		***1,3 & 1,2 **2,3	NS	***1,2 & 1,3 **2,3

Values are means ± S.D; *** $p<0.001$; **$p<0.01$; NS=Not significant.

It is clearly evident from the slopes (Figure 1) that there a considerable difference existed between the values obtained for oxygen consumption and work rate when plotted against corresponding heart rates on treadmill and bicycle ergometry, especially beyond sub-maximal intensites. Therefore, it is suggested that selection of a particular type of ergometry depending on the type of training activity (treadmill for ambulatory activities and/or bicycle ergometer for non-ambulatory activities) is essential in deriving either oxygen consumption or intensity of work rate for precise estimates.

The quantification of the training program showed a significant variation in training loads in terms of workload received by the athletes during a similar training protocol, when they were categorized into 3 groups based on their body weights (Table 4).

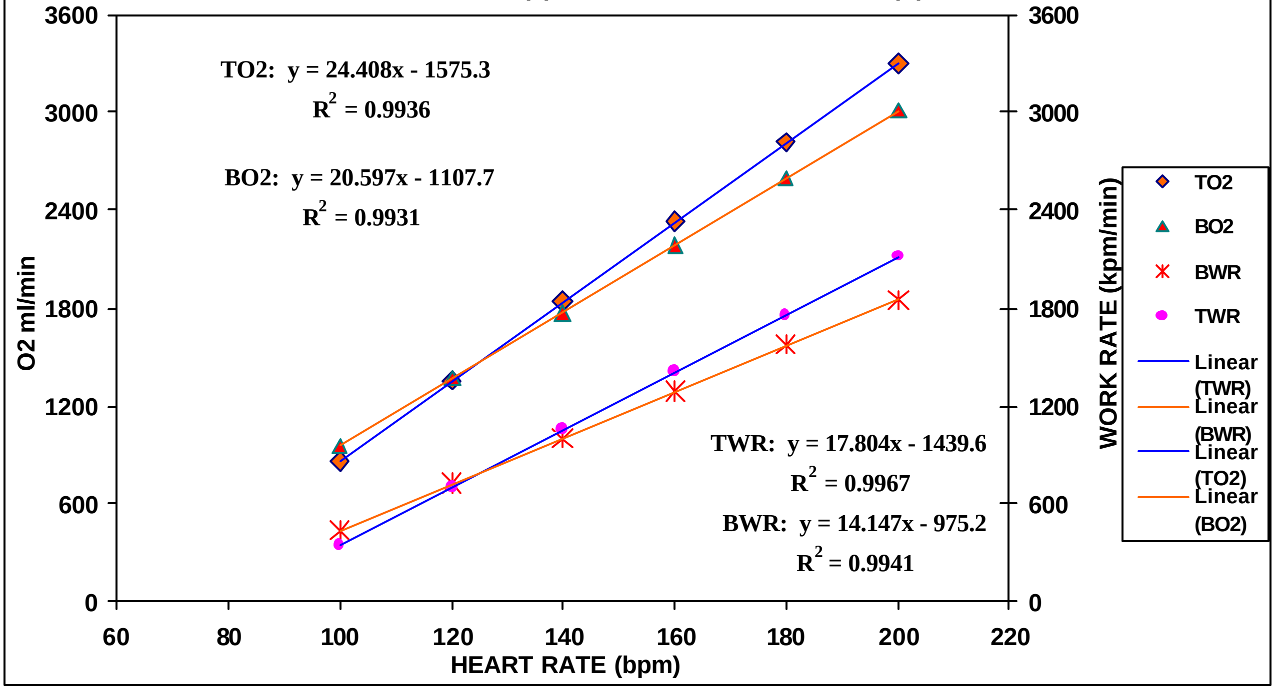

Figure.1: OXYGEN CONSUMPTION (O2) - HEART RATE (HR) - WORK RATE (WR) RELATIONSHIPS ON TREADMILL (T) AND BICYCLE ERGOMETER (B)

DISCUSSION

It is generally accepted that variations in oxygen consumption and physiological variables during different forms of exercise reflect differences in the body mass and muscle mass activated (12,13,14). The experiments carried out by Bobbort (15) and Kasch et al (16) made physiological comparisons on the same subjects during different forms of exercise, and found that greater oxygen consumption was obtained with treadmill experiments and bench stepping than those obtained on the bicycle ergometer.

McArdle, et.al (17) compared the VO_2max of the subjects by giving continuous and discontinuous protocols on bicycle ergometer and treadmill and observed that VO_2max during cycling is 6.4 to 11.2% lower than the treadmill values. The results of the present study also showed a higher oxygen consumption (16.9%) and work output (1.3 folds) on treadmill than on the bicycle ergometer, as the subject's body weight influences the work rate. This was in tune with our earlier observations (18,19) and those of Strandell (20).
The observation of time allocation pattern during training indicates that most of the athletes of the same event are receiving similar workout schedules irrespective of body weights and that persons with higher body weight range (above 60 kg) were receiving higher work rate (23 %) than the persons with lower body weight range (50-55 kg) for a given training schedule. Therefore, the training intensity received by the athletes with lower body weight may not be sufficient to meet the physiological demands of competition.

Thus, the usage of dual exercise test (DXT) would definitely help the coaches, researchers and sports nutritionists to identify scientifically, the influence of body weight on the quantum of workload and in turn associated physiological responses and energy needs. Otherwise the load received by the athletes with lower body weight would have lower VO_2max, cardiovascular and cardio-respiratory response that probably leads to no considerable improvement in performance even though they receive training regularly. Apart from this, dual exercise test would also provide the information regarding energy output of the training load and form an important baseline for the formulation of sound program of diet especially the energy allowances, since diet plays a major role in achieving desirable body weight, composition and optimal performance.

CONCLUSIONS

This study suggests that body weight greatly influences maximal work performance, as is evident from the close correlation between body weight and maximal work performance (a person with higher body weight receives higher intensity of work load than his low body weight counterpart would) when subjected to a given exercise intensity. The additional workload caused by higher body weight in turn increases the demand of cardiovascular and respiratory systems. As a result, oxygen consumption levels, minute ventilation and oxygen pulse were significantly increased. It was observed that athletes were undergoing training in similar types of training schedules during their practice sessions. Thus, it can be implied based on this study that athletes with lower body weight were receiving lower work load/training intensity, resulting in attainment of lower physiological and work efficiencies. Therefore, based on the results of this study, it can be concluded that the identification of variations in amount of work load received based on body weight helps coaches and researchers to formulate individualized training program and to suggest suitable energy needs to achieve desirable body weight, composition and higher levels of work performance during competitions.

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