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PROTOTYPE WHOLE BODY EXERCISE DEVICE MAY BE USEFUL FOR ANAEROBIC EXERCISE TRAINING

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ABSTRACT

The purpose of this study was to document the metabolic effects of exercising on a novel, whole body exercise device (Fish and Kangaroo machine). Metabolic outcomes were broken down into aerobic (oxygen consumption and heart rate) and anaerobic (blood lactate) effects. The Fish and Kangaroo machine allowed for simultaneous arm and leg motion while the subject was lying in a prone position. Variable resistance to motion was controlled by a spring system, which applied 20 pounds of resistance to each arm and 50 pounds of resistance to each leg. For this study we recruited healthy, physically active adults (men=4, women=6) to perform 6 exercise/rest intervals over a period of 42-min (Interval = 1-min of exercise and 4-min of passive recovery). Oxygen consumption (VO_2), ventilation (VE) and energy expenditure (EE) were measured via automated analysis of expired respiratory gas (ParvoMedics). Heart rate (HR) was measured by telemetry (Polar). Blood lactate was measured using a hand held meter (Lactate Plus). With the exception of lactate all other measures were made continuously. An ANOVA with repeated measures was used to test outcome variables and a $P<0.05$. Compared to the peak response of the first exercise interval there was a progress rise in VO_2 (13%; $P<0.0001$), VE (17%; $P<0.0001$), EE (20%; $P<0.001$), HR (13%; $P<0.0001$), and blood lactate (50%; $P<0.0001$) over the course of the exercise intervals. With the exception of HR and blood lactate all of other variables returned to pre-exercise values within 4-min of the end of the last exercise interval. The peak lactate of 10.69±0.72 mmol/L remained elevated at 10-min post exercise, while HR remained elevated by 20% at 10-min post exercise. Further evaluation of these findings demonstrates the current design of the Fish and Kangaroo Machine elicits an exercise response that is primarily anaerobic in nature.

Keywords: Anaerobic Exercise; Whole Body Exercise

INTRODUCTION

Biochemical production of ATP is required to sustain physical exercise at a given intensity. The biochemical pathway responsible for ATP is dictated by the exercise intensity. Short duration, high-intensity exercise tends to favor anaerobic (i.e. ATP-PC, myokinase, and glycolysis), while long-duration, low-intensity exercise tends to favor aerobic (oxidative metabolism of glucose and fatty acids) (1). While the metabolic profiles of cycling, running, and swimming are well defined, there are new, novel exercise devices that may provide additional benefit to standard exercise modes. Beyond applications to the general population, some of these exercise devices like the one in the present study may have applications for spaceflight or other specialized populations due to their compact design.

The present focused on the testing an evaluation of a prototype whole body exercise device design to be used for anaerobic exercise training. One novel aspect of the tested device was that its horizontal positioning requires the subject to have considerable core muscle strength in order to exercise. Also, based on preliminary testing in our laboratory, exercise on this device as it is currently configured is primarily anaerobic in nature, thus the exercise protocol we describe below was designed to include short bursts of activity, followed by recover periods. The results presented in this study resulted form R&D testing that was completed on a prototype exercise device. The purpose of the present study was to evaluate and describe the metabolic effects associated with exercising a novel, whole body exercise device (Fish and Kangaroo Machine).

METHODS

Subjects. All protocols and procedures described in this report, were reviewed and approved by the University of Houston committee for the protection of human subjects, where the human subjects testing was completed. Prior to participating in the study, subjects gave verbal and written informed consent. Ten subjects (4 male, 6 female) were recruited using print and electronic advertisement. Subjects completed a brief medical history form and physical activity readiness questionnaire (PAR-Q). These two surveys were used to assess exclusion criteria. In order to participate in the study a subject had to have a normal BMI (20-25) and have a regular pattern of physical activity (3-5 days per week over the previous 6-months). Subject characteristics are reported in Table 1, stratified by gender.

After a subject was approved for participating in the study, they completed a familiarization protocol on the Fish and Kangaroo Machine (FKM) (Figure 1). The familiarization protocol was designed to orient the subject with the pattern of motion that would be required for their subsequent exercise protocol, which was completed on a separate day.

Table 1: Subject Characteristics Stratified by Gender

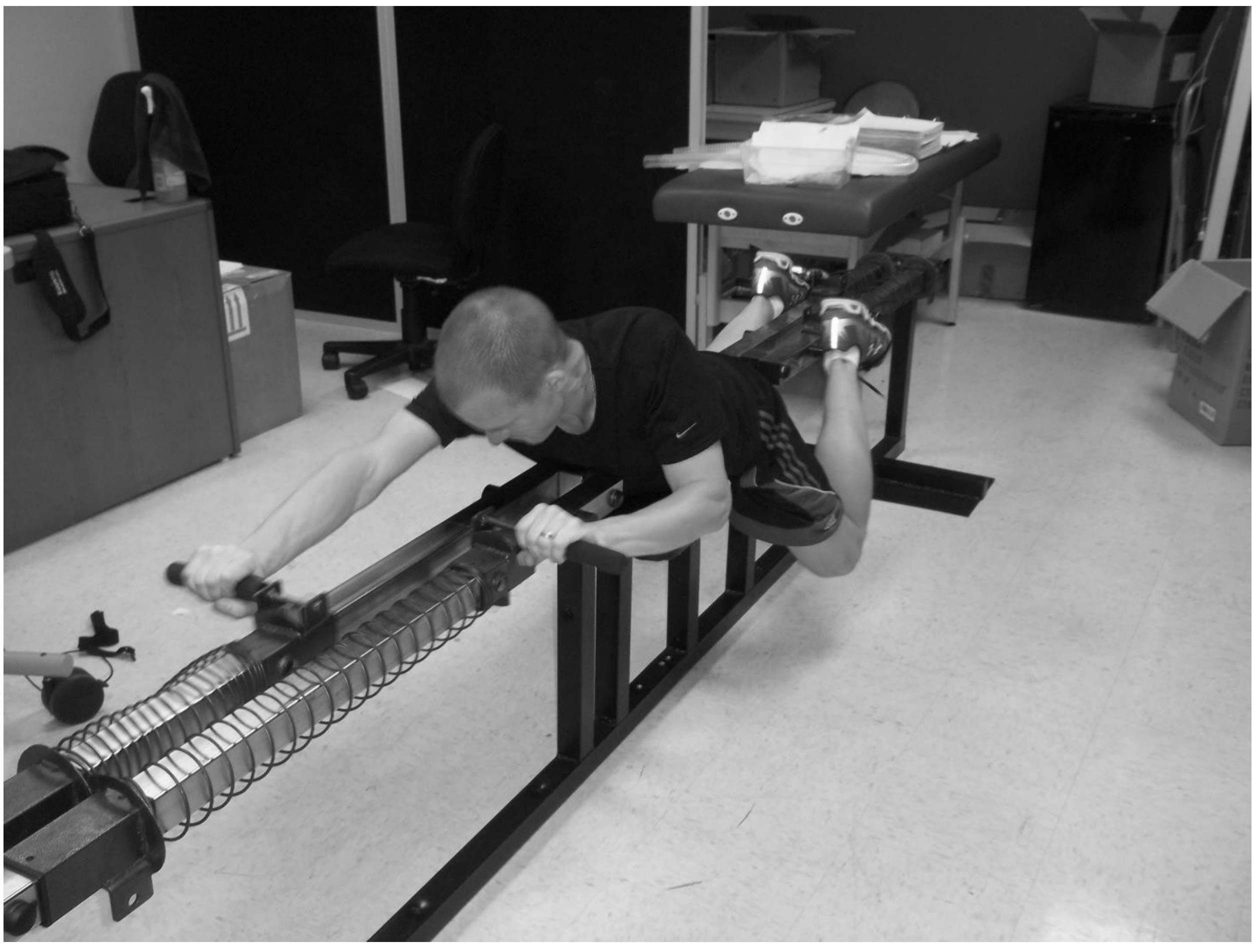
Characteristic	Women (N=6)	Men (N=4)
Age (y)	25 ± 2	24 ± 2
Height (cm)	165.3 ± 6.4	179.0 ± 1.2
Weight (kg)	68.7 ± 10.7	85.0 ± 3.4
BMI (kg/m^2)	22 ± 2.9	23.5 ± 1

Values represent the mean ± SD

Fish and Kangaroo Machine (FKM)

The FKM tested in the present study was a beta prototype device (Fish and Kangaroo Company; http://fishandkangaroo.com). The original concept for the device was that it was developed for a mixed martial arts (MMA) athlete to train for an upcoming event. While similar to a horizontal rower, the device is unique in the sense that it requires significant core strength, as the trunk is unsupported during exercise. The alpha prototype used weight plates to apply resistance; however, the manufacture found inconsistent application of resistance. Thus, the beta unit was modified to use a system of calibrated metal springs to apply the resistance. As designed the springs of the FKM were calibrated to apply a maximum of 20 pounds of resistance to each arm and 50 pounds of resistance to each leg during exercise (as depicted in Figure 1). Obviously a disadvantage of springs was that the resistance was at maximum when the spring was fully compressed and less when the spring was fully expanded. This was obviously a limitation that affected the exercise design in the present study, but the manufacture has already acknowledged that the resistance system will be changed prior to commercial manufacturing. To account for the fact that we could not alter the resistance, we partially accounted for this by recruiting subjects who were about the same height and weight within each gender to minimize this source of variability.

Figure 1: Subject exercising on the Fish and Kangaroo Machine.



This novel exercise used springs to provide a maximum resistance of 20 pounds to each arm and 50 pounds of resistance to each leg. During preliminary testing it was found that the inability to adjust resistance restricted exercise such that it could not be longer than 1-min in duration. Thus, the device was evaluated by having subjects complete 6 exercise (1-min) / Rest (4-min) intervals over a period of 42-min. After the final exercise interval subjects were allowed 10-min of passive recovery.

Study Protocol

After being approved to participate in the study, subjects reported to the lab between 0800 and 1100 following an overnight fast (≥8h) and abstention from exercise (≥12hr). Following 15-min of seated rest, subjects were fitted with a heart rate monitor (Polar USA), nose-clip, and a mouthpiece to collect expired gases. After 2-min of seated rest, subjects began the first of six exercise/rest intervals. Each interval consisted of one-minute exercise on the FKM, in which subjects were instructed to work at their maximum capacity. The 1-min duration of exercise bouts was determined by the pilot test phase as the optimal exercise duration for subjects that were not accustomed to the FKM. During pilot testing it was revealed that exercise on this device had a strong anaerobic component and thus the present protocol was designed to examine the effect of short-term, repeated exercise bouts with recovery. Subjects were allowed 4-min of recovery between exercise intervals. Upon completion of the 6th and final exercise interval, subjects recovered for 10-min. The entire duration of the exercise protocol was 42-min. The experimental testing timeline is demonstrated in Figure 2.

Cardiovascular Measurements

Mixed expired air was collected and analyzed to determine oxygen consumption (VO2), respiratory exchange ratio (RER), ventilation (VE), and energy expenditure (EE) continuously during the 42-min of testing using an automated metabolic cart (Parvomedics; Salt Lake City, UT). Data were averaged and reported as the mean response at the end of each exercise or rest interval.

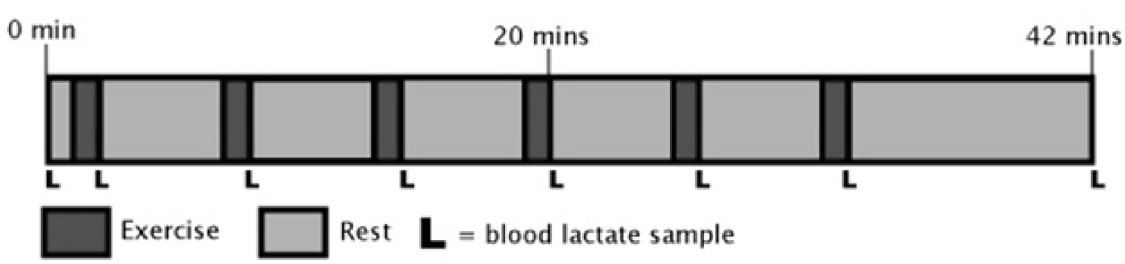
Heart Rate

Heart rate (HR) was continuously monitored via telemetry (Polar, USA). Data were averaged and reported as the mean response at the end of each exercise or rest interval.

Blood Lactate Concentration

Blood was collected from a fingertip at the following 8 time points: at rest, after each exercise bout (6), and 10-min after the final exercise bout. Measurements were made using a handheld analyzer (Lactate Plus; Nova Biomedical; Waltman, MA).

Figure 2. Experimental Design



Dark grey blocks depict exercise intervals, while light grey boxes depict passive rest intervals. Exercise consistent of 1-min of continuous motion. Subjects were encouraged by a member of the study staff to stay in constant motion. Passive rest intervals lasted 4-min (with exception of the final recovery of 10-min) and included the subject sitting in a resting position. Cardiovascular variables (VO2, VE, EE, and RER) were measured continuously via automated analysis of expired respiratory gases on a metabolic cart (Parvomedics). HR was measured via telemetry (Polar). Blood lactate was measured at the indicated time points via fingerstick capillary blood samples and a hand held lactate meter

Statistical Analysis

All statistical analyses were completed using SPSS (v. 20; Chicago, IL). Prior to formal statistical testing data were assessed for normality and constant error variance. Non-normal data were transformed and noted in the results section. Data were tested for gender differences and since no gender effects were apparent, the subjects were collapsed into a single group for analyses. Each outcome variable was analyzed using a single factor (time) ANOVA with repeated measurements. Significance was set at $P<0.05$. The location of significant effects was determined using a Tukey Post-hoc test.

RESULTS

Cardiovascular Measurements

Compared to the peak response of the 1st exercise interval, VO2 (+13%; $F=68.82$; $P<0.0001$; Figure 3A), VE (+17%; $F=72.4$; $P<0.0001$; Figure 3B), and EE (+20%; $F=75.62$; $P<0.0001$; Figure 3C) were all great at the end of the 6th exercise interval. Generally these responses returned to resting levels during the 4-min recovery period between exercise intervals. Given that there was no change in recovery length, it is reasonable to speculate that each exercise interval provided a similar amount of exercise stress. We found no significant change over time for the RER ($F=0.93$; $P=0.36$; Figure 3D), thus it is reasonable to assume that the ratio of carbohydrate to fat utilization was not altered by exercise on the FKM.

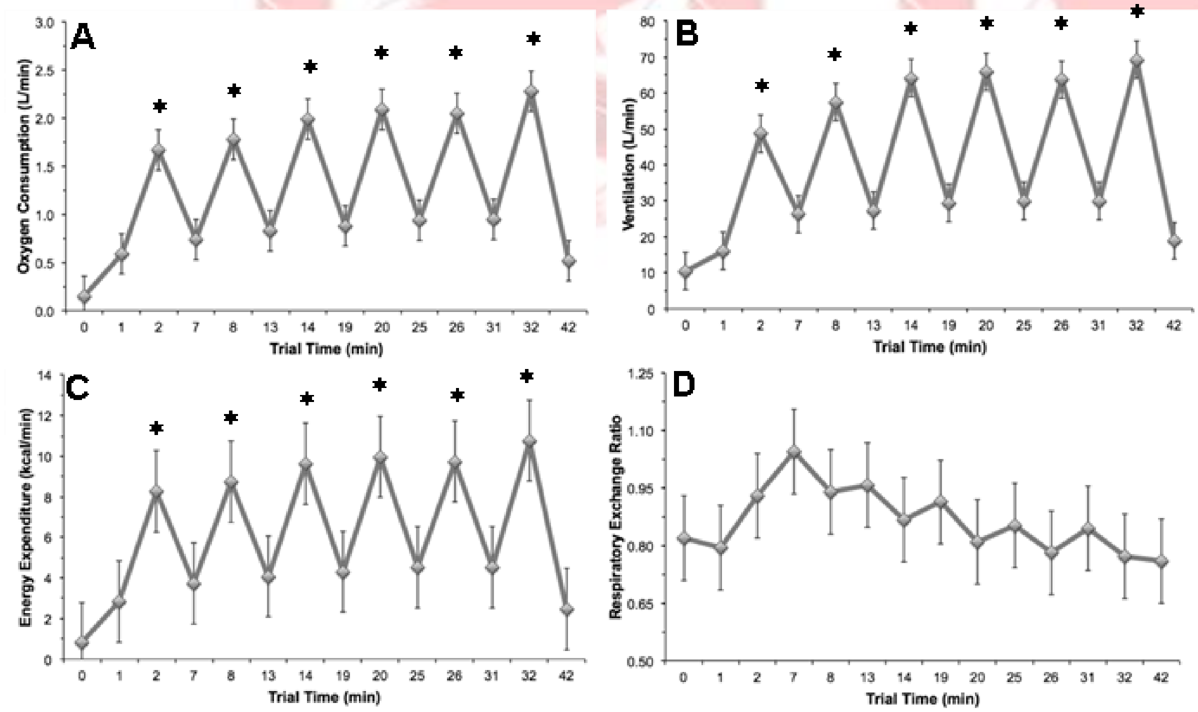
Heart Rate Response

Similar to the metabolic outcome variables, we observed a significant increase in HR from the peak response of the 1st exercise interval to the peak response of the 6th exercise interval (+13%; $F=26.28$; $P<0.0001$; Figure 5). The HR response differed from the metabolic outcomes in that the HR did not necessarily return to pre-exercise values during either the rest intervals of the final 10-min recovery period. In fact at the end of the 10-min recovery period HR was still elevated by about 20%.

Blood Lactate Concentration

Blood lactate concentration was measured as an index of the relative anaerobic contribution to exercise. As anticipated we saw a progressive rise in blood lactate concentration over the course of the exercise protocol ($F=50.73$; $P<0.0001$; Figure 6). The largest increase was between the peak of the 1st exercise interval and the peak of the 6th exercise intervals (+50%). The peak lactate observed was 10.69±0.72 mmol/L, which was approximately 3 times greater than the pre-exercise value (2.90±0.55 mmol/L).

Figure 3. Cardiovascular Response to Interval Exercise on FKM.



Data represent mean ± SEM for A) Oxygen Consumption, B) Ventilation, C) Energy Expenditure, and D) Respiratory Exchange Ratio. Expired respiratory gas was analyzed for volume, oxygen consumption, and carbon dioxide production via automated analysis on a metabolic cart (Parvomedics). Subjects completed 6, 1-min all out exercise intervals, with 4-min of recovery between intervals. * indicates exercise greater than rest ($P<0.05$).

DISCUSSION

The key objective of this research was to examine the effects of anaerobic interval exercise on the Fish & Kangaroo Machine (FKM). The FKM is a prototype, non-commercial device new exercise device that may represent a novel training stimulus. The key findings of the present study were that exercise on FKM had a strong anaerobic component to the response. The rapid recovery of VO2, VE, and EE between exercise-rest intervals indicates that aerobic contributions to this form of exercise were minimal. Further the blood lactate response was large (3 fold increase over rest) and the likely cause underlying the changes in the various metabolic variables over the course of the exercise session. The fact that peak blood lactate concentration remained elevated at 10-min after exercise, suggests that recovery may not be as rapid as the other metabolic variables that appeared fully recovered after 4-min of rest. It is reasonable to speculate that the observed metabolic responses may have been partially due to the progressive rise in blood lactate, which is a known stimulus for elevated cardiorespiratory responses during exercise.

Given that blood lactate concentration is know to effect ventilation and heart rate, it is reasonable to speculate that exercise of the FKM was primarily anaerobic in nature. For example, we observed a progressive, significant rise in blood lactate with each successive exercise bout. Blood lactate peaked at 10.69±0.72 mmol/L after the 4th

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exercise interval and was maintained at this level through the 10-min post exercise measurement (following the 6th and final exercise interval). This combined with the fact that the majority of the cardiovascular parameters returned to pre-exercise values within 4-min of recovery from the 6th exercise interval supports the contention that exercise on the FKM is primarily anaerobic in nature. In comparison, The Wingate Threshold Test is considered the gold standard to measure maximal anaerobic capacity and the level of anaerobic system activation during the Wingate was similar to what we observed with exercise on the FKM machine (2). Fischer et al. reported that physically active men had a peak blood lactate of 10.0±2.3 mmol/L, while women had a peak blood lactate of 12.2±2.6 mmol/L following completion of Wingate test (3). The lactate response in the present study appears similar to values reported with Wingate testing. The biggest difference is the time needed to reach peak lactate, peak lactate was achieved at 4-min of exercise in the present study, while a Wingate test achieves this response in 30-sec. One limitation of the tested design of this FKM machine was an inability to adjust resistance to motion. Thus, it is plausible that had we been able to adjust resistance we could have more closely mirrored the Wingate response.

Similarly, had we been able to alter resistance it may have been possible to create an exercise stimulus with a larger aerobic contribution. With the design limitations of the current FKM machine it was not physically possible for subjects to exercise longer than about 1-min without stopping from fatigue. While there are many causes of fatigue the fatigue in the present study was likely due to acidification of the muscle due to production of excessive lactate by anaerobic glycolysis. For example, Zeni et al. reported that healthy women performing 20-min of continuous interval exercise (treadmill, cycle ergometer, rowing ergometer, Airdyne, stairstepper, and cross-country skiing simulator) had peak blood lactate was <6mmol/L in all conditions4. Obviously the intensity used in the study by Zeni et al. was much less than that of the present study in order to allow an exercise duration of 20-min. Others have reported that various forms of interval exercise with differing intensities result in peak blood lactate concentrations between 5.6 and 10.2 mmol/L (5-7). Thus, our observed findings with exercise on the FKM machine are at least consistent with what others have reported following a period of interval exercise.

The key objective of the present study was to evaluate a new, prototype exercise device called the Fish and Kangaroo Machine. This device was not available for purchase at the time the present study was complete. Within this testing, we sought test a proof of concept for the device, while providing evidence-based practice that could be used to improve future variants of the machine. Using results like those demonstrated in the present study would not be published in a public forum, but the authors felt that the present study provided an important demonstration of the research & development associated with creating a new exercise device. It is out hope that the present study will inspire others companies to be forth coming with regard to their research & development process. More research is needed to determine if this novel exercise device could be modified to provide a mix of aerobic and anaerobic effects. Since anaerobic training has been proven to improve muscle-buffering capacity (8) and greater muscle buffering capacity is positively correlated to improved performance in athletic events such as swimming and running (6), anaerobic training on the FKM machine may be an effective may to improve performance.

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REFERENCES

1. Benardot D. Advanced Sports Nutrition. Champaign, IL: Human Kinetics; 2006. [Google Scholar]
2. Ayalon A, Inbar O, Bar-Or O. Relationships among measurements of explosive strength and anaerobic power. Biomechanics IV 1974:572-577. [Google Scholar]
3. Fischer H, Esbjornsson M, Sabina RL, Stromberg A, Peyrard-Janvid M, Norman B. AMP deaminase deficiency is associated with lower sprint cycling performance in healthy subjects. J Appl Physiol 2007;103(1):315-322. Available from: http://jap.physiology.org/cgi/pmidlookup?view=long&pmid=17463303 PubMed PMID: 17463303. doi: 10.1152/japplphysiol.00185.2007. [Google Scholar]
4. Zeni AI, Hoffman MD, Clifford PS. Relationships among heart rate, lactate concentration, and perceived effort for different types of rhythmic exercise in women.. Arch Phys Med Rehabil 1996;77(3):237-241. Available from: http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+50-21-5 PubMed PMID: 8600864. [Google Scholar]
5. Fontana P, Boutellier U, Knöpfli-Lenzin C. Time to exhaustion at maximal lactate steady state is similar for cycling and running in moderately trained subjects.. Eur J Appl Physiol 2009 Jun;107(2):187-192. Available from: http://www.scholaruniverse.com/ncbi-linkout?id=19551404 PubMed PMID: 19551404. doi: 10.1007/s00421-009-1111-9. [Google Scholar]
6. Vescovi JD, Falenchuk O, Wells GD. Blood lactate concentration and clearance in elite swimmers during competition. International Journal of Sports Physiology and Performance 2011;6(1):106-117. Available from: http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+5

0-21-5 PubMed PMID: 21487154. [Google Scholar]

7. Coutts AJ, Rampinini E, Marcora SM, Castagna C, Impellizzeri FM. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. Journal of Science and Medicine in Sport 2009;12(1):79-84. Available from: http://www.scholaruniverse.com/ncbi-linkout?id=18068433 PubMed PMID: 18068433. doi: 10.1016/j.jsams.2007.08.005. [Google Scholar]
8. Weston AR, Myburgh KH, Lindsay FH, Dennis SC, Noakes TD, Hawley JA. Skeletal muscle buffering capacity and endurance performance after high-intensity interval training by well-trained cyclists.. Eur J Appl Physiol Occup Physiol 1997;75(1):7-13. Available from: http://www.nlm.nih.gov/medlineplus/exerciseandphysicalfitness.html PubMed PMID: 9007451. [Google Scholar]
9. Farrell PA, Joyner MJ, Caiozzo V. American College of Sports Medicine. ACSM's advanced exercise physiology. 2nd ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins 2012;2012. [Google Scholar]