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Comparison of two warm-up models for obese and normal-weight adults performing supramaximal cycling exercise

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ABSTRACT: This study examines the impact of two forms of active warm-up on supramaximal cycling performance among sedentary adults. Thirty-seven adults [23.05 (6.4) years; BMI=26.05 (1.3) kg/m^2, FM=30.1 (4.2)%, VO_{2max}=23.8 (5.8) ml/min/kg] participated in a cross-over randomized study, and all underwent a supramaximal cycling test (SCT) following 5 minutes of two models of warm-up pedalled at a constant velocity of 60 rpm. In the first experimental condition, the warm-up was set at 50% of maximal aerobic power (WU50%MAP). In the second experimental condition, the intensity was set at 50% of maximal heart rate (WU50%MHR). During both experimental conditions the rating of perceived exertion (RPE) at the end of the warm-up and the performance reduction in percentage (ΔPr%) during the SCT were recorded. During the WU50%MAP experimental condition, obese (OB) adults showed higher values of post-warm-up heart rate (~30%) than in the normal weight (NW) group ($p<0.01$). In addition, the RPE scores determined after the warm-up were significantly higher in OB compared to NW (~30%; $p<0.01$). However, after the WU50%MHR experimental condition, no significant differences remained between OB and NW. Moreover, the analyses showed a significant positive association between the elevated heart rate values observed after WU50%MAP and both RPE and ΔPr% (r= 0.71 and r =0.81, p <0.05 respectively). In contrast to NW individuals, the WU50%MHR seems to be more suitable for the OB group undergoing the SCT given that WU50%MAP affected supramaximal cycling performances.

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INTRODUCTION

It the context of training, the warm-up is fundamental to achieve optimal exercise performance [1,2], and its effect on performance is determined by intensity, duration and the recovery interval between warm-up and exercise [3]. For specific populations such as obese individuals, warm-up guidelines are less developed and are still undiscussed. Although numerous studies have focused on the importance of exercise training among obese individuals, and thereby developed and tested different models of exercise intervention [4,5], the scientific basis used to implement and to control the warm-up in such a population remains unclear. To the best of our knowledge, most previous studies have applied warm-up protocols regardless of participant specificity (normal-weight vs. obese). According to Mandengue et al. [6], subjects with different fitness levels respond differently to a single warm-up protocol. This means that an optimal warm-up protocol should be individualized for each subject. For example, Bishop [7] observed that in normal weight individuals a warm-up could positively or negatively affect the subsequent exercise performances depending on how the intensity was regulated. Therefore, if we assume that in obese individuals, the physiological responses as well as the tolerance to an effort for a given relative work load may differ from normal-weight individuals [8,9], it seems possible that subsequent exercise performances would be affected when following a similar warm-up protocol.

Generally, the rate of perceived exertion (RPE) scale is a commonly used assessment to prescribe exercise intensity. It is a reliable indicator of physical discomfort and is strongly correlated with several other physiological measures of exertion [10,11]. In overweight individuals, Ekkekakis and Lind [12] reported a significantly increase in perceived exertion during exercise compared to normal-weight individuals. For Coutts et al. [13], high RPE was associated with high heart rate (HR) values, which negatively affected the performance among experimental subjects. Obese individual studies have reported elevated resting heart rate values compared to normal-weight individuals [14], as well as during exercise conducted within the same relative intensity [12]. Regarding the warm-up, no data exist to date about heart rate responses among obese individuals, or on the consequences of such warm-up procedures for subsequent exercise performance.

Most often, interventional studies prescribe warm-ups in terms of intensity corresponding to ~ 50% of maximal aerobic power/speed [5,15]. As a result, it should not be excluded that such formulas of warm-ups may not be adapted to obese subjects, and therefore may affect subsequent exercise performances. Hence, this study aims to compare the effect of two models of warm-up – the first set at 50% of maximal aerobic power and the second at 50% of maximal heart rate – on both RPE and HR after warm-up and on the subsequent performance developed during supramaximal cycling exercise among adults with different body weight status. Moreover, we were interested in assessing the association between the post-warm-up HR values and RPE changes. We hypothesized that an elevated post-warm-up HR may be associated with an increase in the RPE index that may subsequently affect the exercise performance among individuals.

MATERIALS AND METHODS

Thirty-seven young adults [18 normal-weight: 23.2 (4.4) years, BMI=18.7 (1.2) kg/m^2, FM=17.9 (3.2)%, VO_{2max}= 23.5 (5.6) ml/min/kg, and 19 obese: 22.9 (8.4) years, BMI= 33.4 (1.4) kg/m^2, FM=42.1 (4.2)%, VO_{2max}=24.1 (6.0) ml/min/kg] were recruited from the Moncton campus of the Université de Moncton. Announcements were posted throughout the university campus, and we invited students who met the inclusion criteria to voluntarily participate in the project. The study protocol was approved by the University's Human Research Ethics Committee (UHRC), and all procedures were followed in accordance with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all subjects prior to being included in the study. The inclusion criteria for participation were as follows: participants had to be sedentary (participating in < 60 min.week^{-1} of structured exercise, as assessed by the International Physical Activity Questionnaire [16]), and none of them took part in any systematic exercise training at the time of study enrolment or during the six months that preceded the experiment. Moreover, they had no history of cardiovascular or other chronic disease, no history of drug consumption before the study, and no history of smoking. Before entering this protocol, each participant was thoroughly familiarized with all testing equipment and procedures. The exercise testing was conducted in 3 different sessions (S1, S2 and S3). A period of 48 hours separated each testing session. Subjects were asked to avoid any physical activities for 8 days before all testing.

Anthropometric measurements

Body mass, body fat percentage, fat free mass and fat mass were assessed using a bioimpedance machine (Bodystat 1500, Isle of Man, British Isles). Height was determined to the nearest 0.5 cm with a measuring tape fixed to the wall. Body mass index (BMI) was calculated as the ratio of mass (kg) to height squared (m^2). Following the determination of body composition, participants were separated based on Canadian guidelines for body weight classification in adults [17]: normal-weight (BMI = 18.5 to 24.9 kg/m^2) and obese (BMI > 30 kg/m^2).

Experimental procedures

In S1, all 37 subjects performed a maximal test on an upright cycle ergometer (Monark ergomedic 839E electronic test cycle, Sweden) to determine their maximal oxygen consumption (VO_{2max}) and to ensure that the groups were matched for fitness level. The experimentation started for all subjects at approximately 9 am, 3 hours after a 12-hour overnight fast. The test began with an initial power of 25 W and was progressively increased by 25 W every 5 min until exhaustion. During this maximal test, heart rate values were continuously measured using an electrocardiogram (CASE 16 exercise testing system, Marquette, Wisconsin, USA). A breath-by-breath automated metabolic system (Ergocard MEDI-SOFT, Sorinnes, Belgium) was used to determine VO_{2max} according to criteria established by Spiro [18].

In S2, after 10 min of warm-up, subjects performed a force-velocity test. The force-velocity test was performed on a cycle ergometer using a technique adapted from the study of Vandewalle et al. [19]. This test consists of a succession of supramaximal bouts of approximately 6 seconds with the exercise loads increasing by 1 kg after each bout until inability to continue the test. A passive recovery (5 min) was allowed between successive bouts. The velocity for each bout was recorded every 2 seconds. Only the highest velocity was recorded for each load using an electronic counter (MEV 2000). Power output was calculated by multiplying load and speed, and a power curve was then compiled for each bout. The optimal load corresponding to maximal power (Pmax) was used for the SCT performed on S3.

In S3, experimentation was performed on two different days. All subjects underwent the SCT following 5 minutes of two models of warm-up pedalled at a constant pace of 60 rpm. Actually, the rationale of using SCT in the present study is based on previous results of our laboratory, which has developed and tested a new intervention model based on the SCT [20,21]. This type of intervention increased many health and performance indicators, even after a 6-week period. Considering that warming up prior to exercise is vital to achieve optimum training benefits, we have sought to determine whether specific warm-up methods may have any consequences for subsequent supramaximal cycling performance, which represents the essential basis of our interventional model.

In the first experimental condition (day one), the warm-up was set at 50% of maximal aerobic power (WU50%MAP). In the second experimental condition (day two), the intensity was set at 50% of maximal heart rate (WU50%MHR). In the present study, moderate intensity was chosen and used in the same manner as Racil et al. [22] but based on intensity corresponding to 50% of VO_{2max} (first experimental condition). For this same intensity, we evaluated the relative HR values for each group. The HR was +/- 95 bpm for the normal-weight group and too high for the obese group. Therefore, we established a warm-up model based on 50% of individual HRmax as a second condition.

These two experimental conditions were separated by 48 hours. Regardless of the warm-up method, the heart rate levels were assessed and subjects immediately started the subsequent exercise. The WU50%MAP design is the model most often used in studies targeting obese individuals [18]. The SCT consisted of 6 repetitions of 6-second maximal sprints with a 2-min passive recovery between each repetition and at least 5 min after the SCT. The velocity was again recorded throughout the test and was used to determine mean power output (MP: the mean of all powers developed during the SCT). Performance reduction was determined as the percentage of the power variation from the first to the sixth repetitions (ΔPr%). Subjects were verbally encouraged to sustain a maximal effort throughout the SCT. The fatigue index (FI), i.e., the percentage decrease in power output, was equal to the difference between the highest (PP) and the lowest power (PL) divided by the highest power [23]: Fatigue index = [(PP - PL)/PP] ×100. The S2 and S3 experimentation started at approximately 9 am, 3 hours after a standardized breakfast (10 kcal/kg, 55% carbohydrate, 33% lipid and 12% protein). During all 3 sessions of testing, the participants did not have any safety issues and nobody abandoned the study protocol, therefore the adherence was 100%.

Rating of perceived exertion (RPE)

The rating of perceived exertion (RPE), defined by feelings of stress, strain, discomfort, and fatigue which an individual feels during exercise, was determined using the Borg scale [24]. RPE scores were recorded for each participant after completion of the two models of warm-up, before the SCT and at the end of the SCT. The RPE scale allows participants to provide a subjective exertion rating for a physical task. The scale presents a 15-point scale ranging from 6 (very very light) to 20 (very very difficult). The higher the RPE score, the higher is the rating of perceived exertion.

Statistical analyses

Statistical comparisons were performed between the normal-weight and obese groups in the two experimental conditions (WU50%MAP and WU50%MHR). Before analysis, all data were tested for normality (Kolmogorov-Smirnov test). For normally distributed data, inter- and intra-group comparisons of the variables were computed by two-way ANOVA (group vs. experimental condition), with repeated measurements to determine the main and interaction effects between groups over the two experimental conditions. One-way ANOVA was used to determine differences between groups, followed by Bonferroni's post-hoc comparison tests. Pearson correlations were used to assess the association between the post-warm-up HR values and both ΔPr (%) and RPE changes. A value of $p < 0.05$ was set as the level of statistical significance. Analyses were performed using IBM-SPSS Statistics 19 software.

RESULTS

Subject characteristics are displayed in Table 1. Age and height were not significantly different between the two groups. As expected, the group of obese adults showed significantly higher values for body mass, percentage of body fat and body mass index (BMI) than normal-weight adults. The maximal oxygen consumption, VO_{2max}, expressed per kilogram of body mass, did not significantly differ between the two groups (Table 1).

TABLE 1: Age, anthropometric and fitness of participants.

	NW (n=18) (w=7, m=11)	**OB** (n=19) (w=7, m=12)
Age (years)	23.2 ± 4.4	22.9 ± 8.6
Height (cm)	171.6 ± 6.4	170.9 ± 8.3
Body mass (kg)	68.2 ± 4.3	99.5 ± 11.1 [a]
FM (%)	17.9 ± 3.2	42.1 ± 4.2 [a]
BMI (kg/m^2)	18.7 ± 1.2	33.4 ± 1.4 [a]
VO_{2max} (ml/min/kg)	23.5 ± 5.6	24.1 ± 6.0
HR max (beats/min)	196.9 ± 4.1	195.3 ± 4.1
RER	1.12 ± 0.05	1.11 ± 0.04

Values are expressed as the mean ± standard deviation. w: woman, m: men, NW: normal-weight, OB: obese, n: number of subjects, FM: fat mass, BMI: body mass index, VO_{2max}: maximal oxygen consumption, HR_{max}: maximal heart rate, RER: respiratory exchange ratio. Significant difference with NW: ([a]: p<0.01).

After the WU50%MAP experimental condition, the power developed at the first repetition of the SCT did not differ significantly between the groups. However, decreases in performance were observed starting from the second repetition until the end of the SCT in the OB group when compared to the first repetition and to the NW group (Table 2). Furthermore, the mean power values were significantly lower in the OB group than the NW group ($p < 0.01$). There was no significant decrease between the repetitions in the NW group. Interestingly, OB adults showed higher values of post-warm-up heart rate (~ + 50 bpm) than in the normal-weight ($p < 0.01$) group. In addition, the RPE scores determined after the warm-up and after the SCT during the WU50%MAP experimental condition were significantly higher in OB compared to NW [9.9 (1.8) vs. 14.8 (1.7) and 16.4 (1.5) vs. 18.9 (2.1); $p < 0.01$ respectively]. Finally, the post-SCT heart rate did not differ significantly between the groups (Table 2).

In this study, two-way ANOVA indicated that the main effect of the two warm-up models was significant for RPE and HR changes as well as for MP and ΔPr among obese adults (Table 2). After the WU50%MHR experimental condition, OB adults maintained their power developed during the first 3 repetitions at the same level as NW. After that, the performance decreased significantly compared to NW adults (Table 2). However, the power decreases were significantly smaller than those observed after the WU50%MAP experimental condition in OB adults. As for post-warm-up and post-SCT RPE, there were no significant differences between OB and NW values in the WU50%MHR experimental condition (Table 2). Moreover, post warm-up heart rate did not differ significantly between the two groups. For OB adults, both post-warm-up RPE and HR values obtained in the WU50%MHR experimental condition were significantly lower than those obtained after the warm-up in the WU50%MAP experimental condition.

In this study, a significant association was observed between the heart rate following the warm-up period in the WU50%MAP experimental condition and both ΔPr (%) ($r = 0.81$, $p < 0.05$) and RPE ($r = 0.71$, $p < 0.05$) in OB adults. In addition, the MP and ΔPr (%) measured after the WU50%MHR condition were associated with an improvement in the RPE score ($r = 0.72$, $p < 0.05$) and of index of fatigability (IF) ($r = 0.82$, $p < 0.05$) in obese individuals. No correlation was found between these variables in the WU50%MHR experimental condition.

TABLE 2: Calculated and measured variables after the different warm-up models and during the supramaximal cycling test (SCT).

	WU50%MAP		WU50%MHR		Group*Experimental condition effects	
	NW (n=18) (w=7, m=11)	OB (n=19) (w=7, m=12)	NW (n=18) (w=7, m=11)	OB (n=19) (w=7, m=12)	F	P
Supramaximal cycling performance						
P1 (W/Kg)	5.8 ± 1.5	5.7 ± 0.9	5.9 ± 1.1	5.7 ± 1.4	1.6	0.33
P2 (W/Kg)	5.6 ± 0.5	4.2 ± 0.1 [ab]	5.7 ± 0.6	5.5 ± 1.1 [c]	9.8	<0.01
P3 (W/Kg)	5.8 ± 0.8	4.1 ± 0.8 [ab]	5.8 ± 0.8	5.1 ± 1.3 [c]	12.7	<0.01
P4 (W/Kg)	5.5 ± 1.8	3.7 ± 0.9 [ab]	5.6 ± 1.2	4.1 ± 0.9 [abc]	20.1	<0.01
P5 (W/Kg)	5.7 ± 0.8	3.8 ± 1.8 [ab]	5.7 ± 0.3	4.1 ± 1.2 [abc]	12.8	<0.01
P6 (W/Kg)	5.7 ± 0.8	3.4 ± 0.9 [ab]	5.8 ± 0.4	4.1 ± 0.3 [abc]	12.8	<0.01
MP (W/Kg)	5.7 ± 1.6	4.1 ± 0.8 [ab]	5.7 ± 1.1	4.7 ± 1.1 [abc]	10.3	<0.01
ΔPr (%)	-2 ± 1	-36 ± 8 [a]	-3 ± 3	-18 ± 6 [ac]	14.1	<0.01
IF	1.7	40 [a]	3	28 [ac]	11.2	<0.01
RPE post warm-up	9.9 ± 1.8	14.8 ± 1.7 [a]	9.8 ± 1.6	10.01 ± 1.7 [c]	13.2	<0.01
RPE post SCT	16.4 ± 1.5	18.9 ± 2.1 [a]	16.6 ± 1.4	16.9 ± 3.6 [c]	11.2	<0.01
HR post warm-up(beats/min)	94 ± 9.5	145 ± 20.4 [a]	96 ± 2.9	95 ± 6.4 [c]	12.2	<0.01
HR post SCT(beats/min)	130 ± 12.5	129 ± 10.4	129 ± 12.9	130 ± 9.4	0.2	0.1

Values are expressed as the mean ± standard deviation. w: woman, m: men, NW: normal-weight, OB: obese, n: number of subjects, P: power developed at each repetition, 1, 2, 3, 4, 5, 6: number of repetition, MP: mean of all powers developed during the SCT, ΔPr (%): performance reduction determined as the percentage of the power variation from the first to the sixth repetitions, IF: index of fatigability, RPE: rate of perceived exertion, HR: heart rate. Significant difference with NW: (a: p<0.01). Significant difference with power developed at the first repetition (P1) ([b] p<0.01). Significant difference with WU50%MAP values: ([c]: p<0.01).

DISCUSSION

This study is the first to examine the effect of two forms of warm-up, WU50%MAP and WU50%MHR, on subsequent supramaximal exercise performance among NW and OB adults. The major finding of this study was that a warm-up set at 50% of MAP affected supramaximal cycling performances in the OB group. Furthermore, the increase in post-warm-up RPE scores and in supramaximal performance in OB adults seemed to be related partly to elevated post-warm-up heart rate values observed after WU50%MAP. However, when set at 50% of MHR, this experimental condition led to better performance of OB adults in the SCT.

During SCT, regardless of the experimental conditions, the mean power output was significantly lower in OB compared to NW adults. Similar results have been previously reported by Duché et al. [25] and Sartorio et al. [26]. According to these authors, supramaximal performance assessed by a stair-climbing test [26] or using the force velocity test (F/V) [25] was significantly lower in obese individuals compared to the non-obese. The difference in performance was thought to be related to the excess fat mass in the obese population, thereby leading to a reduction in the motor-unit activation and consequently altering the motor performance and abilities compared with normal-weight individuals [25,26,27]. However, in the present study the power developed at each repetition at the WU50%MAP experimental condition was similar between groups at the first repetition, and then a significant reduction was noted in the OB group and then in the NW group. The performance reduction determined as the percentage of the power variation from the first to the sixth repetition was about -30% for the OB group. A previous study by Ekkekakis and Lind [12] also reported a greater magnitude decrease in supramaximal performance in overweight subjects, which they related to the increased perceived exertion during exercise associated with high heart rates as reported by Coutts et al. [13]. However, in the WU50%MHR experimental condition, the same tendency in performance reduction was observed from the fourth repetition and was about -18% for the OB group.

Interestingly, our results revealed that decreases in performance in OB individuals were mainly affected by the warm-up models followed prior to SCT. In fact, when prescribing WU50%MHR, the performances developed during the SCT were maintained during the first three repetitions at the same level as NW adults, and then decreased less than in the WU50%MAP experimental condition. To date, no studies have considered the effects of warm-up models on exercise performance in obese individuals. Actually [5,15], very often, the warm-up was set to be submaximal (intensity corresponding to 50% of maximal aerobic power/speed or maximal oxygen consumption). According to Bishop [7], an elevated heart rate level after the warm-up may be associated with higher RPE, and such conditions may affect subsequent exercise performances among individuals. It is therefore interesting to note that in the context of the present work, the post-warm-up heart rate values in the WU50%MAP experimental condition were higher in the OB group than those in the NW group. However, when using the WU50%MHR experimental condition, no differences were found between the two groups. In contrast to NW individuals, OB subjects appeared to be affected by the way of warm-up prescription. Indeed, greater improvements in MP and of ΔPr (%) respectively after the WU50%MHR experimental condition were related to improvements in the RPE score and of IF in OB individuals. These results confirm the importance of the warm-up form as a factor affecting performances among OB individuals, and an exaggerated post-warm-up heart rate may be considered as a performance-limiting factor. This assumption is confirmed by the strong relationship found between heart rate and ΔPr (%).

Some limitations of the present study should be considered. In fact, the effect of warm-up procedures on the performance is determined by the intensity, duration and the recovery interval between warm-up and exercise [3]. Therefore, in the WU50%MAP condition, we can speculate that if the OB group was properly recovered prior to SCT, the performance would not have been affected. In addition, in the present study the HR was used as a control tool. However, the performance subsequent to a warm-up period is also conditioned by the rise of core temperature [28]. As a result, further studies are needed to examine the effects of different active warm-up durations and recovery intervals prior to exercise in obese individuals as well as their relationship with HR and core temperature. Such studies may offer new perspectives in terms of training effectiveness among obese individuals.

CONCLUSIONS

In conclusion, WU50%MHR seems to be an appropriate warm-up method for the OB group that underwent the SCT given that WU50%MAP affected supramaximal cycling performances. In contrast to OB individuals, NW subjects appeared not to be affected by the way of warming up. Therefore, controlling heart rate may be a valuable tool for monitoring warm-up prior to exercise especially among obese individuals, given that this variable may greatly affect subsequent performance, as reported in the present study.

Conflict of interest

The authors declared no conflict of interests regarding the publication of this manuscript.

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REFERENCES

1. Al-Nawaiseh A, Albiero A, Bishop P. Impact of different warmup procedures on a 50-yard swimming sprint. Int J Academ Res. 2013;5(1):44-8.
2. Chaâri N, Frikha M, Elghoul Y, Mezghanni N, Masmoudi L, Souissi N. Warm-up durations and time-of-day impacts on rate of perceived exertion after short-term maximal performance. Biol Rhythm Res. 2014;45(2):257-65.
3. Bishop D, Bonetti D, Dawson B. The influence of pacing strategy on VO2 and supramaximal kayak performance. Med Sci Sports Exerc. 2002;34(6):1041-7.
4. Gibala MJ, McGee SL: Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? Exerc Sport Sci Rev. 2008: 36:58–63.
5. Racil G, Coquart JB, Elmontassar W, Haddad M, Goebel R, Chaouachi A, Amri M, Chamari K. Greater effects of high- compared with moderate-intensity interval training on cardio-metabolic variables, blood leptin concentration and ratings of perceived exertion in obese adolescent females. Biol. Sport. 2016:33(2): 145-152.
6. Mandengue S, Miladi I, Bishop D, Temfemo A, Cisse F, Ahmaidi S. Methodological approach for determining optimal active warm up intensity: predictive equations. Sci Sport. 2009;24:9-14.
7. Bishop D. Warm up II. Sports Medicine. 2003;33(7):483-98.
8. Marinov B, Kostianev S, Turnovska T. Ventilatory efficiency and rate of perceived exertion in obese and non-obese children performing standardized exercise. Clin Physiol Funct Imaging. 2002;22(4):254-60.
9. Ward DS, Blimkie CJR, Bar-Or O. Rating of perceived exertion in obese adolescent. Med. Sci Sports Exerc. 1986;18(2):S72
10. Balasekaran G, Loh MK, Govindaswamy VV, Cai SJ. Omni Scale Perceived Exertion responses in obese and normal weight male adolescents during cycle exercise. J Sports Med Phys Fitness. 2014;54(2):186-96.
11. Day ML, McGuigan MR, Brice G, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res. 2004; 18(2):353-8.
12. Ekkekakis P, Lind E. Exercise does not feel the same when you are overweight: the impact of self-selected and imposed intensity on affect and exertion. Int J Obes. 2006;30(4):652-60.
13. Coutts AJ, Rampinini E, Marcora SM, Castagna C, Impellizzeri FM. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. J Sci Med Sport. 2009;12(1):79-84.
14. Mikhail N, Golub MS, Tuck ML. Obesity and hypertension. Prog Cardiovasc Dis. 1999;42(1):39-58.
15. Whyte LJ, Ferguson C, Wilson J, Scott RA, Gill JM. Effects of single bout of very high-intensity exercise on metabolic health biomarkers in overweight/obese sedentary men. Metabolism. 2013;62(2):212-9.
16. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381-95.
17. Canadian Guidelines for Body Weight Classification in Adults - Quick Reference Tool for Professionals. 2003 [Accessed Oct 2016]. Available from: http://www.hc-sc.gc.ca/fn-an/nutrition/weights-poids/guide-ld-adult/index-eng.php
18. Spiro SG. Exercise testing in clinical medicine. Br J Dis Chest. 1977; 71(3):145-172.
19. Vandewalle HP, Heller J, Monod H. Interests and limits of the speed-force relation in human. Sci Mov (in French). 1988;4:38-46.
20. Jabbour G., Iancu H.D., Paulin A. Effects of high intensity exercise training on anaerobic and aerobic contributions to total energy release during repeated supramaximal exercise in obese adults. Sport Medi – Open. 2015; 1:36,
21. Jabbour G., Mauriège P., Joanisse D., Iancu H.D. Effect of supramaximal exercise training on metabolic outcomes in obese adults. J Sport Sci 2016; 1-7.
22. Racil G., Coquart JB., Elmontassar W., Haddad M., Goebel R., Chaouachi A., Amri M., Chamari K. Greater effects of high- compared with moderate-intensity interval training on cardio-metabolic variables, blood leptin concentration and ratings of perceived exertion in obese adolescent females. Biol. Sport. 2016; 33(2): 145-152
23. Souissi N, Driss T, Chamari K, Vandewalle H, Davenne D, Gam A, Fillard JR, Jousselin E. Diurnal variation in Wingate test performances: influence of active warm-up. Chronobiol Int. 2010;27(3):640-52.
24. Borg G.A. Psychophysical basis of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377-81.
25. Duché PA, Ducher G, Lazzer ST, Doré ER, Tailhardat M, Bedu MA. Peak power in obese and nonobese adolescents: effects of gender and braking force. Med Sci Sports Exerc. 2002;34(12):2072-8.
26. Sartorio A, Agosti F, De Col A, Lafortuna CL. Age-and gender-related variations of leg power output and body composition in severely obese children and adolescents. J Endocrinol Invest. 2006;29(1):48-54.
27. Blimkie CJ, Sale DG, Bar-Or O. Voluntary strength, evoked twitch contractile properties and motor unit activation of knee extensors in obese and non-obese adolescent males. Eur J Appl Physiol Occup Physiol. 1990;61:313–318
28. Racinais S, Blonc S, Hue O. Effects of Active Warm-up and Diurnal Increase in Temperature on Muscular Power. Med Sci Sports Exerc. 2005; 37(12):2134-39.