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PREDICTION AND COMPARISON OF MAXIMUM O2 PULSE IN MALE ADOLESCENTS

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Abstract. *The oxygen pulse as an indicator of O2 transport in the circulatory system has recently been subjected to study and clinical investigations, and not much information has been reported about this cardiovascular variable. The purpose of this study has been the prediction and comparison of maximal O2 pulse in male adolescents. For this purpose, 60 adolescents with a mean (S.D) of age, weight and height of 16 ± 0.81 years, 59.92 ± 10.39 kg and 168 ± 8.17 cm respectively, who were sampled randomly, participated in this research. To predict maximal O2 pulse, the subjects performed 4 exercise tests: GXT Treadmill test, PWC 195, PWC 212 ergometer tests and a one mile run test. In order to select the optimum exercise test, the values obtained from 4 exercise tests were compared using the Cooper predictive protocol (criterion protocol). The GXT test, in comparison with the PWC 195, PWC 212 and 1 mile run test, revealed an objective prediction of a maximal O2 pulse (14.40 ml/beat), and did not show any significant difference from the Cooper protocol ($P = 0.519$). The PWC 195 ($P = 0.001$), PWC 212 ($P = 0.001$) and 1 mile run test ($P = 0.003$) showed significant differences (with regards to overestimation, and underestimation) when analyzed with the Cooper protocol. These results suggest that maximal O2 pulse, as an indicator of cardiopulmonary efficiency, is predicted more objectively by the GXT test than other exercise tests, so that the value of O2 pulse max results obtained from this test is very close to the Cooper standards.*

Key words: *maximal O2 pulse, cardiovascular system, exercise tests, adolescents*

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1. INTRODUCTION

The cardiovascular efficiency and function during exercise is one of the challenging arguments in the field of exercise sciences, especially in exercise physiology. In recent years, variables such as heart rate, cardiac output, stroke volume, ejection fraction, rate pressure product, blood pressure and VO2max have been presented and used for the evaluation of cardiovascular function during rest and exercise, in clinical and exercise investigations (Vehrs et al., 1998). But maximum O2 pulse has recently been subjected to clinical (or practical) investigations. This variable is the total volume of oxygen consumed by various kinds of tissue during maximal effort or exercise per heart beat and is the ratio of VO2 peak and HR peak (Wasserman et al., 1999). Therefore, it is one of the main indicators of stroke volume, arterial mixed venous oxygen differences and peak oxygen consumption in cardiodynamic adaptations.

The O2 pulse, as an important index of cardiovascular efficiency, is closely related to health and cardiopulmonary function, as an exercise response with lower peak O2 pulse represents the low SV and cardiac output, the decrease of oxygen delivery to tissues and, therefore, a weak function of the cardiovascular system (Wasserman et al., 1999). Higher O2 pulse values in athletes than in sedentary normal individuals and in healthy individuals in relation to patients emphasize the high efficiency of this variable (Wasserman et al., 1999). In addition, the significance of the O2 pulse as a prognosis indicator has been demonstrated by various studies (Astrand et al., 1988; Grund et al., 2000; Lavie et al., 2004; Pianosi et al., 2000; Wasserman et al., 1999). The effective application of oxygen pulse in the evaluation of cardiovascular fitness has been reported by some investigators (Fellmann et al., 2003; Lehman et al., 1996). For example, Fellmann, et al. (2003), introduced the maximum O2 pulse as an index for the prediction of exercise intensity and energy expenditure. Lehman et al. (1996) found that the O2 pulse max may be important for the determination of AT or for further distinctions of any cardiovascular limitations. Although various studies have been done, the significance and role of the O2 pulse max in adolescents has not been taken into consideration and the extent of the studies is limited. Nevertheless, a few studies that examined maximum O2 pulse in sedentary, healthy and patient adolescents emphasize the greater significance of this cardiovascular physiologic variable (Astrand et al., 1988; Wasserman et al., 1999; Cooper et al., 1984; Wiswell et al., 1979). But the study of maximum O2 pulse in adolescents and other various individuals has not yet been reported in Iran. On the other hand, the close relationship of O2 pulse max with anthropometric and body composition indexes, and these factors' affect on O2 pulse max along with developmental changes and the maturity process show the urgent need to study this variable in adolescents. Jones et al. (1985) and Cooper et al. (1984) studied the maximum O2 pulse in healthy children and adolescents and reported a close relationship between O2 pulse and height.

Although the direct measurement of maximum O2 pulse provides an accurate prediction of this cardiovascular fitness variable, any direct measurement requires considerable expense in terms of time, equipment, trained personnel, and depends on the assessment of risk and the need for medical supervision (Vehrs et al., 1998). The practical limitations of direct testing have lead to the development of an indirect laboratory testing and field methods for predicting O2 pulse max. These prediction models contain numerous maximal, submaximal and non-exercise regression models, which are useful tools in predicting O2 pulse max when working with large groups in a time efficient manner.

The application of predictive methods and exercise protocols for predicting and estimating O2 pulse max (in adults) has been reported by some researchers (Grund et al., 2000; Wei et al., 2004; Klainman et al., 2002; Lavie et al., 2004). But the examination of this index in children and adolescents is accompanied by various limitations such as the use of specific exercise tests, and in addition, due to the limited number of studies of the aforementioned subject, the results can be disputed (Guimaraez et al., 2001; Cooper et al., 1984; Al Hazza., 2001; Opocher et al., 2005). Thus, the prediction of maximum O2 pulse using adolescents specific exercise tests, and the comparison of their values with Cooper predictive protocol values has been the reason behind this investigation.

The exercise protocols used in this study for predicting the O2 pulse max and also the manner in which they were executed along with their comparison for the purpose of an objective prediction of maximum O2 pulse, have not been reported yet, and, therefore, the results of this study may be the first of their kind in Iran. Furthermore, with respect to the kinds of tests and methods used in the study of adolescents, this research presents valuable information about introducing O2 pulse as a high effective evaluating index of cardiovascular efficiency, and in addition to presenting prediction methods of the O2 pulse max, exhibits the optimum specific predictive exercise protocols for O2 pulse max in the laboratory and field domain of study for researchers, and lastly, introduces the maximum O2 pulse as an important indicator variable of physical fitness.

2. METHODS

Participants and procedures: sixty male high school students, 15-17 years of age who were randomly sampled from Urmia College, took part in the study.

The individual's characteristics as adolescents are presented in the Table 1. Prior to their participation, the volunteers read and signed an informed consent document and completed a physical activity and health readiness Questionnaire that was previously approved by the researchers and which was based on pervious investigators' experiences (Wasserman et al., 1999). Then each participant completed four exercise tests: maximal GXT, PWC 195 and PWC 212 cycle ergometry and one mile track jog tests (the tests were performed one week apart) to predict maximum O2 pulse. Despite the fact that each exercise test which was used in this study is more valid and reliable for the purpose of predicting adolescent aerobic power (rgxt = 0.84, rpwc195 = 0.95, rpwc212 = 0.95, r1-mile = 0.87), the tests were validated once again.

Table 1. Physical characteristics of the male adolescents

Variable	Mean	Std.D	Min	Max
Age (yrs)	16.05	0.81	15	17
Height (cm)	168.05	8.17	157	184
Weight (kg)	59.92	10.39	43.00	85.0
HR res (bt/min)	77.10	8.27	66.00	96.0
HRmax (beat/min)	203.95	0.746	203	205
BP rest (mmHg)	10/6	0.95	9/5	12/8
BP exe (mmHg)	15/8	1.70	13/5	20/9
O2pulse rest (ml/bt)	3.39	0.62	2.00	4.47

HRmax: predicted maximal HR; **O2 pulse rest**: oxygen pulse attained using Wasserman, et al equation.

All of the participants were instructed to get sufficient sleep (6-8 hr), and avoid food, caffeine, tobacco products or alcohol for 3 hr prior to testing (Vehrs et al., 1998). Before completing the first test, each participant read a page of written test instructions. The data obtained from the exercise tests was used to predict the maximum O2 pulse.

Instrumentation

The treadmill exercise protocol was completed on a Quinton 3.0 treadmill (Quinton. club track, model: 3.0, USA). All cycle ergometry exercises were completed using a Monark digital ergometer (model Ergomed C 839 E) with the seat height modified for adolescents. A heart rate monitor (Polar, pacer, Denmark) was used to electronically monitor the participants' rest and exercise heart rate during all of the exercise tests. The predictive maximal heart rate of subjects was obtained from age-related methods (220- age). Blood pressure was obtained using an electronically monitored handmade device (model OMRON). The height and weight of the subjects was determined by an electronic device (Seca, Germany). All of the laboratory tests performed under similar environmental conditions with an ambient temperature of 25-29°C and relative humidity ranging between 40-46%, using an Arco device (model Tc 14 P, Germany). Before any testing, the ergometer and treadmill were calibrated with known standard methods (McMurray et al., 1998).

Maximal treadmill GXT The GXT protocol is a graded exercise test that was developed by George et al. (1993). Following 3 min of walking at the level grade, the participants jogged at a self-selected speed between 4.3 mph (6.9 kmh) and 7.5 mph (12 kmh) at a level grade for an additional 3 min. The treadmill grade was then increased 2.5% every min (constant speed) until the participants achieved volitional fatigue and were unable to continue, despite verbal encouragement (Vehrs et al., 1998).

At the end of the exercise, the exercise heart rate and treadmill speed were measured and recorded for each subject. The heart rate was measured as the exercise was ending, was considered as peak HR for the GXT test and was used for the prediction of the O2 pulse max.

PWC 195 test A standard cycle ergometry and exercise protocol was used to predict the O2 pulse max using the PWC 195 equations. The test consisted of three, three-minute stages with all of the adolescents completing all three stages. The initial work load (either 30 or 60 watts) was based on the subject's weight. The resistance during the next two stages increased by 30-60 watts, depending upon the adolescents' heart rate response at the end of the first stage. The highest physical work capacity during this protocol was obtained at 195 beat/min by the subjects. In the present study the test was terminated when each subject reached the heart rate of 195 beat /min at the end of stage 3. The heart rates during the last minute of each stage were used to predict maximum oxygen consumption using the McMurray equation (McMurray et al., 1998). It should be pointed out that the heart rates measured at the end of exercise were considered as peak HR for the PWC195 test and used to predict the O2 pulse max for this exercise protocol.

PWC 212 A standard maximal PWC 212 method (cycle ergometry exercise protocol) was used to predict the maximum O2 pulse and was based on a gender-specific maximal heart rate. This protocol was similar to the PWC 195 test, but the highest physical work capacity for this protocol was obtained at 212 beats per minute by the subjects. In this study the exercise test was terminated when each subject reached a heart rate of 212 beat/ min at the end of stage 3. The heart rates during the last minute of each stage were used for the prediction of maximal oxygen consumption using the McMurray et al. (1998) equation, and also the recorded heart rates at the end of the exercise were considered as peak HR for the PWC 212 test.

1-Mile Track Jog Test The Mile Track Jog Test was performed on the 326m outdoor track. Prior to testing, the participants were instructed on how the 1-mile track jog test was to be performed. The participants then practiced pacing on the running track to familiarize themselves with the test. The one-mile test was performed following the protocol described by George et al. (1993). The participants jogged at a self-selected submaximal steady pace for the entire distance.

A one-lap walk jog warm-up preceded the timed 1-mile track jog to help participants achieve a proper jogging pace. A test administer monitored the elapsed time and exercise HR for each lap to confirm that the participants maintained a steady pace throughout the test distance. Immediately upon completing the track test, the participants' exercise heart rate and elapsed time were recorded and used in a regression equation (Vehrs et al., 1998) to predict maximum oxygen consumption. Also, the exercise HR (Peak HR) was used to predict the O2 pulse max from this protocol.

Prediction of O2 pulse and Maximum O2 pulse (Peak O2 pulse)

To predict the O2 pulse rest, Wasserman et al. (1999) described the equation which was used. The procedure is as follows: the oxygen consumption at rest was calculated using the methods described by McMurray et al. (1998), and the resting heart rate of subjects was also measured and recorded by the investigators, then the O2 pulse equation was used, and the resting O2 pulse for each subject obtained.

To predict the maximum O2 pulse based on the Cooper protocol (criterion protocol), the only regression equation (non-exercise) for children and adolescents which was described by Cooper et al. (1984) was used, and to predict the maximum O2 pulse from four exercise tests the Wasserman et al. (1999) equation was used in such a manner that, with respect to each exercise test, the ratio of peak VO2 and Peak HR was computed to present objective information from this exercise intensity indicator index. Hence, to predict Peak O2 pulse from the GXT test, in addition to the application of the O2 pulse max equation described by Wasserman et al. (1999), Vahers et al. (1998), the equation and also peak VO2 related formulas (Tartibian & Khorshidi., 2006) were used. Furthermore, in predicting the maximum O2 pulse from PWC 195 test, the McMurray et al. (1998) equations were used, in such a manner that, the last minute heart rates at each stage were used to extrapolate a physical work capacity at a heart rate of 195. The PWC was then converted to oxygen uptake using the methods as described (W×12ml O2/ W). The resting metabolic rate was computed based on the World Health Organization gender and age-specific formulas (McMurray et al., 1998). The oxygen uptake at a PWC 195 was then added to the resting oxygen uptake and the total was then multiplied by an age-related correction factor of 1.17 to obtain the predicted VO2max in ml/min. Finally, the results were divided by weight to obtain ml/kg/min. By using these computations and peak VO2-related formulas, the maximum O2 pulse was predicted.

In addition, for the purpose of predicting the O2 pulse max from PWC 212 test, PWC 195, McMurray et al. (1998) described equations and peak VO2-related formulas (Tartibian & Khorshidi., 2006) were used, during which, the stages used for the PWC 195 were repeated for the PWC 212. To predict the maximum O2 pulse from 1-mile track test, also Vehrs et al. (1998) equations and peak VO2-related formulas were used (Tartibian & Khorshidi, 2006).

To analyze the data, an analysis of variance (ANOVA), Post-Hoc (LSD), one sample t-test and Binomial methods were used by means of the SPSS software.

3. RESULTS

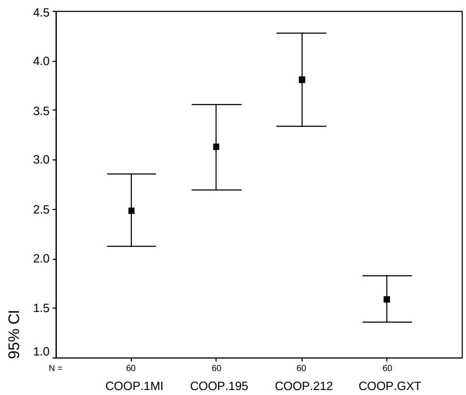
In this study, the O2 pulse max values predicted by the GXT, PWC195, PWC212, and 1-mile track jog exercise tests which were compared with the Cooper predictive value (criterion protocol) gave the following results. It should be pointed out that due to the probable influences of some factors on O2 pulse max values, the statistic trials have been carried out on the basis of the absolute values of mean deviation.

1- *The comparison of exercise- induced O2 pulse values with the Cooper value on the basis of absolute value of mean deviation*.

Table 2 and Figure 1 show that as the result of the comparison of four exercise tests with the Cooper protocol, the values of the GXT test are the least different (1.59 ml/beat) from the Cooper protocol and are very similar to the Cooper protocol in relation to other exercise tests.

Table 2. The absolute value of mean deviation of the exercise tests from the Cooper predictive protocol

Test	mean	Std.D	min	max
Coop- 1mile (ml/beat)	2.49	1.42	0.29	4.79
Coop- PWC195(ml/beat)	3.12	1.67	0.73	7.41
Coop- PWC212(ml/beat)	3.80	1.83	0.17	8.06
Coop- GXT (ml/beat)	1.59	0.90	0.06	3.51



Graph1. Comparison of the absolute value of the mean **deviation** of the maximum O2 pulse of the Cooper protocol from the exercise tests

2 - *The overestimation and underestimation of the comparison of the O2 pulse max values of the exercise tests with Cooper protocol*

The results of the Binomial overestimation, underestimation of the trial shows that in the comparison of the four exercise tests, only the GXT test showed no significant difference ($P = 0.519$) with the Cooper protocol. Furthermore, Graph.1 also showed small differences between the values of the GXT test and those of the Cooper protocol. Therefore the GXT test is very near to the predictive Cooper protocol in the prediction of the maximum O2 pulse. But the PWC 195, PWC 212, and 1-mile track jog tests, had significant differences with the Cooper protocol with respect to overestimation and underestimation ($P = 0.001$, $P = 0.001$, and $P = 0.003$, respectively) (Table 3, Figure 1).

Table 3. Understimation, Overestimation prediction values of the O2 pulse max for exercise protocols compared to Cooper protocol in male adolescents

		Category	N	Prop	Sig.
OU.GXT	Group1	U	33	0.55	
	Group2	O	27	0.45	0.519
	Total		60	1.00	
OU..PWC195	Group1	U	54	0.90	
	Group2	O	6	0.10	0.001*
	Total		60	1.00	
OU.PWC212	Group1	U	54	0.90	
	Group2	O	6	0.10	0.001*
	Total		60	1.00	
OU.1Mile	Group1	U	42	0.70	
	Group2	O	18	0.30	0.003*
	Total		60	1.00	

O: overestimation**, U:** underestimation**, N:** the number of participants in each group, **prop:** observed proportion, *: significance

4. Discussion and Conclusion

The maximum O2 pulse, the ratio of peak oxygen consumption and peak heart rate, are used to evaluate cardiovascular function and fitness. The prediction and comparison of the maximum O2 pulse in male adolescents during the four exercise tests and the presentation of the optimum predictive protocol in proportion to adolescents is the purpose of this investigation.

In this study there were no significant differences between the GXT O2 pulse max values and those of the Cooper predicted protocol, and this exercise test estimated the maximum O2 pulse in adolescents with a smaller margin of error (from the view point of overestimation and underestimation). Unfortunately, no study is available based on the comparison of the maximum O2 pulse value which was the result of the GXT test with the Cooper protocol up to now. Also the mean O2 pulse max values obtained from the GXT test in this study varied from those investigations which used other exercise protocols. In contrast to our results for the treadmill GXT test (14.40 ± 2.03 ml/beat), Douard et al. (1997) (10.7 ± 4.2 ml/beat), and Abarbanell et al. (2004) (7.8 ± 2.4 ml/beat) using the Bruce test on 10-12 yr old healthy children, and Guimaraez et al. (2001) (7.4 ± 1.7 ml/beat) using the Naughton modified treadmill test in 8-9 yr old children and Lavie et al. (2004) (11.4 ± 4.1 ml/beat) using the Ramp protocol on a treadmill on healthy 54 yr old individuals, reported lower values for the estimated O2 pulse max. But Prasad et al. (2001) demonstrated higher values (16 ± 3.8 ml/beat) for maximum O2 pulse in healthy individuals ages 8-30.

In the previously cited studies, the GXT test has not been used for the prediction of the maximum oxygen pulse, but the use of other treadmill protocols in children and adolescents had been reported (Al Hazza., 2004; Opocher et al., 2005; Wei et al., 2004). Mani et al. (2005) reported that the treadmill exercise protocols are easy to use on children, since only the ability to walk is required, and numerous gradations of the exercise level can be achieved. Dobrovolny et al. (2003), in another study, demonstrated that the GXT treadmill protocols were highly reliable ($r = 0.85$) for the prediction of the O2 pulse max. In the present study, the mean O2 pulse max value obtained from the GXT test differs slightly from the Cooper predicted values. It appears that the high validity and reliability of the GXT test in predicting maximum oxygen consumption (Vehrs et al., 1998), and also, the proportionate increase in exercise intensity with respect to the adolescent's characteristics in this protocol, has made the application of this test important. On the other hand, including the correction of the coefficient of the weight and heart rate factors in the GXT regression equation, explains the accurate prediction of the adolescents' O2 pulse max by this protocol in comparison with other exercise protocol equations (Vehrs et al., 1998). This discrepancy between the GXT O2 pulse max values of the present study and those of other investigations can be explained by different exercise protocols that used, secondary to variation in speed, the grade and navigated distance on the treadmill, while these factors may induce varied cardiovascular responses (HR, VO2, SV, a-v O2 diff) in treadmill protocols. The other probable explanations for this difference between our values and the results of other studies can be due to the effective influences of some factors on the O2 pulse max such as age, height, weight, body size, lean body mass, blood volume, hemoglobin concentration, degree of fitness, and level of activity (Tartibian., 2000; Al Hazza., 2001; Astrand., 1988; Grund et al., 2000; Jones et al., 1985; Padilla et al., 2000; Wasserman et al., 1999). In the present study, the subjects' mean weight 59.92 ± 10.39 kg, height 168 ± 8.17cm, and age 16 yr, differed from those of Al Hazza (2001) (7-15 yr old boys), Opocher et al. (2005) (7-12 yr old boys), and Wiswell et al. (1979) (18-25 yr old adolescents). Some of the researchers reported higher maximum O2 pulse values for athletes than normal sedentary individuals and for normal subjects in relation to patients at any exercise level (Wasserman et al., 1999; Douard et al., 1997; Prassad et al., 2001; Lavie et al., 2004, Sharma et al., 2000, Abarbanell et al., 2004; Grund et al., 2000). Also, as the cause of low O2 pulse max values in some researches the presence of factors such as temperature and pressure changes, utilization of some medications, and diseases have been reported (Wasserman et al., 1999).

Our results showed that there were significant differences ($p = 0.001$) between the PWC195 O2 pulse max values and Cooper predicted values (3.13 ± 1.68 ml/beat). In other words, the PWC 195 test was different from the Cooper protocol from the viewpoint of O2 pulse prediction, and showed probable higher predictive error. Likewise, the mean O2 pulse max values obtained from the PWC195 test in the present study were different from other research values. In addition, in contrast to our values for the PWC195 cycle ergometry test (11.35 ± 1.78 ml/beat), Pianosi et al. (2000) (7 ± 1.1 ml/beat), and Grund et al. (2000) (7.5 ± 2.5 ml/beat), reported lower values for the estimated O2 pulse max in 5-10 yr old normal children. However, Padilla et al. (2000) (18-22 ml/beat) and Sharma et al. (2002) (27.1 ± 3.2 ml/beat) obtained higher O2 pulse max values in athletes in comparison to our results. Unfortunately, a study that estimates O2 pulse max in adolescents using the PWC195 protocol and then compares the obtained value with criterion protocol (Cooper protocol), has not been reported. But the accurate estimation of aerobic power using ergometer protocols has been reported by many investigators (Astrand et al., 1954; McMurray et al., 1998). McMurray et al. (1998) pointed out that the most popular methodologies for predicting maximum oxygen consumption in children and adolescents have utilized cycle ergometry to determine physical work capacity (PWC). The valid and reliable predictions of O2 pulse max have been reported from cycle ergometry exercise tests. For example, Grund et al. (2000); Wiswell et al. (1979) and Cooper et al. (1984) studied O2 pulse in children and adolescents, and Padilla (2000), Fellman et al. (2003), and Wax et al. (1999), studied maximum O2 pulse in normal individuals and patients. The results of the present study indicated that the PWC195 test under-predicted the maximum O2 pulse ($p = 0.001$). We suggest that one possible explanation for the low PWC195 O2 pulse max values in relation to Cooper values has been the greater HR during the execution of the PWC195 protocol. Since the subjects must raise their HR to around 195 bt/min during the execution of this exercise test, thus a higher HR in relation to the VO2 can be the cause of this reduction in O2 pulse values in this protocol. Wasserman et al. (1999) also reported that the cause of the lower estimated O2 pulse max value than the predictive value has been the result of lower stroke volume in children and adolescents. These researchers emphasized that if the stroke volume is reduced, the a-v O2 differed and, therefore, the O2 pulse reaches maximal values at a relatively low work rate (Wasserman et al., 1999).

Other probable explanations for low O2 pulse values of the PWC195 test are anemia, carboihemoglobinemia, poor blood oxygenation in the lungs, and/or low peripheral oxygen extraction in adolescents (Wasserman et al., 1999). The peak O2 pulse, which is less than 80% of the predicted values for individuals with exercise-induced anemia, has been reported by Callahan et al. (2002). The "sport anemia" has been attributed to physiologic responses to exercise due to expansion of plasma volume that dilutes red blood cells. The sports anemia may be due to multiple mechanisms such as participation in intense prolonged exercise, dietary iron deficiency, impaired iron absorption, hematoria, and gastrointestinal bleeding, so that in present study, the heart rates of the adolescents were approximately 195 beat/min and the subjects had to tolerated work loads of 100-180 watt during a 9 min exercise which, in turn, could be accompanied by the low extraction of oxygen by any tissue and, as a consequence there were low O2 pulse values in adolescents. On the other hand, an investigation which studied cycle ergometry protocols with various work loads for the estimation of the O2 pulse max in adolescents has not been reported. Nevertheless, it appears that an individual's age, height, weight, body size, lean body mass, blood volume, hemoglobin concentration, degree of fitness and activity level be effective in determining the O2 pulse max in subjects (Wasserman et al., 1999). It appears that any variation in the abovementioned factors is accompanied by concomitant changes in O2 pulse max (Al Hazza., 2001; Wasserman et al., 1998; Tartibian, 2000; Grund et al., 2000). Wasserman et al. (1999), reported that the normal value for the predicted maximum O2 pulse on the cycle ergometer ranges from approximately 5 ml/beat in a 7-year-old child to 8 ml/beat in a 150 cm, 70-year-old women to 17 ml/beat in a 190 cm, 30 year-old man.

The present study showed a significant difference ($p = 0.001$) between the mean O2 pulse max values of the PWC 212 test and the Cooper predictive protocol value (3.808 ml/beat). In other words, the PWC212 test differed more from the Cooper protocol and estimated maximum O2 pulse with a higher estimated error. Unfortunately, in the pervious studies, the investigation which predicted the O2 pulse max in adolescents using the PWC212 protocol and then comprising these values with the Cooper protocol has not been reported. The mean O2 pulse max values obtained from the PWC 212 cycle ergometry test in present study is 10.53 ± 1.54 ml/beat, but the other investigators such as Pianosi et al. (2000) (7 ± 1.1 ml/beat), Padilla et al. (2000) (18-22 ml/ beat), & Sharma et al. (2000) (27.1 ± 3.2 ml/beat), presented different values for estimating O2 pulse max based on different cycle ergometry protocols in various individuals. The effective application of cycle ergometry tests for the measurement of physical work capacity in children and adolescents have been reported by exercise science researchers. For example, McMurray et al. (1998) demonstrated that the PWC 212 is more reliable and valid for determining physical work capacity and the measurement of maximal oxygen consumption in children and adolescents (McMurray et al., 1998). One possible reason for low O2 pulse max values of the PWC212 in relation to the Cooper value in the present study has been a higher heart rate (212 beat/min) during the performance of this protocol. Since the subjects have to increase their HR to about 212 bt/min, hence this greater increase of heart rate has probably lead to the decrease in the O2 pulse max, according to the analysis of Wasserman et al. (1999).

Also, the low O2 pulse value of PWC212 test may be the result of a higher exercise intensity during the execution of the PWC 212 (HR of 212 beat/min, the work load of 180 Watt and, 9 minute pedaling on cycle ergometer) (McMurray et al., 1998). Also other factors such as muscular pain, not having enough motivation in tolerating work loads and ventilatory and circulatory insufficiency can be the cause of low O2 pulse max values in the PWC 212 exercise protocol (Wasserman et al., 1999). Another probable explanation for these lower O2 pulse max values than the Cooper predicted values has been the greater increase of heart rate to 212 beat/min and, therefore, the decrease of stroke volume in the adolescents in the present study, as a lower stroke volume in children and adolescents in relation to adults during intense exercise have been reported (Wasserman et al., 1999). Also, an individual's age, height, weight, lean body mass, blood volume, hemoglobin concentration and activity level, have been the variables which probably affected the maximum O2 pulse values obtained from the PWC 212 protocol (Wasserman et al., 1999).

The results of the one-mile track test showed that this protocol significantly differed from the Cooper predictive protocol in predicting O2 pulse max (2.49 ± 1.49ml/beat). Unfortunately, the investigation that studied the maximum O2 pulse using the 1-mile track test, especially for the case of adolescents, has not been reported yet. A high VO2max estimation of validity and reliability has been demonstrated by several investigators employing the 1-mile track run test (Vehrs et al., 1998). Vehrs et al. (1998) also reported that the 1-mile track test may accurately estimate cardiovascular fitness. Larsen et al. (2002) pointed out that the benefits of the one-mile track test for the prediction of the O2 pulse max are that it allows the participant to self-select an exercise mode, which is most appropriate for subjects with different fitness levels, and the prediction of aerobic power with simple regression equations (Vehrs et al., 1998). The findings of the present study revealed that the 1-mile exercise protocol was inappropriate for the prediction of the maximum O2 pulse, and for the underpredicted O2 pulse max ($p = 0.003$). One probable explanation for the low O2 pulse max values obtained from the 1-mile track test has been the lower arterial venous O2 difference and submaximal heart rate in adolescents. The 1-mile test revealed the submaximal characteristics of subjects, and did not predict cardiovascular changes at maximal levels (Vehrs et al., 1998). In the present study, the 1-mile test estimated the O2 pulse max with less difference in comparison to the PWC 195, and PWC 212 tests, indicating a better prediction of the O2 pulse max with the 1-mile track test in comparison to both cycle ergometry tests. A possible reason for this discrepancy has been the lower heart rate during the execution of one-mile track test and the importance of the maximum O2 pulse equation factors (Wasserman et al., 1999; Vehrs et al., 1998).

In summary, the results of the present study reveal the O2 pulse max as an indicator of cardiovascular efficiency, which can objectively be predicted using the GXT test, in comparison to other 3 exercise protocols, as the GXT O2 pulse max values strongly resemble the Cooper value and, therefore, can be used for the prediction of the O2 pulse max in adolescents. Further studies are needed for recognition of other best and practical exercise protocols for the prediction of the O2 pulse max.

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PREDIKCIJA I POREĐENJE NIVOA KISEONIKA U KRVI KOD DEČAKA ADOLESCENATA

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Nivo kiseonika u krvi kao indikator njegovog transponovanja u krvotok je tek odnedavno postao predmet istraživanja u uslovima vežbanja i kliničkim uslovima, pa stoga i nema dovoljno dostupnih informacija u vezi ove kardiovaskularne varijable. Cilj ove studije je predikcija i poređenje maksimalnog kiseonika u krvi kod dečaka adolescenata. Za ove svrhe koristili smo nasumični uzorak od 60 adolescenata srednjih vrednosti, starostne dobi, kilaže i visine kako sledi: 16 ± 0.81 godina, 59.92 ± 10.39 kg i 168 ± 8.17 cm. Da bi predvideli maksimalni nivo kiseonika u krvi ispitanici su testirani sa četiri testa: GXT-tredmil test, PWC 195, PWC 212 ergometar test i test trčanja jednu milju. Da bi odabrali optimalni test vežbanja dobijene vrednosti nakon četiri vrste testiranja su poređene sa Kuperovim prediktivnim protokolom (P = 0.519), PWC 195 (P = 0.001), PWC 212 (P = 0.001) i testom trčanja jednu milju (P = 0.003) su pokazali značajne razlike (u odnosu na uvećanje ili smanjenje procena) u poređenju sa Kuperovim protokolom. Dobijeni rezultati ukazuju na to da se maksimalni nivo kiseonika u krvi kao pokazatelj kardiopulmonalne efikasnosti može objektivnije predvideti putem GXT testa nego li drugim testovima, tako da vrednosti kiseonika u krvi utvrđene ovim testom jesu veoma slične vrednostima Kuperovog standardnog testa.

Ključne reči: *maksimalne vrednosti kiseonika u krvi, kardiovaskularni sistem, testovi vežbanja, adolescenti.*