Original Research

Intermittent vs Continuous Graded Exercise Test for VO_2max in College Soccer Athletes

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ABSTRACT

Int J Exerc Sci 4(3) : 185-191, 2011. The purpose of this study was to determine if a 1-min active recovery between stages during a graded exercise test (GXT) would result in a higher stage intensity and maximum oxygen uptake in college soccer athletes. Eleven athletes completed two GXT protocols on separate days. Each GXT consisted of 2-min stages performed at a constant running speed and incremental increases of 2.5% grade. One GXT was performed continuously and the other was intermittent with 1-min active recovery between each stage. Tests were performed to volitional fatigue. Following the each GXT and a 10-min active recovery period, participants performed a verification stage at an intensity greater than the final stage of the GXT. All participants completed a higher intensity stage during the intermittent vs continuous GXT. As a result, VO_2max and maximum heart rate (HR) were significantly higher (VO_2: 57.7 ± 5.8 vs. 55.5 ± 5.7 $ml \cdot kg^{-1} \cdot min^{-1}$, HR: 190 ± 6 vs. 187 ± 6 bpm, $p < 0.02$) during the intermittent GXT. Maximum ventilation and respiratory exchange ratio did not differ between intermittent and continuous protocols. Following the intermittent GXT, nine participants completed the verification stage and obtained VO_2 values within the plateau criterion. We conclude that a continuous GXT underestimates VO_2max in some athletes and that the intermittent protocol may provide a more accurate measure of VO_2max.

KEY WORDS: Maximal oxygen uptake, intermittent high intensity training, VO_2 plateau

INTRODUCTION

Soccer is a high-intensity endurance sport that requires intermittent and random bouts of powerful anaerobic activities such as sprints, rapid acceleration and deceleration, turning, jumping, kicking, and tackling (12, 17). Given the duration of the game and the importance of quick recovery from anaerobic bouts of activity, the aerobic contribution is significant with an estimated average intensity of 70-75% of maximal oxygen uptake (VO_2max) (3, 30). VO_2max quantifies the aerobic capacity of an individual and among soccer athletes, is a common measure to assess soccer performance and is used when profiling player positions and teams (9, 30, 33). Further, improvements in VO_2max have been associated with improved soccer performance during competition (i.e., distance covered, average work intensity, involvement with the ball) (15). Thus,

VO_2max is an important physiological measure in soccer.

Intermittent high intensity trained athletes such as soccer players demonstrate physiological adaptations that lead to increased aerobic and anaerobic work capacity as well as improved repeated sprint performance and ability to recover from high intensity exercise (5, 23, 26, 31). Because intensity increases in a linear manner to volitional fatigue during a continuous graded exercise test (GXT) most often used to measure VO_2max, the test does not replicate the intermittent nature of soccer training. To address this issue, Bangsbo et al (2) have created a field test to assess soccer athletes, called the Yo-Yo intermittent recovery test. While performance during the Yo-Yo test correlates well with aerobic capacity, it is not a direct measure of VO_2max. Thus, an intermittent GXT may be more appropriate than a continuous protocol for direct measurement of VO_2max in soccer athletes. It is possible that soccer athletes may demonstrate improved performance during a GXT if allowed to actively recover between stages.

During a maximal GXT, attainment of a VO_2max plateau or lack of increase in VO_2 with an increase in intensity has been traditionally considered an indication that true VO_2max has been achieved (16). However, a relatively low frequency of plateau achievement is common among athletic populations (10, 18, 24, 29). Thus, it is uncertain whether these athletes achieved true VO_2max. Because the plateau phenomenon does not always occur, a stage performed at a higher intensity than the final stage of a GXT following several minutes of recovery has been used to verify whether or not true VO_2max has been achieved (21, 27). Therefore, in addition to an intermittent stage protocol to measure VO_2max, the addition of a longer rest period followed by a verification stage may improve the measurement of VO_2max.

The purpose of this study was to determine if a 1-min active recovery between stages during a GXT would result in a higher stage intensity and maximum oxygen uptake in college soccer athletes. We hypothesized that the intermittent GXT would result in a higher VO_2max compared to the continuous protocol. Because we also wanted to determine whether true VO_2max was achieved in soccer athletes during the intermittent GXT, we included a verification stage and hypothesized that a plateau would be demonstrated in all athletes with a verification stage following the intermittent GXT.

METHODS

Participants

Eleven college male (N = 5) and female (N = 6) soccer athletes participated in this study (Table 1). All athletes were participating in championship season training during the study, had been trained for three consecutive months without interruption, and reported at least twelve years of competitive soccer experience at the amateur level. In addition to competition, weekly training included skill/team training, conditioning protocols that included high-intensity repetitive bouts of sprinting, and resistance training for a combined total of 20 hours per week. Continuous aerobic running sessions were reserved for post-match recovery training days and were limited to less than one time per week. Each participant read and signed a written informed consent approved by Barry University's Internal Review Board prior to participation.

Table 1. Descriptive characteristics of participants.

	Men (N = 5)	Women (N = 6)	Combined (N = 11)
Age (yr)	21.8 ± 1.7	20.6 ± 2.0	21.3 ± 1.9
Body weight (kg)	74.8 ± 10.0	60.5 ± 6.1	68.3 ± 34.9
Height (cm)	180.3 ± 7.3	164.9± 6.4	173.3 ± 10.3

Values are mean ± SD.

Protocol

Each participant visited the human performance laboratory on two separate days, 2-7 days apart. Two maximal GXT protocols were performed, one continuous and one intermittent. The order of the tests was counterbalanced. In preparation for the tests, participants were instructed to consume a meal at least 3-4 hr prior and to not consume caffeine for at least eight hours prior to the tests. Other guidelines for the participants were to maintain a daily diet that was high in carbohydrates and to abstain from drug or alcohol consumption the week prior to testing. Scheduling of the tests was dependent upon the athlete's training or competition schedule such that no strenuous physical activity took place during the previous 24 hours. All participants completed both GXTs at the same time of day and all tests were executed between noon and five o'clock in the afternoon for consistency.

VO_2max Tests

Performed on a motorized treadmill (Quinton, Medtrack SR60, Bothell, WA), each protocol consisted of 2-min stages while running speed was held constant and grade increased 2.5% with each stage. The running speed was pre-determined during a warm up and was associated with a rating of perceived exertion of 13-14 (corresponding to approximately 60-65% VO_2max) on the Borg scale (7). The first stage was run at 0% grade; thereafter, grade was increased until volitional exhaustion. The continuous GXT was performed nonstop while the intermittent GXT included 1-min active recovery periods between stages. During the recovery, participants walked at 4 mph and 0% grade.

During the test, expired gas was collected continuously with an automated system (ParvoMedics TrueOne 2400, Sandy, UT) that analyzed expired gas volumes and O_2 and CO_2 fractions. A 3-liter syringe was used to calibrate the flowmeter and a standard mixture of oxygen and carbon dioxide was used to calibrate the gas analyzers prior to each test. Data were collected continuously for VO_2, ventilation and respiratory exchange ratio (RER). All values were retrieved in single breath measurements. Maximum values were determined from the average of the last 30 seconds in the final stage of the test protocol. Heart rate was continuously measured using telemetry (Polar USA, Lake Success, NY).

After each GXT, the participant walked at a slow pace for 10 minutes. Following the rest period, intensity was increased gradually over a 1-min period until the final stage intensity was reached. At that time, the grade was increased 2.5% and the participant was encouraged to continue running for 2 minutes.

A VO_2 plateau criterion was incorporated to determine whether true VO_2max was obtained during the intermittent GXT. The criterion was an increase of < 2.1 ml·kg^{-1}·min^{-1} (32). The VO_2 measured during the final stage of the intermittent GXT was compared to the VO_2 measured during the verification stage. In addition, the plateau criterion was used to evaluate individual differences in VO_2max between the continuous and intermittent GXTs.

Statistical Analysis

Analyses of data were completed using the Statistical Package for the Social Sciences (SPSS), version 18 for Windows. Statistical significance was set at $p \leq 0.05$ and data were described as mean ± standard deviation. Both GXTs and verification stages were compared using repeated measures ANOVA with Bonferroni's correction for multiple comparisons.

RESULTS

All participants were able to complete an additional stage during the intermittent GXT compared to the continuous GXT. The intermittent GXT resulted in higher mean VO_2max (p = .02) and maximal heart rate (p = .006), but not maximal ventilation or RER (Table 2). Nine participants achieved a higher heart rate during the intermittent GXT compared to the continuous GXT.

When comparing values between GXTs and verification stages, seven participants achieved their highest VO_2 during the intermittent GXT and each of the seven achieved values above the plateau criterion range when compared to the continuous GXT (Table 3). Following the intermittent GXT, nine participants completed the verification stage and obtained VO_2 values within the plateau criterion (Table 3). Two participants were unable to complete the verification stage and consequently achieved values that were 5.8 and 6.3 ml·kg^{-1}·min^{-1} lower than the intermittent GXT.

Because the verification stage following the continuous GXT was performed at the same intensity as the final stage of the intermittent GXT for each participant we compared the VO_2 between these two tests. Mean VO_2 during the intermittent GXT did not differ from the verification stage (Table 3). However, six participants achieved a higher VO_2 during the intermittent GXT and each of these six achieved values above the plateau criterion range.

Table 2. Maximal values during continuous and intermittent GXTs.

Subject	Continuous				Intermittent			
	VO_2 ml·kg^{-1}·min^{-1}	HR b·min^{-1}	RER	$VE_{,BTPS}$ l·min^{-1}	VO_2 ml·kg^{-1}·min^{-1}	HR b·min^{-1}	RER	$VE_{,BTPS}$ l·min^{-1}
1	50.3	180	1.17	100.7	52.0	181	1.17	110.4
2	63.9	192	1.11	163.8	66.9	199	1.13	162.0
3	55.7	188	1.23	128.2	56.1	192	1.24	136.1
4	59.4	201	1.27	180.8	57.8	201	1.12	176.0
5	54.0	188	1.18	109.6	53.9	192	1.16	109.0
6	58.9	182	1.15	193.5	60.9	186	1.04	185.5
7	51.2	191	1.21	140.3	48.6	190	1.14	160.7
8	47.9	184	1.08	105.3	44.5	188	1.11	106.1
9	64.7	188	1.26	127.7	67.1	187	1.17	128.8
10	54.7	182	1.11	144.8	53.3	185	1.11	145.8
11	49.3	179	1.19	110.9	50.4	184	1.17	119.4
Mean	55.5 ± 5.7	187 ± 6.0	1.18 ± .06	136.9 ± 31.3	57.7 ± 5.8*	190 ± 6.0*	1.14 ± .05	140 ± 28.0

Table 3. VO_2max during continuous and intermittent GXTs and verification stages.

Participant	VO_2 (ml·kg^{-1}·min^{-1})			
	C	CV	I	IV
1	50.3	52.0	52.6†	50.8*
2	63.9	66.9†	70.1†	67.4*

3	55.7	56.1	58.5†	58.3*
4	59.4	57.8	59.0	58.8*
5	54.0	53.9	56.0	56.8*
6	58.9	60.9	61.9†	56.0‡
7	51.2	48.6	54.5†	53.9*
8	47.9	44.5	51.4†	45.0‡
9	64.7	67.1†	64.7	66.5*
10	54.7	53.3	53.9	52.2*
11	49.3	50.4	52.5†	52.4*
Mean	55.5 ± 5.7	55.6 ± 7.2	57.7 ± 5.8	56.2 ± 6.6

† achieved VO_2 > 2.1 ml ·kg^{-1} ·min^{-1} from C.
* compared to I, met the plateau criterion.
‡ unable to complete the verification stage.
C = continuous GXT, CV = verification stage following continuous GXT, I = intermittent GXT, IV = verification stage following the intermittent GXT.

DISCUSSION

This study demonstrates that a continuous GXT protocol may limit an athlete's ability to achieve true VO_2max and that an intermittent protocol may be more appropriate. An accurate measurement of VO_2max is believed to exist when VO_2 fails to increase with an increase in work load. The earliest studies that investigated this phenomenon used discontinuous protocols, including stages performed on separate days (14, 22, 32). While these protocols are effective in measuring VO_2max, they are time consuming. Subsequently, continuous protocols were tested and shown to result in similar VO_2max to that obtained during a discontinuous protocol (11, 19, 20). Thus, continuous protocols have become a very common method for measuring VO_2max. However, it has also been shown that the incidence of plateau during a continuous GXT can be relatively low, even among highly trained athletes (10, 18, 24, 29). If a true VO_2max measurement is necessary, it appears that the continuous protocol may not be an effective method in some athletes.

It is widely accepted that VO_2max is limited by the ability of the cardiorespiratory system to deliver oxygen to the muscle (4). However, this idea has been challenged and other models have been brought forth to explain the limitations of performance (25). Among these is the muscle power model that states that the processes involved in contractile activity limit maximal exercise, rather than the delivery of oxygen. Possible mechanisms include impaired Na^+-K^+ pump activity and slowed cross-bridge cycling secondary to increases in H^+, Pi and ADP which could limit the rate of muscle contraction and force production before oxygen delivery limits are reached during a continuous GXT (8, 13, 28). Indeed, compared to the continuous protocol, we observed that all athletes completed a higher intensity stage and seven of these athletes demonstrated higher VO_2 measures during the intermittent protocol indicating that the continuous protocol limited the athletes' performance.

The 1-min active recovery period may have some advantages for the athlete that allows increased work capacity. Active recovery appears to increase clearance of lactate from the muscle and/or increase lactate metabolism in the muscle possibly due to increased muscle blood flow and oxygen delivery (1, 6). The increased blood flow to the working muscle may also promote the phosphocreatine resynthesis which relies on aerobic metabolism (5). These effects, as well as the recovery of intracellular K^+ may contribute to the achievement of a higher intensity during the intermittent GXT.

An interesting observation was the higher VO_2 elicited in six of the participants during the final stage of the intermittent GXT compared to the verification stage performed following the continuous GXT. As these tests were performed at the same running speed and grade, the reason for the higher VO_2 is not clear, although it might be associated with the rest periods. Prior to the verification stage, participants recovered by walking slowly for 10 min, while the rest periods during the intermittent GXT lasted only 1 min and were performed at a brisk walking pace. It is possible that blood lactate, recruitment of type II fibers, epinephrine and body temperature were greater during the intermittent GXT than during the verification stage. These factors are known to affect VO_2 kinetics during high intensity exercise and thus, may have contributed to a greater oxygen cost of running (34).

In conclusion, the hypothesis that an intermittent GXT would more effectively measure VO_2max in college soccer athletes has been supported by the data presented in this study. All athletes achieved a higher intensity during the intermittent protocol and as a result, seven of the 11 athletes achieved higher VO_2max compared to the continuous GXT. All but two of the 11 athletes completed a higher intensity stage following a recovery period that verified the attainment of true VO_2max during the intermittent GXT. We recommend that an intermittent GXT protocol be implemented for soccer athletes in order to improve the accuracy of VO_2max measurements. Further research is needed to determine whether this type of protocol is effective for other types of athletes.

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