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A Comparison of Graded Exercise Test and Two Different Field Tests to Evaluate the Cardiopulmonary Function in Elite Handball Athletes

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Abstract

The purpose of this study is to establish a simpler way to assess cardiopulmonary function in handball athletes whose continuous aerobic ability is vital in games using field tests, as well as to provide basic data on changes in lactic acid concentration. A total of 8 youth elite male handball athletes participated in this study. Participants visited three times in total. The first was assigned to graded exercise test and body composition measurements. Participants were then randomly assigned to a 20-meter shuttle ride or Yo-Yo Intermediate Recovery. All participants measured the lactic acid concentration after each exercise test. There were no significant differences in the VO2max (ml/kg/min) results in each test. There was no significant difference immediately after exercise of each test, after 5 minutes, after 10 minutes, and after 20 minutes. Compared to the golden standard GXT, there is no difference in maximum oxygen intake and lactic acid concentration after the two field tests, so both tests are expected to be efficiently used to evaluate the aerobic ability and develop training programs in the field.

Key words: cardiopulmonary, shuttle run, Yo-Yo test, handball, athletes

Introduction

Handball matches are held for a total of 60 minutes, 30 minutes in the first half and 30 minutes in the second half, and although the content of the game may vary depending on the team, it is a sport in which fast conversion and intense physical body check occur. It is a sport that consumes very fast physical strength during the game, and it is very important to recover

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quickly for the second half of the game through a 10-minute break in the middle of the game. Moreover, handball, a team sport, is one of the most important factors in aerobic exercise (Gharbi et al., 2015).

The maximum oxygen intake (VO_2max) of sports athletes who continue to run at high intensity after a short recovery time, such as handball games that require repeatedly explosive short-distance sprints, is reported to have a significant relationship with the athletic ability (Bishop et al., 2004). The graded exercise test (GXT) to evaluate the aerobic endurance of elite athletes is used as a golden standard test to measure VO_2max (Poole & Jones, 2017). This test is a method of measuring gas exchange between oxygen (O_2) and carbon dioxide (CO_2) using an automatic metabolic analyzer (Mänttäri et al., 2018). GXT for maximal oxygen uptake measurement must be measured using an automatic metabolic analyzer, so there is a difficulty that requires expensive equipment and professionals. Methods for measuring aerobic exercise capacity have been devised to compensate for these problems.

Among them, are the Multistage 20-m Shuttle Run Test (Léger & Lambert, 1982) and Yo-Yo Intermittent Recovery test level 1 (Yo-Yo IR1) (Bangsbo, 1994) were proposed. The ability to perform aerobic exercise is evaluated by the number of times 20-m shuttle run and Yo-Yo IR1 reciprocated at a continuously increasing speed within 20m space. In this regard, studies are being conducted to examine the relationship between 20-m shuttle run (Mayorga-Vega et al., 2015) and Yo-Yo IR1 (Castagna et al., 2006) and maximum oxygen intake in elite athletes. In particular, these two tests have very similar characteristics to handball games with incomplete rest time in the test.

However, tests have been conducted so far to evaluate aerobic exercise performance, and studies on what tests are suitable considering the characteristics of handball sport that repeat repetitive explosive short-distance sprints and intermittent exercises are insufficient. Furthermore, investigate how important changes in lactate concentration appear in glycolysis and aerobic energy systems as well as aerobic exercise performance. Therefore, the purpose of this study is to establish a simpler to assess cardiopulmonary function evaluation for handball athletes whose continuous aerobic ability is important in games using field tests (20-m shuttle run and Yo-Yo IR1 test) and to provide basic data on changes in lactic acid concentration.

Method

Participants

A total of 8 youth elite male handball athletes participated in this study. All participants measured the graded exercise test, the 20-m shuttle run test, and the Yo-Yo Intermittent Recovery Test Level 1 test (Yo-Yo IR1).

All participants voluntarily participated after hearing the procedure and purpose of this study and conducted it after obtaining consent in writing.

The characteristics of the participants are shown in <Table 1>.

Measurement of body composition

In measuring the participants' body composition, the height was measured using an extensometer. Weight, body fat mass, and fat loss were measured using a body composition analyzer (InBody 770, Body Composition Analyzer InBody, Seoul, Korea) by impedance

Table 1. *Characteristics of participants*

	All participants (n = 8)
Age (years)	17.0 ± 1.04
Height (cm)	178.4 ± 5.2
Weight (kg)	79.1 ± 12.6
BMI (kg/m^2)	24.77 ± 3.12
Percent fat (%)	18.4 ± 3.01

measurement. Height and weight were recorded in units of 0.1cm and 0.1kg.

Graded exercise test (GXT)

The graded exercise test was measured using a treadmill and measured using the KISS-M Protocol developed by the Korea Institute of Sports Science. KISS-M Protocol fixes the slope of the treadmill to 6%, the initial start speed is 90 m/min, and the speed of 20 m/min gradually increases every 2 minutes.

The timing of stopping the exercise test is as follows. First, when the athlete's oxygen intake did not increase by more than 150ml/min and the expression of a steady-state appeared, secondly when the expected maximum heart rate was reached (220-age), and thirdly when the respiratory exchange ratio (RER) was 1.15. Fourth, ratings of perceived exertion (RPE) is 17 or more, and fifth, when the lactic acid concentration was 8 mmol or more, it was judged as the maximum exercise load when two or more of the five items were satisfied. Oxygen intake and heart rate during exercise were analyzed with a fully automatic metabolic analyzer (Quark CPET, Cosmed, Italy).

20-m Shuttle Run Test

All participants run a 1x20m section according to the measurement sound coming from the speaker. The beginning start speed starts at 8.5 km/h, and a beep sounds so that the round-trip section speed increases by 0.5 km/h at 1-minute intervals. If the participant did not arrive on time more than twice, the test was stopped.

The maximum oxygen intake according to the 20-m shuttle run test was calculated by referring to the estimation formula developed for adolescents by the National Sports Promotion Foundation (2015), and the calculation formula is as follows:

Estimation formula: VO_2max (ml/min/kg) = 40.368 + 4.943 + 0.069 (age) - 0.525 (BMI) + 0.196 (LAPS)

Yo-Yo Intermediate Recovery Test Level 1 Test

The Yo-Yo Intermittent Recovery Test 1 (Yo-Yo IR1) test allows the participant to run 2×20m to the sound coming from the speaker and then take a dynamic rest in the 5m recovery section before the next stage begins.

The speed of the round-trip section gradually increases, and the speed and distance are presented in <Table 2>.

In addition, Yo-Yo IR1's VO2max estimation was calculated by referring to the estimation equation developed by Bangsbo et al. (2008), and the calculation formula is as follows:

Estimation Formula: VO_2max (ml/min/kg) = IR1 distance(m) × 0.0084 + 36.4.

Measurement of lactic acid concentration

For analysis of blood lactate concentration, 20 μl of blood was collected in a capillary tube immediately after exercise, 5 minutes after exercise, 10 minutes after exercise, and 20 minutes after exercise using the fingertip

Table 2. *Yo-Yo IR1 test protoco*

	Speed ($km \cdot h^{-1}$)	Shuttle bouts (2×20m)	Split distance (m)	Accumulated distance (m)
1	10	1	40	40
2	12	1	40	80
3	13	2	80	160
4	13.5	3	120	280
5	14	4	160	440
6	14.5	8	320	760
7	15	8	320	1,080
8	15.5	8	320	1,400
9	16	8	320	1,720
10	16.5	8	320	2,040
11	17	8	320	2,360
12	17.5	8	320	2,680
13	18	8	320	3,000
14	18.5	8	320	3,320
15	19	8	320	3,640

method. The collected samples were put in a micro test tube containing lactate hemolyzing solution, mixed well, and analyzed using a lactate concentration analyzer (Biosen C-line lactate Analyzer, Germany). All lactate concentration measurements were repeated three times per sample to minimize errors in the measurement results.

Statistics

All statistical analyses were conducted using the SPSS statistical package for Windows, version 25.0 (SPSS, Inc., Chicago, IL, USA). Means and standard deviations were computed for all variables, and all variables were verified through a one-way analysis of variance (ANOVA). A Bonferroni test was used for post hoc analysis. Statistical significance was accepted at a = 0.05.

Results

Result of GXT, 20-m shuttle run, Yo-Yo IR1

The results of the GXT, 20-m Shuttle run, and Yo-Yo IR1 test are shown in <Table 3>.

The results of the GXT showed that the maximum exercise duration was 990 sec and the minimum exercise duration was 780 sec. The 20-m shuttle run test showed that the maximum exercise distance was 2260m (113×20m) and the minimum exercise distance was 1760m (88×20m). Yo-Yo IR1 test results showed that the maximum exercise distance was 2640m (66×2×20m) and the minimum exercise distance was 1840m (46×2×20m).

VO_2max (ml/min) was found to be a maximum of 5088 (ml/min) and a minimum of 2930 (ml/min).

Comparison of maximum oxygen intake per weight

The results of VO2max (ml/kg/min) are shown in <Figure 1>.

Table 3. *Results of GXT, 20-m shuttle run, and Yo-Yo IR1*

		All participants (n=8)
GXT	Exercise duration (sec)	923.75 ± 80.12
	VO_2max (ml/min)	4205.75 ± 883.81
	VE (l/min)	112.58 ± 21.32
	HRmax (bpm)	193.13 ± 8.22
20-m Shuttle run (laps)		102 ± 10.3
Yo-Yo IR1 (laps)		54.63 ± 5.71

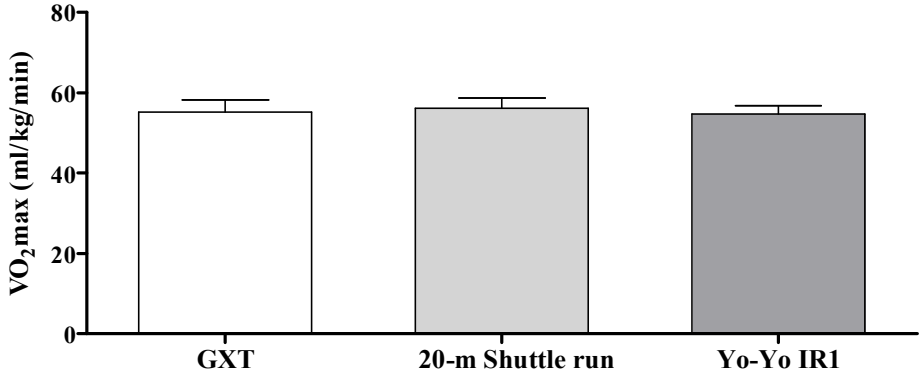

Figure 1. *Comparison of maximum oxygen intake per weight*

The mean value of VO2max (ml/kg/min) shown in the GXT was 55.2 ± 2.9 (ml/kg/min), up to 59.6 (ml/kg/min) and at least 52 (ml/kg/min). The mean value of VO2max (ml/kg/min) estimated by the 20-m shuttle run test was 56.1 ± 2.6 (ml/kg/min), with a maximum of 58.8 (ml/kg/min) and a minimum of 52.3 (ml/kg/min). The mean value of VO_2max (ml/kg/min) estimated by the Yo-Yo IR1 test was 54.8 ± 1.9 (ml/kg/min), up to 58.6 (ml/kg/min), and at least 51.9 (ml/kg/min).

There were no significant differences in the VO_2max (ml/kg/min) results in each test.

Changes in lactic acid concentration

The results of lactic acid concentration measurement after each test are shown in <Figure 2>.

There was no significant difference immediately after exercise of each test, after 5 minutes, after 10 minutes, and after 20 minutes.

Discussion

The purpose of this study is to investigate the change in lactate concentration according to the cardiorespiratory endurance function evaluation test methods that can be accessed in the field in the form of repeated explosive short-distance sprints and rest as a characteristic of handball and to suggest a simple method to measure cardiopulmonary endurance function with a low risk of injury in the field. As a result of the study, there was no significant difference between the GXT and the 20-m shuttle run and Yo-Yo IR1 tests. In addition, there was no significant difference for each section in the lactic acid concentration test.

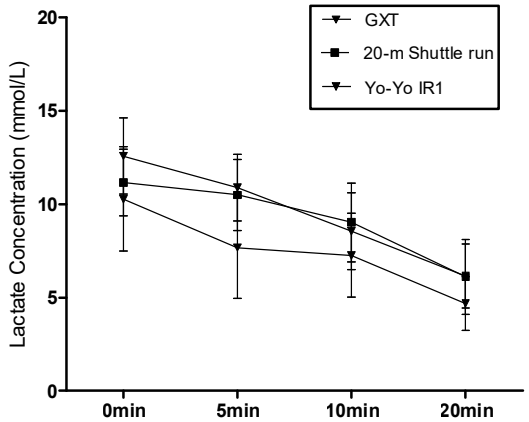

***Figure 2**. Changes in lactic acid concentration*

To evaluate cardiopulmonary endurance, that is, aerobic exercise ability, 20-m shuttle run and Yo-Yo IR1 are used as representative methods in the field. Tomkinson et al. (2019) reported that a 20-m shuttle run has very high reliability and effectiveness in evaluating cardiopulmonary endurance function and exercise ability in adolescence. The correlation between the number of round trips of 20-m shuttle runs and the maximum oxygen intake in healthy adults was 0.87, which was found to be useful in predicting aerobic fitness and maximum oxygen intake in the field (Paradis et al., 2014). Grgic et al. (2019) conducted a Yo-Yo test reliability test on soccer players and reported a correlation coefficient for test-retest reliability between 0.78 and 0.98. In the results of previous studies, it is reported that 20-m shuttle run and Yo-Yo IR1 have secured validity for cardiopulmonary function evaluation.

As a result of this study, there was no significant difference in maximum oxygen intake in the GXT, 20-m shuttle run, and Yo-Yo IR1 measurements. Unlike marathon runners, handball matches do not run continuously during match time, but have a transition between switching offense and defense, operational time, and halftime. The 20-m shuttle run must run continuously during the measurement time, while the Yo-Yo IR1 test can be utilized with time to rest depending on the athlete's abilities during the measurement time. It can be seen that there are differences between the two measurement methods. However, in this study, there is no significant difference between the two measurement methods and the maximum oxygen intake through the GXT, which can be called a golden standard test, so both methods are expected to be used to measure maximum oxygen intake

for handball athletes.

During intense exercise, ATP is mainly produced from blood sugar and muscle glycogen to promote the process, and lactic acid is considered an aerobic metabolite available in skeletal muscle and myocardium when oxygen availability is appropriate, contributing to the formation of acetyl-CoA, the beginning of the aerobic energy system (Proia et al., 2016). In addition, it is known that the accumulation of lactate through continuous exercise releases more K+ and increases fatigue in muscles contracting due to decreased pH in the muscles (Bangsbo & Hostrup, 2019). Traditionally, lactic acid is considered a factor that negatively affects exercise performance as a major cause of waste and muscle fatigue, but it is also considered an intermediate fuel for aerobic metabolism through various recent studies (Dong et al., 2021).

This study compared the lactate concentration with the comparison of maximum oxygen intake through a 20-m shuttle run and Yo-Yo IR1 tests to evaluate aerobic exercise ability in elite handball athletes. Measurement of lactic acid concentrations immediately after three tests (GXT, 20-m shuttle run, and Yo-Yo IR1) showed a numerical difference, but no significant difference for each test type. The exercise volume of golden standard GXT and exercise volume of the two field tests used in this study are almost the same (Comfort & Matthews, 2010), and therefore, they had almost the same effect on the change in lactic acid concentration. As there was no significant difference in lactate concentration between tests, similar to that there was no significant difference in maximum oxygen intake, it is considered that it can be used to evaluate the aerobic exercise ability of elite handball athletes in the field.

The present study has some limitations and points to suggestions for further research. This study consisted only of male handball athletes. In the case of female handball athletes, the same results may not appear. Another limitation is that the sample size was relatively small, and further studies with larger populations are required to validate our findings. Therefore, additional studies with larger sample sizes and different gender are required to determine the effectiveness.

Conclusion

In this study, a 20-m shuttle run and Yo-Yo IR1 test were performed on elite handball athletes, and a valid test to evaluate the cardiorespiratory endurance of handball players was proposed and trained through comparative review with the GXT known as golden standard tests, and to provide basic data for training program development.

Compared to the golden standard GXT, there is no difference in maximum oxygen intake and lactic acid concentration after the two field tests (20-m shuttle run and Yo-Yo IR1 test), so both tests are expected to be efficiently used to evaluate the aerobic ability and develop training programs in the field.

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