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Determination of maximal oxygen uptake through a new basketball-specific field test

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abstract

Background The aim of this study was to develop a new basketball-specific field test (BSFT) that determines the maximal oxygen uptake indirectly and to determine the reliability and validity of the test for measuring aerobic power.

Material/Methods An aerobic endurance-based test totalling 1.5 miles on a basketball court including side steps and running was designed to be completed as quickly as possible. 15-year-old, male basketball players' maximal oxygen uptake (VO_{2max}) levels measured directly as the gold standard laboratory test.

Results Laboratory test results showed a significant negative correlation between the VO_{2max} level and the duration of the BSFT (r = -0.705, p = 0.015). Regression analysis through the BSFT proved moderate validity (R^2 = 0.390), and the following regression formula was then developed to estimate the VO_{2max} level: 122.617–5.461×(BSFT duration). The reliability was evaluated by the test-retest method; there was no difference between the duration of the BSFT (p > 0.05) repeated at intervals, and this test showed high reliability (%CV:8.81 and ICC:0.90).

Conclusions The BSFT, which proved to be reliable and valid for measuring aerobic power indirectly, may be considered to help coaches and athletes by means of its properties that do not require expensive equipment and specialist staff and ensure easy and practical application by using simple basketball-specific movements on basketball courts.

Key words VO_{2max}, basketball, field test, validity, reliability

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INTRODUCTION

Basketball has gained popularity across the world due to its dynamic characteristics. Players perform frequently repeated accelerations and decelerations in different directions at various speeds over a distance of 6.0–7.5 km [1, 2, 3] for 40 mins on an area of 28 m in length and 15 m in width [4]. Basketball game is highly intermittent with substantial contributions from the alactic, lactic and oxidative energy systems and requires players to have well-developed aerobic capability (VO_{2max}) and anaerobic power. A high VO_{2max} level enhances the recovery period during and after intense intermittent exercise via improved lactate removal and enhanced creatine phosphate regeneration [5, 6]. Previous research [7, 8, 9] reported that the VO_{2max} level in young male basketball players ranges from 53.4 to 68.6 ml/kg/min^{-1}; these levels were determined to be in the range of 51.4–53.8 ml/kg.min^{-1} for guards, forwards and pivot players who were under 19 years old [10].

The heart rate (HR) fluctuation throughout the game has been shown in studies on basketball players, arising from the frequency and the intensity of transitions between attacks and defences in basketball. Therefore, HR ranges measured during games were found to be 171 ±4 and 162 ±7 bt/min [8, 10]. It was also found that 20% of the first period of the game was played at maximal intensity, 58% at high intensity, 15% at moderate intensity and 5% at low intensity. During the second period, it was observed that maximal and high-intensity movements decreased, and moderate and low-intensity movements increased [2].

The determination of the VO_{2max} level, which reflects the ability of the cardiovascular system to deliver oxygen to the working muscles, is based on aerobic power tests by direct or indirect methods. Direct measurement methods are maximal tests that continue until exhaustion and are performed in laboratories using metabolic measurement equipment; they are accepted as the “gold standard” in measuring aerobic power [11]. Although the VO_{2max} level is a useful criterion of the overall capacity of an individual to perform exercise aerobically, its direct determination demands sophisticated instrumentation, plenty of time in a laboratory and trained personnel. Consequently, such measurements may not be practicable for large groups of individuals. [12, 13, 14].

Simple field and laboratory tests to provide an estimate of VO_{2max} are generally developed based on distance, time or HR. Although they have such advantages as low cost, applicability through submaximal loads to many people simultaneously, and no need for trained staff, such measurements require well-motivated subjects and an understanding of the test requirements.

Determination of the validity of an assessment necessitates comparing what is measured with the result obtained from a standard test defined as the “gold standard” to comprehend the validity of any test. To approve a predicted test as “validated”, it is usually expected that the validity coefficient should be ≥ 0.80 [15]. Reliability can be defined as the repeatability of a measurement process during the measurement or consistency in repeatability. Field-based test reliability is determined by evaluating the results of the test repeated every other week through the test-retest method [16, 17].

There are few field tests in the literature that measure the VO_{2max} level outside laboratory conditions in basketball, including basketball-specific patterns of movement that can be applied on a basketball court and whose reliability and validity in measuring aerobic capacity are proven.

The aim of this study is to develop a new basketball-specific field test (BSFT) and to examine its reliability and validity in aerobic power measurement in male basketball players who are 15 years old. It is hypothesized that a valid and reliable basketball field test would be developed in estimating the VO_{2max} level.

MATERIALS AND METHODS

The eleven male amateur basketball players aged 15 years were members of a basketball club. They had been training for the last five years (5.18 ±0.41 yrs) with a mean of 12h/wk in the active season. Their mean height, body mass and body mass index (BMI) were 190 ±6.42 cm, 84.4 ±11.6 kg and 23.3 ±2.54 kg/m^2, respectively. The basketball players performed all tests within the arrangement of their lessons, training and game programmes during the season.

They were informed of the nature of the study, and they signed informed consent forms according to the instructions of the Helsinki Declaration Principles and those of the local ethical committee.

The height and body mass of the athletes were measured through standard methods (Seca 769, Hamburg, Germany), and their BMI were calculated. Bland-Altman method was also used to assess the degree of agreement between a new measurement technique (BSFT) and an established one (gold standard test).

For direct measurement of VO_{2max}, adaptation sessions were performed with low loads so that the athletes could easily adapt to the laboratory conditions, the test ergometer, and components of the gas analyser, such as the nozzle and nose clips. A submaximal test protocol initiated at 130-150 pulse levels and increased stage by stage, consisting of 4-, 4-, 4-, 4-, 2-, and 2-mins (at each stage, 0.8-1.0 km/s speed rates), was conducted to detect the beginning load of the VO_2peak test. This test aimed to reach the estimated anaerobic threshold (pulse level 150–170, maximal pulse reserve did not exceed 80%; ~60–70% VO_2peak) [18]. The VO_2peak test began with the load determined as a result of the submaximal test, with 2-min-standard increased stages (0.8 or 1.0 km/s speed increases at each level) aiming at exhaustion. During the tests, the averages of HR, VO_2, and VCO_2 were recorded uninterruptedly, and the respiratory exchange ratio (RER) during the last 30 s of each stage was considered [18]. VO_2peak was confirmed when three or more of the following criteria were met: (a) a plateau in VO_2 despite an increase in the work load, (b) a respiratory exchange ratio (RER) higher than 1.1, (c) a peak heart rate of at least 90% of the age-predicted maximum, and/or (d) visible exhaustion [19].

The verification test was conducted one day after the VO_2peak test to confirm the VO_{2max} level. This test started with the last-stage load of the incremental VO_2peak test and continued until voluntary exhaustion occurred between the 4th and 7th mins of the test.

During the tests, HR was monitored through the telemetrical method (Polar Electro, Tampere, Finland), and respired gases (VO_2 and VCO_2) were analysed through the automatic metabolic system (Cosmed Quark b^2, Cosmed, Italy). Quark b^2 was calibrated in accordance with the instructions of the manufacturer prior to each measurement, and the turbine flowmeter was calibrated via a 3-L syringe (Quinton Instruments, Seattle, USA) [19].

An aerobic endurance test was designed, which includes side steps for intense defence and attack on the 3-point-line and runs on side-lines. The goal was set to finish within the shortest time period, and it was 1.5 miles (2414 m) in total (Fig. 1).

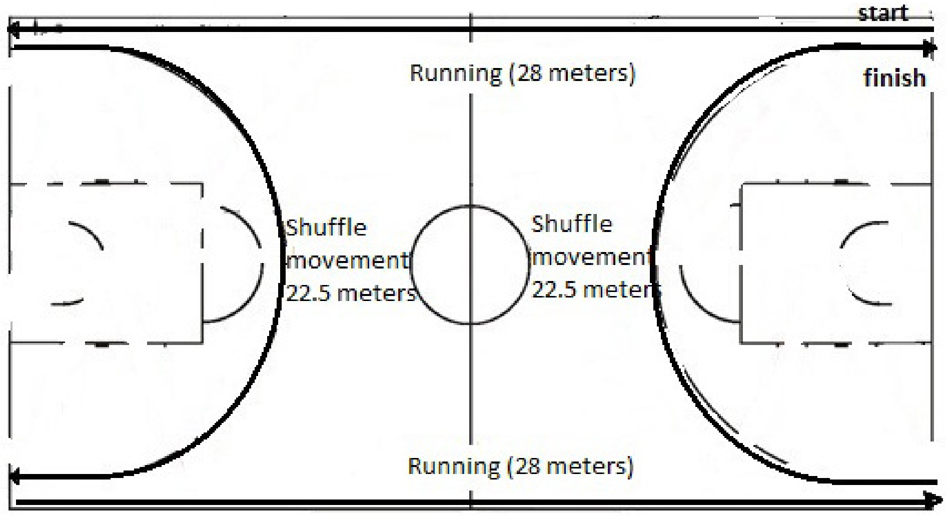

Fig. 1. Basketball-specific field test

The test was performed inside a sports hall which was prepared by marking start and finish lines. The BSFT distance was composed of 23.9 "laps" and the total distance of one "lap" was 101m. In order to ensure that the numbers of laps are followed, more than one player can be tested by starting in 3–4 mins intervals. One trainer provided both verbal motivation and encouragement for the players and informed of the number of laps during the test session. Before performing the test, players did 10-min warm-up exercises which consisted of low intensity running and whole body dynamic stretching exercises and they were also instructed to step on the lines, so the use of any cone was not needed when the area was determined.

While developing the BSFT, some studies were used that identify physical activity needs required for basketball, examine the physiological characteristics of basketball [2] and analyse time and movement in basketball [1, 4]. Professional basketball coaches, trainers and academicians were consulted for their viewpoints while creating basketball-specific patterns of movements in the field-based test. In the BSFT, skills-required movements, such as dribbling, passing and shooting were not included, the reason being that it is possible that skills-required movements will reduce motivation and running performance during the test. A commonly used 1.5-mile running test whose reliability and validity have already been proved was selected while determining the total distance of the field test. A 1.5-mile running distance, which is an indicator of aerobic capacity, is accepted as an appropriate distance in determining the VO_{2max} value [19].

The 1.5-mile running test was performed under similar conditions twice on different days. The completion time of the 2414 m running distance was recorded, and the average measurement was calculated for each individual.

The participants were taken to familiarization trials for the BSFT, and average completion duration of the three field tests carried out on different days which were organised minimum two days interval was then calculated and recorded as min-s. HR was measured through the telemetrical method during each field test.

Data were analysed using SPSS v16.0 (SPSS Inc., Chicago, IL, USA), following normality (Shapiro Wilk test) and homogeneity (Levene test) testing. The reliability levels of the tests were evaluated through the intraclass correlation coefficient (ICC), the coefficient of variation (CV%) = [(SD/mean value) × 100] and the t-test for Dependent Samples or the Wilcoxon Signed Rank Test. The dependent variables, analysed with non-parametric tests, are identified using the "¥" symbol in the tables.

The validity evaluation of the test was based on Pearson's r correlation coefficient analysis through the duration of the BSFT, VO_{2max} test (gold standard test) and duration of the 1.5-mile running test. The level of reflection (R^2) for the VO_{2max} level of the developed test variables was examined through linear regression analysis, and a regression formula was obtained. Finally, this regression formula was applied to the test group, and the results were compared with VO_{2max} results in the laboratory through the t test for Dependent Samples or Wilcoxon Signed Rank Test.

RESULTS

Table 1 indicates the basketball players' HR values (bt/min) and completion durations (min) of the BSFT repeated three times (1-2-3) and 1.5-mile running test repeated twice (1-2). When the data were compared, no significant difference was found in any repeated test results ($p > 0.05$), and high reliability was proved (CV%: 8.81 and ICC: 0.90) (Table 1).

Table 1. Test-retest results (1.-2.-3. repetitions) of the "basketball-specific field test" and "1.5-mile running test" of basketball players

		Min	Max	Mean	± SD	% CV	ICC	p
Basketball-specific field test	HR (bt/min) 1	169	196	183	8.32	4.54	0.97	0.961
	HR (bt/min)2	168	197	183	9.38	5.12		
	HR (bt/min)3	170	195	184	7.87	4.27		
	time (min)1	13.2	16.1	14.3	1.03	7.20	0.90	0.118¥
	time (min)2	13.0	16.1	14.3	1.16	8.12		
	time (min)3	12.1	17.3	13.5	1.49	11.1		
1.5 mile-running test	time (min)1	9.15	13.2	10.7	1.22	11.4	0.94	0.859¥
	time (min)2	9.12	15.2	10.8	1.73	16.2		

± SD: standard deviation, %CV: coefficient of variance, ICC: intraclass correlation coefficient, ¥ shows data evaluated as non-parametric.

A significant positive correlation ($r = 0.816$, $p = 0.002$) was found between the mean completion durations of the BSFT and mean completion durations of the 1.5-mile running test. Furthermore, a significant positive correlation (r = 0.705, p = 0.015) was detected between the VO_{2max} value obtained by formulating the completion duration of the BSFT and VO_{2max} value measured in the laboratory (gold standard). A significant negative correlation was found between VO_{2max} levels measured in the laboratory and the completion duration of the BSFT (r = -0.705, p = 0.015).

In light of this significance level, linear regression analysis was carried out. The validity of the BSFT was proved to be at a moderate level ($R^2 = 0.390$) (Table 2). This following formula was developed via coefficients detected through linear regression analysis to determine VO_{2max} indirectly with the help of the BSFT: VO_{2max} = 122.617 – 5.461 x [test completion duration (min)].

Table 2. Regression analysis result between direct measurement values of VO_{2max} and completion duration of the basketball-specific field test[&]

	Non-standard coefficient		Standard coefficient		
	B	SE	Beta	T	p
Constant value	122.617	32.112		3.818	0.004
Basketball-specific field test end time	-5.461	2.282	-0.624	-2.394	0.040

[&] Dependent variable: direct measurement values of VO_{2max}, SE: standard error

Table 3 indicates comparisons between VO_{2max} values measured directly in the laboratory and obtained indirectly from the formula. No statistical significance between the results was found (p > 0.05).

Table 3. Comparison of the VO_{2max} values calculated by regression formula (ml.kg.dk-1) and VO_{2max} value measured in laboratory

Test in laboratory	Basketball-Specific Field Test–Retest (1-2-3) results			
VO_{2max}	VO_{2max} 1	VO_{2max} 2[¥]	VO_{2max} 3[¥]	Mean VO_{2max}
45.98 ± 9.97	44.49 ± 5.65	44.58 ± 6.34	48.88 ± 8.17	45.98 ± 6.91
p value	0.582	0.182	0.286	0.582

VO_{2max}: Maximal O2 uptake, ¥ shows data evaluated as non-parametric.

Calculated ICC of the two different test methods was found 0.737 with significance at p = 0.029, lower and upper bounds of 95% CI were -0.053 and 0.931.

Bland-Altman method was used to assess the degree of agreement between a new measurement technique (BSFT) and an established one (gold standard test). Differences between two methods were found – arithmetic mean: 0.0018 and its 95% CI: -5.23 to 5.24, p value (H0: mean = 0): 0.9994, standard deviation: 7.79, lower limit:-15.3 and its 95 % CI: -24.5 to -6.04, upper limit: 15.3 and its 95% CI: 6.04 to 24.5. According to graphical results, two VO_{2max} values obtained from different tests were similar and although one sample was out of the upper limit, it did not exceed 95% CI limits range.

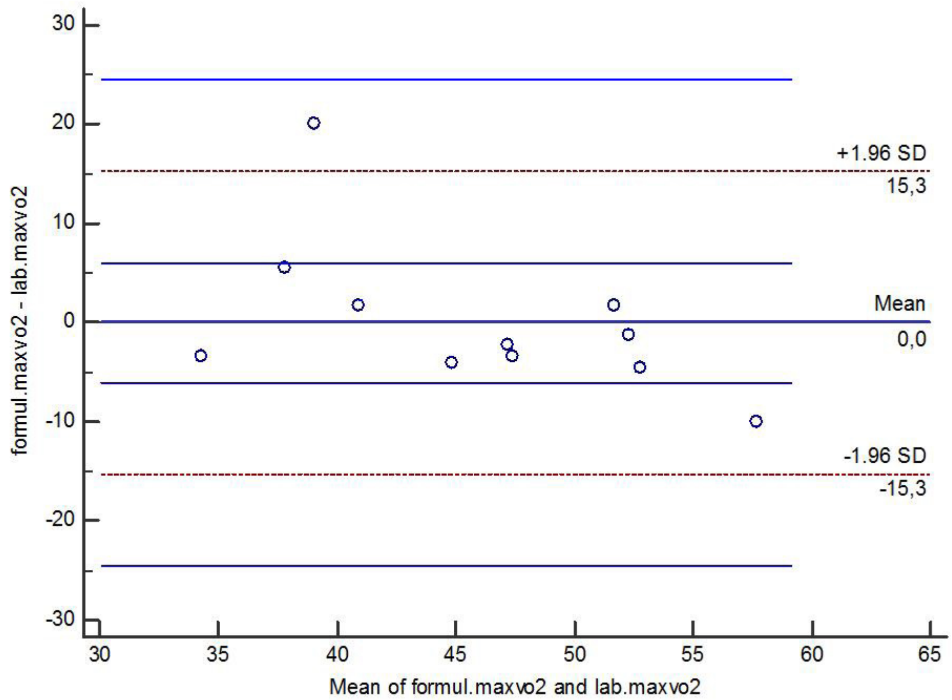

Fig. 2. Assessing degree of agreement between VO_{2max} levels obtained via laboratory test and Basketball-Specific Field Test by Bland-Altman method

DISCUSSION

This study aimed to determine the aerobic power level indirectly by developing a new BSFT. Its reliability, which was based upon the assessment of the "completion duration" of the developed test, appeared to be within the "acceptable" limits in accordance with ICC (0.90) and CV % (0.81). For the test to be reliable, it should fulfil the requirements of ICC > 0.80 and CV % < 10 [20]. A high reliability level will help detect the repeatability of the test results for aims such as talent selection, determination of the performance level or tracking development [21]. For validity analysis, a significant negative correlation was detected between the VO_{2max} test result in the laboratory, which is approved as the gold standard, and completion durations of the BSFT were carried out three times ($r = -0.705$, $p = 0.015$). The reflectivity level for the VO_{2max} level of the developed test variables was examined through linear regression analysis ($R^2 = 0.40$), and a regression formula was obtained through the obtained coefficients. It is suggested that the formula, $VO_{2max} = 122.617 - 5.461 \times$ (test completion duration), can predict the aerobic power level at a 0.40 ratio to be measured. ICC of the two different test methods was found 0.737 with significance at $p = 0.029$. These results were supported by assessing the degree of agreement between the tests ($p = 0.9994$).

Although the test distances are the same, the time of completion of the 1.5-mile test is 10.7 min on average, but the completion duration of the BSFT is 14.0 min on average. The reflectivity level result for the VO_{2max} level of the new field test of 0.40 may be due to the exceeded recommended laboratory test time, which was suggested to last 8–12 mins; this caused local fatigue and prevented the appropriate VO_{2max} level from being achieved [22]. There is another possibility: the regression level depends on the range of results in the sample results. The regression level appeared to be higher in samples with a large range than those with a narrow range [23]. This result may be influenced by the fact that the data on the BSFT analysed in our study did not have a vast range (12.8–16.5 min). The other point to be considered is that players achieved the best BSFT results during the third repetition, even if there were no statistically significant differences between them. Since a large number of repetitions were carried out before the test sessions to eliminate the learning factor, this finding may result from motivational factors of young players.

The 1.5-mile running test is a test developed to detect the general cardiovascular fitness level. This test can be easily carried out, and participants must run with high motivation and at effective speeds for this test to detect the VO_{2max} level accurately. In addition, because it is a maximal test, the test validity depends on participants' maximal efforts. A significant correlation level detected between the 1.5-mile running test applied to male soldiers and the direct measurement of VO_{2max} was found to be higher than that between a 12-min running test and the direct measurement of VO_{2max} ($r = 0.830$ vs. $r = 0.720$) [24].

In the literature, there are several studies examining the reliability and validity of the existing field tests for determining the VO_{2max} level indirectly in basketball. The validity of Yoyo intermittent recovery test-1 was measured for determining the aerobic performance of young basketball players, and 3 different groups (elite, non-elite and sedentary) were subjected to the Yoyo Intermittent Recovery Test. A significant correlation appeared between the body weight of the participants and the Yoyo test performance ($p < 0.017$). These findings are interpreted as follows: the Yoyo test has a characteristic aerobic performance determinant in elite athletes but is not sufficient in determining basketball-specific aerobic performance [25]. However, a significant correlation appeared between the Yoyo intermittent recovery test performance of young basketball players and the VO_{2max} value measured directly on a treadmill ($r = 0.770$, $p < 0.001$). Given these data, it has been interpreted that the Yoyo test is a valid test in determining aerobic performance in basketball [26]. It has been observed in the studies [25, 26] that tests selected to determine aerobic capacity are unsuitable for physical and physiological characteristics of basketball for two reasons: they do not include basketball-specific patterns of movement/running, and they cannot be applied on basketball courts.

There are only a few tests in the literature that are composed of basketball-specific movements and whose reliability and validity are verified.

The Yoyo Intermittent Recovery Test was carried out on semi-professional and recreational male basketball players. In the study, Scanlan et al. were searching for the construct validity and longitudinal validity of the "Basketball Simulation Test (BEST)" they developed. During the BEST, which included basketball-specific patterns of movement, some measurements were recorded: the ratio of the deceleration in speed (%), the average speed (m/s), the round completion time (s) and the total test completion duration (m). Upon comparison of the Yoyo test results with the BEST results, it was suggested that semi-professional basketball players performed better than recreational basketball players, which proved to be significant in both tests ($p < 0.01$). In addition, a strong correlation between the deceleration ratio in speed during the BEST test and changes occurring in Yoyo test performance ($r = -0.815$, $p = 0.014$) has been found. Given these results, the BEST test has been suggested as a valid basketball-specific test [27]. However, it is considered that BEST cannot truly reflect the environment of a basketball game for the following reasons: It is a test carried out on a 3-s corridor, which is a small portion of the basketball court, and its measurement methods are impractical. In addition, it does not indicate any exercise model that is intense enough to determine the VO_{2max} level, a determinant of aerobic capacity in basketball.

Vaquera et al. conducted a study to determine the validity and reliability of the basketball-court-based TIVRE-Basket test in measuring male basketball players' aerobic power. In this study, it was discovered that there is a significant correlation between the average TIVRE-Basket test completion duration and average VO_{2max} value directly measured on a treadmill in the laboratory ($r = 0.824$, $p < 0.001$) [28].

Pilianidis et al. modified the Multi-Stage 20 m Run Test (MSRT 20 m) and developed the Hexagon Multilevel Running Aerobic Test (HMRAT), consisting of 10-m runs to determine young basketball players' (mean age 20.8 ±0.9) aerobic performance. In their study to examine the validity and reliability in determining aerobic performance, they found the coefficient of reliability between two tests to be $r = 0.860$ ($p < 0.01$). Given these findings, it has been discovered that the HMRAT test is reliable and valid in determining basketball players' aerobic performance [29].

LIMITATIONS

A small number of participants of the study and few published sources on the validity and reliability of a branch-specific court test limited the result and the discussion section of the manuscript.

CONCLUSION

It is concluded that a practical and economical test that is easy to apply in basketball and does not require any measurement tool or a huge amount of time is introduced to the literature. The field of application upon the determination of the reliability and validity of the BSFT is developed in measuring aerobic performance. Furthermore, thanks to this test, it may be easy for the trainers to collect determinant tangible data in either the selection of players or the tracking of performance progress.

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