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Accuracy and Criterion-Related Validity of the 20-M Shuttle Run Test in Well-Trained Young Basketball Players

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A B S T R A C T

The purpose of the present study was to evaluate the specificity of a 20-m shuttle run test (SRT) as a measure of maximal oxygen consumption (VO_{2max}) in young well-trained basketball players. Thirty-four volunteers (mean ± SD; age 15.74 ± 1.23 years, height 187.61 ± 7.95 cm, body mass 74.09± 11.61 kg; training experience 6.30± 2.15 years) participated in the study. The 20-m shuttle run test was performed wearing a portable gas analyzer (K4b2, Cosmed) to measure VO_{2max} during the test. SRT-derived VO_{2max} underestimated directly measured values (48.91 ± 4,11 vs 55.45 ± 4.98). Mean bias was 6.54± 3.89 ml kg^{-1} min^{-1} (95% CI- 5.18 to 7.90 ml kg^{-1} min^{-1}). Typical error of the estimate was 3.85 ml/kg/min^{-1} (95% CI- 3.10 to 5.10 ml kg^{-1} min^{-1} ; ES= 0,77). There was a moderate correlation between VO_{2max} directly measured and estimated by SRT (r= 0.65; 95% CI- 0.40 to 0.81, power = 0.84, p < 0.01). Although very popular among coaches, it seems that SRT is not an appropriate field test to measure maximal oxygen consumption in young well-trained basketball players.

Key words: *Team sports, Field test, Maximal oxygen consumption.*

Introduction

Performance in basketball is multifaceted and depends on a complex interaction of several factors, with well-developed physical fitness considered to be one of the most important (Ostojic, Mazic, & Dikic,2006). As the game is saturated with jumps and other explosive activities variable in time and distance (Ben Abdelkrim, Castagna, El Fazaa & El Ati, 2012), anaerobic power is widely recognized as a strong determinant of basketball performance (McInnes, Carlson, Jones & McKenna 1995; Delextrat & Cohen 2008). However, the intermittent activity pattern demands for aerobic qualities sufficient to sustain repeated short bouts of high-intensity anaerobic exercise (Bishop, Edge & Goodman 2004), as restoration of phosphocreatine was found to be largely dependent on aerobic metabolism (Piiper & Spiller 1970). Maximal oxygen consumption (vo_{2max}) has been found to be significantly correlated to both total time spent in high-intensity activity during (Ben Abdelkrim, Castagna, El Fazaa & El Ati, 2012) and basketball-specific repeated sprint ability test after the game, indicating its importance to overall game-intensity (Meckel, Gottlieb & Eliakim 2009). Consequentlly, VO_{2max} is considered an important fitness atribute regularly tested in modern basketball.

Maximal oxygen consumption in basketball players can be evaluated using a variety of testing protocols, with tests on a treadmill measuring gas exchange in laboratory settings considered to be the “gold standard”. However, trained personnel, expensive equipment required and considerable time spent in testing one player at the time, preclude laboratory testing as the preferred method of aerobic fitness assessment in basketball, except for professional players (Gore, 2000). Therefore, several continuous field-tests have been proposed as practical alternatives (Ramsbottom, Brewer & Williams, 1988; Krustrup et al, 2003), with the 20-m shuttle run test (SRT) arguably the most popular. It requires limited equipment, is time-saving and easy to administer. Although several equations have been developed to estimateVO2max from maximal speed attained during the 20-m shuttle run test, Ramsbottom *et al*. equation (via Brewer *et al*. table) is the one commercially presented and widely used in practice. Interestingly, the SRT criterion-related validity has not been thoroughly examined, with controversial results presented accros different populations. While few studies revealed high correlations (r ≥ 0.81; Paliczka, Nichols & Boreham 1987;

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Ramsbottom, Brewer & Williams, 1988), several others reported low correlation coefficient between predicted and measured VO_{2max} (Cooper, Baker, Tong, Roberts & Hanford, 2005; Liu, Plowman & Looney, 1992; Stickland, Petersen & Bouffard, 2003; Ruiz, Silva, Oliviera, Ribeiro, Oliveira, & Mota, 2009). Conflicting results have also been published concerning the accuracy of SRT, with estimated VO_{2max} frequently shown to underpredict data obtained while continously running on the treadmill (Grant, Corbett, Amjad, Wilson & Aitchison, 1995; Penry, Wilcox & Yun, 2011; St. Clair Gibson, Broomhead, Lambert & Hawley, 1988; Stickland, Petersen & Bouffard, 2003).

The 20-m shuttle run test is widely used to estimate aerobic power in team sports, including basketball. Its stop-and-turn actions on a 20m distance clearly resembles a basketball game and practice movement patterns and is therefore believed to have a high level of ecological validity. However, despite its popularity among basketball coaches and purported validity, to the author's best knowledge, no study has been conducted to examine accuracy and criterion-related validity of SRT in young basketball players (population validity; Te Wierike et al, 2014). Although there are several equations to predict VO_{2max} from SRT test results, the table of values presented by Brewer *et al* (1988) and accompanying the original SRT CD has been extensively used in basketball practice. In addition, there is concern about the specificity of conventional treadmill protocols used to produce maximal values of oxygen consumption (Beltrami, Froyd, Mauger, Metcalfe, Marino & Noakes,2012). For example, it has been suggested (Kang, Chaloupka, Mastrangelo, Biren & Robertson, 2001) that the most desirable treadmill test protocol for trained subjects should involve the speed/gradient combination that is similar to what the individual uses during regular training. In that context, it has been argued that the preferred protocol for assesing VO_{2max} in basketball players should mimic sport activity patterns of frequent decelerating and accelerating, which is obtainable through shuttle run test (Flouris & Klentrou, 2005). Portable gas analyzers with high precision and validity have been presented a while ago, making direct metabolic measurements during field-testing feasible (McLaughlin, King, Howley, Bassett & Ainsworth, 2001). Consequently, elucidating the relationship between VO_{2max} directly measured when performing the 20-m shuttle run test and estimated VO_{2max} derived from the 20-m shuttle run test could provide more valid data concerning SRT applicability as a measure of aerobic fitness in basketball youngsters.

The SRT has not been validated using a young basketball playing population. Changes in body size and composition with growth and maturation influence the anaerobic and aerobic performances (Baxter-Jones, 1993) and may in turn influence SRT. Therefore, the aim of the present study was to evaluate the specificity of 20-M shuttle run test (SRT) as a measure of VO_{2max} in young well-trained basketball players.

Methods

Experimental Approach to the Problem

A cross-sectional study design was carried out close to the end of the competition period (first two weeks in April 2011). All tests were performed during early-evening (16^{30}-18^{30}) training sessions on wooden basketball court, at "Lukovski" basketball center in Novi Sad (Serbia). Players not scheduled for testing were engaged in training consisted mainly of low-intensity tactical drills after a standard warm up. The environmental temperature was 22 to 25°C and the relative humidity ranged from 40 to 60% on all testing days. All participants performed the 20-m shuttle run test according to procedure (Brewer, Ramsbottom & Williams, 1988), wearing a portable gas analyser for VO_{2max}. To establish relationships between directly measured and estimated VO_{2max}, obtained results were correlated using Pearson's correlation analysis. Difference between two means was tested with paired t-test.

Subjects

Thirty four volunteers (mean ± SD; age 15,74 ± 1.23 years, height 187.61 ± 7.95 cm, body mass 74.09± 11.61 kg; training experience 6.30± 2.15 years) were randomly chosen within a population of young elite-level basketball players of Vojvodina region (Serbia), in the study approved by the Ethical Advisory Commission. All subjects were members of three teams continuosly competing in the «Serbia quality league», with all teams qualifying for the final-four tournaments for their respective age-group during the calendar year when the study was conducted. All of the subjects and their parents/guardians gave written informed consent after a detailed explanation about the aims, benefits, and risks involved in this investigation. All participants were informed that they could withdraw from the study at any time without penalty. All the players were practicing basketball for at least 3 seasons and participated in 4-5 training sessions a week, for 75-90min per session and played a competitive match every weekend. They were all healthy and free of injuries at the moment of testing, and were not taking any medications. All measurements were obtained by the certified four-man squad. Subjects were familiarized with the test as they perform it as a part of their regular training process over the season. They were advised to avoid intensive exercise 48 h prior to the data collection.

Procedures

Before the testing, body mass and height were measured for each subject. Body mass was measured using body composition monitor (BC-554, Tanita Corporation, Tokyo, Japan) to the nearest 100 gram, and height was determined with portable stadiometer (SECA 210, Hamburg, Germany) to the nearest millimeter, with barefoot participants wearing underwear only. The same investigator carried out all anthropometric measures.

The SRT was performed in accordance to published procedures (Brewer, Ramsbottom, & Williams, 1988). In a nutshell, participants performed the test in groups of 5 and were instructed to run back and fort between two lines 20 m apart, while keeping pace with audio signals emitted from a pre-recorded CD. The speed at the first minute was 8.5 km h^{-1} and was increased by 0.5 km h^{-1} every minute. The test ended when the participant stopped or failed to maintain the prescribed pace for two consecutive signals, based on umpire opinion. Strong verbal encouragement was provided during the test. The final stage reached is recorded and VO_{2max}, estimated using the table provided by Brewer et. al (1988).

During the SRT test, portable gas analyzer was worn by one participant (K4b2, Cosmed, Rome, Italy), with a purpose of sampling metabolic and ventilatory data. Before each test was conducted, the oxygen and carbon dioxide analyzers were calibrated according to the manufacturer's instructions. It has been previously reported that wearing the portable gas analyzer during the 20-m shuttle run test does not significantly alter participants' energy demands (Flouris, Metsios & Koutedakis, 2005). Directly measured VO_{2max} were obtained with VO_{2max} defined as the mean VO_2 value measured during the last 15 seconds of exercise. The criteria for attaining VO_{2max} included any two of the following: volitional exhaustion; attainment of at least 90%

of the age predicted HR_{max} (220-age); RER equal to or greater than 1.10; and VO_2 leveled off even with an increase in intensity (Gore, 2000).

Statistical Analyses

Data analyses were performed using SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Before using parametric tests, the assumption of normality was verified using the Shapiro—Wilks test. Comparison of mean scores for predicted and measured VO_{2max} has been performed with paired *t*-test. Simple correlation was performed using the Pearson product moment correlation coefficient. Confidence intervals (95%CI) were calculated and presented where appropriate. Validity was further elaborated using the typical error of the measurmenet (Hopkins, 2005), which divided by the standard deviation of the criterion measure (Standardized Cohen effect size) was used to determine if the difference between the directly measured and estimated VO_{2max} by SRT were trivial (<0.20); small (0.2-0.6); moderate (0.6-1.2); large (1.2-2.0) or very large (>2.0). Power calculations were calculated using G*Power (Version 3.1, University of Dusseldorf, Germany). The probability of type 1 error (alpha) was set a priori at 0.01 in all statistical analyses. Data are presented as mean ± SD.

Results

All participants achieved maximal effort during the test. Directly measured and estimated VO_{2max} while performing the 20-m shuttle run test were 55.45± 4.98 mLkg^{-1}min^{-1} and 48.91± 4.11 mLkg^{-1}min^{-1} respectively, with significant difference between 2 means (p= 0.000) (Figure 1).

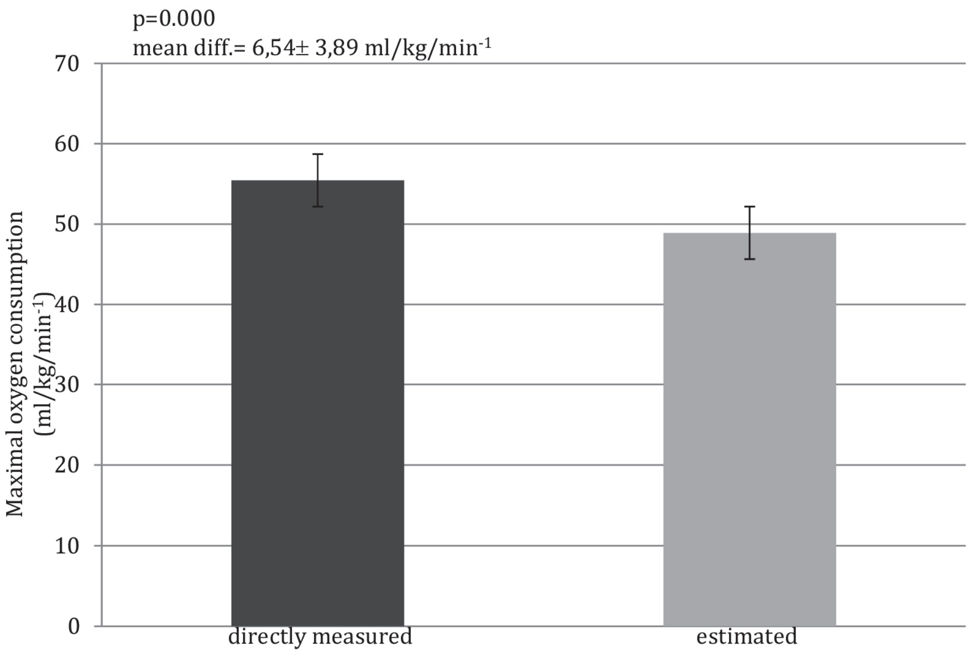

Figure 1. Directly measured and estimated Vo_{2max} (p= 0.000); mean difference= 6.54± 3.89 ml/kg/min^{-1}

Mean difference was 6.54± 3.89 ml kg^{-1}min^{-1} (95% CI- 5.18 to 7.90 ml kg^{-1}min^{-1}). Typical error of the estimate was 3.85 ml/kg/min^{-1} (95% CI- 3.10 to 5.10 ml/kg/min^{-1}), with the corresponding standardized Cohen effect size of 0.77 scored as "moderate". There was a significant correlation between VO_{2max} directly measured and estimated by SRT (r= 0.65; 95% CI- 0.40 to 0.81, power = 0.84, $p < 0.01$) (Figure 2).

Discussion

In this study, we examined the criterion validity of the 20-m shuttle run test to predict VO_{2max} in young male basketball players. The results demonstrated that 20-m shuttle run underestimate directly measured VO_{2max} during the test, with an average value somewhere between 5.18 and 7.90 ml kg^{-1}min^{-1} for the population. Typical error of estimate between measured and estimated VO_{2max} is reported to be of "moderate" magnitude, with only moderate correlation between two measures observed (r= 0.65). To our knowledge, this study is the first to demonstrate that 20-m shuttle run test is not a valid procedure for VO_{2max} estimation in young well-trained basketball players.

Obtained results are in line with several previously reported on the sample of physically trained and/or adolescent population. Kavcic et al (2012) reported that the correlation between the measured and predicted VO2max was too weak (r= .58) to predict the aerobic capacity of young football players, with measured VO2max significantly higher (p<.05), by as much as 8.5 ml kg^{-1}min^{-11} than the SRT-predicted VO2max. Cooper, Baker, Tong, Roberts and Hanford (2005) reported that SRT provides results that are repeatable but underestimates VO_{2max} when compared to laboratory determinations on the sample of 30 active young men. Authors also stated that when scrutinized with more appropriate analysis, the SRT does not provide valid predictions of VO_{2max}. St. Clair Gibson et al (1988) confirmed under prediction of directly measured VO_{2max} by SRT estimation on the sample of 20 trained athletes and reported only "moderate" correlation (r=0.67, p < 0.01), almost identical to result in our study. Sproule, Kunalan, McNeill & Wright (1993) found that 15 out of 20 physical education students had a lower SRT-predicted VO_{2max} value (p < 0.01) compared with results gained by direct measurements. The poorest association between directly measured and SRT-estimated VO_{2max} has been reported in the study of O'Gorman, Hunter, Mc Donnacha and

Kirwan (2000), with nonsignifacant correlation of r=0.41 and r= 0.42 for 15 competitive sports participants and seven international-level rugby players, respectively. Interestingly, when the results from both groups were combined, a significant ($p < 0.05$) correlation ($r = 0.61$) was found. This significant improvement authors attributed to the greater range in both VO_{2max} and SRT scores of combined data.

The present results are also similar to those reported in previous studies done with adolescents. Armstrong, Williams and Ringham (1998) have reported that VO_{2max} in young boys was not accurately predicted by the 20-MST (r= 0.54), while Ruiz et al (2009) reported both similar (r = 0.587; Leger equation) and higher results (r = 0.758; Ruiz equation) for a group of 13- 19 years-old children. The later research is of particular relevance for us, as it has the same study design, with VO_{2max} directly obtained while running the SRT. Interestingly, the reported mean difference for the Leger equation was almost identical to one we found (5.5 vs 6.54 $mLkg^{-1}min^{-1}$) and unusually high in comparison with studies using VO_{2max} values directly measured from treadmill-based protocols (Cooper et al, 2005, Stickland et al, 2003). Although speculative, it could be argued that specific shuttle run movement pattern is likely responsible for the observed difference. It has been reasoned that in order to yield best VO_{2max} results, the test should consist of sport specific performance; VO_{2max} is highly specific to the musculature employed during maximal exercise, as well as to the exercise mode utilized (Stromme, Ingjer & Meen, 1997). Additionally, stopping, turning and side-stepping at the end of each 20-m shuttle has been shown to significantly increase net muscle activation (Besier, Lloyd & Ackland, 2003) and provoke higher maximal level of oxygen consumption compared to steady-state forward running (Flouris, Metsios, Famisis, Geladas & Koutedakis, 2012). Thus, any covered distance during SRT might be by accompanying nomogram assigned with "unspecific" oxygen consumption value. Underestimated energy needs during the continuous cycles of acceleration, deceleration and change in direction consequently produce augmented discrepancy between predicted and measured VO_{2max} during the test.

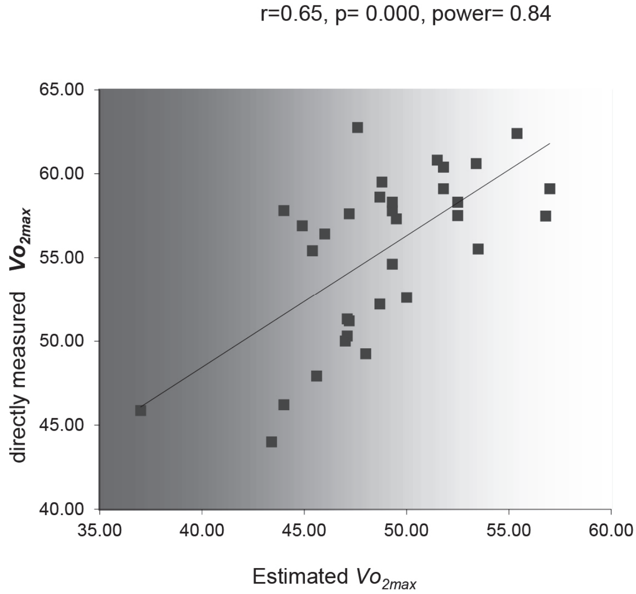

Figure 2. Relationship between directly measured and estimated VO_{2max} (r= 0.65, power = 0.84, $p < 0.01$)

Several other factors could attribute to observed poor applicability of shuttle run test for the prediction of VO_{2max} in young well-trained basketball players. Anaerobic characteristics have been found a strong predictor of distance running performance in well-trained athletes (Houmard, Costill, Mitchell, Park & Chenier, 1991; Marcinik, Potts, Schlabach, Will, Dawson & Hurley, 1991). Authors stated that participants with higher anaerobic capacity are able to exercise for the longer time during an incremental test on treadmill. Considering that shuttle run is also an incremental test it could be hypothesized that this statement is valid for shuttle run test performance, too. Therefore, subjects anaerobic capacity, heavily taxed in the later stages of SRT (Ahmaidi, Collomp, Caillaud, & Préfaut, 1992), likely have profound effect on total distance covered and estimated VO_{2max} and consequently is reasponsible for «bluring» the VO_{2max} – SRT distance covered relationship. Paavolainen, Häkkinen, Hämäläinen, Nummela and Rusko (1999) also suggested that distance running performance could be significantly influenced by the muscle power level, with performance in continuous acceleration-deceleration type of movements likely even more dependent on this physical attribute. It has been reported that leg power development could improve the stretch-shortening cycle efficacy and consequently running economy, especially during movement patterns with frequent changes of direction (Thomas, Nelson & Silverman, 2005). Additionally, in the study by Stojanovic, Stojanovic, Ostojic and Fratric (2007), it was shown that total distance covered during shuttle-run test by young basketball players is not VO_{2max} - only dependent, with standing long jump as a measure of muscle power found to be significant contributor of 65% SRT-variance explained group of predictors. Muscle power is considered to be of great importance in basketball, is used in the identification of talented young players (te Wierike *et al*, 2014) and regularly stressed in training, suggesting that well-trained young basketball players used in present study could posses similar level of this physical quality. However, based on some previous findings (Drinkwater, Hopkins, McKenna, Hunt, & Pyne, 2007) it is reasonable to assume that our group of subjects is not homogenous in this distinct ability Therefore, such discrepancies could affect SRT total distance covered and consequently relationship between directly measured and estimated VO_{2max}.

The present study support the notion of previously reported studies that shuttle run test under predicts VO_{2max} on the sample of trained and/or adolescent population. Further, with only moderate correlation between two measures and typical error of estimate of "moderate" magnitude, SRT should not be viewed as viable procedure for VO_{2max} determination. Several other factors, such as anaerobic characteristics and muscle power are likely influential for the total distance covered and consequently estimated VO_{2max}. As such, 20-M shuttle run test should not be used to evaluate VO_{2max} in well-trained young basketball players.

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