COMPARATIVE STUDY OF MEASURED AND PREDICTED VO_{2max} DURING A MULTI-STAGE FITNESS TEST WITH JUNIOR SOCCER PLAYERS

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Abstract:

The multi-stage 20-m shuttle run test (MSRT) is one of the most popular field tests using equations based on test results or the final speed for an indirect estimation of maximal oxygen uptake (VO_{2max}). The aim of this study was to compare the real VO_{2max} value to the predicted value of VO_{2max} by MSRT and rate the usefulness of the MSRT as a predictor of VO_{2max} in young football players. Fifteen young football players, nominees for the 2004/2005 national Under-18 team, were included in this study. The subjects were 17.9±.2 years old, had an average height of 178.8±7 cm and an average weight of 71.8±7.5 kg. The players came from different Slovenian junior premier football league clubs and trained on average 4 to 5 times per week. Testing was conducted on all subjects over two days, between 9 a.m. and 2 p.m., on synthetic turf. A mobile device for the measurement of O_2 and CO_2 in expired air and ventilation during MSRT was used. On the basis of the test result (the number of levels and repetitions between them) VO_{2max} was calculated. The correlation between the measured and predicted VO_{2max} was determined with Pearson's correlation coefficient. The comparison of both mean values showed that the measured value was significantly higher ($p<.05$), by as much as 8.5 ml O_2 kg^{-1}•min^{-1}, than the MSRT-predicted VO_{2max}. Variables were statistically correlated, but the correlation coefficient amounted to only .58. This study has shown that an indirect evaluation of aerobic capacity based on the multi-stage 20 m shuttle run test can lead to wrong conclusions in young soccer players. The correlation observed between the measured and predicted VO_{2max} was too weak to predict the aerobic capacity of young football players with certainty.

Key words: *football, VO_{2max}, multi-stage 20-m shuttle run test, evaluation, training*

Introduction

Slovenia succeeded to qualify for two major football events, the EURO 2000 and FIFA World Cup 2002 in Japan and South Korea. In fact, Slovenia was the smallest country ever to qualify for a major football tournament, such as the FIFA World Cup. Since then, the Football Association of Slovenia has been placing a stronger emphasis on raising coaching standards. For this purpose, player testing takes place twice a year, when all candidates for U-15 through U-19 junior teams are evaluated on physical fitness and technical skills. One of the eight outdoor or field tests is the multi-stage 20-m shuttle run test (MSRT) (also known as the Leger test, the beep test, the bleep test, etc.), which is used to test aerobic capacities of a sports person (Leger, Mercier, Gadoury, & Lambert, 1988). This is an important piece of information, since, considering the duration of the game (90 minutes) and the fact that football players cover the distance of about 10 kilometres on average (Hoff, Wisloff, Engen, Kemi, & Helgerund, 2002; Baros, et al., 2007), as much as 90% of energy is produced during aerobic metabolic processes (Hoff, et al., 2002). However, this cannot be the same for all players since some studies (Bangsbo, 1994; Reilly, 1996;

Bloomfield, Polman, Butterly, & O'Donoghue, 2005; Bloomfield, Polman, & O'Donoghue, 2007) have shown different energy expenditure according to stature, playing position and overall distances that have been covered by defenders, midfielders and attackers. To ensure that exact and credible aerobic capacity evaluation results are obtained, the players would have to be tested in a laboratory. Laboratory testing has the advantage of allowing exact and direct measurement of all the parameters, which are used to identify players' aerobic performance capabilities. These are evaluated on the basis of the following factors: maximal oxygen uptake (VO_{2max}), anaerobic lactate threshold (LT) and running economy (Hoff, et al., 2002). VO_{2max} is defined as the highest rate of oxygen, which can be taken up and utilized by the body during high-intensity dynamic exercise and as an indicator of aerobic energy. It determines how quickly the energy consumed during aerobic process will replenish itself. Some previous studies (Bangsbo, 1994; Wisloff, Helgerud, & Hoff, 1998) found a significant correlation between VO_{2max} and the distance covered by players during matches. Helgerud, Engen, Wisloff and Hoff (2001) demonstrated that by improving VO_{2max} by 11% (from 58.1 ml O_2 kg^{-1}•min^{-1} to 64.3 ml O_2 kg^{-1}•min^{-1}), players covered 20% more ground during matches, held the ball 23% longer and increased the number of sprints they performed in a match on average by 100%. These results emphasize the advantages of a high VO_{2max} in modern football.

In practice, field tests are often used for assessing the coordination abilities of football players; these testing methods are considerably easier, cheaper and less time-consuming (Svensson & Drust, 2005), but somewhat 'imprecise' since coordination ability is indirectly validated by the test result. In various studies (Leger & Lambert, 1982; Leger, et al., 1988; Ramsbottom, Brewer, & Williams, 1988; Wilkinson, Fallowfield, & Myers, 1999) the MSRT is defined as a good predictor of VO_{2max}. There are equations based on the test results or the final speed used for an indirect estimation of VO_{2max} value. Based on the initial results, Brewer, Ramsbottom and Williams (1988) produced a table which provided a valid estimate of VO_{2max}. Leger et al. (1988) provided an equation based on the maximum speed at the test run for the estimation of VO_{2max} value. However, there is a lack of studies examining the correlation between VO_{2max} estimated by MSRT or measured with golden-standard methods in young soccer players. The aim of this study was to compare the VO_{2max} value measured in field conditions with an ambulatory measuring instrument to the predicted VO_{2max} by using the table originally compiled by Brewer. We have also tried to find the differences between the other physiological characteristics of young players in different field positions.

Methods

Participants

The fifteen young football players who took part in the test were nominees for the 2004/2005 National Under-18 Team. Their participation was voluntary. The subjects were familiarized with the testing procedure, but not with the purpose of the test. On average the subjects were 17.9±.2 years old, had an average height of 178.8±7 cm and an average weight of 71.8±7.5 kg. Players from different Slovenian junior premier football league clubs were recruited. They trained on average 4 to 5 times per week. The subjects were instructed not to eat for at least two hours before each test and to wear suitable sports clothing.

Procedure

The tests and evaluations were carried out in June 2010, at the end of the competitive season. Testing was conducted on all subjects over two days, between 9 a.m. and 2 p.m., on synthetic turf in Siska, Slovenia. MSRT involved continuous running between two lines 20 metres apart in time to recorded beeps. The test subject stops on a marked line, turns by 180º and runs in the opposite direction. He must stop when instructed by a beep from a CD. The speed at the start is 8.5 km/h and after about a minute a sound indicates an increase in speed (0.5 km/h per minute). The test is stopped when the subject is unable to keep up with the pace dictated by the beep sound. All the subjects were instrumented for gas analysis during MSRT with a portable device (Cosmed K4b2, Rome, Italy) for the measurement of O_2 and CO_2 in expired air. Ventilation with VO_{2max} was presented according to the guidelines (Wasserman, Hansen, Sue, & Whipp, 1987). On the basis of the test results (the number of levels and repetitions between them) the Brewer table to calculate MSRT-VO_{2max} was used.

Statistical analyses

The players were divided into three groups according to playing positions (defenders, midfielders and attackers). Descriptive statistics of each of the variables were computed for each playing position. The correlation between the measured and the predicted VO_{2max} was determined with Pearson's correlation coefficient. To analyze the agreement between the two different methods, the Bland-Altman plot was used. A one-way analysis of variance (ANOVA) was used to compare the groups according to playing positions; to determine the between playing position differences the *post-hoc* test (Tukey HSD) was applied. The significance level of alpha was set at 5% ($p<.05$).

Results

Table 1 shows the mean values of the measured and predicted VO_{2max} values, calculated by the Brewer formula, including the closely-related standard deviations. The comparison of both mean values shows the measured value to be significantly higher ($p<.05$), by as much as 8.5 ml O_2 kg^{-1}•min^{-1}.

Table 1 shows the mean values (SD) for individual groups of players playing different positions. The only statistically significant difference was

noted in body height ($p<.05$). On average, the defend-ers were the tallest, followed by the midfielders and attackers. The Tukey's HSD test revealed a statisti-cally significant difference between the defenders and attackers ($p<.05$).

The variables were statistically correlated, but the correlation coefficient amounted to only .58 ($p<.05$, Figure 1).

The relationship between the variables corresponding to the measured VO_{2max} and MSRT levels showed that the variables were not statistically correlated ($p>.05$, Figure 2).

The relationship between the variables corresponding to the predicted value of VO_{2max} by MSRT and MSRT levels showed that the variables were statistically correlated ($p<.01$, Figure 3).

The Bland-Altman plot ignores the repeated nature in the methods; the limits of agreement (0.84 and 16.20) were too much for us to be confident. Therefore, the MSRT cannot be used instead of the "Quark K4b2" for determination of VO_{2max}. The difference between the measured VO_{2max} and the predicted VO_{2max} (y axis) is drawn against the mean of the predicted VO_{2max} and the measured VO_{2max} (x axis) in the 15 measurements in the study. The center line indicates the mean level of bias, and the two outer lines depict the upper and lower 95% limits of agreement (95% limits of agreement = 0.84 to 16.20).

Table1. Descriptive statistics (mean±SD) of soccer players

	MSRT Level	Time (s)	VO_{2max} predicted (ml O_2 kg^{-1}•min^{-1})	VO_{2max} measured (ml O_2 kg^{-1}•min^{-1})	Weight (kg)	Height (cm)†
Defenders (n= 5)	11.7±0.5	661.6±27.7	52.1±1.6	61.2±4.6	76.5±5.4	185.2±5.5*
Midfielders (n= 5)	11.5±1.3	646±81.7	51.6±4.4	60.1±4.5	71.5±7.5	177.3±5.1
Attackers (n= 5)	11.3±0.8	635±49.9	50.7±2.6	58.7±5.9	67.6±7.8	173.9±5.5*
TOTAL (n= 15)	11.5±0.8	647.8±54.3	51.5±2.9§	60±4.8§	71.8±7.5	178.8±7

Notes: † indicates significant difference with ANOVA at $p<.05$; * indicates significant difference as compared to different positions with *post hoc* test (Tukey HSD) at $p<.05$; § indicates significant difference as compared VO_{2max} predicted with VO_{2max} measured at $p<.05$.

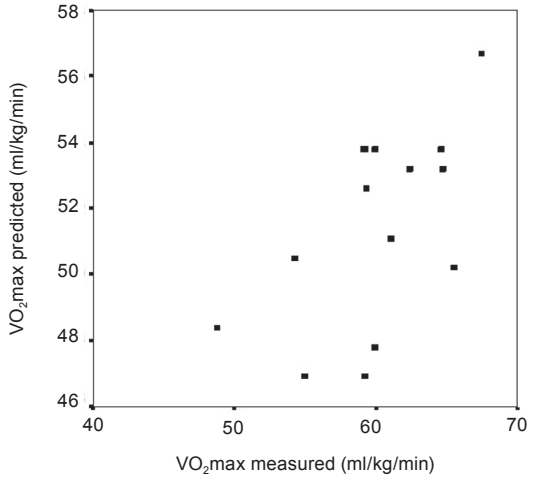

Figure 1. Scatterplot graph of relationship between the variables corresponding to measured VO_{2max} and predicted value of VO_{2max} by MSRT ($r=.584$, $p<.05$).

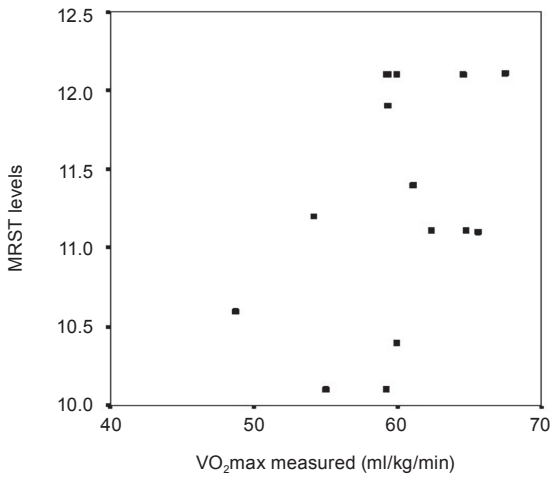

Figure 2. Scatterplot graph of relationship between the variables corresponding to measured VO_{2max} and MSRT levels ($r=.418$, $p>.05$).

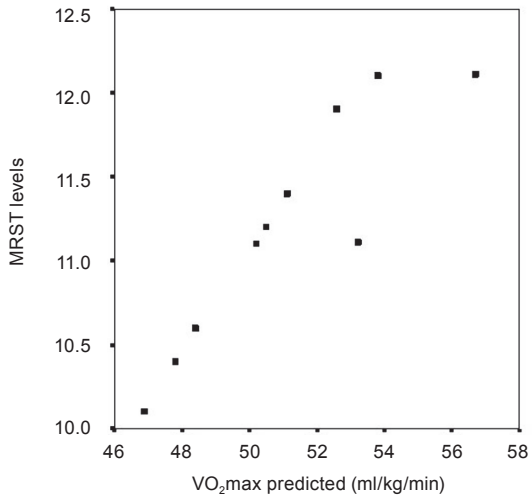

Figure 3. Scatterplot graph of relationship between the variables corresponding to predicted value of VO_{2max} by MSRT and MSRT levels (r=.911, p<.01).

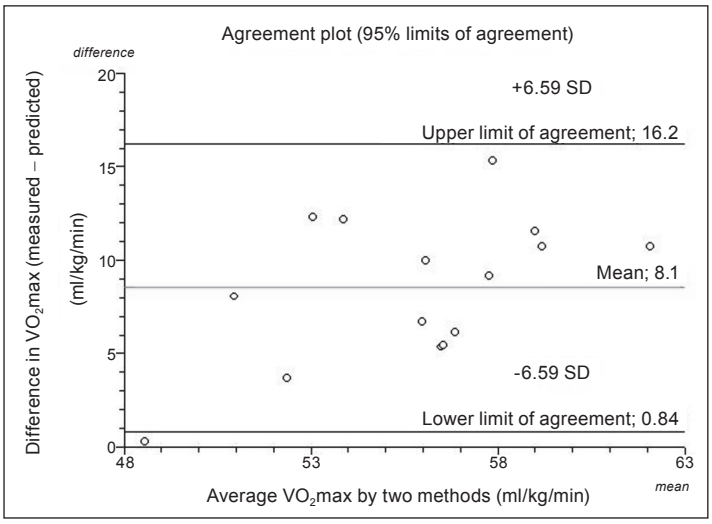

Figure 4. Bland-Altman plots with estimated mean bias and 95% limits of agreement for difference in VO_{2max}, corresponding to real values and predicted value of VO_{2max} by MSRT, plotted against the mean.

Discussion and conclusions

This study was aimed at comparing the aerobic fitness of young football players and to assess whether MSRT is a useful tool for predicting VO_{2max} as compared to the golden-standard procedure. It seems that the predicted and measured values have demonstrated a correlation, but it was too low (r =.63) to be used to accurately predict VO_{2max} in young soccer players. The measured value was considerably higher (8.1 ml O_2 kg^{-1}•min^{-1}) than the values indirectly derived by using the Brewer table. There can be many reasons for such a great discrepancy and, consequently, a low correlation. One of the reasons is the obvious difference between the tests the subjects used in the present study and the tests the subjects recruited for the Brewer's initial study (Brewer, et al., 1998). The Brewer table was prepared on the basis of Ramsbottom et al. (1988) study, which included 36 male subjects and 38 female subjects aged between 19 and 36 years. The table was prepared by applying linear regression analysis to the VO_{2max} value measured in the given test subject (Ramsbottom, et al., 1988). Compared to our homogenous group of young football players, Brewer based his formula on a considerably more heterogeneous group, which included both genders, individuals from different disciplines, with different levels of training and a wider age range. Some studies (Armstrong & Welsman, 2004; Chamari, et al., 2007) warn about the problem of evaluating and comparing the aerobic capacity in subjects of different ages, particularly those who are still growing. Special care has to be taken when interpreting VO_{2max} values in a heterogeneous group of people, in relation to body mass (especially if the people are fat), gender and if the subjects are still growing. All these things should have been taken into account when calculations were prepared for such a heterogeneous group as the one Brewer used. Body composition is one factor which can produce a misleading explanation when relative VO_{2max} (expressed in ml O_2 kg^{-1}•min^{-1}) is used for evaluating the aerobic fitness. As such, it is a functionally imprecise method of assessing running economy, when we deal with persons of different stature (Chamari, et al., 2007). In such cases it pays to use an exponential method to calculate lean body mass and then to use this result for estimating relative maximum oxygen uptake adjusted for body size (e.g. allometric scaling). The analysis of variance revealed a statistically significant difference between the groups of players in different playing positions in terms of height. Some studies (Bloomfield, et al., 2005) showed additional significant differences in terms of the age, stature and body mass index among the players in different playing positions. However, our study has not revealed significant differences for VO_{2max} among the different playing positions, despite the fact that previous research (Bangsbo, 1994) emphasized statistical differences in the distances covered by midfield players during matches. The reason for having such a high level of equalization among players is most probably age-related; players can still change playing positions and joint training programmes are in place, with no provision for special, position-specific training.

This study has shown that an indirect evaluation of aerobic capacity based on the multi-stage 20-m shuttle run test and the Brewer table can lead to wrong conclusions. The correlation observed between the measured VO_{2max} value and the pre-

dicted VO_{2max} value was too weak to predict the aerobic capacity of young football players with certainty. As was demonstrated in some previous studies, the present study has also detected a statistically significant difference among players in different playing positions in terms of height. The shuttle run test will deliver accurate results regardless of age, weight, height, gender, sports discipline and level of exercise, when used together with devices performing direct measurement methods such as "Quark K4b2" for determining VO_{2max} values. This demonstrates that the shuttle run test and the Brewer, indicating approximate VO_{2max} value using the shuttle run test results (level, shuttle), should not always be treated together as a complete test protocol under all circumstances. However, taking a closer look at the segment of the shuttle run test independently, it can be considered as a suitable test protocol when used together with VO_{2max} determining devices indicated previously. This is because the application speed is progressive compared to time, the test is aerobic-based and it drives athletes to the point of exhaustion, similar to VO_{2max} protocols used in treadmill and cycling ergometry.

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KOMPARATIVNA STUDIJA IZMJERENOG I PROCIJENJENOG VO_{2max} U VIŠESTUPANJSKOM FUNKCIONALNOM TESTU PRIPREMLJENOSTI NOGOMETAŠA JUNIORA

Višestupanjski test povratnog trčanja dionica od 20 metara (MSRT) je jedan od najpopularnijih terenskih testova koji koriste jednadžbe za procjenu maksimalnog primitka kisika (VO_{2max}) na temelju ukupnog rezultata testa ili konačne brzine trčanja na kraju testa. Cilj ovog istraživanja bio je usporediti stvarne vrijednosti VO_{2max} s procijenjenim vrijednostima VO_{2max} dobivenima pomoću MSRT te ocijeniti korisnost toga terenskog višestupanjskog testa kao prediktora VO_{2max} u mladih nogometaša. U istraživanje je bilo uključeno 15 mladih nogometaša izabranih za slovensku nacionalnu selekciju U18 u sezoni 2004./2005. Ispitanici su bili u dobi od 17,9±0,2 godina, prosječne visine 178,8±7 cm i prosječne težine 71,8±7,5 kg. Igrači su bili članovi različitih slovenskih prvoligaških juniorskih klubova i trenirali su u prosjeku 4 do 5 puta tjedno. Testiranje je provedeno na svim ispitanicima tijekom dva dana, u vremenu između 9 i 14 sati na umjetnoj travi. Korišteni su prijenosni uređaji za mjerenje O_2 i CO_2 u izdahnutomu zraku i ventilacije tijekom provedbe MSRT. Na temelju rezultata testa (razina otkaza i broj ponavljanja unutar razine otkaza) izračunat je VO_{2max}. Povezanost između izmjerenoga i procijenjenoga VO_{2max} utvrđena je Pearsonovim koeficijentom korelacije. Usporedba prosječnih vrijednosti pokazala je da je izmjerena vrijednost VO_{2max} bila statistički značajno viša ($p<0,05$) za 8,5 ml O_2 $kg^{-1}•min^{-1}$ od procijenjene vrijednosti VO_{2max} koja je izračunata pomoću MSRT. Korelacija između varijabli bila je statistički značajna, ali je korelacijski koeficijent bio samo 0,58. Ovo je istraživanje pokazalo da neizravno vrednovanje aerobnoga kapaciteta rezultatima u testu MSRT može dovesti do pogrešnih zaključaka na populaciji mladih nogometaša. Utvrđena povezanost između izmjerene i procijenjene vrijednosti VO_{2max} bila je preslaba da bi sa sigurnošću mogla poduprijeti procjenu aerobnoga kapaciteta u mladih nogometaša.

Ključne riječi: *nogomet, VO_{2max}, višestupanjski test povratnog trčanja dionica od 20 metara, vrednovanje, trening*

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