Relationship between Maximal Oxygen Uptake and Dynamic Stability in University Rugby and Soccer Players

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Abstract The maximal oxygen uptake and dynamic stability is frequently assessed separately for different team players. However, most research is limited to specific sports players, so the maximal oxygen uptake and dynamic stability in rugby and soccer players are poorly documented. This study provides relationship between maximal oxygen uptake and dynamic stability in university rugby and soccer players. Twenty-eight participants were recruited for the study (14 rugby players and 14 soccer players). Maximal oxygen uptake was determined by multistage fitness test and dynamic stability was determined by Y balance test. A linear regression analysis was used to identify relationship and effect of maximal oxygen uptake and dynamic stability on university rugby and soccer players. Both groups were similar in characteristics. Our findings showed there was a significant relationship between the maximal oxygen uptake and dynamic stability for rugby players ($r=.890$) and soccer players ($r=.811$). Relationship between maximal oxygen uptake and dynamic stability ($r=.836$) was significant for both sports players. Rugby and soccer players achieved good scores in maximal oxygen uptake and dynamic stability and high maximal oxygen uptake scores lead to better dynamic stability in both teams' players. Maximal oxygen uptake affects the dynamic stability. Team coaches and physiologists must consider

functional test outcomes while preparing players for competition. The individual training program should also be established on test outcome, which is more likely to improve performance.

Keywords Beep Test, Y-balance test, VO_{2max} , Maximal Oxygen Uptake, Dynamic Balance, Rugby, Soccer

1. Introduction

Rugby and soccer are two of the most complex sports played around the world. These sports are mainly aerobic types of sports, the elite players covered 10-13 km distance in a game [1]. These games are a combination of high-intensity activity including sprints, acceleration, cutting movements, side stepping, jumping, tackling, specific technical and tactical skills [2]. Players required a well-developed aerobic fitness to maintain repetitive high-intensity movements, accelerate the recovery process, and support physical conditions at the optimum level during the entire game [3]. The maximal oxygen uptake (VO_{2max}) corresponds to the highest work rate at which oxygen can be taken up and utilized by the body during

maximal exercise [4]. VO_2max is one of the most used indicators of aerobic power and metabolism [5] and it is used regularly to measure aerobic performance, VO_2max is considered the gold standard and is the more important measure of maximal oxygen uptake.

There are many fitness tests available to measure aerobic fitness for many team sports [6,7]. The most common field test to predict maximal oxygen uptake is the 20-meter Multistage Fitness Test (MSFT). This test is being used by many teams especially in English Premier League [8]. In this test, players run forward and backward in a movement that resembles the movement pattern as rugby and soccer games. Maximal oxygen uptake can predict the performance in a competitive match. Aerobic fitness evaluated by laboratory-based tests correlates highly ($r=0.78-0.87$) with both multistage fitness test and the YO-Yo intermittent recovery test (Yo-Yo IR1) [9]. The multistage fitness test presents high accuracy and repeatability compared with the directly measured maximal oxygen uptake under laboratory conduction [10].

Dynamic stability is very important for rugby and soccer players to perform various movements for the longer duration and without falling over. While running with ball to avoid being tackled by the opponent, players need more dynamic stability in order to change direction at different speed [11]. During the game, players running at high speed, changing direction frequently, passing the ball, and kicking the ball-players must maintain their stability. Dynamic stability is a fundamental ability to utilize several attributes, with effective execution depends upon the ability to maintain single-leg stance control with simultaneous movement in different planes [12]. There are many tests to evaluate dynamic stability of players, such as the jumping and landing test, balance board test, bass test, star excursion balance test, multiple single-leg hop stabilization test, and Y balance test. Y Balance Test (YBT) is one of the tests used for evaluating dynamic stability in clinical and research purposes for many players. This test is used for assessing strength, flexibility, range of motion, neuromuscular control, proprioception, and risk of injury in players [13]. The test is a valid measure for functional testing, due to its efficiency, speed, consistency, portability, and objectivity [14].

Many sports scientists and scholars have been focused on performance assessment but there is lack of research investigation to find out the relationship between a range of performance abilities in rugby and soccer players. Therefore, the aim of this study was to determine the relationship between maximal oxygen uptake and dynamic stability in university rugby and soccer players. We hypothesized that the relationship between maximal oxygen uptake and dynamic stability is similar. Using maximal oxygen uptake and dynamic stability independently or in tandem may assist coaches, physical therapists, sports medicine, strength, and conditioning professionals in their ability to identify the performance

barrier or injury risks during sports participation through the identification of physical and functional deficiencies in movement.

2. Materials and Methods

2.1. Experimental Design

A cross-sectional study design was used for the present study, to assess the performance abilities of university rugby and soccer players.

2.2. Sampling Technique

Probability sampling technique was chosen to conduct this research. General information regarding the research was imparted to all players. Only those participants were selected who want to participate voluntarily and full fill the inclusion and exclusion criteria.

2.3. Participants

Twenty-eight male participants (14 rugby players and 14 soccer players) voluntarily took part in this study. Fourteen participants in one group were considered sufficient to demonstrate a relationship between the two groups with adequate power (80% at $p \leq 0.05$) [10]. All the participants were university players and had three years of experience playing at this level. Prior to the investigation, all participants explained the purpose of the study and the associated experimental risks during the investigation. Upon their verbal agreement, they signed written informed consent form. The average age of the players was 20.75 ± 1.48 years, height 174.36 ± 5.59 cm., body weight 66.72 ± 6.22 kg., and BMI 21.93 ± 0.94 . Any player with any lower extremity musculoskeletal injury or with a record since the last three months were excluded from the study.

2.4. Maximal Oxygen Uptake

The maximal oxygen uptake was measured using the Multistage Fitness Test (MSFT). The MSFT to measure maximal oxygen uptake in children, adolescents, and adults and was developed in the early 1980's. The test was created to provide a practical and cost-effective prediction of maximal oxygen uptake in a field setting. Research has indicated that the MSFT test is a valid predictor of maximal oxygen uptake [10].

2.5. Dynamic Stability

Dynamic stability was measured using Y Balance Test (YBT). The YBT is a functional test developed to the measure dynamic stability in three directions: anterior,

posterolateral, and posteromedial. The YTB has a good level of interrater test-retest reliability (ICC=0.80-0.85) [15].

2.6. Equipment

To conduct the MSFT, following standardised equipment was used: 20-meter shuttle run space, cones, metronome, and performance recording sheets. The 2x2 meter free reliable space, sticky tape, measuring tape, and performance recording sheets were used to conduct YBT. All these equipments were easily available in the physical education department.

2.7. Testing Procedure

The Y balance platform and 20-meter shuttle run space were marked before participants arrived. Upon arrival at the university indoor hall, the researchers takes their anthropometric measurements and asked them to fill out a sociodemographic questionnaire. Each participant's dominant leg was determined by asking them which leg they used to kick a ball [16]. Participants were wearing the specific sports attire throughout the tests. Participants were warm-up on an exercise bicycle for five minutes prior to the commencement of the test. Participants performed the YBT using the test platform marked in three directions: anterior, posterolateral, and posteromedial. Participants could have practice trails with dominant legs in each direction. The YBT test was performed in order to stand barefoot on the centre platform and await further instructions from researcher. While standing on a single leg, participants were instructed to reach with a free leg in the anterior direction three times, followed by the posterolateral direction, then the posteromedial direction three times. The maximal reach distance was recorded in all trials. A trial was discarded and/or repeated if the participant lost his balance, lift his heel off from the platform, and take any support. The sum of maximal reach distance in each direction was divided by three trails to yield an absolute reach distance, which was used to analysis overall performance of the YBT test. For further data analysis, the scores of dominant legs were used.

The MSFT test was performed as participants were asked to run towards and opposite 20-meter sections in a shuttle format in response to an audible signal (beep)

produce by a metronome (audio player). The speed in the first minute was 8.5km/hr and increased by 0.5km/hr every minute. Participants were required to complete a level before the next beep produce. Participants were expected to complete as many shuttles as possible. The test was terminated, if the participant fails to follow the prescribed pace for two successive shuttles or withdraws from the test due to exhaustion. Maximal oxygen uptake was determined according to Flouris et al (2005) formula as follows [18]:

$$VO_2\text{max (mL/min/kg)} = (\text{max. attained speed (km/h)} \times 6.65 - 35.8) \times 0.95 + 0.182$$

All the tests were conducted using standard procedure and instructions [17,19].

2.8. Statistical Analysis

All statistical analyses were performed using IBM SPSS software (version 21). Prior to analysis, the data were checked for outliers and normality with the Shapiro-Wilk test. Student *t*-test was performed to identify significant differences in age, height, weight, and BMI for rugby and soccer players. A regression analysis test was performed to determine the relationship and effect of maximal oxygen uptake and dynamic stability on university rugby and soccer players. The *p*-level 0.05 was used to determine statistical significance.

3. Results

Data were analysed for all the rugby and soccer player's anthropometric characteristics, normality, relationship, and effect of/on variable between maximal oxygen uptake and dynamic stability. The mean and SD for age was 20.75± 1.48 years, body weight 66.72± 6.22 kg, height 174.36±5.59, and BMI was 21.93±0.94 for both rugby and soccer players. Significant relationship has been seen in rugby and soccer players for maximal oxygen uptake and dynamic stability. Therefore, its evident that hypothesis for this study was accepted as there is similar relationship found for maximal oxygen uptake and dynamic stability for rugby and soccer players.

Table 1 showed that there were no significant differences between rugby and soccer players' anthropometric characteristics in terms of age (*p*=.382), body weight (*p*=.925), height (*p*=.130), and BMI (*p*=.459).

Table 1. Participant's anthropometric characteristics

	Rugby Players (N=14) Mean $\pm$ SD	Soccer Players (N=14) Mean $\pm$ SD	Both (N=28) Mean $\pm$ SD	Sig. ($p=0.05$)
Age	20.50 $\pm$ 1.56	21.00 $\pm$ 1.41	20.75 $\pm$ 1.48	.382
Body Weight	66.83 $\pm$ 6.68	66.61 $\pm$ 5.96	66.72 $\pm$ 6.22	.925
Height	176.07 $\pm$ 4.18	172.64 $\pm$ 6.41	174.36 $\pm$ 5.59	.106
BMI	21.56 $\pm$ 1.09	22.29 $\pm$ 0.59	21.93 $\pm$ 0.94	.037

Table 2. Results of data normality test

	SPORTS TYPE	95% CI		Shapiro-Wilk		
		Lower	Upper	Statistic	df	Sig.
Maximal Oxygen Uptake	RUGBY	58.07	70.58	.881	14	.060
	SOCCER	58.56	70.09	.923	14	.246
Dynamic Stability	RUGBY	35.11	39.09	.974	14	.930
	SOCCER	36.64	40.21	.922	14	.232

Table 3. Correlation test for tested variables

		N	Mean	Std. Deviation	Std. Error Mean	Correlation	Sig.
Rugby	Maximal Oxygen Uptake	14	64.32	10.83	2.89	.890	.000
	Dynamic Stability	14	37.11	3.45	0.92		
Soccer	Maximal Oxygen Uptake	14	64.33	9.99	2.67	.811	.000
	Dynamic Stability	14	38.42	3.09	.83		

Table 4. Regression analysis for tested variables

	N	Mean	Std. Deviation	Std. Error of Estimate	Beta	Sig.
Maximal Oxygen Uptake	28	64.33	10.23	5.71	.836	.000
Dynamic Stability	28	37.77	3.27			

Table 2 showed that there were no significant differences in maximal oxygen uptake and dynamic stability for rugby and soccer players. We can assume that the data for maximal oxygen uptake and dynamic stability were normally distributed and further analysis was done by using the parametric test.

Table 3 showed that rugby and soccer players have a strong relationship ($r=0.890$ and $r=0.811$) in between maximal oxygen uptake and dynamic stability. These strong relationships were significant ($p=.000$) at 0.05 level of significance between maximal oxygen uptake and dynamic stability for rugby and soccer players.

Table 4 showed a strong relationship ($r=0.836$) between

maximal oxygen uptake and dynamic stability for all university players. This strong relationship was significant ($p=.000$) at 0.05 level of significant and dynamic stability affected by maximal oxygen uptake.

The figure 1 showed a linear positive relationship between maximal oxygen uptake and dynamic stability in rugby university players.

The figure 2 showed a linear positive relationship between maximal oxygen uptake and dynamic stability in soccer university players.

The figure 3 showed a linear positive relationship between maximal oxygen uptake and dynamic stability in both rugby and soccer university players.

Figure 1. Scatter plot showing relationship between maximal oxygen uptake and dynamic balance for rugby players

Figure 2. Scatter plot showing relationship between maximal oxygen uptake and dynamic balance for soccer players

Figure 3. Scatter plot showing relationship between maximal oxygen uptake and dynamic balance for rugby and soccer players

4. Discussion

The purpose of this study was to investigate the relationship between maximal oxygen uptake and dynamic stability for university rugby and soccer players. The maximal oxygen uptake values were found to be 64.32 ± 10.83 (ml/kg/min) in rugby players, 64.33 ± 9.99 (ml/kg/min) in soccer players, and 64.33 ± 10.23 (ml/kg/min) in both players ($p < 0.05$) on average. The dynamic stability test scores were estimated to be 37.11 ± 3.45 in rugby players, 38.42 ± 3.09 in soccer players, and 37.77 ± 3.27 in both players ($p < 0.05$). According to the findings of regression analysis on maximal oxygen uptake and dynamic stability in rugby players in our study; the maximal oxygen uptake affected dynamic stability at 79% and the progressive relationship between maximal oxygen uptake and dynamic stability was positively at a strong level and significant ($R^2 = 0.792$; $p < 0.05$). For soccer players, maximal oxygen uptake affected dynamic stability at 66% and the regressive relationship between maximal oxygen uptake and dynamic stability was positively strong and significant ($R^2 = 0.658$; $p < 0.05$). In the comparison of all players regardless of their sport, a positive relationship was also evident between maximal oxygen uptake and dynamic stability scores. A certain increase in aerobic capacities leads to improvement in balance. When we independently calculate the effect of maximal oxygen uptake values on dynamic stability in rugby and soccer players, this had an effect of 89% in rugby players and 81% in soccer players. The regressive relation between maximal oxygen uptake and dynamic stability was positive, strong, and significant in rugby and

soccer players.

The result of this study is in-line with the results of previous studies that examined the relationship between maximal oxygen uptake and dynamic stability. These findings are supported by the results attained by Ali and his colleagues [20], who reported a significant relationship between exercise capacity and balance. They measure maximal oxygen uptake in the laboratory setting with a graded exercise test performed on a treadmill using modified Bruce protocol and stability was measured with Berg Balance Scale. Oliver and Brezzo found in their study that after the functional training, the balance score was improved in volleyball and football collegiate players [21]. Boztepe and Erkut conducted a study with active soccer players have revealed that the balance scores improved as a result of functional training at a significant level [22]. By developing maximal oxygen uptake, trained players increase the range of movement in their joints and flexibility that provides more smooth skilled movement chain that helps to protect them from injuries and cater more stability.

In agreement with different earlier studies assessing maximal oxygen uptake through field-based tests similar to those used in the current study, it was observed that MSFT is a commonly used test for soccer and rugby players. The validity of this test was tested directly measuring maximal oxygen uptake and sports performance [3,6]. The applicability of the test is satisfactory because it can be assessed several players simultaneously and it does not require sophisticated equipment and is therefore low in cost [23]. The maximal

oxygen uptake estimated from the MSFT was similar for under 14 (47.6 ± 4.7), under 15 (47.0 ± 6.9), and under 16 (44.1 ± 5.7) players while under 20 years, category rugby players reported the greatest (53.7 ± 5.1) amount of maximal oxygen uptake [24]. A study showed a positive correlation ($r=0.652$) in measuring maximal oxygen uptake among rugby players, and they concluded that MSFT is an ideally suited test for determining the maximal oxygen uptake for rugby players [25]. In one of the studies, no statistically significant difference was found by Neya et al. in between rugby players and runners for maximal oxygen uptake while they measured maximal oxygen uptake by multistage shuttle test [26]. These statistically insignificant differences might be due to characteristics of the players and nature of sports.

Our study has a few limitations. While interpreting the findings, the constrain of study design must be considered. Primarily, the use of functional test (MSFT & YBT), these tests should be used with great caution with regards to the evaluation of maximal oxygen uptake and dynamic stability of rugby and soccer players. Players are more familiar with these test that may lead them to perform movements require less energy expenditure and maximal heart rate. Additionally, characteristics of these tests, such sudden change in speed, direction, and acceleration, may also induce greater voluntary anaerobic participation.

5. Conclusions

Based on the acceptance of hypothesis from the findings of this research, we conclude that rugby and soccer players had high scores in maximal oxygen uptake and dynamic stability, and the high maximal oxygen uptake scores represented better dynamic stability in rugby and soccer players. On the other hand, the results for maximal oxygen uptake and dynamic stability are significantly related to each other for both sports players. The results of this research confirm the need for a detailed measurement of performance to design and evaluate training programs especially in rugby and soccer players. Team coaches should consider the performance outcome by different functional tests as they prepare training programs for players. Individual training program should also base upon the outcome of the functional tests, it is more likely to lead to improved performance.

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REFERENCES

- [1] J. Bangsbo, M. Mohr, and P. Krstrup, Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Science*, vol. 24, pp 665–74, 2006.
- [2] B. Ekblom, Applied physiology of soccer. *Sports Medicine* vol 3, no 1, pp 50–60, 1986.
- [3] M. Slimani, H. Znazen, B. Miarkam and N.L. Bragazzi, Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. *Jurnal of Human Kinetic*, vol 27, no 66, pp 233-245, 2019. doi: 10.2478/hukin-2018-0060.
- [4] D.R. Bassett, and E.T. Howley, Limiting factors for maximum oxygen uptake and determinants of endurance performance, *Medicine Science & Sports Exercise*, vol 32, no 1, pp 70-84, 2006
- [5] E.T. Howley, D.R. Jr. Bassett, and H.G. Welch, Criteria for maximal oxygen uptake: review and commentary. *Medicine Science & Sports Exercise*, vol 27, pp 1292–1301, 1995.
- [6] Chaouachi, V. Manzi, P. Wong del, et al. Intermittent endurance and repeated sprint ability in soccer players, *Journal of Strength Conditioning and Research*, vol 24, no 10, pp 2663-2669, 2010.
- [7] T.J. Gabbett, D.G. Jenkins, and B. Abernethy, Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players *Journal of Sports Science*, vol 29, no 15, pp 1655-1664, 2011.
- [8] M. Svensson, and B. Drust, Testing soccer players. *Journal of Sports Science* vol.23, pp 601-618, 2005.
- [9] Thomas, B. Dawson, and C. Goodman, The Yo-Yo test: reliability and association with a 20-m shuttle run and $\dot{V}O_{2\max}$, *International Journal of Sports Physiology Performance*, vol 1, no 2, pp. 137-149, 2006.
- [10] A.R. Aziz, F.H.Y. Tan, and K.C. Teh, A pilot study comparing two field tests with the treadmill run test in soccer players. *Journal of Sports Science Medicine*, vol 4, pp 105-112, 2005.
- [11] P.R.Khuman, T. Kamlesh, and L. Surbala, Comparison of static and dynamic balance among collegiate cricket, soccer and volleyball male players. *International Journal of Health & Allied Sciences*, vol 3, no 1, pp 9-13, 2014.
- [12] G.F. Coughlan, E. Delahunt, E. O'Sullivan, K. Fullam, B.S. Green, and B.M. Caulfield. Star Excursion Balance Test performance and application in elite junior rugby union players. *Physical Therapy and Sport*, vol 15, no 4, pp 249-53, 2014. doi: 10.1016/j.ptsp.2013.11.005.
- [13] K.D. Engquist, C.A. Smith, N.J. Chimera, and M. Warren, Performance Comparison of Student-Athletes and General College Students on the Functional Movement Screen and the Y Balance Test. *Journal of Strength Conditioning and Research*, vol 29, no 8, pp 2296-303, 2015.

- [14] A.C. Gonell, J.A. Romero, and L.M. Soler, Relationship between the Y balance test scores and soft tissue injury incidence in a soccer team. *International Journal of Sports Physical Therapy*, vol 10, no 7, pp. 955-66, 2015.
- [15] S.W. Shaffer, D.S.Teyhen, C.L. Lorensen, R.L. Warren, C.M. Koreerat, C.A. Straseske, J.D. Childs. Y-Balance Test: a reliability study involving multiple raters. *Military Medicine*, vol 178 no 11, pp 1264-1270, 2013.
- [16] J.C. Wilkins, T.C. Valovich McLeod, D.H. Perrin, et al. Performance on the balance Error scoring system decreases after fatigue. *Journal of Athletic Training*, vol 39 no 2, pp 156-161, 2004.
- [17] G.R. Tomkinson, L.A. Léger, T.S. Olds, and G. Cazorla, Secular trends in the performance of children and adolescents (1980-2000): an analysis of 55 studies of the 20m shuttle run test in 11 countries. *Sports Medicine*. Vol 33, no 4, pp 285–300, 2004.
- [18] A.D. Flouris, G.S. Metsios, and Y. Koutedakis, Enhancing the efficacy of the 20 m multistage shuttle run test. *British Journal of Sports Medicine*, vol 39, pp 166–170, 2005.
- [19] G.F. Coughlan, K. Fullam, E. Delahunt, C. Gissane, and B.M. Caulfield, A comparison between performance on selected directions of the star excursion balance test and the Y balance test. *Journal of Athletic Training*, vol 47, no 4, pp 366-71, 2012.
- [20] Z.M. Ali, B.H. El-Refay, and R.R. Ali, Aerobic exercise training in modulation of aerobic physical fitness and balance of burned patients. *Journal of Physical Therapy and Sciences*, vol 27, no 3, pp 585-589, 2015 doi: 10.1589/jpts.27.585.
- [21] G.D. Oliver, and R.Di Brezzo, Functional balance training in collegiate women athletes. *The Journal of Strength & Conditioning Research*, vol 23, no 7, pp 2124-2129, 2009. <https://doi.org/10.1519/JSC.0b013e3181b3dd9e>
- [22] Boztepe and O. Erkut, Evaluation of the effect of functional training on athletic performance in young soccer players: [Master Thesis]. Istanbul: Istanbul University, Institute of Social Sciences; 2018.
- [23] A.M. Fornaziero, R. Leite, P. De Azevedo, A. Dourado, L. Daros, R. Osiecki, and L.Stanganelli, Comparative analysis of the performance of soccer players between two aerobic power tests: treadmill and Yo-Yo intermittent endurance test level 2. *Revista Andaluza de Medicina del Deporte*, 2009; 2(3): 82-86
- [24] S.Ball, M. Halaki, T. Sharp, and R. Orr, Injury patterns, physiological profile, and performance in university rugby union. *International Journal of Sports Physiology and Performance*, vol 13, no 1, pp 69-74, 2018. doi:10.1123/ijsp.2017-0023
- [25] W.Tumijan, A.S.Rahit, N.M.Abdullah, R. Adnan, and V. Parnabas, The Relationship Between 20-m Multistage Fitness Test and Yo-Yo Intermittent Fitness Test in Measuring Cardiovascular Fitness Among Kuching Sarawak Rugby Player. In: Adnan R., Ismail S., Sulaiman N. (eds) *Proceedings of the International Colloquium on Sports Science, Exercise, Engineering and Technology 2014 (ICoSSEET 2014)*. Springer, Singapore. https://doi.org/10.1007/978-981-287-107-7_29
- [26] M. Neya, Y. Ogawa, N. Matsugaki, K. Kimura, R. Yoshida, and K. Kobayashi, The influence of acute hypoxia on the prediction of maximal oxygen uptake using multi-stage shuttle run test. *Journal of Sports Medicine & Physical Fitness*, vol 42, no 2, pp 158-164, 2002.