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Original Article

Determining the relationship between VO2max and explosive power of lower leg muscles in soccer and rugby university players

MOHAMMAD AHSAN[1] MOHAMMAD FEROZ ALI[2]
[1]Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam, SAUDI ARABIA
[2]Department of Secondary and Sports Education, College of Humanities and Education, Fiji National University, FIJI

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Abstract:
The present study investigated the relationship between VO2max and the explosive power of the lower leg for soccer and rugby players. A cross-sectional study design was selected with thirty-four (17-Soccer + 17-Rugby players) male participants who were recruited to conduct this study. Their anthropometric characteristics were as age 21.47 ± 1.67 years, body weight 70.28 ± 8.14 kg., height 176.38 ± 5.42 cm., and BMI 22.55 ± 2.04. A bioelectrical impedance analyser and stadiometer cum weighing scale was used to take anthropometric measurements. The lower leg's explosive power was measured using a single-leg vertical jump and VO2max was measured using the beep test. The study results revealed that there was an insignificant difference in anthropometric characteristics between soccer and rugby players. Relationship between VO2max and explosive power in soccer players showed insignificance relationship ($r = .156$, $p = .549$), whereas rugby players showed a significant relationship ($r = .499$, $p = .042$) for VO2max and explosive power. Without regard to types of sports, there is an insignificant relationship between both parameters. Thus, there is no effect of VO2max on explosive power in players. We conclude that the VO2max does not affect the explosive power of the lower leg for soccer and rugby players. However, VO2max and explosive power seem not to be associated with each other for soccer and rugby players. Further examination of these measures may indicate the relevance of VO2max and explosive power assessment in monitoring and screening soccer and rugby players by fitness trainers and team coaches.
Key Words*:* **- Aerobic Exercise, Muscle Strength, Sports Performance, Soccer, Rugby**

Introduction

Soccer and rugby are team sports that require high-intensity techno-tactical activities such as sprinting, dribbling, kicking, jumping, dodging, tackling, rucking, mauling, and scrumming. All these activities and capabilities can only be performed by those players who possess remarkable physical fitness components such as flexibility, body composition, muscular strength and endurance, and cardiovascular endurance (Ekblom, 1986). In such sports, a high level of aerobic ability assists in tolerating a high workload and helping in instant recovery between short, intermittent bouts of high-intensity efforts during the competition (Stølen et al., 2005). Players should have a well-developed aerobic ability to enhance the recovery process and maintain their physical condition at the optimal level during the whole game or competition (Slimani et al., 2019). Helgerud et al. (2001) revealed that an enhance of 11% in VO2max (maximum oxygen uptake) caused 20% more distance travelled in a competition, 23% more time with ball possession, and a considerable increase (100%) in the number of sprints performed. VO2max is one of the most used indicators of aerobic power metabolism (Howley et al., 1995) and is used consistently to determine aerobic performance; VO2max is also deliberated as a gold standard and utmost significant measures aerobic ability (Jemni et al., 2019). Smaros (1980) reported that players with advanced VO2max execute the highest number of sprints and are involved in more indecisive plays during a game than those with lower values. Such players also have an increased rate of recovery (Ekblom, 1986).

The vertical jump is a multi-joint movement that necessitates complicated motor coordination, and it has been discovered as one of the fundamental movements skill (Gallahue, 2002). Vertical jumps are used to measure lower body power and, thus, an indirect measure of performance (Rodríguez-Rosell et al., 2017). The vertical jump is also used to evaluate sprint acceleration and deceleration (Seitz et al., 2014), throwing (Comfort et al., 2012), and change of direction (Nimphius et al., 2010). Several researchers have evaluated the strength and power of the lower leg using the vertical jump test due to its simplicity and richness in outcome information. Determining the explosive strength of the lower limb and preparing training programs for athletes according to it, it has great importance in increasing performance (Pääsuke et al., 2001). The vertical jump test has become the most frequently used test by many sports' performance professionals, healthcare professionals, and sports scientists to evaluate athletes' lower limb explosive power (Cormie et al., 2011; Duthie, 2006).

Corresponding Author: MOHAMMAD FEROZ ALI, E-mail: Ali.feroz@fnu.ac.fj

The assessment of the physical abilities of athletes is one of the most significant issues in the modern era, as various tests are used to make a selection or monitor the effect of the training program (Norkowski, 2002). The vertical jump test is used as a functional field test or laboratory test to measure the ability of the legs output (Malliou et al., 2003). It is deemed one of the performance components due to its involvement in the different explosive sports activities (Tsiokanos et al., 2002). While sports scientists and sports performance professionals have focused on performance evaluation, there is a lack of research studies investigating relationships among them. Parker et al. recognized that explosive movement such as short sprint and vertical jump as major predictors of sportsmen performance. These variables are responsible for more than 50% of the variance in the performance measures (Bompa, 1996). Aerobic capacity and explosive strength are basic motor capabilities that influence the performance of sportspersons. The ability to generate a substantial amount of strength is considered a strong predictor of aerobic capacity (Ahsan & Ali, 2021). The studies mentioned above have improved our understanding of the relationship between VO2max and the explosive strength of lower extremities. None of them determined this relationship for soccer and rugby players. The findings of this study provide objective information relating to the VO2max and explosive strength of lower extremity in soccer and rugby players. Moreover, this study helps find the possible effect of VO2max on the explosive strength of the lower extremity, which may have a significant role in training different sports athletes at different levels.

Material & methods

Study design and setting: A cross-sectional study design was accepted to conduct this study. The study was accomplished in the multipurpose indoor hall of the department of physical education.

Participants: All participants were voluntarily taken part in the study. Participants were informed of procedures and implications (risks and benefits) through a written and explained consent form. Only university rugby and soccer team member were included in the study; they competed in the interuniversity competition and practiced four days per week. Any participant who had musculoskeletal disorder or surgery in lower legs from the past three months was excluded from the study.

Data collection and analysis

Anthropometric characteristics: Bodyweight and stature were measured using a self-calibrated stadiometer cum weighing scale (Decteto-0.65, USA). A bioelectrical impedance analyzer with a tetra-polar impedance-meter (BIA101, Florance, Italy) was used to measure body composition. All measurements were taken in the early morning session, and all the participants wore sport-specific kits without shoes (Ali et al., 2020).

Single leg-leg vertical jump: Single-leg vertical jump was used to measure explosive lower leg peak power. Each participant was instructed to perform a single-leg vertical jump with maximum effort from a stationary position. It was recommended that the participant stands on the dominant leg unsupported beside the wall. To measure standing reach height participants, stretched up one arm and reached the maximum vertical height, then tapped their fingers to put a chalk imprint on the wall. Participants jumped as high as possible, tapped their fingers on the wall, left a chalk imprint at maximum vertical height, and landed on the dominant leg. Arms swings were not restricted during the jump as much as they wanted. Participants performed three trials with 15–25 second rest between each jump, and the best score was recorded. Jump distance was recorded as the difference between standing reach height and peak jump height. The lower leg peak power was determined as per the formula given by Johnson & Bahamonde (1996).

Peak power (W) = 78.5 x VJ (cm) + 31.2 x mass (kg) -15.3 x height(cm) - 1308

Beep Test: The beep test was used to measure the VO2max. The beep test is also known as the 20-meter shuttle run test. A beep test was used to measure VO2max in children, adolescents, and adults. The test provides a practical and cost-effective prediction of VO2max in a field setting. The test was performed as participants were asked to run toward and opposite 20-meter sections in a shuttle format in response to an audible signal (beep) produced by an audio player. The initial running speed was 8.5km/hr, and every minute running speed increased by 0.5km/hr. This increased running speed was described as a change in test level. Participants were required to complete a level before the next beep was produced. Participants were expected to finish as much shuttle as possible. The test was ended if a participant failed to follow the prescribed speed for two consecutive shuttles or withdrew from the test due to exhaustion. VO2max was determined as per the formula given by Flouris et al. (2005).

VO2max (mL/min/kh) = (max. attained speed (km/h) x 6.65 – 35.8) x 0.95 +0.182.

Each participant test scores were expressed as a VO2max obtained by cross-referencing the final level and shuttle number (Completed) at which the participant got exhausted. All tests were conducted using standard procedures and instructions.

Statistical analysis:

Descriptive statistics analysis: Descriptive statistics analysis has been done to determine the mean and standard deviation for VO2max and peak power of lower leg muscles in rugby and soccer players.

Test for normality: A normality test has been done to determine whether VO2max and peak power of lower leg muscles data are normally distributed or not. The Shapiro-Wilk test was performed to check the normality of data using the significance at 0.05 level.

Test for Relationship: We perform a simple regression analysis to define a correlation between VO2max and peak power of lower leg muscles in rugby and soccer players.

All reported p values were two-tailed. P-values of equal or less than 0.05 were considered statistically significant. Statistical analyses were performed using the IBM statistical package for social sciences (IBM SPSS) version 21 for the window.

Results

Table 1: Participant's anthropometric characteristics and body composition

	Soccer Players (N=17) Mean±SD	**Rugby Players (N=17) Mean±SD**	**Both (N=34) Mean±SD**	**Sig. (*p*=0.05)**
Age	21.41±1.62	21.53 ±1.77	21.47±1.67	**.841**
Body Weight	67.82±7.92	72.73±7.82	70.28±8.14	**.079**
Height	176.12±5.50	176.65±5.50	176.38±5.42	**.781**
BMI	21.81±1.70	23.29±2.12	22.55±2.04	**.031**
PBF	20.48±4.34	23.37±5.68	22.94±4.62	**.041**
Fat Mass	8.8±4.78	14.6±3.47	12.27±3.87	**.052**
LBM	49.5±3.38	46.9±4.65	47.84±4.23	**.048**

Table 1 showed that there were no significant differences between rugby and soccer players anthropometric characteristics in terms of age (p=.841), body weight (p=.079), and height (p=.781). At the same time, significant differences have been seen in BMI (p=.031) and PBF (p=.041).

Table 2: Test of normality in VO2max and peak power of lower leg muscles for rugby and soccer players

	SPORTS TYPE	**95% CI**		**Shapiro-Wilk**		
		Lower	**Upper**	**Statistic**	**df**	**Sig.**
VO2max	SOCCER	61.63	67.85	.947	17	.409
	RUGBY	60.63	66.25	.900	17	.068
Peak Power	SOCCER	3075.55	3698.22	.939	17	.305
	RUGBY	3297.18	3910.41	.966	17	.746

Table 2 showed that the statistic values are close to 1, and no significant differences were found in rugby and soccer players for VO2max and peak power of lower leg muscles. Therefore, we assume that data for VO2max and peak power of lower leg muscles were normally distributed, and further analysis was done using the parametric tests.

Table 3: Relationship between VO2max and peak power of lower leg muscles for rugby and soccer university players

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Correlation**	**Sig.**
Soccer	**VO2max**	17	64.74	6.05	1.47	-.454	.067
	Peak Power	17	3386.88	605.52	146.86		
Rugby	**VO2max**	17	63.44	5.47	1.33	.111	.670
	Peak Power	17	3603.80	596.35	144.63		

Table 3 showed that soccer players have a negative relationship (r=-.454) between VO2max and peak power of lower leg muscles. At the same time, rugby players showed a positive relationship (r=.111). The relationship was statistically insignificant for soccer and rugby (p=.067, p=.670) players, respectively, at a 0.05 level of significance.

Table 4: Relationship between VO2max and peak power of lower leg muscles for all university players

	N	**Mean**	**Std. Deviation**	**Std. Error of Estimate**	**Beta**	**Sig.**
VO2max	34	64.09	5.72	.513	1.224	.533
Peak Power	34	3495.34	601.93			

The table showed a positive relationship (ß=1.224) between VO2max and peak power of lower leg muscles for rugby and soccer players. This positive relationship was statistically insignificant (p=.533) at a 0.05 level of significance.

Discussion

This study examined the relationship between VO2max and peak power of lower leg muscles in rugby and soccer university players. VO2max values were found as 64.74±6.05 (ml/kg/min) in soccer players, 63.44±5.47 (ml/kg/min) in rugby players, and 64.09±571 (ml/kg/min) in total players on average. The peak power of lower leg muscles values was found as 3386.88±605.52 (watts) in soccer players, 3603.80±144.63 (watts) in rugby players, and 3495.34±601.93 (watts) in total players on average. According to the results of regression analysis on VO2max and peak power of lower leg muscle in soccer players in our study; The effect of VO2max on peak power of lower leg muscle was 6%, and the progressive relationship between VO2max and peak power of lower leg muscle jump was positively weak and insignificant ($R2=0.104$; $p<0.05$). For rugby players, the effect of VO2max on lower leg muscle peak power was 2%, and the regressive relationship between VO2max and peak power of lower leg muscle was poorly positive and significant ($R2=0.024$; $p<0.05$). In addition to all players, regardless of their sports, a positive correlation ($r=0.32$; $p<0.05$) was also evident between VO2max and lower leg muscle peak power. A certain number of increases in VO2max lead to no improvement in peak power of lower leg muscle. When we independently calculate the effect of VO2max on peak power of lower leg muscle in rugby and soccer players, this affected 50% in rugby players and 16% in soccer players. The regression relationship between VO2max and lower leg muscle peak power was poorly positive and insignificant ($R2=.63$; $p<0.05$) in rugby and soccer players.

The results showed that players VO2max should not be regarded as a limiting factor. Soccer players insignificantly showed a correlation between VO2max and peak power of lower leg muscle. This finding follows (Stojanovic et al., 2007) no correlation was found between VO2max and jump performance in elite players. Matthews et al. investigated the relationship between VO2max and leg strength and revealed no correlation between estimated VO2max and all leg strength measures (Matthews et al., (2004). Chelly et al. (2010) found no significant relationship between vertical jump performance and sprint ability among regional level soccer players. Mccurdy et al. (2010) also revealed in their study that no significant relationship existed between peak power of lower leg and VO2max for female soccer players while they measured the sprinting distance of 25 meters. Kale et al. (2009) also support their findings concerning the insignificant relationship between jump movement and sprint ability for competitive male sprinters. Few studies are in contradiction of present research findings. Wisløff et al. (2004) investigated the relationship between VO2max peak power of lower leg muscle among national soccer players and showed that the VO2max performance significantly correlated with peak power scores. There was a possible reason why this study differed from training level, age, methods to measure VO2max, and lower body peak power determination. Some studies have used the vertical jump to test lower leg explosive strength and VO2max in different athletes. Previous studies indicated that their result ranges from 16.59±2.21 among college-aged males who participated in multiple recreational sports (Sassi et al., 2009) to 20.41±2.63 among college physical education students (Almuzaini & Fleck, 2008). The results of this present study are not similar among earlier results for recreational players, but these findings are identical among more highly trained players.

This study indicated a significant positive relationship between VO2max and the explosive power of lower body muscles. The current study has suggested that the explosive power of lower leg muscles is a determinant of VO2max capacity. The findings are similar to Hennessy & Kilty (2001), who reported a similar relationship between vertical jump performance and running performance in female athletes. Bosco et al. choose to include both female and male participants in their study. They have contributed to a greater range of jump scores, which have indicated a higher correlation between vertical jump height and VO2max (Bosco et al., 1995). Kin-Isler et al. (2008) reported a significant relationship between concentric knee extension strength and anaerobic capacity in American Football players. Gabbett (2000) investigated anthropometric characteristics and physiological parameters for amateur rugby league players. The findings are consistent with the current study as the vertical jump mean scores were 13.27 to 16.73-inch for forward and back players. Similar results were also found with Quarrie & Wilson (2000), who reported a vertical jump height's mean score of 17.72 to 21.26.

The maximum oxygen uptake of players is measured in the laboratory setting using manual or automated treadmills and bicycle ergometers using gas parameters. In this study, a field setting was adopted using a beep test to measure the player's aerobic fitness or VO2max. Other field tests have many similarities as players require to run forth and back over a 20-meter distance on audio signals. However, the other test has a rest period after every 40-meter covered, whereas the beep test is continuous. Thus, the beep test provides a true measure of aerobic fitness. One of the main limitations of the Beep test is the expectation that players put in maximum effort. If this expectation is not met, the effectiveness of the test may be called into question. Measuring the height of the vertical jump in previous studies executing a jump, players were familiar with the way to perform that allows the use of arm freely, and depth of vertical jump was self-selected. This contrasted with the jump they performed in the present study, participants used the only dominant leg to jump, and arms were in a set position while jump was performed. These limitations were applied to confirm that the vertical jump provides a true measure of explosive strength of lower leg muscle without the contribution of coordination arm and other leg movements.

Conclusions

Considering the findings, it can be concluded that non-significant relationships were observed between VO2max and explosive peak power of lower leg muscle for soccer players. In contrast, rugby players showed a significant positive relationship. The research focused on the relationship between explosive peak power of lower leg muscles and VO2max neglecting the opportunity to examine the relationship between body composition and other parameters. However, these findings warrant further investigation in a laboratory setting for VO2max and more specific explosive power-related performance criteria in the coaching evaluation tool. Further examination of these measures may indicate the relevance of VO2max and explosive power of lower leg muscles assessment in monitoring and screening soccer and rugby players.

Conflicts of interest - No.

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