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CORRELATION STUDY BETWEEN OXYGEN CONSUMPTION AND BODY COMPOSITION IN PROFESSIONAL SOCCER PLAYERS AND NON-ATHLETE POPULATIONS WITH AND WITHOUT ANTERIOR CRUCIATE LIGAMENT RUPTURE

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Abstract Introduction: Anterior Cruciate Ligament Rupture (ACLR) in athletes tends to increase annually. Maximal Oxygen Consumption ($\dot{V}O_2$ max) and Body Composition (BC) characteristics influence athletic performance. Purpose: The aim of this study was to analyse the correlation between oxygen consumption and body composition in professional soccer players and non-athletes with and without anterior cruciate ligament rupture. Methods: A Cardiopulmonary Exercise Testing (CPET) was performed to measure the cardiorespiratory capacity of 15 professional soccer players (1 ACLR), age 22.47 ±3.16 years, weight 74.69 ±6.04 kg, height 177.97 ±6.85 cm and 22 non-athlete participants (7 ACLR), age 22.27 ±3.09 years, weight 68.1 ±10.28 kg, height 172.44 ±5.66 cm. Results: Soccer players had higher VO_2 values (L/min) than non-athletes 3.55 ±0.33 vs. 3.23 ±0.38 ($p < 0.05$). Heart rate (/min) was significantly higher in non-athletes than in soccer players 184.35 ±14.11 vs. 182.91 ±14.04. In the non-athletes group (CG), participants without ACLR had higher VO_2/kg (ml/min/kg) than ACLR. Conclusion: Most of the body composition variables correlated significantly with $\dot{V}O_2$Peak (L/min) in both groups. These results demonstrate that an adequate body composition influences the oxygen consumption capacity of professional soccer players and non-athletes, this is relevant in athletes because as stated in previous studies, fatigue is a risk factor for ACL injury.

Key words: sports performance, return to play, knee injury, ergospirometry

Introduction

Several studies highlight the high rate of ACLR in professional soccer players (Balendra et al., 2022; Forsythe et al., 2021; Waldén et al., 2016) and an annual increase in this injury has even been reported in Major League Soccer between 1996 and 2012 (Erickson et al., 2013). ACLR is common among knee injuries suffered by professional soccer players, as well as in other sports, threatening the careers of many athletes (Balendra et al., 2022; Erickson et al., 2013). The surgical procedure is usually used to reconstruct the ACL and advanced rehabilitation procedures allow players to return to sports practice at specific times (Balendra et al., 2022), Using the Knee Injury and Osteoarthritis Outcome Score (KOOS), it was reported that after six months the scores stabilised, which could indicate that this period of time would be sufficient to return to play (Zaffagnini et al., 2014), but some complications can prolong the stages of rehabilitation and return to play between 9 to 12 months (Balendra et al., 2022; Zaffagnini et al., 2014; Waldén et al., 2016; Erickson et al., 2013; Kyritsis et al., 2015; Ardern et al., 2014; Grassi et al., 2020) and even 4% or 5% returned up to two or three years after the injury (Forsythe et al., 2021). Furthermore, it is common for athletes to develop abnormal patterns of strength, proprioception, balance, and neuromuscular control after ACL reconstruction (Dai et al., 2014), adding to the increased risk of chronic knee instability, meniscus injury, cartilage injury, and the development of osteoarthritis (LaBella et al., 2014; Waldén et al., 2016; Erickson et al., 2013).

High values of $\dot{V}O_2$ max can delay the onset of fatigue capable of affecting neuromuscular control (Khalid et al., 2015). $\dot{V}O_2$ max is considered a reliable method to evaluate aerobic capacity, which is essential for the performance of soccer players and their rapid recovery capacity post-competition (Marcos et al., 2018; Tonnessen et al., 2013; Aksoy et al., 2022; Modric et al., 2020).

Average $\dot{V}O_2$ max values are between 50 and 75 mL*kg-1*min-1 necessary for the aerobic capacity demands in men's professional soccer (Tonnessen et al., 2013; Modric et al., 2020). In moderate altitude conditions, values of 50 ±6.9 mL*kg-1*min -1 were reported in 1106 soccer players evaluated between 1998 and 2014 (Roa et al., 2015).

The development of aerobic capacity is essential for rapid post-competition recovery (Aksoy et al., 2022), the effort during a soccer match can generate an inflammatory response due to muscle damage and consequently reduce performance for 24 to 72 hours, according to the role of the player (Poulios et al., 2018), it has been considered that aerobic capacity may be a risk factor for injury because fatigue and inadequate recovery alter muscle control patterns and predispose individuals to possible injuries (Watson et al., 2017). On the other hand, it has been suggested that body composition may be associated with the risk of injury (Watson et al., 2017), and has an influence on aerobic capacity, which may also vary according to the playing position (full-backs, midfielders, attackers, central defenders, goalkeepers), the moment of preparation in which it is measured (preseason, season, end of season), the level of the players (professionals or third to fifth division) (Marcos et al., 2018), or after an ACL injury (Almeida et al., 2018). The aim of this study was to analyse the correlation between oxygen consumption and body composition in professional soccer players and non-athletes with and without anterior cruciate ligament rupture.

Methods

Selection of participants

Participants were selected by non-probabilistic sampling and distributed into two groups: Professional Soccer Players (SPG) (n = 15, age 22.47 ±3.16 years, the sporting age was 16.8 ±2.7 years, they compete in the highest level tournaments of Colombian soccer on average twice a week: Colombian professional league and Colombian cup, some have competed in clubs in other countries and were called up to the national team for the U20 world championships. They train on average 30 hours per week), and healthy non-athletic participants (CG) (n = 22, 22.27 ±3.09 years) were included.

The study was approved by the Research Committee on 7 December 2020, Act 145 of the Universidad de Ciencias Aplicadas y Ambientales U.D.C.A. The participants in both groups signed an informed consent form. Inclusion and exclusion criteria for participants were: being over 18 years old with or without a history of ACLR. When they reported an ACLR, they were required to have completed rehabilitation and have medical approval to return to sports activity. In CG, physical activity levels were estimated with the International Physical Activity Questionnaire (IPAQ) short version (Craig et al., 2003). People were excluded if: a) they report a history or suffer from neurological, motor (neuromuscular) or cognitive disorders, b) they have a BMI >35, c) they report any cardiovascular alteration, d) inability to perform the test, e) or without medical endorsement for return to normal physical practice.

Data collection

Before the test, participants were asked to avoid high-intensity exercise or training 24 hours before the test, to avoid drinks with caffeine or alcohol on the day of the test, and to wear comfortable sports clothing and shoes for the test.

Anthropometric height measurements were taken from the participants with a Seca 213 Stadiometer (Measuring range 20–205 cm, Hamburg, Germany) and body composition by Bioimpedance with the Tanita BC-1500 scale (maximum capacity 150 kg d = 0.1 kg, Japan). All tests were carried out in one week, soccer players (SPG) were evaluated at the beginning of the 2022-2 pre-season, on one day starting at 8:00 am and ending at 4:00 pm. The non-athletic individuals (CG) were evaluated for three days at the same time as the soccer players. The tests were carried out by the same researchers (JB, JR, NO, AS, CS), who have the expertise to use the instruments and carry out the measurements.

The test was carried out in the laboratory at room temperature 16–18º C, relative air humidity ≈ 60%, barometric pressure between 690 to 710 mmHg and 2600 m altitude (moderate altitude), Bogotá, Colombia. The amount of oxygen (O_2) consumed, carbon dioxide (CO_2) produced, and lung ventilation (VE) were measured breath-by-breath with a Metalyzer 3B computerized gas exchange analysis system (Cortex Biophysik GmbH, Leipzig, Germany) and were analyzed with the Metasoft™ program. Before each test, the Cortex unit was calibrated with a previously known gas sample (16% O_2 and 5% CO_2).

Cardiopulmonary Exercise Testing (CPET) was performed using a motorized treadmill, maintaining an incline of 1%, the test included three phases: 1) a 3-minute warm-up walking at 4 km*h-1, 2) the exercise began at 4 km*h-1 followed in increments of 1 km*h-1 every 90 seconds until exhaustion. Verbal encouragement was used at the end of the test. 3) The recovery phase was 3 minutes of walking at 4 km*h-1. Heart rate was measured with a Polar band linked to Metasoft™ software.

Criteria for reaching $\dot{V}O_2$ max it is: a) voluntary exhaustion, b) reaching at least 90% ±5% of the maximum heart rate (Midgley et al., 2007), c) rate of respiratory exchange greater than 1.15, d) $\dot{V}O_2$ max identified by the plateau phase (difference between the last stages < 0.05 L*min -1) and confirming that $\dot{V}O_2$ max increase was less than 2 ml/kg/min between two consecutive stages at peak exercise (Neto et al., 2022).

$\dot{V}O_2$ max was quantified by a sports physician (CS). Ventilatory thresholds (VT1) were determined when the lowest ventilatory oxygen equivalent ($VE/\dot{V}O_2$) was observed before its continuous increase, and the lowest end-tidal oxygen pressure ($PETO_2$) before its continuous increase. The ventilatory threshold (VT2) was determined when the lowest ventilatory carbon dioxide equivalent (VE/VCO_2) was observed before its continuous increase and the highest expiratory carbon dioxide pressure ($PETO_2$) before the abrupt fall (second inflection point of the curves in progressive exercise). This is the transition between stable and heavy rhythms (Almeida et al., 2018).

Analysis of Ventilatory Thresholds

Anaerobic threshold (AT) values were determined using the V-Slope method (Lin et al., 2020). The AT was identified at the intersection of the two straight lines describing the relationship between carbon dioxide production (VCO_2) and oxygen consumption ($\dot{V}O_2$). The determination is performed through regression analysis, where the point of intersection of the regression lines are systematically moved across the data range. The final AT is designed at the location where the remaining sum of squares is minimized (Santos & Giannella-Neto, 2004). This method allows for a precise and objective identification of the metabolic transition point during incremental exercise, providing insights into the physiological threshold between aerobic and anaerobic metabolism.

Statistical analysis

The data were processed with IBM SPSS Corp. 2017. IBM SPSS Statistics for Windows, Version 25. The Shapiro-Wilk test verified the normal distribution of the data. The Student T test for independent samples allowed us to compare the averages of both groups in each variable, the Mann-Whitney U test for independent samples was used in the variables that did not have a normal distribution (non-parametric test). The Pearson test was used to establish the correlation between the variables with normal distribution in consistency with the ranges of 0 null, between 0.01 to 0.20 low; 0.21 to 0.40 weak; between 0.41 to 0.60 average; between 0.61 to 0.80 medium-high; between 0.81 to 0.99 high, 1 perfect, regardless of whether it is positive or negative. Spearman's rank correlation coefficient (non-parametric) was used for variables without normal distribution.

Results

Thirty-seven participants (n = 37) were evaluated, distributed in a group of professional soccer players (SPG) n = 15 (14 without ACLR, 1 ACLR), age 22.47 ±3.16. years, weight 74.69 ±6.04 kg, height 177.97 ±6.85 cm, and the control or non-athlete group (CG) n = 22 (15 without ACLR, 7 ACLR), age 22.27 ±3.09 years, weight 68.1 ±10.28 kg, height 172.44 ±5.66 cm. In the CG, the results of the IPAQ questionnaire showed an average of 356.46 ±187.74; 294.86 ±88.14 and 294.03 ±108.31 min of intense and moderate physical activity and time spent walking per week respectively, while the sitting time on a working day was 184.45 ±117.44 minutes.

The normality of the data in each variable was checked with the Shapiro-Wilk test in SPSS, α = 0.05 (5%) was established. Twenty-eight variables were analysed that describe the general characteristics, body composition and cardiorespiratory capacity of the participants. Eight variables did not have a normal distribution: age (yrs), body fat mass (kg), visceral fat rating, $\dot{V}O_2$/HR (ml), HR (min), Vmax. (km/h), VT (L), FR (min), these data were analysed with non-parametric tests, the results are shown in Table 1.

Table 1. Comparison of non-normally distributed variables in both groups (mean ± standard deviation).

Variables	SPG (n = 15)	CG (n = 22)	p-value
Age (yrs)	22.47 ±3.16	22.27 ±3.09	0.658 NS
Body fat mass (kg)	11.21 ±3.88	10.36 ±4.52	0.262 NS
Visceral fat rating	2.67 ±1.59	2.43 ±1.71	0.366 NS
$\dot{V}O_2$/HR (ml)	19.61 ±4.76	19.27 ±4.6	0.002*
HR (/min)	182.91 ±14.04	184.35 ±14.11	0.002*
Vmax (km/h)	15.12 ±1.22	15.08 ±1.21	0.319 NS
VT (L)	2.6 ±0.4	2.61 ±0.38	0.963 NS
RF (/min)	57.43 ±13.26	56.81 ±12.84	0.127 NS

Asymptotic significance is shown. The significance level is 0.05. * The exact significance for this test is shown. NS: Not Significant. $\dot{V}O_2$: Oxygen Consumption. HR: Heart Rate. V: Velocity. VT: Ventilatory threshold. RF: Respiratory Frequency.

The Mann-Whitney U-test for independent samples showed that $\dot{V}O_2$/HR (ml), and HR (/min) had significant differences. The characteristics of the variables in each group are shown in Table 2.

Table 2. Comparison of variables among SPG and CG groups (mean ± standard deviation).

Variables	SPG (n = 15)	CG (n = 22)	p-value	Mean difference
Weight (kg)	74.69 ±6.04	68.1 ±10.28	0.033*	6.582
Height (cm)	177.97 ±6.85	172.44 ±5.66	0.011*	5.530
BMI (kg/m2)	24.11 ±1.94	22.9 ±2.66	0.142 NS	1.209
Body fat (%)	14.87 ±4.5	13.91 ±5.12	0.561 NS	0.960
Fat-free mass (kg)	63.48 ±5.12	57.9 ±7.35	0.016*	5.575
Body water (%)	61.03 ±3.41	62.05 ±4.35	0.456 NS	–1.012
Body water mass (kg)	45.51 ±3.62	42.00 ±4.46	0.016*	3.511
Muscle mass (kg)	60.34 ±4.89	55.39 ±6.55	0.018*	4.954
Bone mass (kg)	3.17 ±0.23	2.93 ±0.31	0.020*	0.235
BMR (kcal)	1879.6 ±144.49	1729.95 ±203.16	0.019*	149.645
$\dot{V}O_2$Peak (L/min)	3.55 ±0.33	3.33 ±0.34	0.056 NS	0.226
VO_2 (L/min)	3.55 ±0.33	3.23 ±0.38	0.013*	0.321
$\dot{V}O_2$/kg (ml/min/kg)	48.2 ±3.09	48.27 ±4.84	0.959 NS	–0.072
Duration (min)	20.7 ±1.17	21.32 ±1.84	0.262 NS	–0.616
VE/$\dot{V}O_2$	42.36 ±4.6	40.91 ±4.19	0.328 NS	1.448
VE/VCO_2	35.09 ±2.8	36.83 ±2.86	0.076 NS	–1.743
RER	1.2 ±0.05	1.11 ±0.05	0.000*	0.087
VE (L/min)	159.38 ±20.2	144.04 ±19.22	0.025*	15.341
VT1 (L/min)	2.17 ±0.38	1.97 ±0.32	0.104 NS	0.197
VT2 (L/min)	2.86 ±0.36	2.85 ±0.39	0.934 NS	0.010

Note: * There are significant differences $p < 0.05$ between groups using T for independent samples. The duration of the test includes the three phases (warm-up, exercise, recovery). NS: Not Significant. BMI: Body Mass Index. BMR Basal Metabolic Rate. $\dot{V}O_2$: Oxygen consumption. VE/$\dot{V}O_2$: Ventilatory Oxygen Equivalent. VE/VCO_2: Ventilatory Carbon Dioxide Equivalent. RER: Respiratory Exchange Ratio. VE: Lung Ventilation. VT: Ventilatory threshold.

The SPG had greater height (cm) and body weight (kg) than the CG. In the body composition variables, there were also significant differences that demonstrate the effects of systematic training in soccer players: greater fat-free mass (kg), body water mass (kg), muscle mass (kg), bone mass (kg), basal metabolic rate (kcal) compared to CG.

There were no significant differences between the groups in BMI, body fat (%), and body water (%), $\dot{V}O_2$Peak (L/min), $\dot{V}O_2$/kg (ml/min/kg), Vmax (km/h), duration (min), VE/$\dot{V}O_2$, VE/VCO_2, VT (L), RF (/min), VT1 (L/min), VT2 (L /min). There were significant differences in $\dot{V}O_2$ (L/min), $\dot{V}O_2$/HR (ml), and VE (L/min) where the SPG results were superior to the CG. The only variable in which CG had a statistically significant higher value compared to SPG was HR (/min).

In SPG, one participant had ACLR in the working leg (right) when he was 22 years old. The athlete underwent reconstruction surgery and carried out the physical rehabilitation process for 6 to 9 months until returning to professional sports practice. He reported pain and inflammation as symptoms after the ACL injury, in addition, he had a meniscus injury before the ACL injury. This soccer player reached 3.73; 47; 15 and 20.33 in $\dot{V}O_2$Peak (L/min), $\dot{V}O_2$/kg (ml/min/kg), Vmax (km/h) and duration (min), respectively.

On the other hand, in the CG seven participants had ACLR: age 24.28 ±3.8 years, height 174.78 ±5.1 cm, weight 70.71 ±3.9 kg, age at which the injury occurred 20.42 ±2.3 years. All underwent reconstruction surgery and completed physical rehabilitation for 1 to 3 months (n = 3) and >3 to 6 months (n = 4). In addition, they reported medial collateral ligament injury (n = 3) and internal and/or external meniscus injury (n = 2) associated with the ACLR. The mechanism of injury was non-contact during a soccer game (n = 6) and contact (n = 1). Participants with

ACLR recorded 3.22 ±0.2; 44.86 ±2.7; 14.57 ±1.1 and 20.51 ±1.3 in $\dot{V}O_2$Peak (L/min), $\dot{V}O_2$/kg (ml/min/kg), Vmax (km/h) and duration (min), respectively.

The CG results were compared between participants with and without ACLR (Table 3).

Table 3. Comparison between participants with and without ACLR in the CG (mean ± standard deviation).

Variables	ACLR (n = 7)	No ACLR (n = 15)	p-value
$\dot{V}O_2$Peak (L/min)	3.22 ±0.02	3.37 ±0.16	0.33 NS
$\dot{V}O_2$/kg (ml/min/kg)	44.85 ±7.4	49.86 ±23.4	0.01*
Duration (min)	20.5 ±1.7	21.7 ±3.9	0.16 NS
VT1 (L/min)	1.91 ±0.05	2.07 ±0.13	0.54 NS
VT2 (L/min)	2.74 ±0.02	2.89 ±0.2	0.4 NS

Note: * There are significant differences $p < 0.05$ between groups using T for independent samples. NS: Not Significant. $\dot{V}O_2$: Oxygen consumption. VT: Ventilatory threshold.

The only variable in which there was a significant difference when comparing CG participants with or without ACL injury was relative oxygen consumption, where the result was higher in participants without ACL injury. In the other variables, the data are higher in the group without ACL injury, although the differences are not statistically significant.

Pearson's correlation test ($p \leq 0.05$) was used to find the correlation between normally distributed variables (Table 4).

Table 4. Correlation study oxygen consumption and body composition variables in both groups.

Groups	VO_2Peak SPG (n = 15)	VO_2Peak CG (n = 22)
Variable	**r**	**r**
Weight (kg)	0.709**	0.761**
Height (cm)	0.621*	0.461*
BMI (kg/m2)	0.153	0.710*
Body fat (%)	0.033	0.345
Fat-free mass (kg)	0.690**	0.799**
Body water (%)	–0.079	–0.416
Body water mass (kg)	0.671**	0.753**
Muscle mass (kg)	0.686**	0.756**
Bone mass (kg)	0.729**	0.750**
Basal metabolic rate (kcal)	0.679**	0.776**

**. The correlation is significant at the 0.01 level (two-sided).
*. The correlation is significant at the 0.05 level (two-sided).

Both SPG and CG groups had significant correlations between $\dot{V}O_2$Peak (L/min) and body composition variables. These results demonstrate that proper body composition is important for efficient oxygen consumption. The significant correlations found in each group are represented in the graphs below.

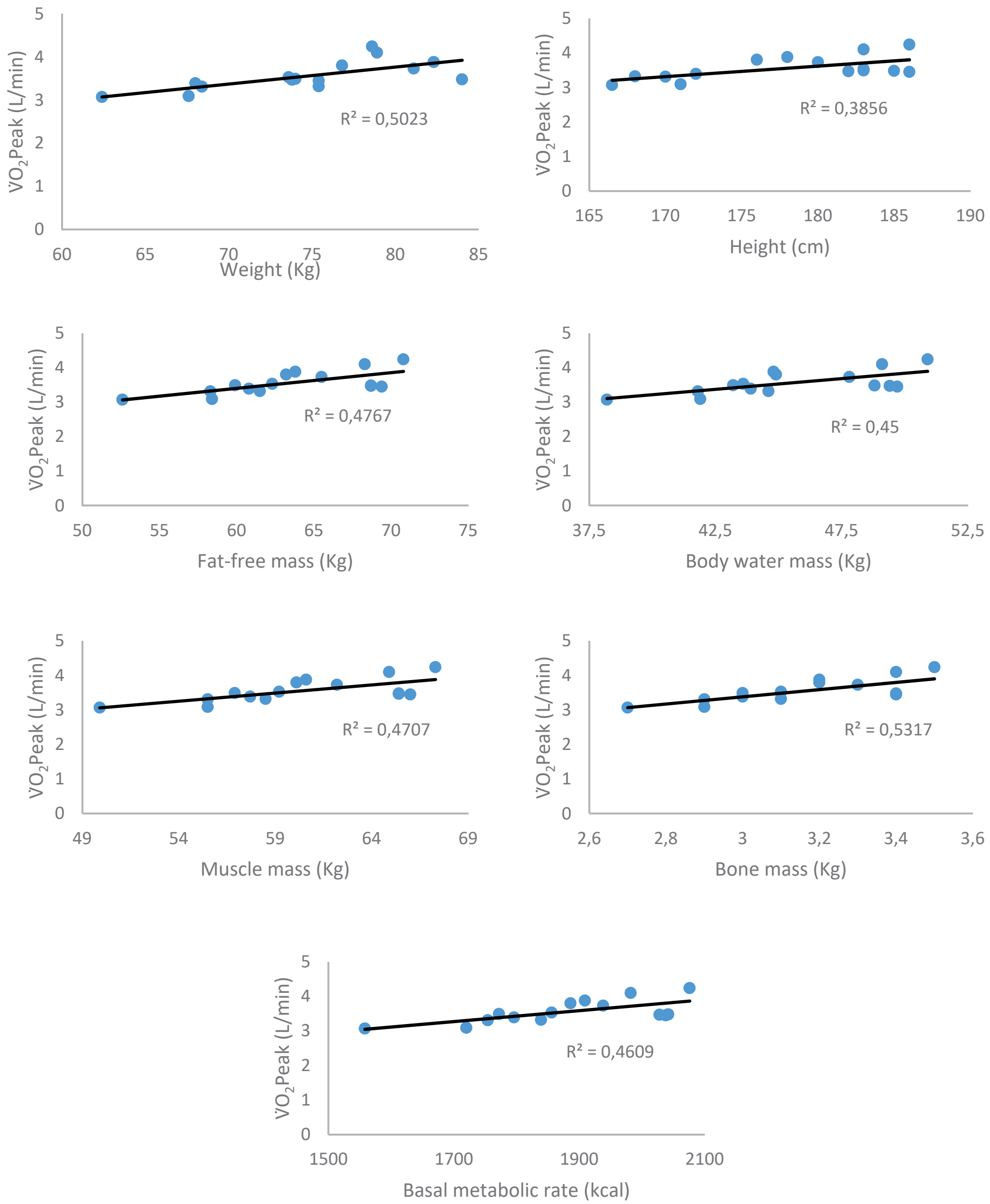

Fig. 1. Correlation between V˙O_2Peak (L/min) and body composition variables SPG.

In SPG there was a medium-high correlation between V˙O_2Peak (L/min) and weight (kg), height (cm), fat-free mass (kg), body water mass (kg), muscle mass (kg), bone mass (kg), BMR (kcal).

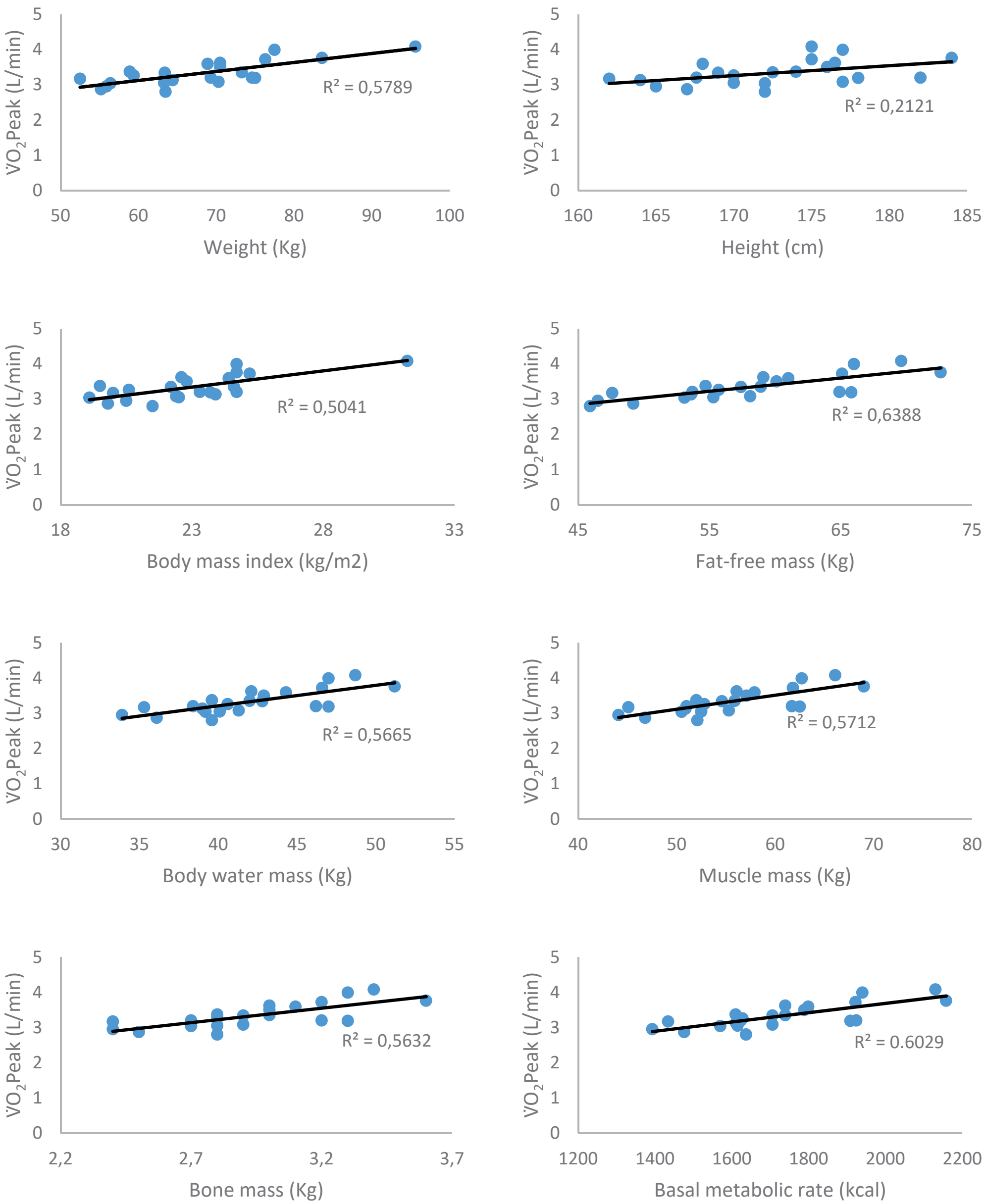

Fig 2. Correlation between $\dot{V}O_2$Peak (L/min) and body composition variables CG.

In CG there was a medium correlation between $\dot{V}O_2$Peak (L/min) and height (cm), and a medium-high correlation between $\dot{V}O_2$Peak (L/min) and weight (kg), BMI (kg/m2), fat-free mass (kg), body water mass (kg), muscle mass (kg), bone mass (kg), BMR (kcal). These results demonstrate that body composition variables can affect oxygen consumption capacity in professional athletes and non-athlete participants.

Discussion

The purpose of this study was to analyse the correlation between oxygen consumption and body composition in professional soccer players and non-athletes with and without anterior cruciate ligament rupture. According to the literature consulted, ACLR is caused by multiple factors including body composition (LaBella et al., 2014). Evaluating physical aspects in Colombian professional soccer players allows the characterisation of fundamental parameters (Blanco-Espitia et al., 2023), revealing distinctive physical characteristics of Latin American professional soccer players in comparison with their European peers (Da Silva et al., 2008). Comparative studies in professional soccer have shown variations in body fat percentages in different populations (Burns et al., 2018). Slimani & Nikolaidis (2019) identified body fat percentages of 11.2 ±4.3 % in healthy Icelandic first division soccer players, this percentage is lower than the result of the professional soccer players in this study (14.87 ±4.5%). Almeida et al. (2018), reported body fat percentages of 14.9 ±5.4 % for athletes with ACL rupture and 12.8 ±4.0 % for healthy athletes, these data are lower compared to the results of this study, whereas the soccer player with ACLR had 19.2% and healthy athletes had 14.6 ±4.5% body fat, highlighting significant variations in body composition between professional soccer players.

The relationship between body composition and cardiorespiratory fitness in population aged 18–70 years from Tehran, Iran was investigated by Davarzani et al. (2020) who found that participants with higher level of physical activity had significantly higher mean lean body mass ($p < 0.001$), right ($p < 0.001$) and left ($p < 0.001$) arm lean mass, skeletal muscle mass ($p < 0.001$) and bone mineral content ($p < 0.001$). They also found a significant negative relationship between physical activity level and fat mass ($p = 0.002$), body fat percentage ($p < 0.001$), visceral fat area ($p = 0.001$) and trunk fat ($p = 0.005$), demonstrating the lower amount of fat in the high physical activity group.

On the other hand, Robles Pino et al. (2019) in the analysis of the players of the U22 Peruvian national soccer team in 2015 found a positive correlation between VO_2 max and relative muscle mass (Spearman's Rho = 0.65; $p < 0.001$) and a negative correlation with relative adiposity (Spearman's Rho = –0.48; $p = 0.018$). While Castiblanco Arroyave et al. (2020) found a statistically significant correlation between cardio respiratory capacity, BMI and fat percentage in university athletes from Manizales (Colombia).

In the analysis of $\dot{V}O_2$ max, Slimani & Nikolaidis (2019) it was reported 59.2 to 66.6 ml/kg/min and 57.8 to 61.7 ml/kg/min in healthy elite and amateur male soccer players respectively. These data are higher than the results of the healthy soccer players in this study 48.3 ±3.2 ml/min/kg. Likewise, Almeida et al. (2018), reported a $\dot{V}O_2$ max of 48.9 ±3.8 ml/kg/min and 56.9 ±4.2 ml/kg/min in Brazilian soccer players with RLCA and healthy players respectively, these data exceed the results of the soccer player with RLCA in this study 47 ml/ min/kg and healthy athletes 48.3 ±3.2 ml/min/kg. However, the results of this study are close to the average of 50 ±6.9 mL*kg-1*min –1 reported in the measurements of soccer players between 1998 and 2014 in the Coldeportes Exercise Physiology Laboratory in Bogotá (Roa et al., 2015), although it is unknown at what time of the season the measurements were made. While Blanco-Espitia et al. (2023) reported $\dot{V}O_2$ max values of 53.2 ±4 ml/kg/min in 39 professional soccer players from Bogota estimated with the Leger test. Thus, information about oxygen consumption in soccer players at average height remains scarce and more studies are required to compare data at each stage of training.

Castagna et al. (2013) determined that the aerobic capacity necessary to meet the minimum requirements in men's professional soccer is 60 ml/kg/min, this value is higher than the result of the soccer players in this study 48.2 ±3.09 ml/min. kg/min. Therefore, soccer players require optimal aerobic capacity to sustain high-intensity repetitive actions, speed up recovery processes and maintain their physical performance during the competition time, which would be at least 90 minutes (Bangsbo, 2014; Faustino-da-Silva et al., 2020).

In the study by Teixeira et al. (2018) thresholds were measured in a maximum incremental exercise test on a motorized treadmill, reporting a VT1 = 2.71 ±0.32 (L/min), this result exceeds what we found in the soccer players in this study 2.17 ±0.38 L/min. On the other hand, it is said that VT2 is responsible for the efficiency of the buffer system and acid-base regulation to maintain the pH in the blood and peripheral muscles. In this regard, Sahlin (2014) determines that there is a significant improvement in the cushioning system (buffer) in subjects who perform post-injury rehabilitation exercises, interpreting that those who adhere to rehabilitation programs improve their VT2. At the second threshold, Teixeira et al. (2018) reported VT2 = 3.28 ±0.50 (L/min) in soccer players aged between 12.5 and 15.4 years, this result exceeds the 2.86 ±0.36 L/min achieved in VT2 by soccer players from present study.

A limitation of this study was the selection of a convenience sample (professional men's soccer team); therefore, selection bias exists and it is advisable to interpret these results with caution. However, it is important to analyse professional soccer players because information about these players is limited, specifically in conditions of moderate altitudes above sea level. Furthermore, it is advisable to carry out further measurements to evaluate the results over time in order to obtain more scientific evidence on this issue.

The data obtained in this study are considered valuable because the use of the cortex Metalyzer 3B Leipzig instrument confirms the validity of the results due to its high quality of monitoring. Validated results were obtained about the cardiorespiratory capacity of male professional soccer players, in the CG it was evident that $\dot{V}O_2$ max is significantly lower in participants with ACLR compared to healthy subjects.

Future research should focus on studying with larger randomized cohorts and longitudinally. Furthermore, this type of research should be carried out on female soccer players since the highest percentage of ACLR falls on the female gender.

Conclusion

The results of this study show that most of the body composition variables: weight (kg), height (cm), fat-free mass (kg), body water mass (kg), muscle mass (kg), bone mass (kg), BMR (kcal) have a significant correlation with $\dot{V}O_2$Peak (L/min) in both groups. These results demonstrate that an adequate body composition influences the oxygen consumption capacity of professional soccer players and non-athletes, this is relevant in athletes because as stated in previous studies, fatigue is a risk factor for ACL injury. As far as we know, this is one of the first studies conducted in Bogota, Colombia, to analyse oxygen consumption and body composition in professional soccer players and non-athletes with and without ACL injury. Therefore, the data obtained constitute a reference for future research on these topics in soccer.

In the body composition variables: weight (kg), height (cm), fat-free mass (kg), body water mass (kg), muscle mass (kg), bone mass (kg), BMR (kcal), SPG had significant results higher than CG. However, in the oxygen consumption variables only $\dot{V}O2$ (L/min) and VE (L/min) had significant differences. It is important to note that SPG was assessed in the first week of the pre-season, this may justify that the oxygen consumption values are close to those of non-athletes, but studies are required at other times of the season to verify these results.

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