Measurement of resting muscle oxygenation and the relationship with countermovement jumps and body composition in soccer players

Medición de la oxigenación muscular en reposo y la relación con los saltos en contramovimiento y la composición corporal en jugadores de futbol

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Abstract

The measurement of resting muscle oxygenation capacity is under investigation in team sports. The aim of the current study was to observe the changes after a preseason, in muscle oxygen saturation (SmO_2) at rest and the relationship with body composition and jump power in soccer players. 17 soccer players (age 21.8 ± 2.2 years) were enrolled. Body composition, somatotype, countermovement jump (CMJ) and single-leg countermovement jump (SLCMJ) were evaluated. Also, SmO_2 at rest in the gastrocnemius muscle using the technique of arterial occlusion in the dominant leg and non-dominant leg was performed. All measurements were made before and after the preseason. The t-student test, Pearson's correlation and inter-individual response of the subject's statistic were applied to measure the magnitudes of change and the effect size. An inverse relationship was observed between SmO_2 at the initial-occlusion (r= -0.82), final-occlusion (r= -0.79) and SmO_2 recovery (r= -0.82) with the SLCMJ power. A moderate relationship was also observed between oxygen consumption and fat mass (r= 0.64). The measurement of SmO_2 at rest can be considered as a possible performance parameter because it has determined its relationship with the ability to produce strength and jumping power in soccer players.

Key words: Performance, jumping power, preseason, NIRS.

Resumen

La medición de la capacidad de oxigenación del músculo en reposo está bajo investigación en los deportes de equipo. El objetivo del presente estudio fue observar los cambios, después de una pretemporada, en la saturación de oxígeno muscular (SmO_2) en reposo y la relación con la composición corporal y la potencia de salto en los jugadores de fútbol. Participaron 17 jugadores de fútbol (edad 21.8 ± 2.2 años). Se evaluó la composición corporal, el somatotipo, el salto de contramovimiento (CMJ) y el salto de contramovimiento de una sola pierna (SLCMJ). Simultáneamente, se midió la SmO_2 en reposo en el músculo gastrocnemio utilizando la técnica de oclusión arterial en la pierna dominante y no dominante. Todas las mediciones se realizaron antes y después de la pretemporada. Se aplico la prueba t-student, la correlación de Pearson y la estadística de respuesta inter-individual de los sujetos para medir las magnitudes de cambio y el tamaño del efecto. Se observó una relación inversa entre SmO_2 en la oclusión inicial (r= -0.82), la oclusión final (r= -0.79) y la recuperación de SmO_2 (r= -0.82) con la potencia SLCMJ. También se observó una relación moderada entre el consumo de oxígeno y la masa grasa (r=0.64). La medición de SmO_2 en reposo se puede considerar como un posible parámetro de rendimiento, porque se identificó su relación con la capacidad de producir fuerza y potencia de salto en jugadores de fútbol.

Palabras clave: Rendimiento, potencia de salto, pretemporada, NIRS.

Introduction

Soccer is characterized by the mix of short-duration sprints, high-intensity running, jumps, duels, tackles, directional changes, movements, walking and standing episodes with an average game intensity ranging from 80 to 90% of maximal heart rate (HRmax) and 70% and 80% and average maximal oxygen uptake (VO_2max) (Saeidi, 2017). In recent years, more attention has been paid to performance in soccer players because it was discovered that the most successful teams had better values in some performance indicators (VO_2max, lactate, heart rate, jump power and body composition) compared to less successful teams (Raiola & D'isanto, 2016).

Three periods can be identified in soccer: preseason, season and a period of transition and/or recovery. Within these periods, the preseason is the stage where the fitness workload is greater, causing higher fitness changes. It is in this period that there is more control over the planning of the training, since the schedule involves fewer games. Therefore it is important to assess performance and adjust the workload to produce specific adaptations in soccer players (Morgans et al., 2014).

Body composition (BC) has been proposed as an indicator of sports performance due to its relationship with the VO_2max performed in a yo-yo test, indicating that thinner players tend to have better values (Lago-Peñas et al., 2014), and a high muscular profile related to better anaerobic performance in an Repeated Sprint Ability (RSA) (Brocherie et al., 2014). BC variables such as muscle mass and waist circumference can influence the ability to recover the jumping power of soccer players (Vasquez-Bonilla et al., 2019). It is also known that BC improvements can be visualized during the changes that occur in the preseason due to the result of a return to the fitness levels lost in the transition period (Argus et al., 2010; Requena et al., 2017). Also, previous research has demonstrated a clear relationship between absolute and relative strength with performance in sprints and jumps in athletes, indicating that stronger athletes demonstrate higher sprint and jump performance (Comfort et al., 2014), In addition, recent studies highlight the single-leg countermovement jump test (SLCMJ) as the most appropriate test to identify differences between limbs with values > 12% that show negative associations with sprint times (Bishop et al., 2018). Furthermore, the above-mentioned authors proposed the evaluation of neuromuscular capacity due to the potential impact on the physical performance of soccer players.

On the other hand, there are portable technologies that allow the assessment of muscle oxygen saturation (SmO_2) using non-invasive near-infrared spectroscopy (NIRS) (Perrey & Ferrari, 2018) as an indicator of performance of the metabolic level in athletes. A better muscle oxygenation capacity has been observed in active people than in sedentary people, so NIRS could be used to estimate mitochondrial function both when resting and during exercise. In addition, NIRS could be used to observe changes in resting muscle oxygen after a period of short and transient artery occlusion (Buchheit et al., 2011). These measurements have demonstrated good reproducibility and have been established as measurements of muscular oxidative capacity (Nygren et al., 2014; Terence E. Ryan et al., 2012). Likewise, muscle oxygenation at rest using this technique, has potential to characterize states of fatigue related to excess oxygen within the muscle in the recovery period (Bonilla, A. A. V., Timon, R., Camacho-Cardeñosa, A., Camacho-Cardeñosa, M., Guerrero, S., & Olcina, 2020), it is currently the only study that used the arterial occlusion technique in soccer players. Therefore, it should continue to be studied in this population.

In team sport there are few studies conducted with an SmO_2 assessment, even though it is considered one of the promising physiological markers of performance, but there is a scientific gap about its use as an indicator of performance and possible relationships with other physical abilities. The questions to address in this study were: 1) could the SmO_2 at rest be used as a variable to assess changes in performance and in muscle metabolism after the preseason?; 2) Is SmO_2 related to changes in the BC, and the power generated in the high jump and jumping to one leg? Therefore, the aim of the current study was to observe the changes after a preseason, in muscle oxygen saturation (SmO_2) at rest and the relationship with body composition and jump power in soccer players.

Methods

Participants

Seventeen male soccer players competing in the Spanish third division voluntarily participated (age: 22 ± 2 years; experience: 8 ± 2 years). Participants were instructed to eat normally and to avoid: unusual physical activity, alcohol and any toxic substance until the end of the study. Both coaches and soccer players of the clubs signed the informed consent form that testifies that they understood the possible risks of this study. In addition, the methodology of this research was approved by the Scientific and Ethical Committee of the University of Extremadura with Number of registration: 131/2018 and it was in accordance with the principles of the Declaration of Helsinki.

Instruments

I. Body composition assessment

All anthropometric measurements were performed according to the International Society of Advancement of Kinanthropometry (ISAK) protocol (Marfell-jones & Olds, 2008) And following the recommendations of the International Biological Program (Weiner, Joseph Sidney and Lourie, 1969). Height (cm) was measured using a SECA 220 measuring rod (Hamburg, Germany), with precision to within 1mm. Body Mass (BM) (kg) was measured using SECA 225 scales to within 0.1kg. Body Mass Index (BMI) was calculated using the BM / height2 (kg / m2) equation. Muscle perimeters (cm) (arm, contracted arm, waist, hips, thigh and calf muscles) were assessed using a tape-mesaure (SECA203) with precision to within 1mm. Skinfolds (mm) (tricipital, abdominal, subscapular, iliac crest, front thigh, and calf) were analyzed using the skinfold caliper (Harpenden skinfold calipers, Southam, UK: HAB International), with precision to within 0.2mm. The sum of six skinfolds (skinfolds) and percentage of fat mass (% fat mass) were estimated using the six subcutaneous fat skinfolds (Yuhasz, 1974): Fat Mass%: (Σskinfolds * 0.097) + 3.64. the two diameters were mesaured: bi-epicondylar humerus and bi-epicondylar femur breadth (Holtain bone calipers, Pembrokeshire, UK: Holtain) accurate to within 1mm. Anthropometric measurements have a coefficient variation ranging between 0.776 and 1.00 for skinfolds, between 0.875 and 0.992 for circumferences, and 1.00 for weight and height, measured between two certified anthropometrists (Santos et al., 2014). The somatotype components (endomorphy-mesomorphy-ectomorphy) were calculated according to the Carter & Heath method (Boldsen et al., 1991), using the somatotype software method (SomatotypeV.1_2_5).

II. Jumping in countermovement (CMJ) and single-leg countermovement jumping (SLCMJ)

The lower limbs' power was measured through a countermovement jump (CMJ) and single-leg countermovement (SLCMJ). First, the vertical height of the jump was determined based on the flight time, using a contact platform (Chronojump-Boscosystem, Barcelona, Spain). Each participant performed three maximal CMJs to a self-selected depth on the jump's platform. Participants kept their hands on their hips for all jumps, keeping legs straight during the flight phase of the jump. Each jump was separated by 50 s. The SLCMJ was then performed, where the participant started the jump test from a place their hands on their hips. The non-jumping leg was slightly flexed at the knee with the foot hovering next to the ankle of the jumping leg. No additional swinging of the non-jumping leg was allowed during the jump and hands were required to remain fixed at the hips. Any deviations from these criteria resulted in a void trial and subsequently retaken. The mean value of the jump was used as the measure of performance criterion for each athlete. The average power was determined by the Sayers formula for the CMJ (Sayers et al., 1999).

III. Assessment Muscle Oxygen Saturation at rest

The Muscle Oxygen Saturation at rest data were evaluated with the MOXY sensor (Fortiori Design LLC, Minnesota, USA), which uses the NIRS technology with four independent light sources covering the wavelength ranging from 630 to 850 nm to measure SmO2 in accordance with the modified Beer-Lambert law. All the data evaluated with MOXY provide a functional scale from 0% to 100% that is reliable in terms of repeatability and reproducibility under conditions of arterial occlusion method (AOM) (Feldmann, A., Schmitz, R. W., & Erlacher, 2019). The device is considered valid for application in sports performance analysis (McManus et al., 2018). Furthermore, evaluating the SmO_2 variables at rest with AOM is an alternative method to finding the true muscle oxygen consumption at rest (Bonilla, et al., 2020).

For the muscle oxygenation kinetics analysis was performed in the gastrocnemius muscle, since it has been demonstrated its reliability in the measurements made with NIRS (Southern et al., 2014). Also because this muscle has less adipose tissue than the thigh, a factor that could have a negative influence on the evaluations (Bielemann et al., 2016). The device was connected with adhesive tape and completely covered with a neoprene sleeve. Participants were sitting in a semi-right position to keep their gastrocnemius muscles relaxed. AMO were performed using a rapid inflation cuff (aneroid sphygmomanometer, Missouri brand, Embu, SP, Brazil)) placed on the thigh directly above the patellofemoral joint and under a pressure of 250–275 mmHg as previously described (Southern et al., 2014). Two occlusions were performed; each occlusion lasted 30 s and was separated by a rest period of 30 s. Subsequently, for the final analysis, the values of the two occlusions were averaged.

Following the scientific literature (Ferrari et al., 2011), different measured parameters of SmO_2 at rest were established: initial occlusion ($SmO_{2\ O\text{-}I}$) – the maximally deoxygenated plateau identified as minimum SmO_2, as the occlusion-final ($SmO_{2\ O\text{-}F}$) was determined by the average of the last 20 s or 10 s occlusion data points, provided this met the condition of a visual plateau. The maximum oxygenated state identified as Maximum SmO_2, as the SmO_2 recovery ($SmO_{2Recovery}$) was determined as the average output SmO_2 peak of more than 10 s or 5 data points after the end occlusion as a result of the hyperaemic effect. Also, the difference between $SmO_{2\ O\text{-}I}$ and $SmO_{2\ O\text{-}F}$ which means the muscle oxygen consumption rate ($\Delta SmO_{2\ Slope\ 1}$) and difference from $SmO_{2\ O\text{-}F}$ to $SmO_{2\ Recovery}$ which means an estimate of the muscular oxidative capacity, since it is similar to recovery phosphocreatine (PCr) ($\Delta SmO_{2\ Slope\ 2}$). SmO_2 values were taken at the points of the highest and lowest value observed on the curves. It also took time to stabilize again at baseline ($SmO_{2\ Recovery\text{-}Time}$). These variables are widely described in the studies by Aldo Vasquez and Southern (Bonilla et al., 2020;Southern et al., 2014). All the variables were taken for the dominant leg (DL) and the non-dominant (Non-DL) of each player in order.

Procedure

The tests were performed in the laboratory at a temperature of 22.0 ± 0.5 °C and a relative humidity of 55 ± 2%. Body composition was initially evaluated together with the specific measurement of the medial gastrocnemius. This analysis was included due to the substantial effect of adipose tissue thickness (ATT) on the NIRS signal (Van Beekvelt et al., 2001). The mean value of the medial calf skinfold was (5.8 ± 1.5 mm). Since values of less than 12 mm of the skinfold cannot affect the measurement of muscle oxygenation, physiological ischaemic calibration was performed with arterial occlusion for the subsequent calculation of saturation and muscle oxygen consumption in each subject, following previously described protocols (T. E. Ryan et al., 2012).

A prepared researcher performed the arterial occlusion methodology for 5 minutes in each leg to assess the SmO_2 at rest. Data were collected at the beginning and at the end of the preseason period, which lasted 4 weeks. The main objective of the preseason training programme was to develop the physical, technical and tactical capacity of the players in preparation for the season period. The practical sessions lasted between 60 and 90 minutes and the players trained 5 days (along with friendly games).

Statistical analysis

Data were presented as mean ± standard deviation (SD) and analysed using two approaches: 1) approach based on clinical evidence, considering statistically significant differences when $p<0.05$; and 2) non-clinical approach: mechanical inference based on the inter-individual response of the subjects (Hecksteden et al., 2018; Hopkins et al., 2009; Ross et al., 2019). A t-student test was performed for independent samples (comparison between DL and Non-DL and comparison between PRE and POST preseason). In addition, %change and effect size (ES) were provided using the differences and standard error of the mean. The criteria used to interpret the magnitude of the ES were: ≤0.2 (trivial); > 0.2 (small);> 0.6 (moderate); > 1.2 (large); and > 2.0 (very large), as described above (Hopkins et al., 2009). If the 90% confidence limits overlap, the small positive and negative values for the magnitude are considered unclear; otherwise, that magnitude was considered as the true change and they were expressed qualitatively in increase and decrease. With this approach, the focus shifts from classifying individuals based on their measured change scores to classifying the change scores themselves, to find the inter-individual response (Ross et al., 2019). In addition, the minimum detectable change (MDC) in the SmO_2 with limits of agreement of 95% was evaluated; this has been calculated as: $\pm 1{*}96 \sqrt{2}{*}$ mean square error (MSE) (Impellizzeri et al., 2008). For the study of the relationships, the Pearson correlation test between SmO_2 variables with BC and jump power was used and they were qualitatively assessed with the Hopkins scale (2009). To interpret the magnitude, the following criteria were adopted: correlation (r) < 0.1, trivial; > 0.1–0.3, small; > 0.3–0.5, moderate; > 0.5–0.7, large; > 0.7–0.9, very large; and > 0.9–1.0, almost perfect. The analyses were performed with the SPSS software (version 22).

Results

Table 1 describes the changes in mean values ± standard deviation of body composition during the preseason. In soccer players, a decrease was observed in the fat mass (90% limits= lower: -1.0 to upper: 0.0; p value= 0.039) and of the endomorphic somatotype (90% limits= lower -1.9 to upper 0.1; p value= 0.000) at the end of the preseason.

Table 1. Changes in Body Composition during the pre-season in soccer players.

Body composition	Initial preseason	Final preseason	Change (%)	Effect Size	Mechanical Inference
Weight (kg)	74.5 ± 10.1	75.2 ± 10.0	0.9	0.07	Unclear
Body Index Mass (BIM)	22.5 ± 2.08	22.5 ± 1.95	0	0	Unclear
Fat Mass (kg)	9.5 ± 2.3	8.6 ± 2.3	-9.5*	0.39	Decrease/Trivial
Muscle Mass (kg)	31.8 ± 4.0	32.8 ± 2.9	3.2	1.01	Unclear
Ectomorphy	3.08 ± 0.99	3.13 ± 1.00	1.6	0.04	Unclear
Endomorphy	3.24 ± 1.24	2.77 ± 1.11	-14.5**	0.40	Decrease/Trivial
Mesomorphy	4.42 ± 1.47	5.34 ± 1.51	20.8**	0.19	Increase/Trivial

*p value<0.05 and **p value <0.01 statistically significant in changes Initial preseason to Final preseason, Possibilities (%) the true change was determined at 90%.

Table 2. Changes in Jump CMJ, SLCMJ and Symmetry Index during the preseason in soccer players.

Variables CMJ	Initial preseason	Final preseason	Change (%)	Effect Size	Mechanical Inference
CMJ (cm)	31.9 ± 3.0	33.4 ± 2.7	4.7	0.88	Increase
SLCMJ Dominant Leg (cm)	15.1 ± 2.8 ¶	16.5 ± 3.0	9.3	0.39	Unclear
SLCMJ Non-Dominant Leg (cm)	16.1 ± 2.6 ¶	17.8 ± 2.4	11.3	0.76	Increase
Power CMJ (watts)	933 ± 145	963 ± 129	3.2	0.22	unclear
Power SLCMJ Dominant Leg (watts)	637± 101	679± 125	6.6	0.46	unclear
Power SLCMJ Non-Dominant Leg (watts)	665± 129	698±108	5	0.41	unclear

*p value<0.05 and **p value <0.01 statistically significant in changes Initial preseason to Final preseason and ¶ p value <0.05 and ¶¶ p value <0.01 statistically significant in difference between Dominant Leg and Non-Dominant Leg. The possibilities of true change (90%) were expressed qualitatively: increase, decrease and unclear.

Table 2 describes the changes in mean values ± standard deviation of the CMJ and the average power expressed in watts during the preseason. An increase evaluated by the magnitude of mechanical change of the CMJ (90% limits= lower: 0.0 to upper: 3.0) and the SLCMJ of the non-dominant leg (90% limits= lower: 0.2 to upper: 3.2) is observed. Likewise, a difference was observed between SLCMJ at the beginning of the preseason (difference 6%; p= 0.048) and at the end of the preseason there were no differences.

Table 3 describes the changes in mean values ± standard deviation of the SmO_2 variables expressed in percentages of 1-100% during the preseason. An increase in $SmO_{2\ O\text{-}F}$ values was observed in DL (90% limits= lower: 1.6 to upper: 16.4; p = 0.029) at the beginning of the preseason and it changed with the training. Likewise, there was a decrease in SmO_2-Slope 1 (DL) (90% limits= lower: -8.5 to upper: -3.5); SmO_2 Slope 2 (DL): (90% limits= lower: -14.9 to upper: -5.1) and SmO_2-Slope 2 (DNL): (lower: -5.5 to upper -0.5). The MDC of $SmO_{2\text{-}}$Slope 1 was 5% in DL and 3% in NDL. SmO_2-Slope 2 at recovery was 4% in DL and 1% in Non-DL.

Likewise, a difference was observed between legs at the beginning of the preseason: $SmO_{2\ I\text{-}O}$ (difference 7%; p = 0.023), $SmO_{2\ F\text{-}O}$ (difference 11%; p= 0.021) and SmO_2 Slope 2 (difference 33%; p = 0.43). At the end of the preseason there were no differences.

Table 4 describes the correlation between jump height, jump power and body composition with the SmO_2 variables at rest during the preseason. Regarding the force shown, SLCMJ has a correlation with a very large, the values of the muscle oxygenation kinetics at rest in the variables SmO_2 I-O (r2= 0.51; p < 0.01); SmO_2 F-O (r2= 0.58; p < 0.01) and $SmO_{2\ Recovery}$ (r2= 0.38; p < 0.01), also, a relationship with a very large was observed between power SLCMJ with the variables SmO_2 I-O (r2= 0.67; p < 0.01); SmO_2 F-O (r2= 0.63; p= 0.01) and $SmO_{2\ Recovery}$ (r2= 0.68; p= 0.01), additionally, a relationship with the large correlation of SmO_2-Slope 1 with power of CMJ and SLCMJ (r2= 0.34; p= 0.023; r2= 0.34; p= 0.018) respectively.

Regarding the relationship of variables of body composition and somatotype with the resting muscle oxygenation kinetics, we highlight the large relationships between $SmO_{2\text{-}}$Slope 1 with Weight (r2= 0.41; p < 0.01); Fat Mass (r2 = 0.40; p < 0.01); Muscle Mass (r2= 0.31; p < 0.01) and Endomorph (r2= 0.28; p= 0.014), also the $SmO_{2\text{-}}$Slope 2 with the Weight (r2= 0.30; p= 0.01) and Fat Mass (r2= 0.25; p= 0.022) respectively.

Discussion

The main findings of this study were the decrease in the consumption of resting muscle oxygenation of

Table 3. Changes in Muscle Oxygen Saturation at rest variables during the pre-season in soccer players.

Variables Sm_o2	Initial preseason	Final preseason	Change (%)	Effect Size	Mechanical Inference
Dominant Leg					
$SmO_{2\ I\text{-}O}$	72 ± 9 ¶	75 ± 13	4,2	0,27	unclear
$SmO_{2\ F\text{-}O}$	64 ± 12 ¶*	73 ± 13*	14.1	0.72	Increase
$SmO_{2\ Recovery}$	79 ± 8	78 ± 10	-1.3	0.11	unclear
$SmO_{2\ Slope\ 1}$	8 ± 6**	2 ± 2**	-75	1.50	Decrease
$SmO_{2\ Slope\ 2}$	15 ± 10 ¶**	5 ± 5**	-66.7	1.33	Decrease
$SmO_{2\ Recovery\text{-}Time}$	23 ± 6	26 ± 12	13	0.56	unclear
Non-Dominant Leg					
$SmO_{2\ I\text{-}O}$	77 ± 11 ¶	76 ± 10	-1.3	0.19	unclear
$SmO_{2\ F\text{-}O}$	71 ± 13 ¶	71 ± 13	0	0.08	unclear
$SmO_{2\ Recovery}$	81 ± 9	79 ± 10	-2.5	0.32	unclear
$SmO_{2\ slope\ 1}$	6 ± 4	4 ± 2	-33-3	0.67	unclear
$SmO_{2\ slope\ 2}$	10 ± 8 ¶*	7 ± 8*	-30	0.38	unclear
$SmO_{2\ Recovery\text{-}Time}$	24 ± 7	28 ± 12	17	0.42	unclear

*p value<0.05 and **p value <0.01 statistically significant in changes Initial preseason to Final preseason and ¶ p value <0.05 and ¶¶ p value <0.01 statistically significant in difference between Dominant Leg and Non-Dominant Leg. the possibilities of true change (90%) were expressed qualitatively: increase, decrease and unclear.

Table 4. Relationships between jump power and body composition with the index Symmetry of Muscle Oxygen Saturation in soccer players.

Variables	$SmO_{2\ I\text{-}O}$	$SmO_{2\ F\text{-}O}$	$SmO_{2\ Recovery}$	$SmO_{2\ slope\ 1}$	$SmO_{2\ Slope\ 2}$	$SmO_{2\ Recovery\text{-}Time}$
CMJ	0.168	0.199	0.023	-0.138	-0.344	0.329
CMJ Power (watts)	-0.281	-0.283	-0.031	0.581**	0.466	0.234
SLCMJ (cm)	-0.713**	-0.762**	-0.614*	-0.246	-0.353	0.189
SLCMJ Power (watts)	-0.822**	-0.794**	-0.825**	0.582*	0.18	0.494*
Weigth (kg)	-0.382	-0.396*	-0.154	0.641**	0.546**	0.019
Fat Mass (kg)	-0.436*	-0.460*	-0.311	0.633**	0.501*	0.321
Muscle Mass (kg)	-0.259	-0.314	-0.042	0.560**	0.406*	0.088
Endomorphy	-0.482*	-0.494*	-0.294	0.530*	0.437	-0.267
Mesomorphy	0.075	0.102	-0.181	0.258	-0.020	0.067

*p value<0.05 and **p value <0.01 statistically significant correlations. Qualitative Interpretation= > 0.5 - 0.7, large and > 0.7 - 0.9, very large.

the SmO_2-slope 1 and SmO_2-slope 2 curves in soccer players and the relationship that it has with the improvement of the body composition profile and also the absolute values of SmO_2 kinetics, with the ability to produce unilateral jumping power. This allows us to advance in the vision of how to use the SmO_2 at rest as an indicator of performance metabolism and power of muscle in the athletes.

Firstly, the improvement in body composition and somatotype are comparable with the study of. Bolonchuk & Lukaski, 1987 and Owen et al., 2018, who found changes in the average mesomorph 5.4 and endomorph 2.4 and approximate changes of 1 kg in increases in muscle mass and fat-free decreases through the evaluation of skinfolds. Also CMJ change (increment) was weak, but changes were observed in mechanical inferences of ≤5%, this percentage being associated with improvements in physical performance and different tasks in soccer (Bishop et al., 2019). These same authors propose the evaluation of SLCJ during different phases of the season, and in the present study a higher jump force was observed in the NDL. According to Iga et al., 2009, soccer players almost never use both legs with equal emphasis. The preference of soccer players that use one side more than the other is related to the hemispheric domain of the brain on the opposite side; this is the possible cause of the deficit abnormality in professional soccer players. Furthermore, studies such as that of García-López et al., 2001 and Haugen, 2018 showed that preseason changes can be up to 1 to 2 cm in professional and amateur players, As in our study, this means that they improve performance after the preseason.

Regarding the changes produced in the SmO_2, especially in the decrease of the SmO_2-slope 1 and SmO_2-slope 2 curves at the end of the preseason, these could be influenced by metabolic adaptations to the training explained by S. Jones et al., 2017, who observed lower resting oxygen consumption after weeks of training, also evaluated with venous-arterial occlusion (0.25–0.21 µM-Hbdiff / s). This mechanism occurs because the muscle is more adapted to training. This has been shown in improvements of homeostatic stability and therefore the muscle consumes less oxygen at rest (Zoladz, Szkutnik, & Grassi, 2018). Also, due to training, it is possible that the oxygenation difference between DL / NDL decreases. According to B. Jones et al., 2015, intermittent training can cause changes over time at the peripheral level and adaptations in the skeletal muscle.

In the same context, an increase in oxygenated haemoglobin and a higher deoxygenation expressed in the result of the drop in SmO_2, gives us visual evidence that muscle oxygenation has decreased at the end of the preseason. A possible response to this mechanism is expected as highly trained subjects usually obtain a high activity of nitric oxide synthesis (NOS) (McConell et al., 2007), which compensates for muscle metabolism and it has been observed that in arterial occlusion it can cause fewer changes or less use of resting oxygen by the muscle. It is likely that this higher expression of the NOS protein expressed in skeletal muscle (nNOSµ) is associated with a higher production of NO by skeletal muscle, which is less dependent on oxygen locally (McConell et al., 2007). NO seems to be a key factor in the mechanistic response to arterial occlusion (Incognito et al., 2016). the problem is that this fact has not been proven in this study, since its measurement is impractical to use as an indicator of performance in soccer players; however, it is a possible explanation for the lower consumption of muscle oxygen at the end of the preseason.

Also, the decrease in the use of SmO_2 could be due to better fitness levels, indicating that a more trained person has a lower oxygen consumption curve (SmO_2-$_{slope\ 1}$) and a faster recovery (SmO2-$_{slope\ 2}$) (Bonilla, A. A. V et al., 2020; Soares, R. N., McLay, K. M., George, M. A., & Murias, 2017). This could mean that, through training, metabolism was improved with faster transit of the muscle oxygen and this was correlated with the change in weight and somatotype, since it depends on oxygen consumption (Miroshnichenko et al., 2018). Likewise, the relationship between CMJ and SLCMJ power with the absolute values of SmO_2 I-O, SmO_2 F-O and SmO_2 recovery can be explained by studies such as that of Mantooth et al., 2018 in which a greater contraction caused by force is associated with a greater desaturation over time, and Gómez-Carmona et al., 2019 who found that a higher value of SmO_2 and faster stabilization to baseline "SmO2 recovery" values are associated with greater fatigue after squatting, so this could support the results found in this study. Even so, it is difficult to find a direct explanation without there being other complementary measurements to muscular work. But we emphasize that this is the first time that the results of the SmO_2 kinetics at rest with arterial occlusion methodology have been presented.

One of the limitations of this study was the lack of exhaustive control of the physiological variables that can influence the measurement, such as cardiovascular capacity through heart rate. We recommend replicating this study with a randomized controlled longitudinal design to clarify the changes produced in the muscular metabolism of each leg, in addition to taking daily measurements to investigate the intra and inter-individual response between subjects. But with this study we highlight the use of portable NIRS as a technique to measure SmO_2 at rest, since it is methodologically one more alternative to control metabolic changes influencing performance. Also, invite the scientific community to execute other AOM protocols, since we assume that in athletes the occlusion of 30 s can be very short, to identify more precise changes such as the stabilization time factor of SmO_2.

Conclusions

The measurement of SmO_2 at rest can be useful to identify changes in muscle metabolism after planned training, it can also be considered as a possible performance parameter because it has determined its relationship with the ability to produce strength and jumping power in soccer players. Specifically, we propose the analysis of the curves of oxygen consumption and recovery in different environments, such as in congested weeks, fatigue and / or recovery conditions and different adjustments in rehabilitation and adaptation. But it must be used carefully by sports scientists, as more studies in team sports are needed for practical use.

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