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The effect of vo2max on muscle oxygen saturation (SMO2) in University Badminton Athletes

El efecto del VO2máx sobre la saturación de oxígeno muscular (SMO2) en atletas universitarios de bádminton

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Abstract. Muscle oxygen saturation (SmO_2) is an additional physiological parameter that helps identify the transition from aerobic to anaerobic workload. Additionally, it can be used to predict performance by calculating Vo_2 and energy expenditure. Muscle oxygen saturation (SmO_2) is a measure of oxygen saturation in muscle tissue that can be used to evaluate metabolic zones, training intensity, and athlete performance. An athlete's muscle oxygen saturation (SMO_2) is a measure of how well their muscles use oxygen, which is important for evaluating performance and creating training programs. This research is a week-long experimental study with a one-shot case study design, research intends to look at the effect of Vo_2Max on muscle oxygen saturation (SMO_2) in university badminton athletes. The subjects of this research are student athletes who actively practice badminton. There were 6 respondents who were willing to be research subjects and had met the specified criteria, namely actively exercising three times a week and being in good health. Then the author took data on athletes who had the highest and lowest Vo_2Max to analyze SMO_2 optimization, which was the focus of this research. The results of the analysis show that there is a significant influence between Vo2max and SMO_2 optimization; this can be seen by the difference through the t test with a sig (2-tailed) value of $0.000 < 0.05$. Another finding is that athletes with higher Vo2max show better SMO_2 recovery results. better than athletes with low Vo_2max; in this study, athletes with higher Vo_2max showed a 37% increase in SMO_2 over two minutes, while athletes with lower Vo_2max showed a 21% increase. This is an interesting finding for coaches and athletes regarding the importance of Vo_2 max capacity in optimizing SMO_2.
Keywords: SMO_2, Badmimton, SMO_2 Recovery, Vo2Max

Resumen. La saturación de oxígeno muscular (SmO2) es un parámetro fisiológico adicional que ayuda a identificar la transición de la carga de trabajo aeróbica a la anaeróbica. Además, se puede utilizar para predecir el rendimiento calculando el Vo2 y el gasto energético. La saturación de oxígeno muscular (SmO2) es una medida de la saturación de oxígeno en el tejido muscular que se puede utilizar para evaluar las zonas metabólicas, la intensidad del entrenamiento y el rendimiento del atleta. La saturación de oxígeno muscular (SMO2) de un atleta es una medida de cuán bien sus músculos utilizan el oxígeno, lo cual es importante para evaluar el rendimiento y crear programas de entrenamiento. Esta investigación es un estudio experimental de una semana con un diseño de estudio de caso único. La investigación tiene como objetivo analizar el efecto del Vo2Max en la saturación de oxígeno muscular (SMO2) en atletas universitarios de bádminton. Los sujetos de esta investigación son estudiantes atletas que practican badminton de manera activa. Hubo 6 encuestados que estaban dispuestos a ser sujetos de investigación y que cumplían con los criterios especificados, a saber, hacer ejercicio activamente tres veces a la semana y estar en buena salud. Luego, el autor recopiló datos sobre atletas que tenían el Vo2Max más alto y más bajo para analizar la optimización de SMO2, que fue el enfoque de esta investigación. Los resultados del análisis muestran que hay una influencia significativa entre la optimización de Vo2max y SMO2; esto se puede observar a través de la diferencia en la prueba t con un valor de sig (bilateral) de $0.000 < 0.05$. Otro hallazgo es que los atletas con un Vo2max más alto muestran mejores resultados de recuperación de SMO2. mejor que los atletas con bajo Vo2max; en este estudio, los atletas con un Vo2max más alto mostraron un aumento del 37% en SMO2 en dos minutos, mientras que los atletas con un Vo2max más bajo mostraron un aumento del 21%. Este es un hallazgo interesante para entrenadores y atletas sobre la importancia de la capacidad de Vo2 max en la optimización de SMO2.
Palabras clave: SMO2, bádminton, recuperación de SMO2, Vo2Max

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Introduction

Muscle oxygen saturation (SMO_2) is a measure of the relative concentrations of oxygenated and deoxygenated hemoglobin and myoglobin in the underlying tissue and reflects the balance of local O_2 delivery and O_2 extraction during exercise (Vasquez Bonilla et al., 2023). SMO_2 decreases with exercise intensity; exercise zones such as the zone of maximum lipid oxidation (Fatmax), ventilation threshold, and maximum aerobic power during graded exercise tests are usually identified through decreases in SMO_2 (Yogev et al., 2023). SMO_2 is a complementary physiological parameter to identify the transition from a more aerobic workload to an anaerobic workload and can be used to predict performance by estimating VO_2 and energy expenditure. SMO_2 can also be used to determine the lactate threshold without having to complete invasive laboratory tests.

Muscle oxygen saturation (SMO_2) is a measure of oxygen saturation in muscle tissue that can be used to evaluate metabolic zones, training intensity, and athlete performance. An athlete's muscle oxygen saturation (SMO_2) is a measure of how well their muscles use oxygen, which is relevant for evaluating performance and designing training programs (Negara, 2023). Research has shown that SMO_2 is associated with factors such as critical oxygenation and anaerobic work capacity in athletes, and this can be measured using devices such as Moxy (Bonilla et al., 2022). For example, research on cyclists found a positive correlation between

SMO_2 and critical oxygenation (Negara, 2023). Additionally, technological solutions using SMO_2 data analysis have been proposed to prevent injuries in high-level footballers (Pineda et al., 2021). These findings highlight the importance of SMO_2 monitoring in assessing and optimizing performance in sporting activities.

Muscle oxygen saturation can be influenced by various factors, McCully (2010) found that passive stretching can decrease oxygen saturation in certain muscles, temporarily, Belardinelli et al (1995, 2004) observed a decrease in saturation during heavy exercise, especially at higher work levels. This decrease was associated with increased VO_2 and tissue lactic acidosis. McCully et al (1994) further demonstrated that elderly individuals with peripheral vascular disease experienced a slower recovery of oxygen saturation after exercise. These findings highlight the complex interaction of factors that can influence muscle oxygen saturation.

SMO_2 in physical activity yielded some interesting findings. (Ogino et al., 2021) suggested that levels of mitochondrial function Superoxide Dismutase 2 (mRNA SOD2) in the blood may serve as a biomarker for exercise. However, Rauner et al (2015) found that physical activity, including SMO_2, is a fluctuating variable with low stability over time. This is further complicated by potential exposure to indoor air pollutants during physical activity (Carlisle et al., 2001; Ramos et al., 2014). These studies underscore the need for further research to better understand the role of SMO_2 in physical activity and its potential impact on health.

Research consistently shows that muscle oxygen saturation decreases during exercise, and the magnitude of the decrease is influenced by the intensity and frequency of muscle contractions (Bylund-Fellenius et al., 1984, 2015). This decrease in oxygen saturation is associated with changes in muscle metabolites, such as phosphocreatine, the ATP/ADP ratio, and the lactate/pyruvate ratio. The importance of oxygen in maintaining intracellular energy and redox states during exercise is highlighted by these findings. In addition, the role of oxygen consumption, lactate accumulation, and sympathetic responses during prolonged exercise under hypoxia is an area that requires further investigation (Bouissou1 et al., 1987).

Method and material

Method

This research is a week-long experimental study with a one-shot case study design (Darajat & Abduljabar, 2014), the author did not provide direct intervention because the respondents were athletes who carried out routine and structured training provided by the coach. Researchers took data over a certain period to see how Vo_2max influenced badminton athletes' SMO_2.

Subject Research

The respondents in this study were student athletes who actively practiced badminton. There were 6 respondents who were willing to be research subjects and had met the specified criteria, namely actively exercising three times a week and being in good health. Then the author took data on athletes who had the highest and lowest Vo_2Max to analyze SMO_2 optimization, which was the focus of this research.

Instrument

SMO_2 can be measured using portable near-infrared spectroscopy (NIRS) devices, such as Moxy (Negara et al., 2021; Vasquez Bonilla et al., 2023). In this research, the author used the Moxy Monitor Sensor tool, as seen in Figure 1.

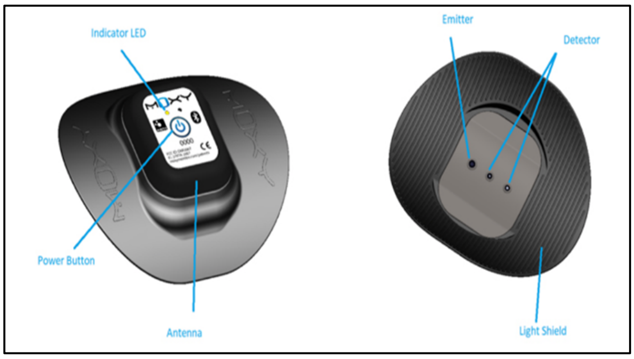

Figure 1. “Moxymonitor” Oxygen Saturation Sensor

Procedure

Respondents carried out the same test, namely the Vo_2Max beep test or multi-stage Vo2max test. The Moxy monitor was installed on the respondent's thigh area (quadriceps) during the Vo2 Max test, and the data was then integrated with an application on the iPad device so that the data was captured in real time. Respondents carried out the Vo_2Max test to the maximum, and then another activity was to see SMO_2 recovery after the test by looking at SMO_2 recovery two minutes after the test was carried out.

Result

To get a general overview of the SMO_2 test results using Moxy Monitor, the data description is presented in the form of an SMO_2 graph during the Vo2Max test, followed by the SMO_2 recovery data demographics in the form of a bar chart. Next, to see the effect of VO_2max on SMO_2 during physical activity, it was analyzed using descriptive statistics (mean, standard deviation) as well as testing the difference between SMO_2 with low and high Vo_2Max using the independent sample t test.

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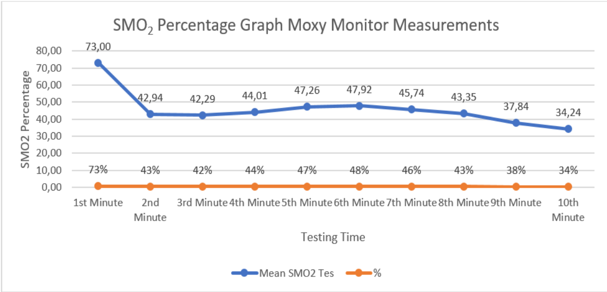

Figure 2. First Respondent SMO_2 Graph

Figure 2 shows a graph of the SMO_2 percentage during the test. The sample successfully carried out the Vo2 Max test for 10 minutes with a Vo2Max of 45.5 ml/kg/min. The SMO_2 percentage at the start of the test was 73%, and at the end of the test, it was 34%.

Figure 3 shows a graph of the SMO_2 percentage during the test. The sample successfully carried out the Vo2 Max test for 5 minutes with a Vo2Max of 26.8 ml/kg/min. The SMO_2 percentage at the start of the test was 51%, and at the end of the test, it was 27%.

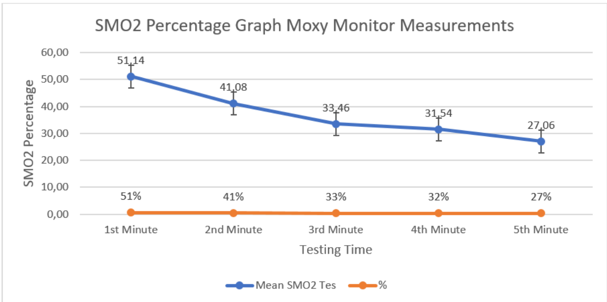

Figure 3. Second Respondent's SMO_2 Graph

Table 1.
Description of SMO_2 Test Data

	Category Vo2Max	N	Mean	Std. Deviation
SMO2	SMO2 Vo2_Max_High	151	50.05	12.201
	Vo2_Max_Low	132	37.98	9.348

Table 2.
SMO_2 t test analysis when testing

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
SMO2	Equal variances assumed	5.144	.024	9.242	281	.000
	Equal variances not assumed			9.405	276.384	.000

Based on the analysis results in Table 1, the mean SMO_2 value for athletes with high Vo_2Max is 50.05 with st. Dev 12,201 from a total of 151 data captured by Moxy Monitor, while the mean SMO_2 value for athletes with low Vo2Max is 37.98 with st. Dev 9,348 from 132 data captured by Moxy Monitor. Meanwhile, the results of the independent sample t test analysis (table 2) show a sig (2-tailed) value of 0.000 < 0.05, meaning that there is a significant difference in SMO_2 optimization between athletes who have high and low Vo2max. Where athletes who have a high Vo_2max are more optimal than those who have a low Vo_2max.

Next, the author looked at how to optimize SMO_2 recovery after the Vo_2Max test of the two athletes two minutes after finishing the test. The results show that the SMO_2 of athletes who have a high Vo_2Max with a mean of 58.32 increases by 37%, while athletes who have a low Vo_2Max with a mean of 35.31 increase by 21%. The analysis results show that athletes who have high Vo2max have a better SMO_2 recovery response than those with low Vo_2max.

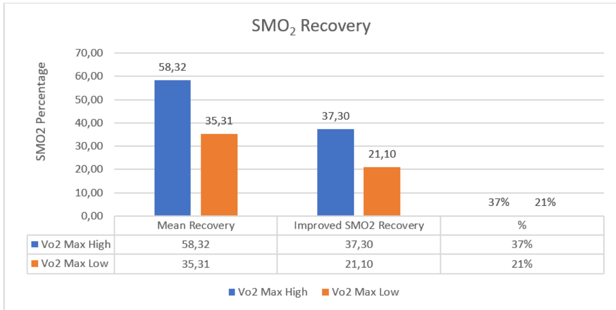

Figure 4. SMO_2 Recovery Demographics (2 Minutes After Test)

Table 3.
SMO_2 Recovery Data Description

	Category Vo2 Max	N	Mean	Std. Deviation
SMO2 Recovery	Vo2_Max_High	53	58.32	10.024
	Vo2_Max_Low	54	35.31	7.042

Table 4.
SMO_2 Recovery Test Analysis

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
SMO2 Recovery	Equal variances assumed	5.533	.021	13.485	105	.000
	Equal variances not assumed			13.442	93.131	.000

Based on the analysis results in Table 3, the mean SMO_2 recovery value for athletes with high Vo_2Max is 58.32 with st. Dev 10,024 from a total of 53 data captured by the moxy monitor for 2 minutes, while the mean SMO_2 value for athletes with low Vo2max is 35.31 with st. Dev 7,042 from 52 data captured by the moxy monitor for 2 minutes. Meanwhile, the results of the independent sample t test analysis (table 4) show a sig (2-tailed) value of 0.000 < 0.05, meaning that there is a significant difference in SMO_2 recovery between athletes who have high and low Vo_2max. Athletes who have high Vo_2max experience better recovery than athletes with low Vo_2max.

Discussion

This study aims to examine the effect of Vo2max on optimizing muscle oxygen saturation (SMO_2) during sports activities. The results of the research presented are to see how to optimize SMO_2 for research subjects who have high and low Vo2max as well as optimize SMO_2 recovery after sports activities. The analysis results show that there is a significant difference in SMO_2 optimization between athletes who have high and low Vo_2max, with a sig value of 0.00. This proves that Vo2max has an influence on optimizing SMO_2 in athletes when carrying out training activities. This is an interesting finding about how important Vo2max capacity is for athletes to improve performance, and that Vo_2max is closely related to SMO_2. This is supported by research conducted by Michailidis et al (2020) who found that higher aerobic capacity is associated with faster muscle reoxygenation after an anaerobic sprint test in soccer players. Goodrich, Ryan, and Byrnes (2018) also observed a strong correlation between hemoglobin mass and VO_2max, with no additional influence of oxygen saturation on VO_2max. Raberin et al (2019) reported that athletes with exercise-induced hypoxemia had specific muscle and brain oxygenation responses during exercise, thus indicating a potential impact on VO_2max. Żebrowska, Weippert, and Petelczyc (2021) further supported these findings, showing a negative relationship between recovery time and relative peak VO_2, indicating a potential relationship between muscle oxygenation and aerobic capacity.

The results of other studies show that with increasing exercise intensity, muscle oxygen saturation decreases, while VO_2 variability slightly decreases (Thiel et al., 2011). his shows the possibility of a relationship between the two. Horstman, Gleser, and Delehunt (1976) further supported this by showing that VO_2max is limited by oxygen delivery, not muscle intrinsic factors. McCready, Arnold, and Davis (2016) found that muscle oxygenation decreased more slowly during midseason, coinciding with an increase in VO_2max, suggesting a potential link between the two. Yano et al (2005) also found a significant correlation between VO_2max and muscle oxygenation at fatigue during additional exercise. These studies collectively demonstrate a relationship between VO_2max and muscle oxygen saturation.

Another finding is that optimizing SMO_2 recovery for athletes who have a higher Vo_2max shows better recovery results than athletes with a low Vo2max. In this study, athletes who have a higher Vo_2max have a value of increasing SMO_2 with a percentage of 37% for two minutes better than Vo_2max athletes., namely 21%. Research on the restoration of muscle oxygen saturation during exercise has also produced interesting findings. Żebrowska et al. (2021) found that muscle oxygenation and whole-body oxygen uptake kinetics during recovery after fatiguing exercise were related to aerobic capacity. Pratama and Yimlamai (2020) compared active, passive, and combined recovery protocols in swimmers and found that the combined protocol was most effective in increasing muscle reoxygenation. Jones et al (2022) found that changes in muscle tissue saturation during exercise were associated with post-occlusive reactive hyperemia, namely increased blood flow to the tissue after a period of decreased blood flow. Lastly, observed that muscle oxygenation responses during repeated double-poling sprint exercise differed in normobaric and normoxic hypoxia, with greater increases in deoxygenated hemoglobin in exercise-induced hypoxia. These studies collectively highlight the complex interactions between muscle oxygenation, recovery, and exercise performance.

Research has shown that muscle oxygen saturation during exercise and recovery can be effectively measured using near infrared spectroscopy (fNIRS) (Ansari et al., 2014; Sumartiningsih et al., 2022). his method has been used to study the recovery time of calf muscle oxygen saturation after exercise, with potential application in diagnosing vascular disease. Similarly, a muscle tissue spectrophotometer has been used to measure the recovery time of hemoglobin and myoglobin desaturation in the quadriceps muscles of elite competitive rowers. The slow increase in oxygen consumption during vigorous exercise has been associated with a progressive decrease in muscle oxygen saturation. Lastly, non-invasive measurement of hemoglobin oxygen saturation in calf muscle has been used to study exercise-induced changes in elderly subjects with peripheral vascular disease, with potential application in evaluating oxygen saturation kinetics (McCully et al., 1994). Crispin (2019) suggests that anemia can affect muscle oxygen saturation, thereby potentially affecting daily activities. Gómez-Carmona et al (2019) found that strength training can affect lower limb muscle oxygenation, with higher training loads leading to lower saturation levels. Henni and Abraham (2017) noted that patients with peripheral arterial disease experienced a greater decrease in muscle saturation when fatigued. Miranda-Fuentes et al (2022) reported that increasing exercise intensity and duration did not significantly change muscle oxygen saturation but did cause a substantial increase in hemoglobin concentration. These studies collectively highlight the complex interplay of factors that can influence muscle oxygen saturation during exercise.

The importance of having good Vo2Max is very important for athletes to support performance; there is a strong relationship between Vo2Max and the interaction of training on athlete skills. Regular training with high intensity carried out three times a week for 2 months can improve physical fitness, especially Vo2max. The regulation of training intensity and volume must also be considered in the first and last weeks to avoid fatigue that can reduce athlete performance. In addition, calories are also an important factor in training; various health problems will arise related to poor energy balance. In addition, something that is no less important for athletes in the university environment is how they manage their time in terms of training and free time to rest and pay attention to their academics.

Conclusion

The aim of this study was to determine the effect of Vo_2max on optimizing muscle oxygen saturation (SMO_2)

during exercise. The research results presented aim to show how SMO_2 can be optimized for athletes with high and low Vo2max, as well as how SMO_2 recovery after exercise can be optimized. Our analysis revealed significant differences in SMO_2 optimization between athletes with high and low Vo2max. This proves that Vo_2max influences the optimization of an athlete's SMO_2 when carrying out training activities. Additional research results show that athletes with higher Vo_2max have better recovery outcomes than athletes with lower Vo_2max; in this study, athletes with higher Vo_2max showed a 37% increase in SMO_2 over two minutes, while athletes with lower Vo_2max showed a 21% increase. This provides conclusions and recommendations for athletes and sports coaches that Vo_2max is a very important element in sports performance, especially in the availability of oxygen in muscles to support performance during physical activity and sports. The author recommends always carrying out tests to measure oxygen saturation in muscles with a Moxy monitor to monitor the athlete's condition during training and before competing.

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