Cycling Athlete Performance: Analysis of Muscle Oxygen Saturation through Moxy Measurement

Jajat Darajat Kusumah Negara
Universitas Pendidikan Indonesia, Indonesia

Abstract
This study was aimed at conducting an analysis related to the performance of cyclists, namely the analysis of oxygen saturation in the muscles using muscle oxygen monitoring. This study used a single-subject design. Respondents of this study were road bike athletes preparing for multi-event competitions in West Java province. The measured data were related to oxygen saturation as measured by Moxy (Muscle Oxygen Monitoring), the tool used to examine how well our muscles use oxygen. The instruments included a smartwatch as an additional data collection tool and the Elevate Heart Rate sensor on the watch to record heart rate. The results found that the respondent muscle oxygen saturation was in the fairly good category for the female because the average result fell in the range of 70–80%, not much different from the starting point of the test. The analysis showed that there was a positive correlation between $\text{SmO}_2$ and $\text{THb}$, where $\text{SmO}_2$ gave a contribution of 61%. The result of this analysis is expected to be used as an evaluation for coaches in preparing athlete training programs.
INTRODUCTION

Aerobic and anaerobic powers are required for competitive cycling (Tanaka et al., 1993). The ability to generate a relatively high power output for a brief time during the mass start, steep climbing, and race finish is necessary for road and off-road bicycle racing (Faria et al., 2005). Maximum oxygen consumption (VO2max) is one of the best determinants of success in competitive road cycling (Burke, 1980; Burke et al., 1977). Horowitz et al. (1994) compared two groups of cyclists with significantly different gross efficiencies but similar mean performance VO2 (4.46 vs. 4.48 L*min^-1). In a one-hour cycling performance test, they found that the group with the higher efficiency had a significantly better average power output (342 W versus 315 W) (Horowitz et al., 1994). Sprint interval training (SIT) is a type of training that helps cyclists perform better. It consists of short sprints of 20-30 seconds, with long recovery periods (≥ 2 minutes) which has been shown to increase the strength and endurance of cyclists (Laursen et al., 2002). Even though the time spent at >90% VO2max during a SIT session is low (typically 0-60 seconds in trained cyclists for the entire training session), muscle O2 requirements remain high due to the high number of sprints, with low levels of muscle oxygenation (Buchheit et al., 2012).

Although SIT training has been shown to improve exercise performance and some measures of muscle metabolism, the majority of studies have focused on how it alters sports performance (Gibala & McGee, 2008). There has not been much study on power measurement as compared to professional riding, despite the fact that cycling power meters have been sold for over 25 years (Vogt et al., 2007). However, the evolution of modern sensor technology has resulted in wireless and mini near infrared spectroscopy devices that can be used for applications in the field and during real racing. This technology can provide more accurate measurements of muscle oxygenation and respond more quickly to changes in exercise intensity (Born et al., 2017; Shibuya et al., 2004).

Near-infrared spectroscopy (NIRS) has established itself as a valid, dependable, and inexpensive wireless instrument in the field of health and physical activity (Farzam et al., 2018; Feldmann et al., 2019; Miranda-Fuentes et al., 2020; Scholkmann & Scherer-Vrana, 2020). Additionally, this technology is able to evaluate the equilibrium between muscle oxygen supply and demand during physical activity in real time (Peikon, 2019). The Moxy monitor is one of several options for measuring local oxygen saturation (SmO2) and total hemoglobin (THb) at the oxygen concentrator in the horizontal position using infrared spectroscopy (NIRS) (Crum et al., 2017). Moxy is also said to be able to measure exercise intensity zones, instead of using speed, strength, or heart rate (HR) which are affected by environmental conditions, fatigue, or mental stress, to guide exercise prescriptions based on the effects of specific mechanical workloads on muscle O2 requirements (Design, 2015).

Research conducted by (Simmons, 2017) on six 21-year-old students at the University of Carolina, who were trained in endurance through a high-intensity 30-second sprint interval test with a 125% watt VO2 max on the ergometer, showed an inverse relationship between SMO2 and heart rate and VO2 during high intensity. In this study, the test conducted was an endurance test with a multi-step level of 5–1–5 for cyclists, where the endurance test measured the relationship between SM02 and total hemoglobin in the blood (Thb), which is the novelty of this research.

METHODS

This study employed a descriptive technique with a quantitative approach since the research design involved a description of the variables to be researched. The factors examined in this study were total hemoglobin volume and SMO2 levels (THb).

Participants

The single subject design was the technique used in this study. The subject of this study was a cyclist in the city of Bandung who was preparing to compete in regional multi-event competitions, namely a 19-year-old female road bike athlete, with a body weight of 50 kg and a body height of 169 cm.

Instrument and Procedure

The instrument used in this research was Moxy (Muscle Oxygen Monitoring). This tool is used to see how well our muscles use oxygen. Moxy Monitor (Fortiori Design, LLC, Hutschinson, MN, USA) has proven its validity and reliability for use in the sports world. Validity of Moxy to measure SmO2: statistically analyzed and very good results, correlation between
trials for all participants (SROC: r = 0.842–0.993, ICC: r = 0.773–0.992, p < 0.01) (Jaén-Carrillo et al., 2022). Moxy can be used to measure muscle oxygenation and has a validity of 0.92 compared to direct measurement of venous oxygen saturation and a reliability of r = 0.77 to 0.99 (P 0.01) (Sucharit et al., 2018). In this study, a smartwatch was used as an additional data collection tool. The Elevate Heart Rate sensor on the watch recorded heart rate and how it varied from time to time. This information was used to calculate heart rate variability (HRV). Another tool used in the study was the Ergo-cycle. The Ergo-cycle works in the same way as a bicycle, but the ergo-cycle itself does not move when in use. This tool is useful for racing cyclists when the weather is bad or there is not enough time to ride a regular bike. By using an ergo-cycle, cyclists can experience realistic cycling and the resistance changes depending on how they ride, whether doing structured exercises or cycling in a virtual world.

Procedure

There were several steps taken in this research. After determining the population and sample, the researchers conducted a muscle oxygen saturation test using the Moxy (Muscle Oxygen Monitoring) tool. Moxy has many settings, but researchers set Moxy on the quadriceps based on the cyclist’s foot. After the athletes warmed up, the researchers told them to pedal at different levels until they reached exhaustion. Researchers tracked the cyclist cadence (the number of times they had to pedal per minute) to make sure they were working their best. Researchers used the 515 assessment, which means 5 minutes of activity and 1 minute of rest. The athlete pedaled a bicycle starting from binary 1 (level 2, 60 watts) continuously until they reached a level of fatigue, with a record of cadence kept between 40 and 50 smO2 (%). Then, the researcher gave a stop sign to the athlete.

Data Analysis

In this study, the data obtained from the results of measurements using the Moxy monitor were in the form of quantitative data on the result of oxygen saturation in muscle, or SmO2 [%] with total hemoglobin (THb). In addition to the descriptive analysis of performance profiles for cyclists, the relationship or correlation between muscle oxygen saturation (SmO2 [%]) and total hemoglobin (THb) was calculated.

RESULT

Data from the results of the subject’s biometric test collected SmO2 levels, which were then processed and analyzed descriptively between road bike athlete during high-intensity training and muscle oxygen saturation. Sample demographic data are shown in Table 1.

Table 1. Physical characteristics of the subjects

<table>
<thead>
<tr>
<th>SmO2 [%]</th>
<th>THb[THb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>78.1785364</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>8.7060831</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>75.7958835</td>
</tr>
<tr>
<td>Minimum</td>
<td>52.4099998</td>
</tr>
<tr>
<td>Maximum</td>
<td>89.2399978</td>
</tr>
</tbody>
</table>

| Count | 82 | Count | 82 |

Confidence Level (95.0%) 1.91293625 Confidence Level(95.0%) 0.024000

Based on the demographics of the research subjects in Table 1, the average SmO2 (%) was 78.18 while the average THb was 11.8. The standard deviation of SmO2 was 8.71, and the standard deviation of THb was 0.11.

The data in the graph shown in Figure 1 explain how cycling (power cycling) can affect muscle oxygen saturation levels. The purple line shows how muscle oxygen saturation levels change over time while cycling, while the red line shows the THb between cycling and muscle oxygen saturation levels.

Data description of 515 assessment shows the respondent muscle oxygen saturation while cycling on an ergocycle. In binary 1, round 1 (level 2, 60 watts) with a given time of 5 minutes, they managed to cover a distance of 1.4 km with an average speed of 11.4 rpm, burning 23 calories with an average SmO2 of 74.38% and Hb of 11.78 mg/dL. In binary 1, round 2 (level 2, 60 watts) with a given time of 5 minutes, they managed to cover a distance of 3 km with an average speed of 11.46 rpm, burning 47 calories with an average SmO2 of 74.28% and Hb of 11.79 mg/dL. In binary 2 round 1 (level 4, 100 watts) with a given time of 5 minutes, they managed to cover a distance of 1.5 km with an average speed of 11.8 rpm, burning 36 calories and having an average SmO2 of 85.49 and Hb of 11.85 mg/dL.
In binary 2 round 2 (level 4, 100 watts) with a given time of 5 minutes, they managed to cover a distance of 3.1 km with an average speed of 11.64 rpm, burning 71 calories and having an average of 83.97% SmO2 and 11.76 mg Hb/L. In binary 3 round 1 (level 7, 140 watts), with a given time of 5 minutes, they managed to cover a distance of 1.48 km with an average speed of 11.6 rpm, burning 46 calories and having an average of SmO2 of 84.1 and Hb of 11.82 mg/dl. In binary 3 round 2 (level 7, 140 watts) with a given time of 5 minutes, they managed to cover a distance of 2.96 km with an average speed of 11.18 rpm, burning 93 calories and having an average of 79.37% SmO2 and 11.76 mg Hb/L. In binary 4 round 1 (level 9, 180 watts), with a given time of 5 minutes, they managed to cover a distance of 1.33 km with an average speed of 11.18 rpm, burning 51 calories and having an average SmO2 of 75.07 and Hb of 11.71 mg/dl.

Based on Table 3, it can be seen that the test results of all respondents were similar while cycling. The respondent successfully tested up to binary 4 round 1 (level 9, 180 watts). With an average speed of 11.33 rpm, they managed to cover a distance of 14.77 km and burned 367 calories with an average oxygen saturation level of 78.17% and an average hemoglobin of 11.77 mg/dl. The result of the respondent muscle oxygen saturation was good for the female gender because the average results were in the range of 70–80%, not much different from the starting point of the test. The researcher used multiple regression analysis to look at the determinants of road bike athletes. Figure 2 shows that there is a positive correlation between SmO2 and THb, where SmO2 contributes 61%. There is THb.

Table 2. Achievement of 515 Smo2 and Watt Tests

<table>
<thead>
<tr>
<th>Binary</th>
<th>Half</th>
<th>Minute</th>
<th>SmO2</th>
<th>Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>5</td>
<td>12.5</td>
<td>60-90</td>
</tr>
<tr>
<td></td>
<td>Rest 1 menit</td>
<td></td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>5</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>Rest 1 menit</td>
<td></td>
<td>1.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>9.3</td>
<td>100-130</td>
</tr>
<tr>
<td></td>
<td>Rest 1 menit</td>
<td></td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>5</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Rest 1 menit</td>
<td></td>
<td>1.1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>14.2</td>
<td>140-180</td>
</tr>
<tr>
<td></td>
<td>Rest 1 menit</td>
<td></td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>5</td>
<td>14.6</td>
<td></td>
</tr>
<tr>
<td>Rest 1 menit</td>
<td></td>
<td>12.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>190-230</td>
</tr>
</tbody>
</table>

In binary 2 round 2 (level 4, 100 watts) with a given time of 5 minutes, they managed to cover a distance of 3.1 km with an average speed of 11.64 rpm, burning 71 calories and having an average of 83.97% SmO2 and 11.76 mg Hb/L. In binary 3 round 1 (at level 7, 140 watts) with an allotted time of 5 minutes, they managed to cover a distance of 1.48 km with an average speed of 11.6 rpm, burning 46 calories and having an average of SmO2 of 84.1 and Hb of 11.82 mg/dL. In binary 3 round 2 (level 7, 140 watts) with a given time of 5 minutes, they managed to cover a distance of 2.96 km with an average speed of 11.18 rpm, burning 93 calories and having an average of SmO2 of 79.37% and 11.76 mg Hb/L. In binary 4 round 1 (level 9, 180 watts), with a given time of 5 minutes, they managed to cover a distance of 1.33 km with an average speed of 11.18 rpm, burning 51 calories and having an average SmO2 of 75.07 and Hb of 11.71 mg/dl.
DISCUSSION

This study, on cyclists, showed a positive correlation between SmO2 and THb, as seen from the moxi monitor measurements shown in Figure 1. In the first binary, the SmO2 value showed an average SmO2 value of 74.38% and Hb 11.78 mg/dl, but in the second binary, there was an increase, namely an average of SmO2 85.49 and Hb 11.85 mg/dl. This shows that the need for SmO2 in the muscles will be in harmony with THb; muscle performance at high intensity requires high oxygen to support the activities carried out. Based on the data presented, it seems interesting to verify the usefulness of SmO2 and THb measurements using the Moxy device for the selection and evaluation of high-intensity aerobic exercise. This is in line with research (Alvares et al., 2020), where there is a strong relationship between NIRS-derived tHb and BF Doppler ultrasound during the exercise phase with a value of $r = 0.83$.

During exercise, control of blood flow is determined by how well the muscles can use oxygen, which is largely determined by how much oxygen the muscles get and how much oxygen the muscles demand (Casey & Joyner, 2011). VO2max is what determines the diffusion of oxygen in the muscles, where the percentage of SmO2 during exercise can be an index of the capacity of oxygen diffusion in the muscles (Shibuya et al., 2004). During training transitions, the muscles will experience a more marked increase in oxygen availability than oxygen consumption, indicating that the body uses more oxygen to produce energy during the exercise phase (Cerretelli & Di Prampero, 2011; Grassi, 2000). A study conducted by (Rossiter et al., 2001) found that exercise intensity caused Vo2 to increase by about 70% of the maximum for knee extensor exercises.

VO2 Max is important for physical performance and overall health. VO2 Max can be determined by various exercises that activate the body major muscle groups, provided that the intensity and duration of the exercise are sufficient to maximize aerobic energy transfer (Doijad et al., 2013). A study found that cyclists could maintain high levels of oxygen uptake for short periods of time but could also continue to use more oxygen for longer periods of time when they took occasional breaks (ÅStrand et al., 1960). Strength training can improve cycling performance. By increasing the fraction of maximum oxygen uptake (VO2max), it can

| Respondents | 4.1 | 137.65 | 11.33 | 14.77 | 367 | 78.17 | 11.77 |

Copyright © 2023, authors, e-ISSN : 2580-071X , p-ISSN : 2085-6180
save energy and still make the bike go faster (Vikmoen et al., 2016). Additionally, increased muscle efficiency can compensate for low VO2max, allowing world-class cyclists to compete at a high level or even innate physiological responses to training and competition, allowing athletes to achieve better results (Santalla et al., 2009).

CONCLUSION

In short, the results of this study indicate that there is a positive correlation between SmO2 and THb, where VO2 max is aligned with THb. High-intensity cycling activities, such as those performed by cyclists, require high levels of oxygen to support exercise performance. This study only carried out on one subject, namely road bike athlete. It is hoped that further research can be carried out on other sports to add to the neurophysiological scientific knowledge in sports.

ACKNOWLEDGEMENT

The authors would like to thank athlete voluntary participation in the study. Deep gratitude is extended to Agus Gumilar for their assistance in data collection.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES


Simmons, J. (2017). The assessment of muscle oxygen saturation in students during maximal VO2 exercise and high intensity intervals.


Vikmoen, O., Ellefsen, S., Troen, Ø., Hollan, I., Hanes-tadhaugen, M., Raastad, T., & Rønnestad, B. R. (2016). Strength training improves cycling perfor-

Copyright © 2023, authors, e-ISSN : 2580-071X , p-ISSN : 2085-6180