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Lactic acid and cognitive function: An investigation among female volleyball athletes

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ABSTRACT

Lactic acid is a by-product of anaerobic metabolism and is commonly associated with muscle fatigue. However, recent research suggests that lactic acid may also positively affect cognitive function. Thus, this study aimed to investigate the relationship between lactic acid and cognitive function in female volleyball athletes. The study involved 12 female volleyball players from the Student Education and Training Centre (PPLP) of Riau Province, and a total sampling method was utilised. Data collection involved cognitive function tests using the Concentration Grid Test (CGT) instrument and lactic acid measurements using Accutrend lactate. The results revealed a significant correlation between lactic acid and cognitive function, with athletes with higher lactic acid levels after the training session performing better on cognitive tests. This suggests that lactic acid may enhance cognitive function by increasing glucose availability, which serves as the brain's primary energy source. However, it is essential to consider the potential negative effects of excessive lactic acid levels, such as muscle fatigue, breakdown, and lactic acidosis, on both of the body and brain. Despite demonstrating the role of lactic acid in cognitive function among female volleyball athletes, caution must be exercised to prevent undue lactic acid production. Overall, this study provides valuable insight into the intricate relationship between lactic acid and cognitive function, which has implications for optimising cognitive ability in female volleyball athletes and potentially in other professional sports. Future research is needed to establish optimal lactic acid levels for cognitive function in diverse athletic contexts.

Keywords: Lactic acid; cognitive function; female atletes; volleyball

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INTRODUCTION

As interest in exercise and health increases, researchers have turned their attention to the relationship between lactic acid and cognitive function in athletes. Lactic acid is a by-product of anaerobic metabolism that accumulates in muscles during intense exercise (Coco et al., 2019; Hall et al., 2016). Although lactic acid's role in fatigue and muscle soreness has long been recognized, its effect on cognitive function is still a topic of interest for research (Hakked et al., 2017; Holfelder et al., 2020; Irwin et al., 2018; Pokorski, 2015).

Exercise and regular physical activity have been shown to provide significant health benefits, including improved cognitive function (Alderman et al., 2019; Coppinger et al., 2020). In particular, women's volleyball athletes have been the focus of recent research on this topic.

Volleyball is a high-intensity sport that requires quick reflexes, spatial awareness, and decision-making abilities (Miura et al., 2020; Özgül, 2018; Santoso & Irwanto, 2018). These cognitive abilities are critical to success in the sport (Vestberg et al., 2017), and impairment of these abilities can have a significant impact on an athlete's performance (Holfelder et al., 2020). As an athlete, having good cognitive performance is very important to achieving optimal results in sports (Hakked et al., 2017; Jacobson & Matthaeus, 2014; Lundgren et al., 2016). Cognitive abilities such as attention (De Waelle et al., 2021), information processing, memory (Gomes da Silva & Arida, 2015), and decision-making are important factors in the success of athletes (Bianco et al., 2017). Therefore, the effects of lactic acid on cognitive function can have significant consequences on athlete performance.

A better understanding of the relationship between lactic acid and cognitive performance could help athletes and coaches design more effective training programs and exercises (Coco et al., 2019). Additionally, knowledge of these relationships may enable the development of better nutritional strategies to maximize athlete performance (Closs et al., 2020). Several studies have been conducted to evaluate the relationship between lactic acid and cognitive performance in athletes (Coco et al., 2019; Hall et al., 2016). Nonetheless, there are still many questions that need to be answered about the mechanisms underlying this relationship. Therefore, further research is needed to understand in more detail the effects of lactic acid on cognitive performance in athletes.

Exercise has been shown to affect cognitive function, but the results reported include both positive and negative effects (Coco et al., 2019). Methodological differences between studies could be factors influencing observed effects, such as duration and intensity of exercise, age, gender, and fitness level of participants, type of cognitive task used, and timing of cognitive testing (Gasquoine, 2018; Kilger & Blomberg, 2020; Vestberg et al., 2017). Based on a number of meta-analyses, exercise has been found to have a positive effect on cognitive performance (Vestberg et al., 2017).

Although the physiological mechanism for this effect remains unclear, several studies have linked the effect to exercise-induced mood improvements (Abbott et al., 2020, 2022). The observed positive effects appear to be long-lasting. This suggests that exercise may have long-term effects on cognitive performance. There are also differences in the effect of exercise depending on the duration and intensity of the exercise (Antonioni et al., 2019; Holfelder et al., 2020; Kraft, 2012; Ren et al., 2021). A greater positive effect tended to be observed when the exercise was performed for a short duration but regularly, compared to training for a longer duration but not regularly (Antunes et al., 2020; D'Angelo, 2019). This suggests that routine, shorter-duration exercises may be more effective in improving cognitive performance (Hakked et al., 2017; Lundgren et al., 2016). Therefore, further research is needed to understand the physiological mechanisms underlying this effect and to develop training programs that are more effective in increasing cognitive performance.

Despite mounting evidence that cognitive aspects are crucial in many sports domains, research on these determinants of sport resilience, specifically in volleyball performance, is currently lacking. Many studies on this subject have concentrated on the impact of cognitive techniques and on the caliber and performance of soccer and running (Kraft, 2012; Wallhead et al., 2021). However, there is a significant gap in the literature regarding the study of lactic acid and cognitive function in women, especially in the context of volleyball.

While research has explored different cognitive strategies, such as associative and dissociative techniques, in various sports (Kraft, 2012; Wallhead et al., 2021), the specific relationship between lactic acid and cognitive function in female volleyball athletes remains unexplored. Previous studies have demonstrated the benefits of an external focus of attention on performance, such as in running (da Silva et al., 2021). However, the role of lactic acid in cognitive function and its potential influence on volleyball performance is yet to be thoroughly examined.

Therefore, this research aims to fill this gap in the literature by investigating the relationship between lactic acid and cognitive function in female volleyball athletes. By exploring how lactic acid levels impact cognitive performance, this study seeks to provide comprehensive information about the importance of lactic acid and cognitive function in enhancing volleyball performance. The findings from this research will contribute to the understanding of the physiological and cognitive factors involved in volleyball resilience and success, ultimately aiding athletes in optimizing their performance in the future.

In conclusion, this study addresses the current research gap regarding the study of lactic acid and cognitive function in female volleyball athletes. By focusing on this unique population and examining the relationship between lactic acid and cognitive function, the research aims to provide valuable insights for athletes, coaches, and sports scientists, promoting a comprehensive understanding of the factors that contribute to successful volleyball performance.

METHOD

The data collection method used in this study was a quantitative approach. Twelve female volleyball athletes were recruited to participate in this study. All participants were given an explanation, both of in orally and in writing. Regarding the aims, procedures, and research risks. All participants were selected by the purposive sampling method. Participants were directed to fill out a form if they decided to participate in this study. The research protocol was approved by the Riau research ethics committee. The research was conducted using a correlational design. Field Hall A Rumbai Pekanbaru was chosen as the research location because it was where the athletes took place. The data collection time was Tuesday to Thursday, February 21 to 23, 2023. Lactic acid data was collected 7 minutes after exercise, and cognitive function was also performed after exercise. To get the results of lactic acid, researchers used AccutrendPlus. The results of the blood lactic acid data collected can be seen directly on the tool. Next, all participants were asked to sit down and complete a cognitive function test with the Concentration Grid Test (CGT) (Yongtawee & Woo, 2017). Statistical analyses were performed using SPSS (version 22). The Universitas Riau research ethics committee has accepted every research involving human use that complies with all applicable national rules and institutional norms, as well as the Declaration of Helsinki's guiding principles.

RESULTS AND DISCUSSION

The findings of a study on female volleyball players from the PPLP Riau Province, which included a total of 12 respondents, are reported in this section. The study was carried out in February 2023. The study's findings are as follows:

Lactic Acid

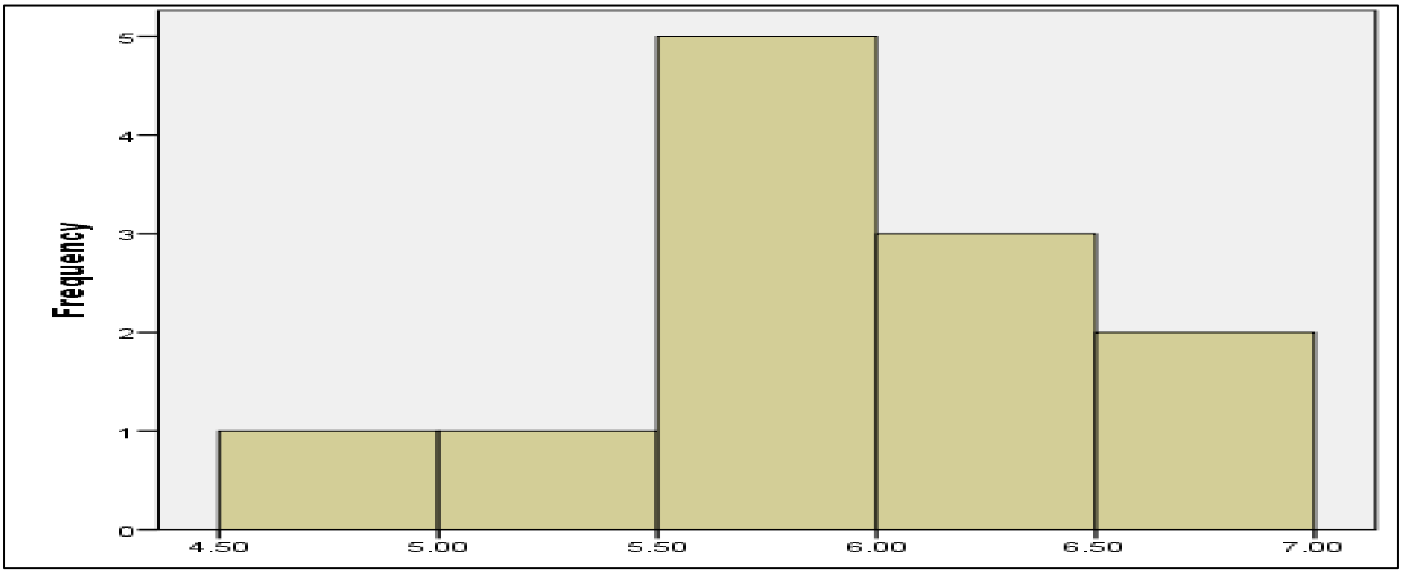
The data from AccutrendPlus was used to calculate the athlete's lactic acid level. The table below provides more information based on AccutrendPlus results:

Table 1. Lactic Acid Test Result

			Statistic	Std. Error
Lactic Acid	Mean		5.9617	.14047
	95% Confidence Interval for Mean	Lower Bound	5.6525	
		Upper Bound	6.2708	
	5% Trimmed Mean		5.9719	
	Median		5.9150	
	Variance		.237	
	Std. Deviation		.48660	
	Minimum		4.99	
	Maximum		6.75	
	Range		1.76	
	Interquartile Range		.44	
	Skewness		-.498	.637
	Kurtosis		.553	1.232

(Primary data of lactic acid, 2023)

According to Table 1, the average value of lactic acid ranges 5.9617 with a standard deviation of 0.48660. For more details, real lactic acid data can be seen in the image below:



Graph 1. Lactic Acid Test Result

Cognitive Function

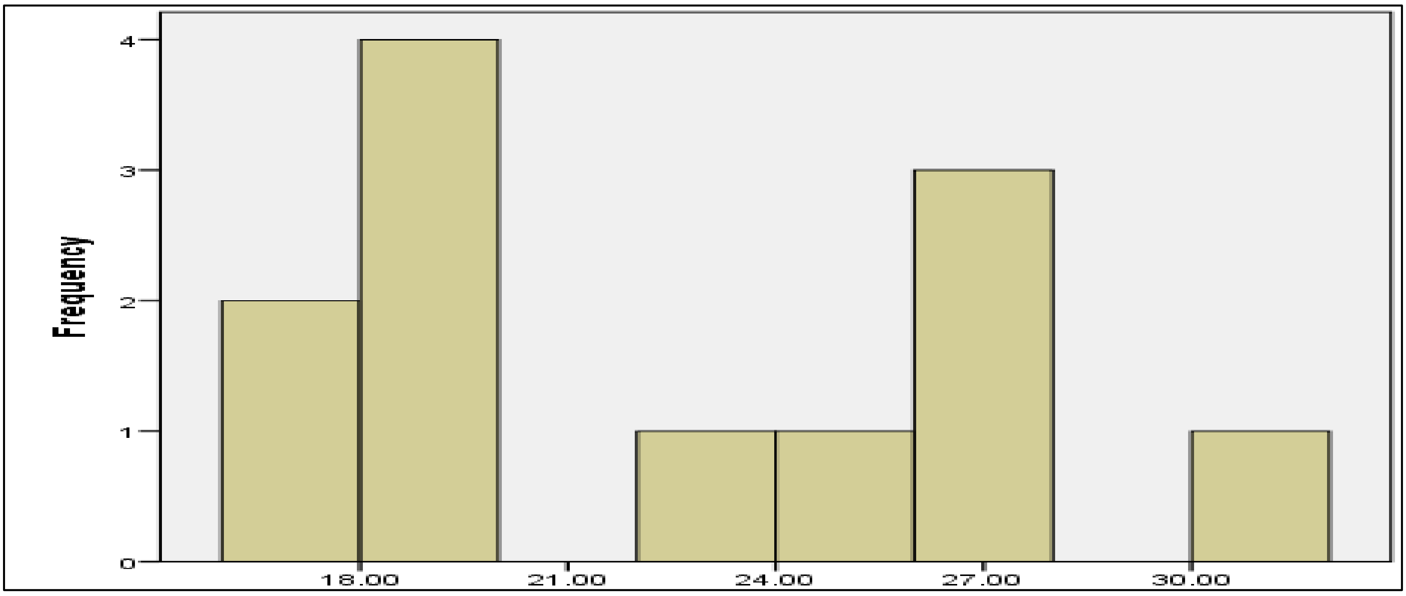
Data from the Concentration Grid Test (CGT) is used to calculate the athlete's cognitive function. The table below provides complete information based on the results of the Concentration Grid Test:

Table 2. Cognitive Function Test Result

			Statistic	Std. Error
Cognitive Function	Mean		22.1667	1.35866
	95% Confidence Interval for Mean	Lower Bound	19.1763	
		Upper Bound	25.1571	
	5% Trimmed Mean		21.9630	
	Median		20.5000	
	Variance		22.152	
	Std. Deviation		4.70654	
	Minimum		17.00	
	Maximum		31.00	
	Range		14.00	
	Interquartile Range		8.50	
	Skewness		.559	.637
	Kurtosis		-1.003	1.232

(Primary data of cognitive function, 2023)

Based on Table 2, the average value of cognitive function is 22.1667, with a standard deviation of 4.70654. For more details, cognitive function data can be seen in the image below:



Graph 2. Cognitive Function Test Result

Table 3. Correlations

		Lactic Acid	Cognitive Function
Lactic Acid	Pearson Correlation	1	.802**
	Sig. (2-tailed)		.002
	N	12	12
Cognitive Function	Pearson Correlation	.802**	1
	Sig. (2-tailed)	.002	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

It was determined from the study's Pearson test results that there was a correlation between lactic acid and the cognitive function of female volleyball athletes in Riau Province, with the value of r = 0.802 being higher than the r table and a significance value of 0.002 less than the significant standard (0.05). As an athlete, it is very important to turn attention to what is relevant and ignore irrelevant or distracting information, allowing us to verify the large amount of information we encounter every day and achieve our planned goals (in this case, the coach also has an equally important role). Therefore, cognitive function skills are very important in all types of sports, including volleyball, martial arts, basketball, and soccer. Aarsland et al. (2020) explained that cognitive function related to physical and social experiences is regulated by the frontal lobe, whereas other types of attention are non-triggering and triggered by external stimuli regardless of previous experience. In his research, Loprinzi (2019); Miyamoto et al. (2018); Ohko et al. (2021) stated that when performing maximum strength training, there is an increase in the demand for oxygen, glucose, and lactate in the central nervous system (CNS). This results in greater muscle and brain (cognitive function) activation during physical activity. Increased blood flow to the brain occurs about 20–30% from the resting phase to reach VO2max (Howard et al., 2019; Piepmeier et al., 2020).

However, the increased energy requirements are not evenly distributed throughout the central nervous system but are more protected in areas of the brain associated with movement, maintaining balance, cardiorespiratory control, and vision. In other discussions, several authors have considered the possible influence of high blood lactate levels on cognitive performance, especially in the attention mechanisms involved in sports such as aerobics and anaerobics. Numerous studies have shown that when the brain uses large amounts of glucose, oxygen, and lactate, poor oxygenation of frontal cortex tissue can occur (Hostinar et al., 2012; Singh & Staines, 2015), which can affect exercise performance (Coco et al., 2019; Hammami et al., 2018; Shahrbanian et al., 2021). The higher the amount of lactate produced, the worse the sports performance. However, there is still little literature linking the relationship between cognitive-lactate function and playing volleyball. Ahmad et al. (2015); Ali et al. (2021); Wong (2020) concluded that lactate functions as a link between glycolysis and oxidative metabolism. Apart from being the brain's main fuel, lactate is also considered a signal sender in the brain. The effects of exercise can be directly related to increased lactate and lactate tolerance, which can change the type of fuel used by the brain (Clark et al., 2020; Howard et al., 2019; Mills et al., 2020). Therefore, this study aims to examine the relationship between cognitive function and blood lactate levels during volleyball practice in female athletes.

CONCLUSION

The research findings reveal a significant relationship between lactic acid and cognitive function in female volleyball athletes. This discovery has significant implications for the field of sports science, as it highlights the potential influence of lactic acid on cognitive performance. Coaches, sports trainers, and sports team management should pay close attention to these results and consider the impact of lactic acid levels on the cognitive abilities of female volleyball athletes. By recognizing this link, sports professionals can design more tailored training programs and optimize athletes' cognitive performance, leading to potential improvements in their overall athletic capabilities. However, it is crucial to acknowledge that the scope of this study was limited to female volleyball athletes. Therefore, the generalizability of the findings to other sports or athlete populations may be restricted. To obtain a comprehensive understanding of how lactic acid affects cognitive function across diverse athletic contexts. Future research should explore male volleyball athletes and athletes participating in various sports disciplines. This expansion of the study's participant pool will contribute to a more robust body of knowledge, enabling sports professionals to apply these findings to a broader range of athletes and sports.

Furthermore, in light of the significance of the research, it is advisable for future researchers to conduct longitudinal studies. Investigating the long-term effects of lactic acid on cognitive function and its implications for athletic achievements can offer valuable insights. Additionally, exploring potential interventions to regulate lactic acid levels and understanding their impact on cognitive performance may pave the way for innovative strategies to enhance overall athletic performance. By continuing to deepen our understanding of the relationship between lactic acid and cognitive function, the sports community can develop more effective and targeted approaches to optimize both physical and mental performance, leading to improved outcomes in competitive sports and better athlete well-being.

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CONFLICT OF INTEREST

The authors state no conflict of interest.

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