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Enhancing athletes performance: the impact of Perhutani honey on cognitive function and lactic acid levels

Mejora del rendimiento deportivo: el impacto de la miel Perhutani en la función cognitiva y los niveles de ácido láctico

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Abstract

Introduction: Cognitive function and lactic acid levels are crucial determinants of athletic performance, impacting both physical and mental capabilities during training and competition.
Objective: This study aims to evaluate the effects of Perhutani Honey administration during Special Preparation Stage (SPS) on cognitive function and lactic acid reduction among male athletes from Student Education and Training Center (PPLP) at Riau Province in Indonesia.
Methodology: The study procedures were carried out using 45 male athletes, who were divided into 2 groups, namely control and Perhutani Honey supplementation. In addition, cognitive function and lactic acid levels were measured at each phase. The data obtained were analyzed using ANOVA (Analysis of Variance) to determine statistical significance, with a significance level set at $p<0.05$.
Results: These results suggested that Perhutani Honey supplementation during SPS training significantly enhanced cognitive function and reduced lactic acid accumulation in male athletes. ANOVA test results showed that there were significant improvements in cognitive function and reductions in lactic acid levels among athletes who received the intervention.
Conclusions: Future studies are advised to explore the long-term sustainability of the recorded benefits while controlling for additional variables, such as diet, sleep patterns, and other forms of exercise, to further isolate the specific effects of Perhutani Honey and SPS.

Keywords

Perhutani Honey; Cognitive Function; Lactic Acid; Athletes.

Resumen

Introducción: La función cognitiva y los niveles de ácido láctico son determinantes cruciales del rendimiento atlético, ya que repercuten en las capacidades físicas y mentales durante el entrenamiento y la competición.
Objetivo: Este estudio tiene como objetivo evaluar los efectos de la administración de Miel Perhutani durante la Etapa de Preparación Especial (SPS) sobre la función cognitiva y la reducción del ácido láctico entre los atletas masculinos del Centro de Educación y Formación de Estudiantes (PPLP) en la provincia de Riau en Indonesia.
Metodología: Los procedimientos del estudio se llevaron a cabo utilizando 45 atletas masculinos, que se dividieron en 2 grupos, a saber, control y suplementación con miel Perhutani. Además, se midieron la función cognitiva y los niveles de ácido láctico en cada fase. Los datos obtenidos se analizaron mediante ANOVA (análisis de la varianza) para determinar la significación estadística, con un nivel de significación fijado en $p<0,05$.
Resultados: Estos resultados sugirieron que la suplementación con Miel Perhutani durante el entrenamiento SPS mejoró significativamente la función cognitiva y redujo la acumulación de ácido láctico en atletas masculinos. Los resultados de la prueba ANOVA mostraron que se produjeron mejoras significativas en la función cognitiva y reducciones en los niveles de ácido láctico entre los atletas que recibieron la intervención.
Conclusiones: Se aconseja realizar estudios en el futuro para explorar la sostenibilidad a largo plazo de los beneficios registrados mientras se controlan variables adicionales, como la dieta, los patrones de sueño y otras formas de ejercicio, para aislar aún más los efectos específicos de la Miel Perhutani y el SPS.

Palabras clave

Miel Perhutani; Función Cognitiva; Ácido Láctico; Atleta.

Introduction

The pursuit of sports achievement remains a major focus for sports academics, practitioners, and coaches striving to enhance athletes' performance. However, coaching success is largely dependent on personal experience than systematic and evidence-based methodologies. A significant number of coaches have been reported to lack a comprehensive understanding of long-term achievement planning or fail to implement it effectively, leading to low competitive performance. To ensure sustainable performance improvements, it is important to accurately predict athletes' developmental trajectories and implement well-structured training programs (T.O. Bompa & Buzzichelli, 2019). Traditional training programs often contribute to athletes injuries and fail to optimize physical condition. These challenges have prompted scientists and sports trainers to explore evidence-based methods for achieving optimal physical fitness and facilitating peak performance. Key factors influencing performance include suboptimal physical condition, cognitive abilities, particularly cognitive function, and elevated lactic acid levels. Therefore, addressing these factors through scientifically designed training programs is essential for enhancing performance and minimizing the risk of injuries (Viegas et al., 2021).

In addition to optimal physical condition, sports disciplines also require strong cognitive abilities, particularly for the effective application of methods and tactics during competitions. Several studies have shown the essential role of training in enhancing cognitive function among athletes. Well-structured training programs not only improve physical capabilities but also significantly enhance cognitive skills, leading to better decision-making, strategic implementation, and overall performance during high-pressure situations (Holfelder et al., 2020; Stenling et al., 2021).

Athletes who participate in targeted and well-planned training programs, such as Special Preparation Stage (SPS) Training, are likely to experience significant improvements in cognitive function and performance (Mazuera-Quiceno et al., 2023; Rodríguez-Cayetano et al., 2023; Trisnadi, 2023). Cognitive function is fundamental as it promotes critical processes, such as decision-making, technique execution, and tactical precision. Enhancing cognitive abilities through systematic training can sharpen athletes' mental acuity, enabling more strategic play, accurate decisions, and better overall performance during competitions. Previous studies also suggest that regular physical exercise induces significant structural and functional changes in the brain, further enhancing cognitive function. In addition, regular exercise has been reported to improve memory, executive function, and overall mental sharpness by stimulating physiological mechanisms. These mechanisms include increased cerebral blood flow, neurogenesis (the growth of new neurons), and the release of neurotrophic factors like Brain-Derived Neurotrophic Factor (BDNF) (Alves et al., 2013; Coles & Tomporowski, 2008; Viegas et al., 2021). These mechanisms collectively improve brain plasticity, strengthen synaptic connections, and enhance cognitive abilities. Structural changes, such as increased hippocampal volume, a brain region critical for learning and memory, have been observed, alongside functional improvements, including enhanced neural connectivity and efficiency across brain regions. By incorporating regular exercise into training routines, athletes can not only optimize their physical fitness but also foster long-term brain health and cognitive performance. This comprehensive approach ensures athletes are equipped to perform at their peak, both physically and mentally (Alves et al., 2013).

A previous study demonstrated a significant impact of exercise on both cognitive function and physical health. These findings show the crucial role of regular physical activity in enhancing not only physical well-being but also mental capabilities. Exercise was found to improve cognitive functions, such as memory, attention, and executive function, which are key components for effective decision-making and problem-solving. In addition, the positive effects on physical health include enhancements in cardiovascular health, muscular strength, and overall endurance. These benefits contribute to improved performance in both athletic endeavors and daily activities, indicating the holistic advantages of incorporating regular exercise into routine (Stenling et al., 2021). Various studies have utilized cognitive function tests, such as the Choice Reaction Time Test (CRT), Concentration Grid Test (CGT), Visualization of Rotations (VR), and Digit Symbol Substitution Test (DSST), to assess the impact of exercise on mental performance (A Yongtawee et al., 2021; Atcharat Yongtawee & Woo, 2017). Regular exercise has been reported to offer substantial psychological advantages, especially for young adolescents. Consistent engagement improves mood, alleviates symptoms of anxiety and depression, and enhances overall mental well-being. Exercise stimulates the release of endorphins and other neurochemicals, which contribute to feelings of happiness and relaxation.

Apart from enhancing mood, exercise has been shown to improve cognitive function, including memory, attention, and executive function. This is particularly significant during adolescence, a crucial period for brain development. By promoting better mental health and cognitive abilities, exercise helps manage stress, build resilience, and foster a more positive self-image. It can also enhance social skills and cultivate a sense of community and belonging, especially when participation involves team sports or group activities. These social interactions are essential for developing communication skills and forming healthy relationships (Gendron et al., 2020). Various cognitive function tests can help uncover the relationship between athletes' mental readiness and their ability to achieve peak performance. By evaluating cognitive abilities, such as memory, attention, and decision-making skills, these assessments provide valuable insights into how mental preparedness affects performance outcomes. Understanding the relationship enables coaches and trainers to design more effective training programs that not only improve physical condition but also optimize cognitive function, thereby supporting athletes in reaching their full potential.

Previous studies suggest that exercise can lead to anatomical changes in the brain, particularly by increasing neural volume in key areas such as the prefrontal cortex and the temporal lobe. These changes are significant because the prefrontal cortex is involved in executive functions, decision-making, and social behavior, while the temporal lobe plays a crucial role in memory and auditory processing. Enhanced neural volume in the areas can contribute to improved cognitive function, greater mental flexibility, and better overall brain health. This shows the multifaceted benefits of regular exercise, not only for fitness but also for enhancing brain structure and function (Fil'o & Janoušek, 2021; Gendron et al., 2020). Other studies in the field of neurology suggest that tests that help map cognitive function in athletes may provide an objective way to assess the potential development and future performance (Kilger & Blomberg, 2020). The description above shows that it is necessary to explore cognitive function in Volleyball athletes to improve achievement.

To support athletes' performance, it is necessary to reduce lactic acid levels during competitions by administering honey. In Riau Province, Indonesia, there is a product called Perhutani Honey, which has better quality compared to others. This product contains Diastase Activity (3.80 DN) Hydroxymethylfurfural (not detected), Reducing Sugar as Glucose (75.03%), Ash Content (0.30%), Moisture Content (18.96%), Acidity (39.51 mLNaOH1N/kg), Total Plate Count (8.3x103 colony/g), Sucrose (not detected), and Water Insoluble Solids (0.10%). Hajizadeh Maleki et al. (2016) and Tartibian & Maleki (2012) showed that honey was able to modulate exercise-induced peroxidative, antioxidant, and immunological changes in male road cyclists after chronic low to intensive exercise training. Therefore, honey can be used as an anti-inflammatory and antioxidant supplement for competing athletes participating in long-term sports protocols of moderate to intensive intensity.

Despite the extensive body of literature on sports science, no study has yet explored the effects of Perhutani Honey on cognitive function and lactic acid levels within the athletic domain. The current study was conducted with the Student Education and Training Center (PPLP) volleyball athletes in Riau Province, who exhibited suboptimal lactic acid clearance and cognitive function. These deficiencies may be attributed to inadequate application of sports science principles. Post-exercise blood samples showed elevated lactate levels, and cognitive tests demonstrated a significant decline in performance following training. Nutritional assessments also indicated insufficient intake of key nutrients and recovery supplements. The absence of a structured, science-based periodization approach in the athletes' training programs exacerbated the issues. The results suggested that the observed suboptimal performance in PPLP athletes may be linked to elevated lactic acid levels and insufficient cognitive function enhancement. Therefore, this study aims to determine the effect of Perhutani Honey supplementation during SPS training on cognitive function and lactic acid levels in athletes.

Method

This experimental study was carried out using a Pretest-Posttest Control Group Design with Matched Subjects, as outlined by (J.R. Fraenkel, Norman Wallen, 2011). The design allowed for variations comprised of two or more different treatment groups (J. R. Fraenkel, 2008). The primary objective of this study was to analyze improvements in cognitive function and changes in blood lactic acid levels among PPLP athletes in Riau Province, Indonesia. The 12-week training program included the administration of Kuantan Singingi honey to the athletes as part of the intervention. To ensure a robust comparison, the study included both an experimental group, which received honey supplementation, and a control group, which did not. In addition, the athletes in the experimental group were given Perhutani Honey sourced from Kuantan Singingi Regency. The honey supplementation consisted of 70 grams diluted in 250 milliliters of water, administered 90 minutes prior to physical activity or exercise.

Participants

Despite the growing body of study on sports science, no prior investigation had explored the effects of Perhutani Honey on cognitive function and lactic acid levels in athletic domain, making this study highly original. This report involved a total of 45 Regional PPLP athletes from Riau Province (23 males, 22 females, age range: 15-18 years, mean age: 16.7 ± 1.2 years) who were actively training in PPLP program for an average of 2.3 ± 0.8 years. The study team included PPLP coaches from Riau Province, with over 10 years of coaching experience, and a specialized team of lactic acid field experts (n=3) for physiological assessments. The Diaspora (Youth and Sports Office) of Riau Province granted official permission to conduct training program and study activities. An analysis team (n=4), comprising sports scientists and data analysts, was responsible for recording and reviewing the results of all report activities. This comprehensive method ensured a thorough examination of athletes' performance, physiological responses, and the effectiveness of their training regimen. Blood lactate analysis showed elevated levels post-exercise, while cognitive tests indicated a significant decline in performance following training. Additionally, nutritional assessments revealed inadequate intake of key nutrients and recovery supplements, and the review of training regimens highlighted a lack of structured, science-based periodization and recovery protocols. These results suggested that the suboptimal performance observed in PPLP athletes could be influenced by elevated lactic acid levels and insufficient cognitive function enhancement. Therefore, it was necessary to conduct an empirical study on the effect of Perhutani Honey supplementation during SPS training on cognitive function and lactic acid levels in athletes.

An empirical investigation into Perhutani Honey supplementation during SPS training was essential to address gaps in the existing literature. The selected group of PPLP athletes from Riau Province provided an ideal sample due to their structured training environment and controlled conditions. Participants were required to meet specific inclusion criteria, including PPLP athletes from Riau Province, physically able-bodied, in good health without disabilities, willing to participate in the study, and possess a doctor’s recommendation. Athletes were excluded when unwell, absent from training sessions, or unwilling to participate. These selection criteria ensured the validity and applicability of the results to similar athletic populations. To further strengthen the study’s validity, several measures were implemented. First, the involvement of experienced coaches and lactic acid field experts ensured accurate physiological assessments and adherence to scientifically validated training protocols. The use of the Analysis of Variance (ANOVA) test for statistical analysis provided a rigorous approach to identifying significant differences in the data. In addition, the study controlled for critical variables, including training consistency and participants' health status.

The detailed methodology contributed significantly to the study's internal validity and replicability. Specific training program phases, namely Pretest, Midtest, and Posttest, were clearly defined, alongside the precise measurements of cognitive function and lactic acid levels. This structured approach established a clear framework for other researchers to follow. The inclusion and exclusion criteria ensured that future studies could replicate the participants selection process, enhancing the generalizability. The robust use of ANOVA for data analysis offered a solid statistical foundation for identifying reliable patterns and results. The comprehensive documentation of procedures and methodologies facilitated reproducibility, enabling other investigators to confirm the study's findings and validate its reliability.

Procedure

The implementation of the 12-week training program included the administration of Perhutani Honey to athletes during every exercise session. Perhutani Honey, known for its potential health benefits, was sourced from Kuantan Singingi Regency. This experimental study involved providing specific treatments and subsequently analyzing the results in the field to determine the effectiveness of Perhutani Honey in enhancing athletic performance and recovery according to Hajizadeh Maleki et al., (2016), Tartibian and Maleki, (2012). Additionally, honey was given in the amount of 70 g + 250 ml of water and given 90 minutes before activity/exercise, and the energy content of 70 g honey + 250 ml of water was calculated to be 468 g per glass.

The intake of honey was strictly monitored to ensure uniform adherence to the protocol. Athletes were supervised during honey consumption process to confirm that each athletes ingested honey mixture at the specified time. Compliance was tracked through individual log entries maintained by the study team, and any deviations were promptly addressed to maintain consistency across all participants. Ethical issues related to blood sampling procedures in this study were anticipated and addressed proactively. Detailed explanations were provided to participants about the procedures to be performed, the benefits of the study, potential side effects, and the steps to mitigate these side effects. All participants were fully informed and had the freedom to withdraw from the study at any stage without any impact on the quality of service received. Furthermore, individuals were not charged for any laboratory examinations, and the study commenced after receiving approval from the Study Ethics Committee of Riau University Nursing Science Study Program, ensuring adherence to ethical standards and participant welfare. This involved several key steps which included Preparation of Study Proposal, Submission to the Ethics Committee, Ethics Committee Review, Feedback and Revisions, Ethical Approval, Implementation, and Reporting.

Instrument

The Edge Blood Lactate Monitoring System was utilized to measure blood lactate levels in milligrams per deciliter (mg/dL), as referenced by (Aly et al., 2019). Lactate measurements were taken at 3 key phases namely Pretest, Midtest, and Posttest. Additionally, blood lactate levels were measured 7 minutes after completing each exercise session or maximal test to monitor changes in training program. Primary nutritional intake and dietary patterns of participants were evaluated to provide a comprehensive understanding of their nutritional status before and during the study. Detailed dietary assessments, including food diaries and nutritional questionnaires, were conducted to monitor participants' intake of key nutrients and recovery supplements. This analysis was crucial to determine whether any lack of improvement in some aspects was related to nutritional deficiencies or when the observed benefits could be significantly attributed to honey supplementation. Participants engaged in 4 cognitive function tasks designed to assess various aspects of their mental capabilities. These tasks included CRT, CGT, VR, and DSST, following the methodologies established (Atcharat Yongtawee et al., 2021; Atcharat Yongtawee & Woo, 2017). The cognitive tests selected for this study were selected due to their alignment with the data requirements and their high levels of validity and reliability. These tests were well-suited to measure the specific cognitive skills relevant to the study's objectives, ensuring that the data collected were both accurate and dependable. By using the validated and reliable cognitive assessments, this study aimed to establish a strong link between cognitive function improvements and athletic performance, providing robust and credible results.

Data Analysis

Data analysis was performed using SPSS version 26.0, and the descriptive statistics for all variables were calculated and reported as mean ± standard deviation (SD) unless otherwise specified. The level of significance for all statistical tests was set at $p<0.05$. Effect sizes were determined using Cohen's d for t-tests and partial eta-squared (η^2) for ANOVA, and to control for Type I errors, Bonferroni corrections were applied for multiple comparisons. Data normality was assessed using the Shapiro-Wilk test, and non-parametric tests, such as the Wilcoxon signed-rank test and the Friedman test, were employed for data that did not follow a normal distribution.

Results

The normality test for the study data on Cognitive Function and Lactic Acid levels before, mid, and after SPS training with Perhutani Honey, as well as for the group of male athletes not given honey, was conducted using the Kolmogorov-Smirnov test ($p > 0.05$). The results indicated that the data for Cognitive Function and Lactic Acid levels were normally distributed, allowing for the use of the dependent t-test. For data that were not normally distributed, the Wilcoxon test was applied to determine the effect of the treatment.

Several cognitive function tests were employed to compare the influence between the group given Perhutani Honey and the group not given honey during SPS training, namely CRT, CGT, VR, and DSST. The Bonferroni test ($p < 0.05$) was used to assess cognitive function differences between honey-supplemented and non-supplemented groups at different stages of SPS training (Pretest, Midtest, and Posttest). In addition, this was the analysis of the Cognitive Function measurement using CRT for athletes treated with Perhutani Honey and those not treated.

Table 1. Results of Cognitive Function Measurement

Test Phase	Group 1 (ms)	Group 2 (ms)	p-value	Cohen's d
Pretest	842 ± 51.76	818 ± 40.46	0.123	0.49
Midtest	668 ± 42.85	762 ± 47.38	0.001	2.08
Posttest	576 ± 31.74	653 ± 68.91	0.005	1.36

Note: Values were presented as Mean ± Standard Deviation in milliseconds (ms).

This table showed the improvement in reaction times among athletes who received Perhutani Honey compared to those who did not, with significant differences observed during Midtest and Posttest phases. The p-values and Cohen's d indicated statistically significant improvements and effect sizes respectively, reinforcing the effectiveness of Perhutani Honey in enhancing cognitive function during training program.

Table 2. Results of Cognitive Function Measurement with Concentration Grid Test (CGT)

Test Phase	Group 1 (Honey)	Group 2 (No Honey)	p-value	Cohen's d
Pretest	6 ± 1.669	7 ± 1.67	0.234	0.60
Midtest	14 ± 1.06	11 ± 1.15	0.002	2.75
Posttest	16 ± 0.52	12 ± 1.13	0.001	4.00

Note: Values were presented as Mean ± Standard Deviation.

This data demonstrated a significant improvement in cognitive function for the group given Perhutani Honey, particularly evident at Midtest and Posttest stages. The p-values and Cohen's d reflected substantial differences and effect sizes, highlighting the effectiveness of Perhutani Honey in enhancing cognitive abilities during training program.

Table 3. Results of Cognitive Function Measurement with Visualization of Rotations (VR)

Test Phase	Experimental Group	Control Group	p-value	Effect Size (Cohen's d)
Pretest	5.00 ± 1.85	5.00 ± 1.35	1.000	0.00
Midtest	13.00 ± 1.31	7.00 ± 1.35	<0.001*	4.50
Posttest	17.00 ± 0.52	12.00 ± 0.69	<0.001*	8.21

Note: Values were presented as Mean ± Standard Deviation. SPS = Time to Peak.

This data highlighted the significant improvements in cognitive function for athletes given Perhutani Honey, particularly in Midtest and Posttest stages. The p-values and effect sizes indicated strong differences between the experimental and control groups, showcasing the effectiveness of Perhutani Honey in enhancing cognitive performance during training régimen.

Table 4. Results of Cognitive Function Measurement with Digit Symbol Substitution Test (DSST)

Phase	Experimental (Honey)	Control (No Honey)	Between-Group Comparison	Within-Group Comparison (Experimental)	Within-Group Comparison (Control)
Pretest	42 ± 2.91	43 ± 1.73	p = 0.187, d = -0.42	-	-
Midtest	64 ± 5.45	51 ± 2.06	p < 0.001, d = 3.20	p < 0.001, d = -5.48	p < 0.001, d = -4.64
Posttest	67 ± 3.99	54 ± 1.21	p < 0.001, d = 4.55	p = 0.048, d = -0.67	p < 0.001, d = -1.93

Note: Values were presented as Mean ± Standard Deviation. Cohen's d effect sizes: small (0.2), medium (0.5), large (0.8), very large (1.2+).

This data showed that athletes who received honey showed significantly better cognitive performance on DSST across all testing phases. The effect sizes and p-values indicated substantial improvements in cognitive function for honey-supplemented group, particularly at Midtest and Posttest stages.

Table 5. Results of Lactic Acid Measurement with The Edge Blood Lactate Monitoring System

Test Phase	Mean (Exercise)	Mean (Control)	Mean Difference	Pooled SD	Cohen's d	p-value
Pretest	176 ± 5.58	177 ± 5.44	-1	5.51	-0.18	<0.05
Midtest	160 ± 6.76	169 ± 5.96	-9	6.38	-1.41	<0.01
Posttest	152 ± 5.01	163 ± 7.98	-11	6.72	-1.64	<0.01

This table summarized mean values, mean differences, pooled standard deviations, Cohen's d, and p-values for each test. The results showed that the group given honey exhibited significantly lower lactic acid levels at Midtest and Posttest stages compared to the control group, highlighting the potential benefits of Perhutani Honey in managing lactic acid levels during intensive training.

ANOVA Results for Cognitive Function and Lactic Acid Levels

Table 6. Choice Reaction Time Test (CRT)

Test Phase	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-value
Pretest	Between Groups	245.68	1	245.68	3.23	0.123
Midtest	Between Groups	3050.12	1	3050.12	53.23	0.001
Posttest	Between Groups	1801.52	1	1801.52	20.92	0.005

Table 7. Concentration Grid Test (CGT)

Test Phase	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-value
Pretest	Between Groups	3.68	1	3.68	1.43	0.234
Midtest	Between Groups	27.38	1	27.38	68.75	0.002
Posttest	Between Groups	48.96	1	48.96	104.75	0.001

Table 8. Visualization of Rotations (VR)

Test Phase	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-value
Pretest	Between Groups	0.00	1	0.00	0.00	1.000
Midtest	Between Groups	216.00	1	216.00	202.13	<0.001
Posttest	Between Groups	312.00	1	312.00	526.78	<0.001

Table 9. Digit Symbol Substitution Test (DSST)

Test Phase	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-value
Pretest	Between Groups	6.68	1	6.68	1.79	0.187
Midtest	Between Groups	715.38	1	715.38	48.43	<0.001
Posttest	Between Groups	812.68	1	812.68	50.78	<0.001

Table 10. Lactic Acid Measurement

Test Phase	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-value
Pretest	Between Groups	0.48	1	0.48	3.45	<0.05
Midtest	Between Groups	256.12	1	256.12	40.11	<0.01
Posttest	Between Groups	308.12	1	308.12	55.67	<0.01

Tables 6, 7, 8, 9, and 10 presented ANOVA results, summarizing the source of variation, sum of squares, degrees of freedom, mean square values, F-Values, and p-values for each cognitive function test and lactic acid measurement. This detailed analysis highlighted the significant differences observed between the experimental group (given Perhutani Honey) and the control group across the different test phases.

Discussion

The results showed that administering Perhutani Honey alongside SPS Exercise significantly enhanced cognitive function and reduced lactic acid levels among athletes. These improvements were evident from Midtest measurements and peaked at Posttest, highlighting the efficacy of this combined regimen for male athletes both with and without honey supplementation during SPS training. Optimal cognitive abilities were essential for athletes to make rapid and accurate decisions during competitions. In addition, athletes must master a range of technical skills, tactics, and playing strategies to excel in their respective sports.

This comprehensive method not only boosted physical capabilities but also sharpened the mental acuity necessary for competitive success. By integrating Perhutani Honey into the training program, athletes could achieve a more holistic enhancement of their performance metrics (Esatbeyoglu et al., 2021; Marszałek et al., 2018; Reynaud & American Sport Education Program., 2011). The pattern of motion in athletic activities, particularly those involving heavy physical exertion, necessitated both aerobic and anaerobic capacities. Good aerobic capacity was crucial for sustained endurance, while robust anaerobic capacity was essential for high-intensity efforts. During these intense activities, athletes inevitably produced lactic acid as a byproduct of anaerobic metabolism. Managing and optimizing both aerobic and anaerobic capacities was vital for peak performance and effective recovery (Ceylan et al., 2016; Reeser & Bahr, 2008).

Energy sources came from both aerobic and anaerobic metabolism, leading to the production of lactic acid and free radicals because athletes engaged in fast, intense exercise. Efforts to enhance aerobic capacity aimed to reduce reliance on anaerobic metabolism. This enhancement was achieved through an Exercise Periodization Program, comprising the General Preparation Stage (GPS), SPS, Pre-Match Stage, Match Stage, and rest period. During SPS, additional supplements, including honey, were provided to boost both aerobic and anaerobic capacities. By integrating Perhutani Honey into the training program, athletes could achieve a more holistic enhancement of their performance metrics. This comprehensive method not only boosted physical capabilities but also sharpened the mental acuity necessary for competitive success (Mosavat et al., 2014; Wong, 2020; Woolfolk, 2012).

Providing food supplements, including Perhutani Honey aimed to improve physical abilities of athletes (Gastin et al., 2017; Holden et al., 2019; Tang, 2022). Honey contained rich nutrients, including organic acids, flavonoids, amino acids, minerals, polyphenols, and vitamins, and a total of 80% carbohydrates and 19% water (Hills et al., 2019). Perhutani Honey, known for its superior quality and high carbohydrate content, provided the necessary energy for athletes' brain functions. Cognitive abilities such as intelligence, speed of thinking, and decision-making accuracy relied heavily on carbohydrates. The study results revealed that athletes given Perhutani Honey during SPS training exhibited better intelligence, faster thinking speeds, and more accurate decision-making compared to those who were not given honey. For instance, the thinking speed test showed results of 576 ± 31.749 ms for athletes given honey versus 653.86 ± 68.909 ms for those not given honey. Accuracy of thinking was 16 ± 0.52 for honey group versus 12.43 ± 1.13 for the non-honey group. The ability to predict results was 17 ± 0.52 versus 13 ± 0.69 ($p < 0.05$). These results indicated that the carbohydrates in honey effectively supplied the brain with energy, enhancing cognitive function (Henry, 2016; Holden et al., 2019; Tang, 2022; Wong, 2020).

The results of the study showed that related to cognitive, found a positive relationship between exercise and good cognitive performance in a person (Gasquoine, 2018; Mills et al., 2020; Ploughman, 2008). According to Miyamoto et al., (2018), physical exercise could successfully increase hippocampal volume and improve cognitive function. SPS training which in its implementation was carried out in a measured and well-programmed manner from the results of the study on athletes found a significant increase in brain cognitive function as previously described ($p < 0.05$). Other reports in the form of experimental studies explained molecular and metabolic mechanisms through exercise could affect the maintenance or improvement of cognitive abilities (Kraft, 2012). This was also found that exercise could increase neurogenesis and increase the overall survival of existing neurons (Antunes et al., 2020; Azman et al., 2018; Li et al., 2019). Other studies had found a direct interaction between physical performance and athletes' cognition, specifically in team sports (De Waelle et al., 2021; Holfelder et al., 2020; Leal et al., 2021; Stenling et al., 2021). In addition, it was also found from the results of the study that measurable and well-programmed training could improve brain structural and cognitive function (Alves et al., 2013; Viegas et al., 2021).

In this study, lactic acid levels were significantly lower at the end of SPS Exercise periodization program in athletes who received Perhutani Honey. Specifically, the initial lactic acid level in athletes was 176 ± 5.58 mg/dl, which decreased to 152 ± 5.01 mg/dl at the end of SPS ($p<0.05$). In contrast, male athletes who were not given honey showed relatively unchanged lactic acid levels, from 179 ± 3.99 mg/dl at the beginning to 168 ± 8.35 mg/dl at the end of SPS. The observed reduction in honey-supplemented group was attributed to the flavonoid antioxidants in Perhutani Honey, which protected mitochondria from oxidative damage, thereby promoting aerobic metabolism over anaerobic pathways when the aerobic capacity was better. The supply of oxygen to the tissue was more optimal and could cause lactic acid metabolism in the muscle to take place at 20% and the remaining 80% to occur in the liver (Cairney & Veldhuizen, 2017; Cairns, 2006; Wong, 2020). A growing body of evidence had emerged since the early 1990s showing that lactate accumulation and acidosis had detrimental effects on muscle performance (Cairns, 2006). During high-intensity exercise, intramuscular lactic acid accumulation had long been considered one of the most important factors in fatigue. This had played a key role in traditional theories of muscle fatigue and endurance performance limitations. In addition, it was believed that once exercise intensity exceeded the maximal oxygen consumption level, metabolism shifted from aerobic to anaerobic, causing a sudden increase in blood lactate levels and resulting in metabolic acidosis. This lactic acidosis was thought to impair muscle contractility, ultimately leading to fatigue, injury, and exercise discontinuation. A well-measured training program improved the ability of the cardiovascular system and was the single parameter for physical condition of athletes (Antunes et al., 2020; Gasquoine, 2018; Othman et al., 2015). Components for players must be optimized for training to successfully achieve the desired achievements. According to T.O. Bompa and Buzzichelli, (2019), Tudor. O Bompa and Carrera, (2015), as well as Reynaud and American Sport Education Program (2011), the important physical skills were strength, VO2Max, speed, agility, power, and flexibility. In addition to technical aspects, all components of physical condition must be able to compete in their “top performance” and must be maintained by paying attention to many factors, one of which was the application of sports science.

The study showed the benefits of Perhutani Honey and SPS training in improving cognitive function and reducing lactic acid in male athletes. However, like any scientific study, it had its limitations and areas for improvement. Conducting long-term studies could help in assessing the sustainability of the benefits observed in the short term. Future studies aimed to control for additional variables such as diet, sleep, and other exercise to isolate the effects of Perhutani Honey and SPS training.

Conclusions

In conclusion, the experimental study showed that the administration of Perhutani Honey during SPS significantly enhanced cognitive function and reduced lactic acid levels among male athletes at Riau Province PPLP. The rigorous training program, which included Pretest, Midtest, and Posttest phases, revealed that athletes who received Perhutani Honey supplementation showed marked improvements in cognitive performance and significant reductions in lactic acid levels compared to those who did not receive the supplement. These results underscored the potential of Perhutani Honey as an effective natural supplement for improving both physical and cognitive performance in athletes. Future studies must focus on assessing the long-term sustainability of the benefits observed with Perhutani Honey supplementation and must incorporate larger and more diverse athletes’ populations to generalize the results more broadly. Additionally, it was crucial to control for other variables that could impact cognitive function and lactic acid levels, such as diet, sleep, and other exercise, to isolate the specific effects of Perhutani Honey and SPS training. Investigation into the biochemical mechanisms through which Perhutani Honey exerted its effects could provide deeper insights and strengthen its application in sports nutrition. Finally, exploring different dosages and forms of administration could optimize its usage for enhancing athletic performance.

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