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# Correlation between hydration status and $VO_2$max in Pencak Silat athletes
# Correlación entre el estado de hidratación y el $VO_2$máx en atletas de Pencak Silat

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**Abstract.** Maintaining proper hydration conditions is important to support athlete performance. The study aimed to determine the relationship between hydration status and the $VO_2$max capacity of martial arts athletes. The research was conducted using a correlational method. The subjects of the study were 14 Pencak Silat Athletes Special Class for Sports at State Junior High School (JHS) 1 Surakarta. Self-Urine Check (SUC) test data collection to test hydration status and Bleep Test to measure athletes' $VO_2$max capacity. Data analysis techniques with product-moment correlation tests. The results obtained the relationship coefficient between hydration status and $VO_2$max capacity was r = -0.844; p = 0.001. Therefore, there was a significant negative relationship between these two variables. This study concludes that there was a negative correlation between hydration status and $VO_2$max capacity in JHS Special Sports Class athletes. The novelty of this study lies in the observation of stable hydration levels among Pencak Silat athletes in the Special Sports Class of SMPN 1 Surakarta. The results of this study can be used as a reference for athletes to maintain adequate hydration during activities, and for coaches to ensure that all athletes are in a well-hydrated state to avoid dehydration.
**Keywords:** Hydration Status, Junior High School, Pencak Silat, Special Sport Class, $VO_2$max Capacity

**Resumen.** Mantener unas condiciones de hidratación adecuadas es importante para apoyar el rendimiento del deportista. El estudio tuvo como objetivo determinar la relación entre el estado de hidratación y la capacidad de $VO_2$max de atletas de artes marciales. La investigación se realizó mediante un método correlacional. Los sujetos del estudio fueron 14 atletas de Pencak Silat de la clase especial de deportes en la escuela secundaria estatal (JHS) 1 Surakarta. Recopilación de datos de la prueba Self-Urine Check (SUC) para evaluar el estado de hidratación y Bleep Test para medir la capacidad de $VO_2$max de los atletas. Técnicas de análisis de datos con pruebas de correlación producto-momento. Como resultado se obtuvo que el coeficiente de relación entre el estado de hidratación y la capacidad de $VO_2$max fue r = -0,844; p = 0,001. Por lo tanto, hubo una relación negativa significativa entre estas dos variables. Este estudio concluye que hubo una correlación negativa entre el estado de hidratación y la capacidad de $VO_2$max en atletas de la Clase Deportiva Especial JHS. La novedad de este estudio radica en la observación de niveles estables de hidratación entre los atletas de Pencak Silat en la Clase de Deportes Especiales de SMPN 1 Surakarta. Los resultados de este estudio pueden usarse como referencia para que los atletas mantengan una hidratación adecuada durante las actividades, y para que los entrenadores se aseguren de que todos los atletas estén en un estado bien hidratado para evitar la deshidratación.
**Palabras clave:** Estado de hidratación, escuela secundaria, pencak silat, clase de deporte especial, capacidad de $VO_2$max

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## Introduction

The performance of the sports branch of pencak silat in Indonesia is often put down, so there is a need for special attention to the desired performance (Andriawan & Irsyada, 2022; Pertiwi, 2021; Purnomo, Mukhti, & Rahayu, 2020; Rachmawati, Rahmawati, Penggalih, & Kandarina, 2014). Physical fitness has an important role as the primary capital to support the achievement of athlete performance (Pratama, Mintarto, Kusnanik, & Pratama, 2018; Winata & Mujiriah, 2021; Yanti, Gustian, Gani, & Setiawan, 2022). To obtain good performance, there must be programmed, regular and measured exercises.

Primary physical fitness is essential for improving the physical condition, muscle strength and balance of an athlete (Granacher et al., 2016; Hrysomallis, 2011; Pavlovic, Mihjlovic, Radulovic, & Gutic, 2021; van Biesen & Pineda, 2019). Therefore, physical fitness needs to be observed and trained so that athlete's performance continues to increase. Exercises to improve the fitness of athletes are with aerobic exercises involving almost all the muscles of the body large and small continuously and rhythmically (Bakinde, 2022; Park & Kwak, 2016; Smith, Scott, Girard, & Peiffer, 2022). However, since pencak silat is a martial art, many of the motor actions during competition are primarily glycolytic in nature, meaning that a higher level of endurance facilitates quicker ATP resynthesis during rest periods. In order to reveal the level of physical fitness, the Bleep Test running can be used at a distance of 20 meters to find out how the body organs work using $O_2$ as a source of energy (Akhmad & Suharjo, 2018; Ariestika, Widiyanto, & Nanda, 2020).

In addition to having a primary physical fitness, it is necessary to pay attention to the intake of fluid that enters the body during exercise or during the game (Jeukendrup, 2011; Logan-Sprenger, Palmer, & Spriet, 2011; Maughan, 1991), because at that time the body temperature will increase. Dehydration, even at mild levels, can significantly impact cardiovascular function by increasing blood viscosity, which elevates the workload on the heart (Watso & Farquhar, 2019). This increase in blood viscosity leads to a higher resistance within the blood vessels, forcing the heart to pump harder, which in turn causes an increase in heart rate (tachycardia) and myocardial oxygen consumption (Watanabe, et al., 2020). The fluid in the body if continuously decreased without the presence of intake will cause the function of the lungs to decrease so that respiration increases. When the function of the lungs decreases. The fitness of the athlete will also decrease, which will disrupt the performance of athletes that affect

the concentration, speed of reaction, even dehydration that can lead to death. Therefore, the fluid that enters the body is very important as a replacement for the released fluid.

Dehydration is the body loses too much water that will affect body performance (Cahyo, Prasetyo, Rismayanthi, & Delano, 2023; Surur et al., 2023). The need for efficient Adenosine triphosphate (ATP) resynthesis becomes more critical during dehydration, as the body struggles to maintain energy production and muscle function. In the context of combat sports like pencak silat, $VO_2$max plays a crucial role not only in sustaining high-intensity efforts but also in facilitating rapid recovery between rounds (Vasconcelos, et al., 2020). This is particularly important during the final third of a match, where the ability to maintain focus and reaction time is essential for success (Cooper & Lochbaum, 2022). A reduction in $VO_2$max due to dehydration can severely impair an athlete's recovery, increasing the likelihood of fatigue and suboptimal performance (Januszko & Lange, 2021). In the long term, chronic adaptations to aerobic training, such as improvements in $VO_2$max, are driven by mechanisms like mitochondrial biogenesis, which is the process by which new mitochondria are formed in the cell (Hughes, et al., 2018). This biogenesis is crucial for enhancing the oxidative capacity of muscles, allowing for sustained aerobic performance (Vargas-Mendoza, et al., 2021). Molecular biology studies have shown that consistent aerobic training leads to an increase in mitochondrial density and function, particularly through the activation of signaling pathways such as PGC-1α, which regulates the expression of genes involved in energy metabolism (Huertas, et al., 2019). If the body is easy to feel thirsty, dizziness, mouth and skin become dry, quickly feel tired to urinate rarely and the dark color of the urine smells bad is an early sign of the athlete has dehydration. A loss of 1-2% of fluid will result in a decrease in $VO_2$max by 10-20% so that if the loss of 4% of fluids will be further reduced to 50%. Therefore, the athlete who will exercise or compete is required to pay attention to the hydration status of his body in order to remain in a balanced condition.

Observations of the Pencak Silat Special Sports Class athletes at SMPN 1 Surakarta have revealed several issues: (1) Decreased performance in the second half, athletes kicking not in line with the goal; (2) Lack of focus on the game so as to perform less effective techniques; and (3). Athletes quickly feel tired during the game. In addition to some of the above problems, when waiting for the scheduled matches, the athletes seemed to rarely consume either fluids from water or liquids from fresh fruit and after followed the reason athletes did not consume fluids was for fear of a full stomach and fear of frequent urination.

Based on the above problem, this study aims to investigate the correlation between hydration status and $VO_2$max capacity in athletes of the SMPN 1 Surakarta on special sports class. Understanding the role of hydration in maintaining energy production and delaying fatigue, particularly through efficient ATP resynthesis, is crucial for improving athlete performance in glycolytic sports like pencak silat. Furthermore, this research seeks to deepen the understanding of how chronic adaptations to aerobic exercise, mediated by mitochondrial biogenesis, contribute to improved $VO_2$max. This research is expected to give an understanding to athletes and trainers to before starting training or competition pay more attention to the intake of fluids so that the body remains at a balanced hydration level. This is due to if at the time of training or competition the athlete is at a balanced hydration level, athletes will have a good endurance performance and reaction or response speed. Therefore, the athletes have a better performance.

## Material & methods

### *Study design*

This study employed a quantitative study using correlational methods with cross-sectional study design (Curtis, Comiskey, & Dempsey, 2016; Lau, 2017; Pramono et al., 2024). The samples used in this study were all Pencak Silat athletes from the Special Sports Class of SMPN 1 Surakarta totaling 14 athletes consisting of 11 male athletes and 3 female athletes, 13-15 years old, and have a minimum $VO_2$max in the good category. The sampling technique uses total sampling. Participating athletes are informed of the study protocol, their rights, and associated participation risks before providing written informed consent. Ethical approval based on the principles of the Helsinki Declaration was obtained from the Ethics Committee of the POLTEKKES Kemenkes SEMARANG No. LB.02.01/6/KE.099/2022.

### *Data collection*

Self-Urine Check (SUC) Test data collection was used to test hydration status pretest and posttest. Meanwhile, the Bleep Test was used to measure the athlete's posttest $VO_2$max capacity. The research procedure was carried out by starting with the SUC Test (Hydration Test I), carrying out the Bleep Test, and again doing the SUC Test (Hydration Test II). All test procedures are carried out at one time. Test carried out in the outdoor area of the New Building, Manahan Stadium, Jl Adi Sucipto No.1 Manahan Surakarta (57139), Indonesia between 06.00-08.00 A.M. During data collection, all subjects were not given food or drink in any form. Food and drink were provided immediately after data collection was completed.

### *Statistic analysis*

In the initial stage, the data were analyzed using normality tests, and paired sample t-tests. After that, the results of the relationship between the independent variable (hydration status) and the dependent variable ($VO_2$max) are sought using pearson product moment correlation coefficient with a significance level of 5%.

## Results

The results of participant characteristics, hydration status and $VO_2$max are shown in Table 1. Hydration status I was the athlete's hydration state before the Bleep Test, while Hydration status II was the athlete's hydration state after the Bleep Test (Figure 1). Meanwhile, the relationship between hydration status and $VO_2$max can be seen in Figure 2.

Table 1.
Characteristics of participants, hydration status and $VO_2$max

| Parameters | n | Mean | Std. Deviation |
|---|---|---|---|
| Age (yrs) | 14 | 14.07 | 0.83 |
| Systolic blood pressure (mmHg) | 14 | 115.00 | 7.59 |
| Diastolic blood pressure (mmHg) | 14 | 80.00 | 6.79 |
| Resting heart rate (bpm) | 14 | 64.29 | 5.08 |
| Body temperature (°C) | 14 | 36.04 | 0.49 |
| Oxygen saturation (%) | 14 | 98.36 | 0.75 |
| $VO_2$max I (mL/kg/min) | 14 | 45.85 | 5.71 |
| $VO_2$max II (mL/kg/min) | 14 | 46.79 | 1.50 |
| Hydration status I (score) | 14 | 2.93 | 0.67 |
| Hydration status II (score) | 14 | 3.71 | 0.92 |

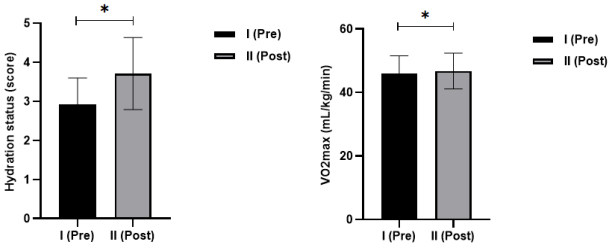


Figure 1. The results of hydration status and $VO_2$max. Description: (*) significant at pretest ($p \leq 0.001$). p-value was obtained by paired sample t-test.

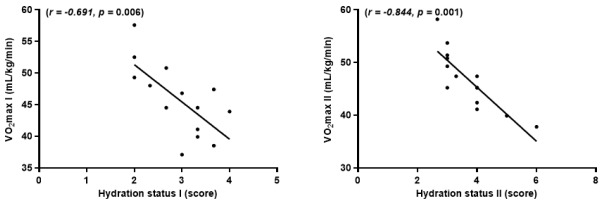


Figure 2. The relationship between hydration status and $VO_2$max. Description: Pearson correlation coefficients (r) and p-values are displayed in each graph.

## Discussions

Fluid is an essential component in the body, especially in the sports branches of pencak silat. While adequate hydration is undeniably important for athletic performance, especially in preventing dehydration and its adverse effects, the enhancement of $VO_2$max is primarily attributed to chronic adaptations arising from systematic and progressive endurance training. These adaptations include improved resting heart rate, increased stroke volume, and enhanced cardiac output, which collectively contribute to better oxygen uptake and utilization during physical exertion. If an athlete loses 1-2% of fluid, it will result in a 10-20% decrease in VO2max and if it loses 4% of fluids it will fall to 50% (Genton, Melzer, & Pichard, 2010; Ronald J Maughan & Shirreffs, 2012). During exercise or competition, nutritional intake in the form of food and electrolytes does not provide any significant benefit; the only beneficial intake is water (Kerksick et al., 2017; McCubbin et al., 2020). The balance of the body's metabolism is crucial during exercise, and adequate water intake ensures that the body's metabolism remains stable (Calvo Rico, Fernandes Monteiro, Aznar Laín, & García García, 2017; Murray, 2007). In order to prevent the dehydration, it is recommended that athletes drink 150-250 ml of water every 10-20 minutes while exercising (Bausad, 2023; Zart & Fröhlich, 2019). However, this study's reliance on urine color to assess hydration status, while practical given limited resources, does not fully capture the complexity of hydration's impact on $VO_2$max.

In this study, hydration status refers to the amount of fluid in the body (Jéquier & Constant, 2010). Water is lost from the body through urine, stools, sweat, and breath. To assess hydration status, measurements of body weight, urine type, urine volume, and urine color can be used (Kostelnik, Davy, Hedrick, Thomas, & Davy, 2021; Kulczycka, Staśkiewicz, Stelmach, & Kardas, 2022; Webb, Salandy, & Beckford, 2016). This study used urine color as an indicator due to limited resources. Although this method is widely accepted, it should be noted that it does not capture the full complexity of hydration status and its effects on performance, particularly $VO_2$max (Sekiguchi, Martin, Yoshihara, & Casa, 2023). The kidneys in the body regulate the mechanism that produces urine of varying colour which falls into the categories of both moderate, mild, severe dehydration and severe dehydration.

Result of the description of the frequency distribution of hydration status I indicates that there were 8 athletes with a presentation of 57% entering the medium category and 6 athletes with the presentation of 43% entered the category of mild dehydration. On the description of the frequency distribution of the hydration status II, there were 7 athletes with a presentation of 50% entering the medium category and 7 sportsmen with a presentation of 50% entered the light dehydration category. The results from this study showed that the athletes generally maintained a stable hydration level throughout the testing period. However, this stability in hydration does not necessarily correspond with improved $VO_2$max, as other physiological factors such as systematic endurance training likely play a more substantial role in enhancing $VO_2$max. The lack of significant change in hydration status might indicate that other factors, such as chronic training adaptations, played a more substantial role in determining $VO_2$max outcomes. Therefore, it is important to consider that while hydration is critical for overall performance, its immediate impact on $VO_2$max in this context may be limited. The results of the paired test of the t-test sample showed that there was no increase in the hydration level between the Hydration I status and the Hydration II status with the result showing the sig (2-tailed) value of $1.000 \geq 0.05$. Then, there is no significant difference between the hydration status I and hydrating status II after performing $VO_2$max, meaning that the hydrate status of the athlete is already at a balanced hydratory level. It is crucial to interpret these findings with

caution, considering the potential methodological limitations and the influence of chronic physiological adaptations to training.

Results from the average frequency distribution of the overall hydration status in this study included 6 athletes with a 43% presentation in the medium category and 8 athletes with a 57% presentation in the mild dehydration category that showed a yellow to yellow-yellow urine color. However, this stability might not necessarily translate into improved $VO_2$max, as $VO_2$max is influenced by various physiological factors, including but not limited to hydration. Dehydration, even when mild, can negatively affect oxygen diffusion, transportation, and absorption in tissues. Reduced plasma volume due to dehydration increases blood viscosity, which heightens vascular resistance and cardiac workload, potentially leading to decreased oxygen delivery to working muscles and impaired aerobic metabolism. This can exacerbate fatigue and reduce performance during high-intensity activities (Watso & Farquhar, 2019; Watanabe et al., 2020). Furthermore, $VO_2$max is largely determined by chronic adaptations in the metabolic, cardiovascular, and ventilatory systems, which are influenced by long-term aerobic training and mitochondrial biogenesis. Mitochondrial biogenesis is a key process in improving the oxidative capacity of muscles, leading to enhanced aerobic performance (Hood, 2009; Little et al., 2010; Torma, et al., 2019). Studies have shown that consistent aerobic training activates signaling pathways such as PGC-1α, which plays a crucial role in the regulation of genes responsible for mitochondrial function and energy metabolism (Kong, 2022). These factors were not specifically controlled for in this study, which may limit the ability to generalize the findings to broader athletic contexts. The results of this research are consistent with the results of previous studies (Sekiguchi et al., 2023; Sulastio, Afniza, & Vai, 2022).

$VO_2$max refers to the maximum volume of $O_2$ that can be utilized during intense exercise and is a key indicator of overall cardiorespiratory fitness (Ardian et al., 2024; Ellyas et al., 2021; Kong, 2021; Smoląg, Krzyszkowski, Puszczałowska-Lizis, & Derek, 2024). To find out the level of physical fitness, one can use the Bleep Test running at a distance of 20 meters to find out how the body organs work using $O_2$ as a source of energy (Ahsan & Ali, 2021; Gabryś et al., 2019). $O_2$ is needed to help the body's metabolic processes. This metabolism will produce the energy the body needs to activate. The result of the $VO_2$max frequency distribution was 6 athletes in both categories with a presentation of 43%, 6 in the category of excellent with a presentation of 43% and 2 athletes in the very good category of 14%. The lowest bleep test score was at level 7 reversal 4 with $VO_2$max 37.8 and the highest level is level 13 reverse 4 with $VO_2$max 58.2.

Based on the results of the analysis obtained the correlation coefficient between hydration status with $VO_2$max capacity of 0.570 ≥ r table 0.532 and its significance value of 0.033 which is less than 0.05. This indicates a statistically significant positive relationship between the two variables, it is important to recognize that $VO_2$max results from a complex interplay of factors, including long-term aerobic training and physiological adaptations that were not fully addressed in this study. The better the hydration status, the higher the $VO_2$max capacity. Therefore, the correlation observed should be interpreted as suggestive rather than definitive. Nevertheless, it is likely that improvements in $VO_2$max are more strongly related to chronic physiological adaptations from systematic endurance training rather than acute hydration status alone. Thus, if an athlete maintains a balanced hydration level, their $VO_2$max capacity is likely to improve. The correlation found does not necessarily imply causation, and other factors such as the athlete's training history, nutritional status, and overall fitness level could also contribute to $VO_2$max performance. Future studies should aim to control for these additional variables and consider repeated $VO_2$max assessments to better understand the relationship between hydration and athletic performance. These findings are consistent with previous studies that also found a positive correlation between these two variables (Kuswari, Nuzrina, Gifari, Dhyani Swamilaksita, & Tri Hapsari, 2018; Oktavrianto & Noordia, 2020; Sermaxhaj, Arifi, & Bahtiri, 2017; Southard & Pugh, 2004; Travers, Nichols, Riding, González-Alonso, & Périard, 2020).

By being in a balanced hydration state, the water in the body will be sufficient so that the water will perform its functions properly. The metabolism becomes smooth and the oxygen intake from the lungs to the whole body is unhindered. However, it is essential to recognize that the primary drivers of $VO_2$max improvement are likely systematic training-induced adaptations, with hydration playing a supporting role in overall athletic performance. Chronic physiological adaptations to training, such as those that improve $VO_2$max, are likely the primary drivers of performance improvement, with hydration playing a supporting but not determinative role. Thus, there is a positive correlation between hydration status and $VO_2$max capacity in athletes of the Special Sports Class of SMPN 1 Surakarta in 2023, this relationship should be interpreted within the broader context of multiple factors influencing athletic performance, particularly those related to chronic training adaptations. The influence of hydration, while important, is one part of a more complex physiological picture that includes long-term cardiovascular, metabolic, and ventilatory adaptations derived from consistent and progressive aerobic training.

In conclusion, while maintaining a balanced hydration state is important for overall athletic performance, the improvement of $VO_2$max is primarily driven by chronic physiological adaptations from systematic endurance training. Hydration plays a supportive role, ensuring that the body's metabolic processes remain efficient, but it is not the primary determinant of $VO_2$max improvements. These

findings align with previous research, reinforcing the idea that hydration is one piece of a complex puzzle in optimizing athletic performance.

## Conclusions

Based on the results of research and discussion, it can be concluded that there was a negative correlation between hydration status and $VO_2$max capacity in the athletes of the Special Sports Class in SMPN 1 Surakarta Year 2023. However, this correlation should be interpreted with caution, as $VO_2$max is influenced by multiple factors, including chronic training adaptations, which may have a more significant impact on performance than hydration alone. The results of this study can be used as a reference for athletes to always maintain the need for body fluids needed during activities and for coaches to condition all athletes in a condition to avoid dehydration. Further research is needed to explore the relative impact of hydration compared to other factors, such as training intensity and recovery practices, on $VO_2$max capacity.

## Conflicts of interest

The authors declare no conflict of interest.

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