Journal of Health and Nutrition Research
Vol. 4, No. 3, 2025, pg. 1395-1402, https://doi.org/10.56303/jhnresearch.v4i3.1078
Journal homepage: https://journalmpci.com/index.php/jhnr/index

e-ISSN: **2829-9760**

Water Intake, Hydration Status, and Physiological Fluid Requirements among Universitas Tanjungpura Students during Equatorial Solar Culmination in Pontianak, Indonesia

Dzul Fadly[1]*

[1] Department of Food Science and Technology, Faculty of Agriculture, Universitas Tanjungpura, Indonesia

Corresponding Author Email: dzul.fadly@faperta.untan.ac.id

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ORIGINAL ARTICLES

Submitted: 16 October 2025

Accepted: 25 November 2025

Keywords:
Equatorial Region Climate, Fluid Requirements, Hydration Status, Solar Culmination, Water Intake

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ABSTRACT

Water is an essential nutrient that plays a central role in maintaining physiological functions, including thermoregulation, nutrient transport, and metabolic balance. Pontianak, a city located precisely on the equatorial line, experiences a humid tropical climate with intense solar exposure. Although ambient temperatures during the study period remain within the city's normal range, the solar equinox substantially increases direct solar radiation intensity, resulting in greater heat exposure and potential fluid loss. This study aimed to investigate the relationship between water intake and physiological fluid requirements among Universitas Tanjungpura students during the autumnal solar equinox (September 21-23). A cross-sectional design was applied involving 100 students aged 18–22 years selected through purposive sampling. Water intake was assessed using two consecutive 24-hour dietary recalls, and individual fluid requirements were estimated using the standard energy-based hydration formula (1 mL per kcal of total energy expenditure), with energy needs calculated using the Harris–Benedict equation. Pearson's correlation test was used to analyze the association, with water intake treated as the independent variable. The results showed that mean water intake was 1,706 ± 485 ml/day, while mean physiological fluid requirements reached 1,954 ± 349 ml/day; 45% of participants met adequate hydration levels. A strong and significant positive correlation was observed between water intake and fluid requirements ($r = 0.62$; $p < 0.001$). Urine color assessment indicated that 40% of students exhibited signs of mild to moderate dehydration. These findings suggest that most students did not achieve optimal hydration, particularly under elevated environmental heat associated with solar culmination. .

Key Messages:

- Campus-based hydration education and improved access to safe drinking water are essential to promote better hydration practices.
- Strengthening hydration education and improving access to drinking-water facilities on campus are necessary to support better hydration practices among students

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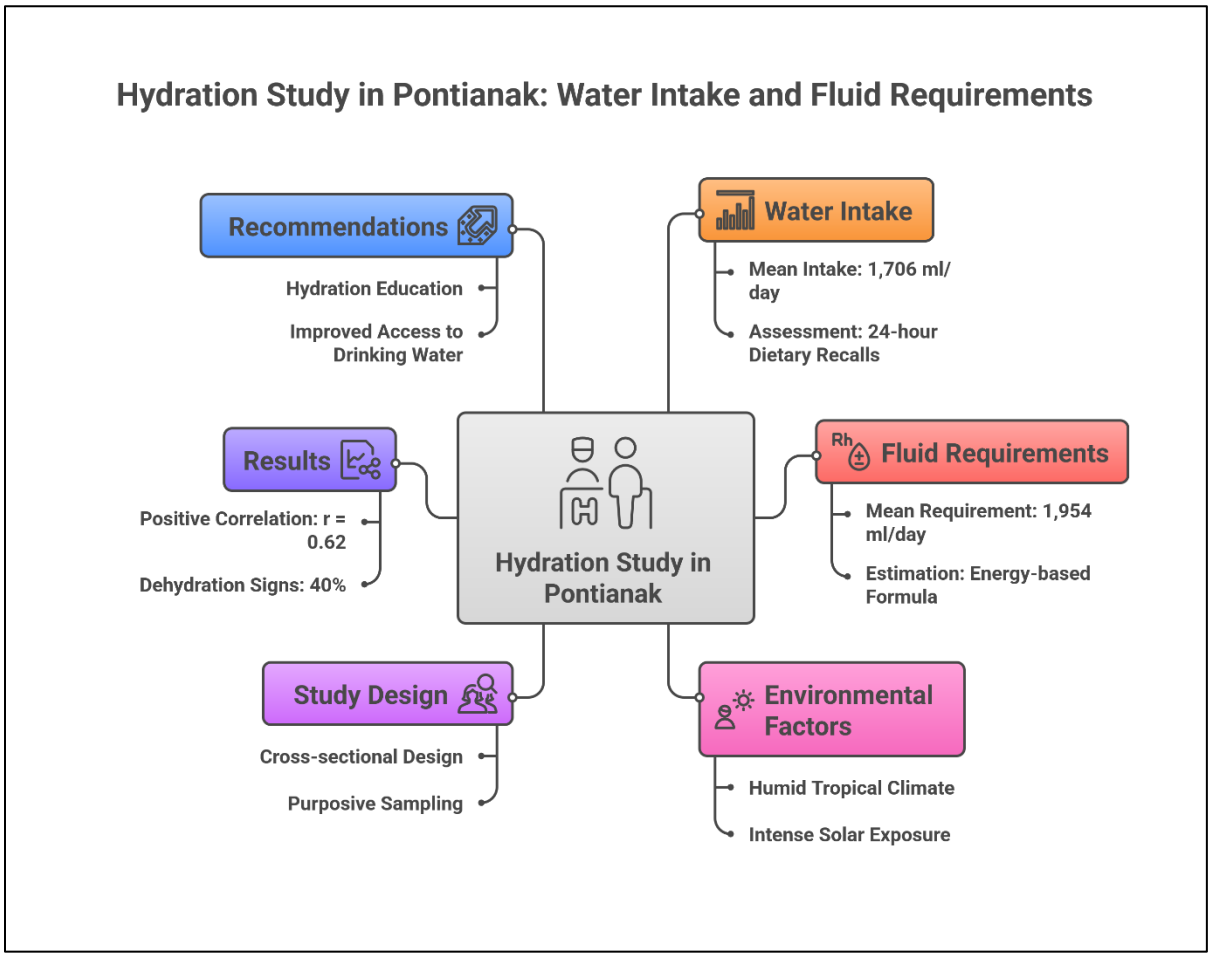
GRAPHICAL ABSTRACT



INTRODUCTION

Water is the largest component of the human body, comprising approximately 60–70% of an adult's body weight. Its functions are essential for maintaining physiological homeostasis, including thermoregulation through evaporative heat loss, the transport of nutrients and oxygen to tissues, joint lubrication, and the excretion of metabolic waste via urine and sweat (1,2). Water also serves as the medium for intracellular biochemical reactions and is crucial for maintaining blood volume. Hydration status is determined by the balance between water intake and water losses (3,4). When water consumption does not match physiological requirements, organ function may be impaired, physical and cognitive performance may decline, and longer-term metabolic disturbances may occur (5,6). Ensuring adequate daily fluid intake is therefore an important component of balanced nutrition.

Despite this fundamental role, research indicates that awareness of adequate water consumption remains low, particularly among young adults such as university students (7,8). Many students do not meet their daily fluid needs due to factors such as sedentary lifestyles, heavy academic workloads, limited time, and irregular drinking habits (9). The preference for caffeinated or sugar-sweetened beverages over plain water may further increase dehydration risk. Limited knowledge regarding hydration and the absence of routine drinking habits exacerbate this problem. Persistent mild fluid deficits can impair concentration, hinder learning capacity, and negatively affect overall health (10,11).

Pontianak, located precisely on the equatorial line, experiences a humid tropical climate characterized by persistently high temperatures and elevated moisture levels. Annual temperature variation is minimal, with monthly average highs ranging from 30.6°C (87.1°F) to 32.5°C (90.5°F) and lows consistently between 23.3°C (73.9°F) and 24.3°C (75.7°F). Relative humidity remains consistently high, oscillating between 79% and 85%, creating warm and moisture-dense environmental conditions

https://doi.org/10.56303/jhnresearch.v4i3.1078

throughout the year (12). This geographic position also exposes the city to intense solar radiation, particularly during solar culmination, which occurs twice annually around the March and September equinoxes. Although daily air temperatures during the equinox do not rise far above the city's usual range, the intensity of direct sunlight increases sharply, producing a higher heat load and greater evaporative loss. At local noon, shadows disappear, a phenomenon known as Hari Tanpa Bayangan or the "Day Without a Shadow" (13). This additional heat exposure can raise fluid losses through sweating even during routine daily activities.

University students form an important group for studying hydration in this environment. Their daily routines often require walking between lecture halls, faculty buildings, and outdoor campus areas during midday hours, when solar exposure is highest. These movements, combined with tight academic schedules, can lead to long periods without drinking and increase the risk of insufficient fluid intake. Students aged 19–21 years typically engage in low-to-moderate physical activity, yet many do not recognize early signs of mild dehydration such as tiredness, headaches, or reduced concentration. Even a small fluid deficit—equivalent to a 1–2% loss of body weight—can affect cognitive performance, making this group particularly vulnerable in a hot and humid setting like Pontianak.

Most studies on water consumption in Indonesia have focused on the general population and have not considered local climatic conditions or extreme environmental heat. Research linking water intake among university students with periods of intense solar radiation, such as the equinox in Pontianak, remains limited. Earlier studies often relied on body weight or activity level to estimate fluid needs and did not take into account the additional requirements caused by equatorial heat. This gap highlights the importance of understanding how environmental conditions influence hydration needs among students living in humid tropical regions.

This study examines the relationship between daily water intake and physiological fluid requirements among students during the solar culmination period in Pontianak. The findings are expected to contribute to campus-based nutrition education efforts and support the development of health policies that take local climatic conditions into account. This study aims to assess the relationship between water intake and physiological fluid requirements among Universitas Tanjungpura students during the solar culmination period.

METHODS

This quantitative study employed a cross-sectional design to examine the relationship between water intake, physiological fluid requirements, and hydration status among undergraduate students at Universitas Tanjungpura. Data collection was conducted during the autumnal solar equinox (22–23 September), when Pontianak experiences the solar culmination phenomenon and ambient temperatures typically reach their peak. The survey was administered on 23 September 2022, during which environmental temperature ranged between 32–34°C. Even though the air temperature during the equinox stays within Pontianak's usual daily range, the intensity of overhead sunlight increases substantially, leading to a higher heat load and faster evaporative fluid losses. Conducting the study within this period was intended to capture fluid losses that may increase under the city's hot equatorial conditions.

A total of 100 active students were recruited using purposive sampling. Inclusion criteria were: age 18–22 years, self-reported good health, and light physical activity as defined by the WHO Physical Activity Level (PAL) classification. Students who were ill, on a medically prescribed diet, or unwilling to complete all study procedures were excluded. Sociodemographic and anthropometric characteristics—including age, sex, body weight, and physical activity—were obtained through a structured questionnaire and direct measurements. Body weight was measured to the nearest 0.1 kg using a calibrated digital scale. Ambient temperature and environmental conditions were monitored throughout data collection to confirm solar culmination conditions.

Water intake was assessed using two non-consecutive 24-hour dietary recalls, capturing all beverages consumed, including plain water, tea, coffee, and sugar-sweetened drinks. Individual fluid requirements were calculated by first estimating each participant's Basal Metabolic Rate (BMR) using the Harris–Benedict equation. Adequacy of water intake was categorized as "adequate" when intake met ≥90%

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of the calculated requirement and "inadequate" when intake was <90%. The calculation of water intake was done according to the following formula:

$$Daily\ fluid\ requirement\ (Ah)\ =\ 1\ mL\ \times\ Daily\ energy\ requirement$$
$$Daily\ energy\ requirement\ =\ Basal\ metabolic\ rate\ \times\ Activity\ factor\ (1.3)$$
$$Basal\ Metabolic\ Rate\ (man) = 66 + (13.7 \times body\ weight) + (5 \times body\ height) - (6.8 \times age)$$
$$Basal\ Metabolic\ Rate\ (woman) = 655 + (9.6 \times body\ weight) + (1.8 \times body\ height) - (4.7 \times age)$$

Hydration status was assessed using urine color scoring based on an eight-point standardized scale. Urine samples were collected as spot urine between 10:00 and 11:00 a.m., prior to lunch, to reflect hydration status during active daytime hours rather than overnight fluid restriction. Urine colors 1–2 indicated good hydration, 3–4 reflected suboptimal hydration, and 5–8 indicated varying degrees of dehydration. Hydration categories were analyzed descriptively and further examined in relation to water intake levels.

Descriptive statistics were used to summarize participant characteristics, water intake, fluid requirements, and hydration status. The correlation between water intake and fluid requirements was analyzed using Pearson or Spearman correlation tests, depending on data distribution. Associations between water intake categories and hydration status were examined using chi-square tests. All analyses were performed at a 95% confidence level ($p < 0.05$).

RESULTS

The mean age of the participants was 20.0 ± 0.7 years, indicating that most respondents were young adult university students with relatively homogeneous academic activity patterns. Male students had higher body weight compared to females (67.5 kg vs. 54.3 kg), which correspondingly affected their daily water requirements. According to principles of fluid requirement calculation based on body weight and metabolic energy expenditure, males required more water (2,363 ± 207 ml/day) than females (1,630 ± 152 ml/day). However, the actual daily water intake in both groups did not meet the recommended requirements. The mean water intake among students was 1,706 ± 485 ml/day, representing approximately 87% of the estimated requirement, with only 45% of students achieving ≥90% of their daily water needs. These findings indicate that more than half of the students did not reach optimal hydration levels, which may increase the risk of mild dehydration, particularly under the hot and humid climate conditions characteristic of Pontianak during periods of solar culmination.

Table 1. Participant Characteristics, Water Requirements, and Intake

Variable	Male (n=45)	Female (n=55)	Total (n=100)
Age (years)	20.1 ± 0.8	19.9 ± 0.7	20.0 ± 0.7
Body weight (kg)	67.5 ± 5.9	54.3 ± 5.1	60.3 ± 8.4
Physical activity	Light	Light	Light
Water requirement (ml/day)	2,363 ± 207	1,630 ± 152	1,954 ± 349
Water intake (ml/day)	1,874 ± 493	1,568 ± 461	1,706 ± 485
Adequate water intake (%)	44.4	45.5	45.0

The analysis showed a significant positive association between water intake and total fluid requirements ($r = 0.62$; $p < 0.001$). This finding indicates that individuals with higher fluid needs—determined by body weight and activity level—tend to consume more water. A correlation coefficient of 0.62 falls within the category of a strong relationship, suggesting that students' drinking behavior generally aligns with their physiological fluid needs, although their intake has not yet reached an optimal level.

Table 2. Correlation between daily water intake and fluid requirements

Variable	r	p-value	Descriptions
Water intake (ml/day) vs. Fluid requirement (ml/day)	0.62	<0.001	Significant association

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The distribution of hydration status based on urine color indicates that most students were in the well-hydrated to adequately hydrated category (60%), while approximately 40% showed signs of mild to moderate fluid deficit. A total of 15% of respondents had very pale urine, indicating optimal hydration. Meanwhile, 18% displayed dark yellow urine, and another 15% showed signs of mild dehydration. These findings suggest that a considerable proportion of students fall within a suboptimal hydration range, which is consistent with their water intake not yet meeting daily requirements.

Table 3. Urine color score and hydration status

Urine Color Score	Color Description	Hydration Status	Physiological Interpretation	Category (%)
1	Clear / very pale	Very good	Adequate fluid intake; normal urinary excretion; low osmolality	15
2	Light yellow	Good	Optimal fluid balance; fluid loss balanced with intake	25
3	Moderate yellow	Fair	Within normal limits but beginning to show increased urine concentration	20
4	Dark yellow	Mildly low	Early sign of fluid deficit; increased water intake recommended	18
5	Deep yellow / golden	Mild	Fluid deficit of approximately 1–2% of body weight	15
6	Light brown	Moderate	Significant fluid loss; increased urine osmolality	7
7–8	Dark brown / cloudy	Severe	Indicates >3% body-weight fluid deficit; requires immediate intervention	0
Total	–	–	–	**100**

The table presents the distribution of students' hydration status across different levels of water intake. Among the 38 respondents with high water intake (>2000 ml/day), most were classified as well-hydrated (24 students; 63%), followed by those with inadequate hydration (12 students; 32%), while only 2 students (5%) fell into the dehydration category. In the moderate intake group (1500–2000 ml/day), the proportion of well-hydrated students decreased to 17 (41%), while inadequate hydration increased to 18 students (44%) and dehydration to 6 students (15%) out of 41 respondents. The most concerning pattern was observed in the low-intake group (<1500 mL/day), where only 3 students (10%) were well-hydrated. In contrast, most students in this category experienced dehydration (19 students; 73%), and another 5 students (17%) showed inadequate hydration.

Table 4. Relationship Between Water Intake and Hydration Status

Water Intake	Well Hydrated	Inadequately Hydrated	Dehydrated	Total	P-value
High (>2000 ml)	24 (63%)	12 (32%)	2 (5%)	38	<
Moderate (1500–2000 ml)	17 (41%)	18 (44%)	6 (15%)	41	0.001
Low (<1500 ml)	3 (10%)	5 (17%)	19 (73%)	27	
Total	44	35	27	100	

Overall, the data reveal a consistent pattern: lower water intake is associated with poorer hydration status among students. The statistical test produced a p-value < 0.001, indicating a significant association between water intake level and hydration status. These findings demonstrate that the hydration status of Universitas Tanjungpura students is strongly influenced by the adequacy of their daily water consumption.

https://doi.org/10.56303/jhnresearch.v4i3.1078

DISCUSSION

The findings indicate that the average daily water intake of Universitas Tanjungpura students remains below the recommended fluid requirement. The mean intake of 1,706 ± 485 ml/day meets only about 87% of the average requirement of 1,954 ± 349 ml/day. This pattern aligns with the results reported by (1) in USA and (14) in China, young-adult (university-aged) individuals frequently fail to meet recommended fluid intakes due to low hydration awareness and the tendency to replace plain water with caffeinated or sugar-sweetened beverages. Given that the study participants were 18–22 years old—late adolescence to early adulthood—and shared relatively similar academic activity patterns, the sample is sufficiently representative of the hydration status of young adults living and studying in Pontianak during the study period.

Environmental conditions in Pontianak further exacerbate this issue. High temperatures and humidity increase insensible and sweat fluid losses, often without individuals realizing it. For every 1°C increase in temperature, total fluid intake (TFI) is projected to rise by an average of 24 mL, while plain water intake (PWI) specifically increases by approximately 12 mL (15). As noted by (6), Environmental factors like humidity and temperature influence urine output, with colder climates typically increasing it and hotter climates, alongside prolonged activity, decreasing it as the body loses more water through sweat. National Environmental Satellite, Data, and Information Service (16) stated that during the autumnal solar equinox, when the Sun stands more directly over equatorial regions and seasonal solar radiation peaks, the risk of heat strain and sweat evaporation increases, thereby elevating fluid requirements even in the absence of changes in physical activity. These climatic characteristics during the study period reinforce the relevance of the sample as a representation of hydration conditions among young adults living in humid tropical environments.

The difference in water requirements between male and female students in this study can be attributed to variations in body composition and body weight. Male students generally have greater muscle mass and higher body weight, which increases their fluid needs to maintain plasma volume and electrolyte balance. This finding is consistent with the results of Gazzan et al. (2016) in France, who reported that men require a higher daily water intake (approximately 2.5 L/day) compared with women (2.0 L/day). Despite these differences in requirements, the similar proportion of males and females who met their respective needs suggests that drinking behavior among students is shaped more by habit, routine access to water, and campus activities than by physiological demand alone.

The strong positive correlation between water intake and physiological fluid requirements ($r = 0.62$; $p < 0{,}001$) demonstrates that individuals with greater fluid needs tend to consume more water. Physiologically, adequate water intake is essential to maintain total body fluid volume, urine concentration, and electrolyte homeostasis; insufficient intake leads to fluid deficits, which manifest as concentrated urine. These results support the concept of fluid homeostasis, in which water intake is regulated through thirst mechanisms mediated by hypothalamic osmoreceptors (17,18). However, research by (6) and (19) indicates that among younger populations, the sensation of thirst does not always accurately reflect actual fluid requirements. In this study, the tendency for students to drink only after experiencing discomfort such as fatigue or reduced concentration reflects a behavioral rather than physiological response, reinforcing that hydration among young adults in hot climates is strongly influenced by habits formed during daily academic routines.

The assessment of hydration status based on urine color further supports these findings. A total of 40% of students exhibited signs of mild to moderate fluid deficit, indicated by dark yellow to light brown urine. This result is consistent with (14) in China and (1) in the United States, les than half young-adult population observed were classified as having suboptimal hydration. The presence of concentrated urine during the equinox period indicates that students may not adjust their drinking behavior adequately in response to increased heat exposure. Even though heat acclimatization is common in tropical populations, it does not eliminate the need for sufficient water intake.

Heat-acclimatized individuals living in tropical regions—such as students in Pontianak—tend to sweat earlier and more efficiently, with lower electrolyte concentration in sweat compared with individuals from temperate climates. This adaptation reduces sodium loss but does not substantially decrease total

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water loss. Therefore, despite physiological acclimatization, the elevated sweat rate during solar culmination still increases overall fluid requirements. This may explain why a considerable proportion of students showed concentrated urine despite living in a climate they are accustomed to.

Pontianak's geographical context adds an important dimension to these results. Situated on the equator and experiencing solar culmination twice a year, the city reaches temperatures up to 34°C with humidity levels of 80–90% (12). (20) reported that fluid needs may rise by 10–20% in such environments. Although the students' average water intake approaches WHO recommendations (1.5–2.0 L/day), the combination of high humidity and peak solar radiation means that these volumes are still insufficient to maintain euhydration during equinox conditions.

The strong association between daily intake and hydration status, supported by a chi-square p-value < 0.001, underscores that hydration is largely determined by drinking behavior rather than environmental exposure alone. Students who consumed more water were consistently better hydrated, while those with lower intake showed higher rates of dehydration. Given that academic schedules often limit opportunities to drink, behavioral and environmental modifications on campus may be necessary to support adequate hydration.

Overall, the study shows that even in populations acclimatized to heat, such as university students in Pontianak, inadequate drinking habits can lead to mild dehydration—especially during periods of extreme solar exposure. Because the sample reflects the dominant age group in local universities, the findings can reasonably describe hydration conditions among late adolescents and young adults in this region.

Limitations of the Study

This study has several limitations. First, hydration status was assessed using urine color, which, although practical for field settings, is less precise than biomarkers such as urine osmolality or specific gravity. Second, water intake was measured using 24-hour recalls, which depend on participant memory and may under- or overestimate true intake. Third, the cross-sectional design limits the ability to determine causal relationships. Finally, the study was conducted during a specific climatic event (the equinox), so the findings may not reflect hydration patterns during other periods of the year.

CONCLUSION

This study shows that most students at Universitas Tanjungpura, Pontianak, did not meet their daily fluid requirements, with a mean water intake of 1,706 ± 485 ml/day, equivalent to approximately 87% of the estimated fluid needs (1,954 ± 349 ml/day). Although water intake demonstrated a strong positive correlation with total fluid requirements ($r = 0.62$; $p < 0.001$), more than half of the participants were classified as having inadequate hydration to mild dehydration. These findings indicate that students' awareness of adequate hydration remains low, particularly given the high environmental temperatures during the solar culmination period in Pontianak. Suboptimal hydration status may impair cognitive performance and physiological well-being, underscoring the need for targeted hydration education and improved access to drinking water facilities on campus to promote healthier drinking behaviors and support fluid balance among students living in humid tropical environments.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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