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Evaluating the Relationship Between Drinking Behaviour and Hydration in Competitive Cyclists

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ABSTRACT

Optimal hydration is crucial for high-performance athletes' performance, recovery, and thermoregulation. Despite the recognized importance of fluid balance, limited data exist on hydration behaviours specifically on the objective assessments among elite cyclists in Malaysia. This study investigates the hydration status and fluid intake behaviours among the Selangor State Cycling Team cyclists. Nineteen high-performance cyclists completed a structured questionnaire assessing total water intake (TWI), total fluid loss (TFL), water balance (WB), and the Fluid Behaviour Index (FBI). Descriptive statistics demonstrate a mean TWI of 3,847.45 ± 324.79 ml, a mean TFL of 3,514.43 ± 284.86 ml, and a positive WB of 333.02 ± 254.50 ml. Correlation analyses revealed a weak, non-significant positive relationship between FBI and TWI ($r = .146$, $p = .550$), as well as a weak, non-significant negative relationship between FBI and TFL ($r = –.166$, $p = .496$). These findings indicate that self-reported hydration behaviour is not a significant predictor of hydration status in this study. The absence of significant associations underscores the multifactorial nature of hydration regulation and suggests that behavioural indices alone may not adequately reflect individual hydration needs. Future research should incorporate objective physiological markers, as well as psychological and environmental variables, to achieve a comprehensive understanding of hydration determinants in competitive cycling.

Keywords: *fluid intake behaviour, fluid loss, fluid intake, elite athletes, hydration status, sport hydration, water balance*

INTRODUCTION

Hydration and water balance are essential to human health. Adequate hydration is required throughout life, from infancy to old age, and fluid balance is particularly vital in situations involving activity, sports, and certain illnesses. Fluid intake is a basic requirement for human existence. Without eating, a person may go more than 50 days without getting sick, but only a few days without drinking. The main component of the body is water, which accounts for around 60% of a 70 kg man's weight (42

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litres) and somewhat less in women due to their higher proportion of body fat. A baby's body has roughly 75% water, while an elderly person contains only 55% water (Arnaud, 1998).

Consider the impact of inadequate hydration techniques on a team of high-performance athletes aiming for excellence. Staying hydrated is essential for overall health, but it is especially critical for high-performance athletes who must balance exhausting training programmes, competitions, and rest periods. The decisions they make about water consumption may have a substantial impact on their overall health and athletic performance. Despite inconsistent results across several experimental techniques, research suggests that dehydration has a minor but considerable impact on cognitive performance. Dehydration may impact higher-order cognitive processing (e.g. attention and executive function) and motor coordination more than lower-order mental processing (Wittbrodt & Millard-Stafford, 2018).

According to Ambarsari and Yetti (2021), hydration status is a significant component in maintaining the functions of the bodywork system. Despite the widely acknowledged importance of hydration for athletic performance, there is little awareness of hydration behaviours among Selangor state cyclist athletes. This knowledge gap raises questions regarding whether current water intake strategies are adequate for maintaining appropriate hydration and improving athletic performance throughout training and competition. Personalised hydration plans are crucial for maximising athletes' safety and performance during competition. Hence, this study investigated the relationship between water intake behaviour and hydration status among Selangor State Cyclist athletes.

LITERATURE REVIEW

Importance of hydration in health and athletic performance

Hydration is fundamental in maintaining physiological function, supporting thermoregulation, and optimizing physical and cognitive performance, particularly among athletes. It plays as the main role in sustaining cellular function, cardiovascular efficiency, thermoregulation and neuromuscular coordination (Casa et al., 2000). Thermoregulation is the body’s ability to regulate internal temperature, especially dependent on adequate fluid availability. During prolonged physical exertion, particularly in warm or humid conditions, fluid is lost primarily through sweating and respiratory evaporation. If these loses are not sufficiently replenished, the resultant hypohydration may lead to hyperthermia, increased cardiovascular strain and impaired metabolic responses (Sawka et al., 2007).

In endurance sports such as cycling, fluid losses through sweat can be substantial. Fluid loss can exceed 1 – 2% of body weight, a threshold beyond which decrements in performance become physiologically significant (Cheuvront & Kenefick, 2014). Dehydration at this level is associated with reduced plasma volume, elevated heart rate, decreased stroke volume and impaired thermoregulatory responses. These physiological disruptions can lead to early onset of fatigue, diminished power output and reduced time to exhaustion. Moreover, hydration status also influences the cognitive function, which is integral to performance in endurance sports that demand continuous decision making, spatial awareness and strategic pacing. Empirical evidence has demonstrated that dehydration can adversely affect attention, reaction time, memory and mood (Lieberman, 2007), thereby compromising both physical and cognitive dimensions of athletic performance.

Therefore, maintaining adequate hydration is essential for ensuring both physical endurance and mental sharpness. Effective hydration strategies should encompass pre-exercise fluid intake to establish a baseline state, individualized fluid replacement protocols during exercise based on sweat rates, and systematic post-exercise rehydration to facilitate recovery and physiological restoration (Thomas, Erdman, & Burke, 2016). Such comprehensive hydration management is particularly essential for endurance athletes like cyclists, whose performance and safety are directly influenced by fluid balance throughout training and competition.

General perspectives on hydration and health

Hydration is increasingly recognized as a central component of human health, with implications that span across cellular homeostasis, metabolic regulation, physical performance, cognitive functioning, and chronic disease risk (Popkin, D'Anci, & Rosenberg, 2010). Water, as the most abundant and essential nutrient, facilitates physiological processes such as nutrient transport, temperature regulation, waste removal, and cellular signalling. Even mild dehydration is defined as a 1–2% reduction in body water can adversely affect physical and cognitive performance (Maughan & Shirreffs, 2010), while chronic inadequate hydration has been linked to long-term health outcomes.

Recent studies have extended the traditional focus on hydration in sports and thermoregulation to a broader context of population health and disease prevention. For instance, suboptimal hydration has been associated with increased risks of urinary tract infections, nephrolithiasis, and impaired renal function (Strippoli et al., 2011). Emerging research also suggests a potential link between habitual low fluid intake and cardiometabolic disturbances, including elevated blood glucose, reduced insulin sensitivity, and increased risk of metabolic syndrome (Johnson et al., 2015). These findings highlight hydration as not merely a concern of acute performance, but a modifiable lifestyle factor that intersects with chronic disease prevention and healthy aging.

The ideal daily water consumption is generally between 2.5 and 3.5 Liters to support the excretion of about 2 to 3 Liters of dilute urine. Proper hydration should restore daily fluid losses and ensure sufficient urine output to prevent dilution and excessive saturation, which could lead to poor health consequences (Perrier et al., 2021). Benelam and Wyness (2010) conducted a comprehensive review emphasizing the significance of water consumption for overall health. Their investigation addressed the body's water control processes and assessed how fluid intake variabilities affect energy expenditure, body weight, and physical and cognitive performance. Similarly, Popkin et al. (2010) comprehensively studied water intake patterns, factors influencing consumption, and the physiological mechanisms regulating water homeostasis. Their review demonstrates the importance of water in preventing noncommunicable illnesses associated with nutrition and recommends further investigation on population-level fluid intake evaluation. The valuable effects of health promotion programs on adults' hydration awareness and health consequences were emphasized in a more recent systematic review by Garcia-Garcia (2022), highlighting the necessity of educational measures to enhance hydration practices.

Hydration in athletic populations

Due to their increased fluid elimination during physical exertion, athletes have high hydration demands. Hypohydration from lacking fluid replenishment before or after exercise can affect thermoregulation, reduce endurance, and increase perceived exertion. According to previous studies, sports performance can be adversely affected by even mild dehydration (Sawka et al., 2007; Casa et al., 2010). Nevertheless, research has shown that athletes in various sports have irregular hydration habits, despite the physiological need to be hydrated. This divergence could be caused by misunderstandings regarding thirst and fluid requirements, a lack of information, or restricted access to fluids (Garth & Burke, 2013). Furthermore, there may be a discrepancy between perceived and physiological necessity since self-reported hydration behaviour does not always match measured hydration status (Muñoz et al., 2015).

Dehydration and a higher core body temperature can affect both submaximal and maximal endurance performance. Reduced oxygen delivery to local tissues and organs, a greater reliance on muscle glycogen and cellular metabolism, changes in neural activity, and, in situations requiring nearmaximal capacity, impaired muscle aerobic metabolism and overall aerobic function are all linked to these decreased performance (Trangmar & González-Alonso, 2019). Holland et al. (2017) reported that endurance cycling performance (ECP) declines when fluid intake during high-intensity, 1-hour cycling falls within the range of 0.15 to 0.34 mL/kg body mass/min. Conversely, fluid consumption at 0.15–0.20 mL/kg body mass/min during moderate-intensity cycling lasting between 1 and less than 2 hours has improved performance by at least 2%. Additionally, Funnell et al. (2019) showed that under hot conditions, time trial performance is considerably impacted by hypohydration associated with a 3% decrease in body mass. Notably, the study also discovered that athletes' knowledge of their hydration level did not reduce the detrimental effects of hypohydration on performance, indicating that aerobic capacity in the heat is primarily a physiological rather than psychological issue.

Recent evidence from Sansone et al. (2022) provides additional insight into the thermal effects of dehydration by demonstrating that fluid restriction, even in the absence of exercise, elevates core temperature more significantly than exercise-induced dehydration. This supports the notion that the method of fluid loss modulates physiological strain. These results align with earlier findings by Funnell et al. (2019), which showed that hypohydration equivalent to 3% of body mass significantly reduces time trial performance in the heat, and that subjective hydration knowledge offers limited protective effect.

There is still a lack of context-specific research in Malaysia, especially among high-performance cyclists, even though hydration in general and athletic groups has received a lot of attention. Cultural hydration practices, training loads, and local environmental factors may influence water intake and fluid loss. Additionally, little research has examined the connection between this population's objectively determined hydration status and self-reported hydration behaviour. To fill this knowledge vacuum, the current study examines professional cyclists' fluid intake and hydration state in Selangor, Malaysia. The results may help guide athlete training programs and focused hydration techniques.

MATERIALS AND METHOD

Respondents and Research Design

This study used a quantitative research design to investigate the relationship between high-performance cyclists in Selangor's water intake behaviours and hydration status. In total, 19 Selangor Cycling Team athletes participated in the study and answered a structured questionnaire to evaluate their fluid consumption behaviours and level of hydration. The questionnaire consists of four sections. Section A gathered demographic data (age, gender, height, weight, years of experience and smoking status). Section B evaluated the athletes' level of physical activity. Section C examined their level of hydration. In this section, it has four items which include a) Medical history; b) Hydration habits and knowledge; c) Water, beverages and food frequency questionnaire (WBFFQ) and d) Water elimination (WE). This information allows for the estimation of water balance (WB). With values of 0.832 and 0.852, the Cronbach's α indicated a high and comparable consistency Finally, Section D analysed their fluid consumption habits. To calculate a fluid behaviour index, the score from the ordinal variable addressing the number of ounces reported daily (ranging from 0 to 4) was added to the "yes" responses (each yes receiving 1 point) for beverage proximity, drinking when not thirsty, and keeping an eye on urine items that were linked to higher reported fluid intake.

Ethical Approval

The UiTM Research Ethics Committee had approved this study, and all participants were provided with written informed consent. (600-UiTMPs (PJIM&A/UPK-ERC 54/2024).

Instrumentations

The International Physical Activity Questionnaire - Short Form (IPAQ-SF), the Hydration Status Questionnaire (HSQ), and the Fluid Behaviour Index (FBI) were the three reliable instruments used in this study to investigate the link between water intake behaviour and hydration status.

The IPAQ-SF is widely employed to explore sedentary behaviour and physical activity in research and public health settings. The questionnaire has proven reliable and consistent when collecting physical activity data for epidemiological research, health evaluations, and intervention planning.

Hydration-related factors were evaluated using the Hydration Status Questionnaire (HSQ), which was created by Laja-García et al. (2019). A medical history, hydration habits and knowledge, a water, beverages, and food frequency questionnaire (WBFFQ), and water elimination (WE) comprise the four sections of the HSQ. These elements make it possible to assess each person's water balance. With Cronbach's α scores of 0.832 and 0.852, the questionnaire's internal consistency was high and above the generally recognized cutoff of 0.70.

The Fluid Behaviour Index (FBI), adopted from Veilleux et al. (2020), was developed as a rapid self-report tool to assess hydration behaviours. The index score is derived from the sum of ordinal responses to daily fluid intake (scored 0–4) and binary responses ("yes" = 1) to behaviour-related items such as fluid accessibility, drinking without thirst, and monitoring urine colour. These variables have been associated with higher total fluid intake in previous research.

Data Analysis

The data were analysed with SPSS v.27 (IBM Corp., Chicago, IL, USA). Descriptive statistics were employed to summarize total water intake, fluid loss, and water balance. Pearson's correlation analysis was conducted to examine relationships between fluid behaviour (FBI), total water intake (TWI), total fluid loss (TFL), and hydration status variables. A significance level of $p < 0.05$ was adopted for statistical inference.

RESULTS

Table 1 presents the demographic and anthropometric characteristics of the 19 high-performance cyclists who participated in the study. The sample comprised 52.6% male (n = 10) and 47.4% female (n = 9) athletes, indicating a relatively balanced gender distribution.

The mean height of participants was 1.67 ± 0.072 m, and the mean body weight was 58.26 ± 8.03 kg. Based on these values, the mean Body Mass Index (BMI) was 20.76 ± 1.36 kg/m². This BMI range is within the "normal" weight range according to World Health Organization (WHO) classifications, indicating that participants maintained a healthy body composition, which is crucial for the best possible endurance performance and thermoregulation during exercise.

Table 2 illustrates the descriptive statistics about TWI, TFL, WB, and the FBI among the participants (n=19). The mean TWI from beverages was 3422.24mL ± 269.60mL, while the average water intake derived from food sources contributed 425.22mL ± 305.60mL, concluding in a TWI of 3847.45mL ± 324.79mL. This indicates that most water intake originates from beverage consumption, with a comparatively smaller proportion obtained from dietary sources.

The findings also demonstrate a mean TFL of 3514.43mL ± 284.86mL, which indicates substantial fluid elimination processes within the participants. The mean WB was reported at 333.02mL ±

254.50mL, reflecting a slightly positive hydration status. This positive WB suggests that the participants' fluid intake adequately compensated for fluid losses on average, thus supporting optimal hydration levels.

The FBI, which evaluates hydration-related habits and consumption behaviours, yielded a score of 4.26 ± 1.63. This score reflects consistent and potentially effective hydration practices among the participants.

Overall, the results highlight that the participants generally maintained sufficient fluid intake to achieve a positive water balance, complemented by fluid consumption behaviours indicative of adequate hydration awareness.

According to Table 3, FBI exhibits a weak and non-significant positive correlation with TWI ($r = 0.146$, $p = 0.550$) and a weak, non-significant negative correlation with TFL ($r = -0.166$, $p = 0.496$). These findings indicate that fluid consumption behaviours, as measured by the FBI, are not strongly associated with either the volume of water intake or fluid elimination among the participants.

Conversely, there is a moderate to strong positive correlation between TWI and TFL ($r = 0.659$, $p = 0.002$), which is statistically significant at the 0.01 level ($p < 0.01$). This correlation suggests that increases in water consumption are proportionately associated with increases in fluid loss, reflecting a balanced hydration mechanism among the study participants. The correlation analysis underscores the interrelationship between water intake and fluid loss, indicating that fluid behaviour, as indexed by FBI, is not directly predictive of these hydration metrics.

Table 1: Descriptive Statistics of Participants. (n=19)

Gender	Frequency	%
Male	10	52.6
Female	9	47.4
	Mean	**SD**
Height	1.6711 m	0.072 m
Weight	58.26 kg	8.027 kg
BMI	20.76 kg.m^2	1.3555 kg.m^2

Table 2: Descriptive Statistics of Total Water Intake, Fluid Loss, Water Balance, and Fluid Behaviour Index (n=19)

	Mean	SD
Total water intake from beverages	3422.24mL	269.60mL
Total water intake from food	425.22mL	305.60mL
Total water intake (TWI)	3847.45mL	324.79mL
Total fluid loss (TFL)	3514.43mL	284.86mL
Water balance (WB)	333.02mL	254.50mL
Fluid Behaviour Index (FBI)	4.26	1.63

Table 3: Pearson Correlation Coefficients between FBI and Total Water Intake and Total Fluid Loss (n=19)

	Fluid Behaviour Index (FBI)	Total Water Intake	Total Fluid Loss
Fluid Behaviour Index (FBI)	1.00	.146	-0.166
		(.550)	(.496)
Total water intake (TWI)	.146	1.00	.659**
	(.550)		(.002)
Total fluid loss (TFL)	-0.166	.659**	1.00
	(.496)	(.002)	

*Note: Values in parentheses represent p-values. **Significant at the 0.01 level (2-tailed).*

DISCUSSION

This study examined the relationship between water intake behaviour and hydration status among high-performance cyclists in Selangor. Using validated instruments, including the International Physical Activity Questionnaire – Short Form (IPAQ-SF), Hydration Status Questionnaire (HSQ), and Fluid Behaviour Index (FBI), data were collected from 19 athletes. Descriptive statistics revealed that participants maintained a positive water balance (WB), with a mean total water intake (TWI) of 3847.45 ± 324.79mL and a mean total fluid loss (TFL) of 3514.43 ± 284.86mL. This indicates adequate hydration levels among the cohort during training periods. However, Pearson correlation analysis demonstrated no significant association between self-reported fluid intake behaviour (FBI) and hydration status markers (TWI and TFL), suggesting that subjective hydration practices may not reliably predict physiological hydration.

The results are consistent with the earlier studies showing that during organized training programs, athletes frequently maintain positive water balance (Casa et al., 2010; Sawka et al., 2007). However, research showing the significance of behavioural awareness in achieving optimum hydration (Garth & Burke, 2013; Muñoz et al., 2015) contrasts with the poor correlations between FBI and hydration markers. The difference could be explained by variations in the athletes' awareness, the environment, and the accuracy of their self-reported fluid consumption. Furthermore, since physiological reactions and individual sweat rates differ greatly across athletes. Meanwhile, Popkin et al. (2010) and Perrier et al. (2021) suggest that fluid behaviour alone is insufficient for reaching optimal hydration.

Additionally, the significant correlation between TWI and TFL underscores the physiological balance mechanism that regulates fluid intake and loss during physical exertion. These findings are consistent with Holland et al. (2017), who reported that fluid consumption directly influences hydration status during high-intensity activities. Nevertheless, the lack of correlation between FBI and hydration indicators suggests that self-monitoring behaviours, as measured by FBI, may not reflect actual hydration needs. This supports Funnell et al. (2019), who found that awareness of hydration status does not always mitigate performance deficits during hypohydration.

Although the athletes in this study demonstrated a positive water balance, a potential risk of overhydration or excessive hydration remains. Excessive hydration occurs when water intake surpasses fluid loss, leading to an imbalance (Cai et al., 2023). However, this state is not detrimental and sometimes may improve athletic performance, particularly in endurance sports such as cycling, where fluid loss through sweat is significant.

Goulet et al. (2008) showed that pre-exercise hyperhydration could extend the period before dehydration during a 2-hour session of moderate to intense cycling in a temperate environment with restricted fluid intake (equivalent to 33% of sweat losses). Their findings indicated that hyperhydration improved endurance capacity and peak power output, while simultaneously reducing heart rate and thirst sensation, although it did not significantly affect rectal temperature. Similarly, Jardine et al. (2023) concluded that hyperhydration enhances exercise capacity by increasing plasma volume, which helps reduce heart rate and core temperature during sustained exercise until exhaustion. However, despite these clear benefits, tolerance and individual response to hyperhydration remain important considerations. Some participants in recent trials reported gastrointestinal discomfort, particularly when glycerol or sodium-based solutions were used at higher concentrations or over shorter loading periods. This underscores the necessity of individualization and field-testing of protocols before implementation in competitive settings.

Furthermore, the generalizability of current findings remains limited. The majority of hyperhydration studies to date have focused on male endurance athletes performing in hot environments, often using cycling as the primary mode of exercise. Very few studies have explored the effects in female athletes, who may exhibit different fluid regulatory responses due to hormonal influences. Similarly, real-world applications in mixed-modality sports or cooler conditions remain underexplored.

These results have practical significance for endurance athletes' hydration management. Relying exclusively on self-reported fluid intake behaviours may not be enough to maximize hydration throughout training and competition, given the limited connection between hydration behaviour and real hydration state. Coaches and sports nutritionists should consider using objective hydration monitoring techniques like urine-specific gravity or plasma osmolality tests to provide more precise evaluations.

Furthermore, by highlighting the drawbacks of thirst-driven consumption and promoting proactive fluid intake, focused education initiatives could improve athletes' comprehension of efficient hydration techniques. This strategy may promote athletic performance and lower the risk of dehydration-related impairments by bridging the gap between perceived and actual hydration demands.

Several restrictions about this study must be pointed out. The findings may not be as applicable to broader athletic populations due to the limited sample size (n = 19). Furthermore, response bias may be introduced when fluid intake and behaviour are based solely on self-reported data. Future studies should use objective hydration markers and bigger, more varied samples to validate the results. The association between self-reported behaviours and physiological hydration status should be further clarified by longitudinal studies that evaluate hydration behaviours over several training cycles and competitive events. Furthermore, studying environmental variables like humidity and temperature would provide light on how they affect athletes' hydration behaviours.

All things considered, this research advances our knowledge of hydration behaviour and how it relates to physiological hydration in high-performance cycling, emphasizing the demand for more reliable monitoring techniques to maximize fluid balance and sports performance.

CONCLUSION

This study explored the Selangor high-performance cyclists' water intake behaviours and hydration levels and how they relate to one another. The results showed that although athletes tended to maintain a positive water balance, there was no significant correlation between self-reported hydration behaviour (as assessed by the FBI) and either total fluid loss (TFL) or total water intake (TWI). This finding implies that among high-performance cyclists, perceived hydration habits are insufficient predictors of real hydration status. The findings further emphasize the significance of objective hydration monitoring that extends beyond self-evaluation, especially in endurance sports where there is considerable fluid loss from perspiration and metabolic activity. Combining behavioural evaluations with physiological data, like urine-specific gravity or plasma osmolality, may improve the precision of hydration status assessments and promote better hydration practices.

The study also highlights the significance of focused hydration guidelines, stressing proactive fluid intake and knowledge of fluid loss during sport and training. To maximize performance and lower the risk of dehydration-related impairments, athletes can better match their intake behaviours with physiological needs by filling in knowledge and monitoring gaps regarding hydration. Future studies should examine the effects of environmental conditions on endurance athletes' fluid requirements and the effects of longitudinal hydration monitoring on athletic performance. The findings' generalizability might be further improved by increasing the sample size and incorporating a more varied sports group. In conclusion, even though the study's high-performance cyclists showed positive water balance, the poor relationship between physiological measurements and self-reported hydration behaviour indicates the need for improved monitoring techniques to maximize hydration and athletic performance.

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AUTHORS' CONTRIBUTION

Sadli, H. S. designed, planned, and conducted the data collection. Jamaludin, M. carried out the data processing and took the lead in writing the manuscript. Ismail, Z. contributed to the interpretation of the results. Kamaruddin, H. K. provided critical feedback. Abu Bakar A. H. and Zaker, N. A. helped shape the research, analysis, and manuscript.

CONFLICT OF INTEREST DECLARATION

We certify that the article is the Authors' and Co-Authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication nor has it been published in whole or in part elsewhere. We testify to the fact that all Authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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