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Identification of Urine Specific Gravity in Female Workers Exposed to Hot Environments in Indonesia: A Cross-Sectional Study

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ABSTRACT

Introduction: Dehydration can affect body functions related to temperature regulation and blood circulation. Persistent dehydration can lead to fatigue, impaired concentration, and kidney dysfunction. Workers in labor-intensive environments, such as the brickmaking industry, are at a higher risk due to strenuous physical activity and prolonged exposure to high temperatures. Direct sunlight and the brick-firing process further increase the risk of fluid loss, highlighting the need to assess hydration status among brickmaking workers.

Methods: This study employed a cross-sectional design involving 105 brickmaking workers. Individual characteristic factors, worker habit factors, work factors and work environment factors as independent variables, while the dependent variable was hydration status. Hydration status was measured using reagent strips for urinalysis, and other variables were collected through structured interviews using a questionnaire. Data collection was conducted over a period of 14 days. Data were analyzed using the Spearman rank correlation test and multiple linear regression to identify the most influential factors.

Results: The majority of study subjects were severely dehydrated, as indicated by Urine Specific Gravity (USG) measurements ranging from 1021 to 1030. The highest distribution was found in the USG range of 1026–1030, with a percentage of 36.2%. Significant factors associated with hydration status included water consumption ($p = 0.000$), physical workload ($p = 0.000$), and clothing use ($p = 0.005$). Other factors, such as age, nutritional status, work duration, years of experience, and heat stress, did not show a significant relationship with hydration status. Multiple linear regression analysis revealed that water consumption had the most significant influence on hydration status (p=0,000).

Conclusion: Water consumption significantly impacts hydration status. These findings highlight the need for hydration education and workplace interventions, such as accessible drinking water and awareness programs, to enhance worker safety and health in brickmaking environments.

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INTRODUCTION

Dehydration is a significant health issue frequently encountered by individuals engaged in strenuous physical activities, particularly in high-temperature working conditions (1). This condition occurs when the body loses fluids through sweating, respiration, or urination without sufficient replenishment (2). As a consequence, dehydration disrupts critical bodily functions, including temperature regulation, blood circulation, and cognitive performance(3). In the short term, dehydration leads to fatigue, decreased productivity, and impaired concentration, while prolonged dehydration may result in organ dysfunction, especially affecting kidney health (3).

Despite its severe and potentially life-threatening effects, dehydration is often underestimated. It is commonly identified by a body weight loss of 2% or more or a urine-specific gravity (USG) value of 1.020 or higher (4). Dehydration is particularly prevalent in occupations requiring high physical exertion and extended exposure to heat, significantly increasing the risk of fluid loss (5). Without proper prevention and intervention, dehydration compromises health, reduces productivity, and poses a serious safety risk to workers (6). Contributing factors include individual aspects such as knowledge levels, overall health conditions, and medication use. Work-related factors involve clothing choices, the use of personal protective equipment, and limited access to drinking water and sanitation facilities. Additionally, excessive workplace heat is a major environmental factor exacerbating the risk of dehydration (7).

Studies have consistently highlighted the high prevalence of dehydration among workers exposed to hot environments. In Florida, 53% of workers were already dehydrated before starting their shifts, rising to 81% post-shift (8). Another study at an open-air worksite in the same region found that 96.8% of 1,020 end-of-shift USG measurements from 111 farmworkers exceeded 1.020, indicating dehydration (9). Similarly, 46.7% of agricultural workers in North Carolina were dehydrated before work, increasing to 100% by the end of their shifts (10). Research also shows that 37.5% of workers in high-temperature environments experience dehydration, with workplace heat identified as a primary risk factor (11). In Indonesia, many workers exposed to extreme heat fail to meet their daily hydration needs, consuming only an average of 2.1 litres of water per day, well below the recommended amount. Consequently, 87.1% of these workers exhibited elevated USG levels, indicating dehydration (12).

The brickmaking industry is among the occupational sectors with a high risk of dehydration. This physically demanding work takes place in environments that often lack adequate health support facilities. The production process is traditionally performed using manual labour and simple tools, with workers producing approximately 3,000–4,000 bricks per day over nine-hour shifts. Prolonged exposure to direct sunlight, combined with extreme heat generated during the two- to three-day brick-firing process, significantly increases the risk of fluid loss.

Preliminary studies in Candisari Village indicate that persistently high ambient temperatures pose a major challenge for brick workers. Limited access to clean drinking water due to the remote locations of brickmaking sites near paddy fields and riverbanks, coupled with low awareness of hydration importance and unsupportive work habits, further increase dehydration risks. Commonly reported symptoms include excessive sweating, fatigue, intense thirst, and weakness, demonstrating the direct impact of insufficient fluid intake. These conditions negatively affect both worker health and productivity, highlighting the need for targeted interventions to mitigate dehydration risks(6). Additionally, a preliminary study measuring hydration using urine color analysis found that 87.5% of brickmaking workers experienced severe dehydration, with all female workers affected (13). However, since various factors can influence urine color, a follow-up study was conducted using alternative indicators to provide a more accurate assessment of hydration status.

Prior research has established USG measurement as an effective method for assessing hydration status (14,15). Although this method has been widely used across various occupational sectors, studies specifically evaluating the hydration status of brickmaking workers using USG remain limited. Addressing this research gap is essential, as a significant portion of Indonesia's workforce operates in the informal sector, including brickmaking, which plays a crucial role in the national labour structure.

This study aims to identify the hydration status of brickmaking workers using USG as the primary indicator. Specifically, it examines the factors influencing hydration status, including individual characteristics, work habits, work-related factors, and environmental conditions. By analysing these factors, the research seeks to enhance the understanding of occupational health in the informal sector and provide a foundation for recommendations to improve worker health and safety.

Furthermore, the findings can serve as a reference for policymakers in developing regulations to enhance workplace hydration strategies, ensuring better health protection for informal sector workers. This research also supports policy development and workplace intervention programs aimed at improving hydration awareness and occupational health standards in high-risk labor environments. Additionally, it lays the groundwork for practical safety and intervention strategies tailored to the unique challenges faced by brickmaking workers, ensuring the implementation of effective hydration management practices in their workplaces.

METHOD

This study used a cross-sectional design and was conducted in 2024. The population of this study was 105 brick-making workers in Candi Sari Village, Demak, Central Java, Indonesia. This study included all female brick-making workers as the sample, ensuring a focused analysis on their hydration status. Data collection was carried out over 14 days to ensure comprehensive assessment and minimize daily variability. The independent variables in this study are individual characteristic factors (age, nutritional status), worker habit factors (amount of drinking water consumption, use of clothing), work factors (physical workload, work period and work environment) and work environment factors (heat stress) while the dependent variable is hydration status. Data collection was conducted using interviews with a questionnaire instrument containing questions about age, length of employment, length of service. Observation sheet for variable of clothing use. The amount of drinking water consumption was measured using a 24-hour food recall questionnaire, while the workload was assessed based on calorie needs according to energy expenditure using the Indonesian National Standard (SNI) SNI_7269_2009. Nutritional status was measured by Body Mass Index (BMI) using Omron HN 289 Digital Scales and height using Stature Adult Height Meter MT-701. Hydration status was measured using urine specific gravity (USG) with Urinalysis Reagent Strips.

This study was conducted following ethical research procedures. Participants provided informed consent by signing an approval form before participating in interviews and urine specific gravity (USG) measurements. Urine Specific Gravity (USG) has certain limitations as a hydration assessment method, as it only reflects hydration status at a specific point in time and does not provide a comprehensive evaluation over an extended period. Data analysis included univariate analysis, which presented data in tabular form containing frequencies and percentages for each factor. Bivariate analysis was conducted to examine the relationship between factors and hydration status using the Spearman rank test. Multivariate analysis was used to identify the factors most associated with hydration status through multiple linear regression tests. The software used for data analysis in this study was IBM SPSS Statistics 21.

Ethical Approval

Ethical approval for this study was obtained from the ethics committee, with certificate number No. 583/KE/08/2024.

RESULTS

Tabel 1. Univariate Test Analysis of Individual Characteristics, Work Habits, Work and Work Environment Factors

Factors	Mean±SD	Median (Min-Max)	f (%)
Individual Characteristics			
Age (years)	44,97 ± 6,776	45,00 (23-55)	
17-25			2 (1,9)
26-35			6 (5,7)
36-45			46 (43,8)
46-55			51 (48,6)
BMI (kg/m^2)	22,63± 2,345	23,00 (17-27)	
< 18,5			2 (1,9)
18,5-22,9			45 (42,9)
23-24,9			32 (30,5)
25-29,9			26 (24,8)

Factors	Mean±SD	Median (Min-Max)	f (%)
Work Habits			
Total Drinking Water Consumption (ml)	3,306 ± 1,2370	3,200 (1,0-6,1)	
≥ 5,760			8 (7,6)
< 5,760			97 (92,4)
Clothing Usage	3,96 ± 2,170	5,00 (1-7)	
Using (> score)			53 (50,5)
Not Using (< score)			52 (49,5)
Work-Related			
Physical Workload (kkal/jam)	402,15 ± 265,963	288,00 (178-892)	
100-200			25 (23,8)
>200-350			46 (43,8)
> 350			34 (32,4)
Length of Work (hours/day)	9,16 ± 0,761	9,00 (8-10)	
≤ 8			23 (16,1)
> 8			82 (78,1)
Working Period (years)	14,35 ± 5,517	14,00 (2-27)	
≤ 5			7 (6,7)
> 5			98 (93,3)
Hydration Status (gr/dl)	1024.43 ± 5.731	1025,00 (1000-1030)	
USG ≤ 1015			7 (6,7)
USG 1016-1020			29 (27,6)
USG 1021-1025			32 (29,5)
USG 1026-1030			38 (36,2)
Work Environment			
Heat Stress (°C)	37,011 ± 2,7993	38,200 (30,1-39,7)	
> 28			105 (100)
(Source: Data Primer, 2024)			

The results of the ivivariate test in Table 1 show that the age of the subjects in this study ranged from 23 to 55 years, with the youngest age being 23 years and the oldest being 55 years. The largest age group was 46-55 years (48.6%), followed by the 36-45 years age group (43.8%), while the smallest age group was 17-25 years (1.9%). The subjects' Body Mass Index (BMI) showed a range from 17 to 27 kg/m². Most subjects were in the normal category (18.5-22.9) at 42.9%, while the smallest category was underweighted (<18.5) at 1.9%.

Most subjects (92.4%) had drinking water consumption below the high recommended limit of <5,760 ml, with the lowest consumption value of 1.0 litter and the highest of 6.1 litters. Regarding the use of appropriate clothing for working conditions, the distribution of subjects was almost even, with slightly more subjects using appropriate clothing (50.5%) than those who did not (49.5%).

The physical workload of the subjects was mostly in the moderate category (>200-350 kcal/hour) at 43.8%, followed by the high category (>350 kcal/hour) at 32.4%, and the light category (100-200 kcal/hour) at 23.8%. Most subjects (78.1%) worked more than 8 hours per day, with the average daily working time reaching 9.16 ± 0.761 hours. In addition, almost all subjects (93.3%) had a working period of more than 5 years, with a minimum working period of 2 years and a maximum of 27 years.

The majority of subjects' hydration status was in the USG range of 1021-1030, with the highest distribution in USG 1026-1030 (36.2%). This indicates the potential for mild dehydration in most subjects. Meanwhile, the heat stress temperature in the subject's work environment had an average of 37.011 ± 2.7993°C, where all temperature measurements (100%) exceeded the recommended threshold of 28°C. These findings suggest that the work environment poses a significant risk to workers' health.

Tabel 2. Normality Test Analysis

Variabel	p*	Keterangan
Age	0,008	Abnormal**
BMI	0,002	Abnormal**
Total drinking water consumption	0,001	Abnormal**
Use of clothing	0,000	Abnormal**
Physical workload	0,000	Abnormal**
Length of service	0,200	Normal***
Length of employment	0,000	Abnormal**
Heat Stress	0,000	Abnormal**
Hydration status	0,000	Abnormal**

*Kolmogorov-Smirnov; **p>0,05; ***p≤0,05
(Source: Data Primer, 2024)

The results of the normality test analysis in Table 2 show that most of the variables, such as age, nutritional status, amount of drinking water consumption, clothing use, physical workload, heat stress, and hydration status, had abnormal distributions (p < 0.05). Only tenure showed a normal distribution (p = 0.200). Since the dependent variable had a non-normal distribution, the correlation analysis was continued with the Spearman Rank non-parametric test.

Tabel 3. Bivariate Factors Associated with Hydration Status

Factors	Hydration Status	
	p*	Information
Individual Characteristics		
Age	0,537	No relationship ***
BMI	0,677	No relationship ***
Work Habits		
Total Drinking Water Consumption	0,000	There is a relationship **
Clothing Usage	0,005	There is a relationship **
Work-Related		
Physical Workload	0,000	There is a relationship **
Working Period	0,830	No relationship ***
Length of Work	0,877	No relationship ***
Work Environment		
Heat Stress	0,339	No relationship ***

*Spearman's Rank Correlation; **p≤0,05; ***p>0,05
(Source: Data Primer, 2024)

The results of bivariate analysis with the Spearman Rank test showed that some factors had a significant relationship with hydration status, namely the amount of drinking water consumption (p = 0.000) and the use of clothing (p = 0.005). Other factors, such as age (p = 0.537), nutritional status (p = 0.677), tenure (p = 0.830), length of service (p = 0.877), and heat stress (p = 0.339), did not show a significant association with hydration status (p > 0.05). These findings highlight the importance of work habits, particularly drinking water consumption and clothing use, in influencing workers' hydration status. Although all measured heat stress levels exceeded the Threshold Limit Value (TLV), no significant relationship was found with hydration status. This may be due to workers' adaptive responses to chronic heat exposure, variations in individual thermoregulation, or compensatory behaviours such as increased fluid intake. Additionally, hydration status is influenced by multiple factors, including workload intensity, sweat rate, and individual fluid replacement strategies, which may have a more direct impact than heat stress alone.

Tabel 4. Multiple Regression Linear Model for Hydration Status

Factors	β	SE	BETA	p
Individual Characteristics				
Age	-0,234	0,138	-0,277	0,092**
BMI	0,010	0,166	0,004	0,058**
Work Habits				
Total Drinking Water Consumption	-3.165	0,327	-0,683	0,000*
Clothing Usage	-0,218	0,185	-0,083	0,241**
Work-Related				
Physical Workload	0,003	0,002	0,125	0,082**
Working Period	0,334	0,176	0,322	0,060**
Length of Work	-0,840	0,592	-0,112	0,159**
Work Environment				
Heat Stress	0,085	0,142	0,041	0,552**

*p≤0,05; **p>0,05

The results of multiple linear regression analysis in Table 4 show that only the amount of drinking water consumption (β = -3.165, p = 0.000) has a significant influence on hydration status, with a negative relationship indicating that low drinking water consumption adversely affects hydration status. Other factors, such as age (p = 0.092), BMI (p = 0.058), clothing use (p = 0.241), physical workload (p = 0.082), tenure (p = 0.060), and heat stress (p = 0.552), did not show a significant influence on hydration status. These findings emphasize the importance of drinking water consumption as a major factor in maintaining workers' hydration status.

DISCUSSION

The majority of study subjects were aged 45 years, with older workers generally experiencing reduced cardiovascular efficiency and higher heat absorption. However, this study found no significant relationship between age and hydration status. This may be due to other dominant factors such as drinking water consumption, workload, clothing use, and heat exposure duration, which play a more substantial role in influencing hydration. Similar findings were reported in studies on agricultural and fish processing workers, where age did not significantly impact hydration status (10) (11). While physiological aging may contribute to a slower heat dissipation process, the body's ability to adapt in productive age groups likely minimizes this effect (16).

BMI was also not significantly related to hydration status, likely due to the stronger influence of water intake. Although BMI can influence water requirements, most workers in this study had low water consumption, which may have a more direct impact on hydration levels (17). Studies in Greek workers similarly found no significant relationship between BMI and hydration status, reinforcing that hydration is primarily determined by fluid intake rather than body mass index (18).

Hydration status was significantly related to drinking water consumption, with 92.4% of workers consuming insufficient water. This is due to poor drinking habits, as many workers dislike drinking plain water and prefer consuming beverages such as tea, coffee, and syrup. These drinks can significantly affect hydration dynamics (18). These preferences can increase calorie and free sugar intake (19,20), potentially compromising hydration status and overall workforce health. A study on agricultural workers in North Carolina found that, as part of a humoral practice to restore body balance while working in the heat, workers commonly consumed soda or other sugary drinks (21,22).

Additionally, workplace facilities do not support adequate hydration. There is no drinking water supply at the workplace, so workers rely on a single bottle of water brought from home. Moreover, the absence of toilets in the workplace causes some workers to limit their water intake to reduce the frequency of urination. Research has shown that access to toilets is a factor affecting body fluid balance (18), leading workers to adapt by suppressing thirst. This finding aligns with previous research on production workers at a fish processing company, which demonstrated a relationship between drinking water intake and dehydration (11). The study found that workers who consumed less than 1,475 ml of water were more likely to suffer from dehydration.

The use of clothing is related to hydration status, as it moderates heat exchange through convection, conduction, radiation, and sweat evaporation (23) (24). However, many workers did not use clothing that effectively absorbs sweat, reducing heat dissipation. Clothing with high air and water vapor permeability can better facilitate sweat evaporation and help maintain hydration (25). Physical workload was also significantly associated with hydration status. Most brick making workers have moderate and heavy workloads as much as 77.1%. Physical workload refers to the physical strain that workers experience while performing their duties (26). The literature has evaluated physical workload by measuring various work elements, such as posture (standing, sitting, or bending), type of activity (walking, running, or manual material handling), body weight, and exercise capacity (27). Brick-making workers in Candi Sari Village Demak still use traditional tools, which makes their workload tend to be heavier. The tools are not designed to reduce the physical strain experienced by workers, thus increasing work intensity and the potential for fatigue. The impact of physical workload is directly related to hydration status. Workers engaged in high-intensity physical activity in hot climates are more likely to become dehydrated(28). The ability to self-regulate work pace can help reduce the risk of dehydration and associated cardiovascular strain (29). Previous research states that there is a relationship between physical workload and hydration status, heavy workloads result in increased metabolic heat and cause more severe dehydration (30).

The test results explained that there was no relationship between work period and hydration status with p = 0.830. This is due to the uneven working period of workers, most workers have a working period of > 5 years at 93.9% while workers with a working period of ≤ 5 years are 6.7%. Every worker, old workers and new workers have different experiences that they feel (31). Years of service have both positive and negative impacts on performance (32). The positive impact is that as the length of service increases, professional experience also increases. The negative impact is that the longer the working hours, the greater the benefits that workers receive due to the working environment and other reasons (33). The longer the working hours, the greater the risk of exposure to occupational and environmental hazards (34).

However, the working period is related to the adaptability of workers, their work and the work environment, both positive and negative adaptation. If negative, it will lead to dehydration and decreased psychological and physiological functions (33). Conversely, the longer a person works, the greater the body's ability to adapt to heat exposure (35). This is because the longer a person works and the more accustomed to the work he does, the greater the effect on his body's resistance.

The results of the analysis using the Spearman rank test obtained p=0.877, indicating that there is no significant relationship between work duration and hydration status in brick making workers. The average brick making worker in Candi Sari Demak Village works for 9 hours in 1 day. While workers who work more than 8 hours have a higher potential for dehydration due to heat exposure and longer physical activity, the difference found in this study sample was not large enough to be considered statistically significant (36). This suggests that work duration alone is not the only determinant of a worker's hydration status, as there are other factors that can influence these results.

The results of heat stress measurements in the brick making industry environment showed an average value of 37.01 ◦C, which exceeded the threshold value of 28 ◦C. The human body can maintain a constant internal/core body temperature (approximately 37 ± 1 ◦C), despite the influence of a varied thermal environment (37). Then, the results of the relationship test showed no relationship between heat stress and hydration status in this study. This happened because there was a work section where the range of heat stress measurement results was 30.1 ◦C - 38 ◦C, namely in some workers in the semi-indoor-outdoor area, namely workers who were in charge of stacking bricks in the kiln hut before the combustion process occurred. This is in line with previous research that indoor workers and workers in the shade have a 12% reduced risk of heat stress compared to outdoor workers who are directly exposed to the sun (38).

Things are different in the outdoor work section which is the area for the majority of brick making workers. The working environment in brick making that causes high temperatures is influenced by the location in Candi Sari Village Demak, which is located in a rice field and riverside area. This location was chosen because this is where the main raw material, clay, can be found, and access to water sources is close and easy because it is on the banks of the river. Workers work in an oudoor area reaching a heat stress level of 39.7◦C.

This study has several limitations. The cross-sectional design limits causal inference, as it only establishes associations rather than cause-effect relationships. Additionally, self-reported data may introduce recall bias, particularly in water consumption reporting. The study also did not conduct in-depth category-specific analyses, which could have provided more insights into the interactions between various factors affecting hydration status. Future research should consider longitudinal studies to assess hydration patterns over time, incorporate objective hydration assessments such as urine osmolality or plasma osmolality, and analysed the effects of specific workplace interventions to improve hydration behavior.

CONCLUSIONS

Our study of brick makers in Demak, Central Java, revealed an average USG of 1024.43 gr/dl, indicating significant hydration challenges. A strong correlation was found between water intake, workload, and clothing use with hydration status. Given the low fluid consumption observed, it is crucial to ensure the availability of clean drinking water at each worksite and implement targeted hydration education—such as recommending 24 glasses per shift (or one 240-ml glass every 20 minutes). Additionally, providing work uniforms made from breathable, moisture-absorbing fabrics is essential for effective heat dissipation. Limited access to toilet facilities, which discourages adequate hydration, must also be addressed. Water intake plays a crucial role in maintaining hydration levels. These findings underscore the importance of education and workplace interventions, including readily available drinking water and awareness programs, to improve worker safety and well-being in brickmaking environments. This study contributes to the development of public health interventions and informs occupational health policies in Indonesia, emphasizing the need for broader regulatory measures to protect workers. Future research should further explore category-specific factors to refine these policy recommendations.

AUTHOR'S CONTRIBUTION STATEMENT

SD: conceptualization, investigation, methodology, supervision, data analysis, writing–original draft, writing–review and editing; HMD: methodology, writing–original draft; YS: methodology; formal analysis, writing–original draft; DL: methodology, writing–original draft; CTP: methodology; formal analysis, writing–original draft;

CONFLICTS OF INTEREST

All authors have no conflict of interest regarding this article.

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