



Heat Acclimatization among New Conscripts in Army Training Units in Bangkok, Thailand: A Prospective Cohort Study

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Abstract

Heat-related illness (HRI) remains a major occupational health concern among new conscripts undergoing military training in tropical environments. This study aimed to evaluate heat acclimatization and its influencing factors among new military conscripts in Bangkok, Thailand. A prospective cohort study was conducted among 383 conscripts recruited from 11 randomly selected training units during November–December 2022. Eligible participants aged 21–29 years were classified by body mass index (BMI) and participation in the Health Promotion and Prevention Medicine (HPPM) exercise program, which incorporated aerobic and resistance training with progressive overload, structure rest, and supervision to enhance cardiovascular and thermoregulatory adaptation. Heat acclimatization was assessed using repeated measures of skin temperature, heart rate, and sweat response. Associations were analyzed using chi-square tests and multiple logistic regression. Overall, 18.5% of conscripts achieved full heat acclimatization by week 4. Participation in the HPPM program was associated with a higher rate of acclimatization in later training weeks (20.8% vs 17.1%). Higher BMI was negatively associated with acclimatization (AOR = 0.271, 95% CI: 0.102–0.719, $p = 0.009$), whereas higher knowledge levels (AOR = 4.054, $p = 0.019$) and strong peer support (AOR = 2.654, $p = 0.006$) significantly increased the likelihood of acclimatization. Environmental factors, including temperature and humidity, were also significant. In conclusion, heat acclimatization remains limited among new conscripts. The HPPM program shows beneficial effects, and targeted interventions for high-risk groups should be integrated into military training policies to reduce HRI risk and improve occupational health outcomes.

Keywords: Army training unit, New conscripts, Heat acclimatization, Heat-related illness, Occupational heat stress, Thailand

What was Known

- Heat-related illnesses (HRI) are a major occupational health problem among military personnel and other workers exposed to hot and humid environments, with new military recruits being particularly vulnerable due to intense physical training and lack of prior heat acclimatization.
- Key risk factors for HRI include high body mass index (BMI), inadequate hydration, and insufficient heat acclimatization; although preventive guidelines and BMI-based training adjustments are implemented in the Royal Thai Army, HRI continues to occur at a substantial rate.
- Heat acclimatization develops through repeated heat exposure over 1–4 weeks and is associated with measurable physiological adaptations—such as reductions in core temperature and heart rate, and changes in sweating response—which are commonly used as indicators of improved heat tolerance, although no single universal standard exists for its assessment.

What's New and Next

- This study provides empirical evidence that changes in core temperature, heart rate, and sweat volume between weeks 1 and 4 of training can be used together as practical physiological indicators of heat acclimatization in new military recruits, particularly highlighting delayed adaptation among recruits with overweight BMI.
- The findings support a shift from reliance on BMI-based classification alone toward a multidimensional surveillance approach that integrates physiological monitoring, environmental conditions, and individualized training adjustments to improve prevention of heat-related illnesses.
- The study establishes a foundation for future implementation of real-time monitoring technologies and longitudinal follow-up, enabling the development of evidence-based training programs and risk-alert systems that enhance heat safety while maintaining military training effectiveness.

Introduction

Heat-related illnesses (HRI) occur when the human body fails to dissipate excess internal heat, resulting in elevated body temperature and potentially life-threatening complications.^{1,2} These conditions range from mild heat cramps and exhaustion to severe heatstroke. The risk of HRI is particularly high among military personnel, particularly recruits, who perform prolonged physical activities under harsh outdoor training conditions.

Heat acclimatization, defined as the physiological adaptation to repeated heat exposure, is central to the prevention of HRI. This process improves thermoregulatory and cardiovascular efficiency, resulting in lower skin or core body temperature, reduced heart rate, and enhanced sweat response during heat exposure^(3,4). Complete acclimatization typically develops within 7–14 days of continuous exposure⁽¹⁾. In this study, complete heat acclimatization was defined as meeting all three physiological criteria: reduction in skin temperature, reduction in heart rate, and improvement in sweat response, which are practical for field-based military assessment.

Globally, HRI remains a persistent occupational health concern in the military. Reported incidence rates include 1.9 per 1,000 personnel in the United Kingdom and 187 cases in Singapore⁽⁵⁾. In Thailand, a tropical country with persistently high temperature and humidity, the Royal Thai Army documented an average of 51 HRI cases per 1,000 soldiers between 2016 and 2020⁽⁴⁾. Major contributing risk factors include abnormal body mass index (BMI), poor hydration, inadequate heat acclimatization, and intensive physical activity under extreme heat⁽⁶⁾. Although total training hours were temporarily reduced during the COVID-19 pandemic, training intensity and environmental exposure remained largely unchanged⁽⁷⁾.

To address this issue, the Royal Thai Army implemented several preventive strategies consistent with medical guidelines, including pre-training screening for high-risk individuals, regulated training–rest schedules, real-time monitoring through the “Heat Stroke AMED” mobile application, and the HPPM Exercise Program for personnel with BMI >28 kg/m²^(7,8). The HPPM program integrates aerobic and resistance exercises with progressive overload, structured rest, and supervision to promote cardiovascular and thermoregulatory adaptation^(8,9). While these measures have reduced the incidence of heatstroke, HRI continues to affect new conscripts.

Despite well-documented benefits in other contexts,⁽¹⁰⁾ data among Thai recruits remain limited. Most local studies are descriptive and lack a comprehensive analysis of physiological and contextual determinants. This study applies the determinants of health framework to examine

individual, interpersonal, organizational, and environmental factors influencing heat acclimatization among new conscripts in Bangkok. Findings will support evidence-based training protocols to improve heat tolerance, reduce HRI risk, and promote the health and operational readiness of military personnel in high-heat environments.

Materials and Methods

1. Study design, participants, sample size and sampling technique

This prospective cohort study was conducted among new conscripts in Army training units in Bangkok, Thailand, during the official training period from November to December 2022. The sample size was calculated using a formula for comparing two proportions, assuming a 95% confidence level ($Z = 1.96$), 80% statistical power, and proportions of 0.91 and 0.79 in normal ($BMI < 23 \text{ kg/m}^2$) and elevated BMI groups ($BMI \geq 23 \text{ kg/m}^2$), respectively, based on previous studies^(11,12). The minimum required sample size was 300 participants. A total of 11 out of 25 training units were selected using simple random sampling, and all eligible conscripts aged 21–29 years who provided informed consent were included. Individuals who were unable to complete training due to illness, injury, or other conditions were excluded.

2. Measurements

Data were collected using structured questionnaires, physiological recording forms, and standardized measurement instruments. The questionnaire assessed three domains: (1) individual factors (e.g., BMI, body surface area, body fat percentage, underlying diseases, medication use, alcohol consumption, prior heat exposure, knowledge, behaviors, and participation in acclimatization programs), (2) interpersonal factors (peer and instructor support), and (3) organizational factors (training policies and resource support). Knowledge was assessed using 11 true/false items, while behaviors and other factors were measured using three-point Likert scales. Content validity indices ranged from 0.86 to 1.00. Reliability testing demonstrated a KR-20 coefficient of 0.71 for knowledge and Cronbach's alpha coefficients of 0.80, 0.86, and 0.85 for behaviors, interpersonal factors, and organizational factors, respectively.

Physiological parameters were measured at 15:00 on days 5, 12, 19, 26, 33, and 40 of training. Measurements included axillary skin temperature ($^{\circ}\text{C}$), heart rate (beats per minute), and sweat rate (mL/hour). Each parameter was measured twice, and the average value was used for analysis. Sweat rate was calculated as (pre-training body weight – post-training body weight + fluid intake – urine volume) divided by training time (hours)^(13,14). Complete heat acclimatization was

defined as meeting all three criteria between day 1 and day 26: a reduction in skin temperature ≥ 0.20 °C, a decrease in heart rate ≥ 5 bpm, and an increase in sweat rate ≥ 200 mL/hour⁽¹³⁾

Physiological measurements were obtained using calibrated instruments, including a mercury thermometer (± 0.2 °C), fingertip pulse oximeter (Yonker YK-80B), digital weighing scale (Tanita HA-801), and measuring tape. Environmental data, including ambient temperature and relative humidity, were measured at each training unit, while wind speed data were obtained from the Thai Meteorological Department⁽¹⁵⁾. All measurements were recorded at the same time point to ensure consistency.

The Health Promotion and Preventive Medicine (HPPM) exercise program was implemented among conscripts with BMI > 28 kg/m² as part of routine training. The program comprises aerobic and resistance training with progressive overload, structured rest periods, supervision, hydration management, and physiological monitoring to enhance cardiovascular and thermoregulatory adaptation. Participation in the HPPM program was recorded and analyzed as an exposure variable.

To ensure data quality, all instruments were calibrated according to manufacturer recommendations and regularly checked throughout the study. Data collectors were trained using standardized protocols. Inter-observer and intra-observer reliability were assessed prior to data collection and demonstrated acceptable agreement.

3. Data analysis

Data were analyzed using SPSS version 29.0. Descriptive statistics were used to summarize participant characteristics and study variables. Categorical variables were presented as frequencies and percentages, while continuous variables were summarized using means and standard deviations. Changes in physiological parameters over time were analyzed using Friedman's test and the Wilcoxon signed-rank test. Associations between independent variables and heat acclimatization were assessed using binary and multiple logistic regression analyses. The magnitude of associations was reported as adjusted odds ratios (AORs) with 95% confidence intervals. Statistical significance was set at $p < 0.05$. Missing data, if present, were handled using case-wise exclusion.

Result

A total of 383 new conscripts participated in the study. The mean BMI was 25.1 kg/m², with 59.3% classified as overweight or obese (BMI $\geq$ 23 kg/m²). Most participants had no chronic diseases (77.0%) and did not use regular medication (82.5%). Approximately half reported alcohol consumption (52.7%) and no regular exercise (53.0%). High levels of knowledge and behaviors related to heat acclimatization were observed in 47.8% and 46.7% of participants, respectively. Among conscripts with BMI $\geq$ 28 kg/m², 38.9% participated in the HPPM exercise program (Table 1).

Regarding contextual factors, 51.7% of conscripts reported high peer support, while 71.8% reported high instructor support. Most participants demonstrated high recognition of training policies (84.3%) and resource support (75.7%) (Table 2). Environmental conditions during training included temperatures ranging from 29.6 to 30.1 °C and relative humidity between 59.7% and 74.1% (Figure 1).

Overall, 18.5% of conscripts achieved complete heat acclimatization by week 4. When stratified by participation in the HPPM program, both groups reached peak acclimatization at week 4; however, the HPPM group demonstrated higher rates in later weeks (20.8% vs 17.1%). Although the non-HPPM group showed a higher rate in week 2 (10.3% vs 2.0%), rates became comparable in week 3 and subsequently favored the HPPM group in weeks 4–6 (Figure 2).

Bivariate analysis showed that heat acclimatization was significantly associated with BMI and relative humidity (Table 3). In multivariable analysis, higher BMI was negatively associated with heat acclimatization (AOR = 0.271, 95% CI: 0.102–0.719, $p = 0.009$). In contrast, moderate and high levels of knowledge were positively associated (AOR = 4.054, $p = 0.019$; AOR = 3.910, $p = 0.024$), as was high peer support (AOR = 2.654, $p = 0.006$). Interestingly, high instructor support was inversely associated (AOR = 0.368, $p = 0.012$). Environmental factors, including temperature and relative humidity, were also significant predictors, while organizational factors were not (Table 3).

Table 1 Baseline characteristics of new conscripts (n = 383)

Variables	Number	Percent
Individual Factors		
Body Mass Index (kg/m²)		
< 23 (normal)	156	40.7
23.00–27.99 (overweight, risk level 1)	78	20.4
28.00–29.99 (obese, risk level 2)	69	18.0
≥ 30 (severely obese)	80	20.9
Mean = 25.1, S.D. = 5.1, Min = 15.6, Max = 37.9		
Chronic illness		
None	295	77.0
Present	88	23.0
Regular medication use		
None	316	82.5
Present	67	17.5
History of alcohol consumption		
Non-drinker	181	47.3
Drinker	202	52.7
Frequency of exercise per week		
Never	203	53.0
Often	164	42.8
Daily	16	4.2
Exercise environment (n = 180)		
Comfortable room	49	27.2
Outdoor / non-air-conditioned	131	72.8
Participation in HPPM program		
Did not participate	234	61.1
Participated	149	38.9
Level of heat acclimatization knowledge		
Low	43	11.2
Moderate	157	41.0
High	183	47.8
Mean = 8.1, S.D. = 1.5, Min = 2, Max = 11		
Behaviors promoting heat acclimatization		
Low	52	13.6
Moderate	152	39.7
High	179	46.7
Mean = 15, S.D. = 3.3, Min = 4, Max = 20		

Table 2 Contextual factors related to heat acclimatization (n = 383)

Variables	Number	Percent
<u>Interpersonal Factors</u>		
Perceived support from peers		
Low	96	25.1
Moderate	89	23.2
High	198	51.7
Mean = 7.2, S.D. = 2.5, Min = 0, Max = 10		
Perceived support from military instructors		
Low	31	8.1
Moderate	77	20.1
High	275	71.8
Mean = 7.5, S.D. = 1.5, Min = 0, Max = 8		
<u>Organizational Factors</u>		
Heat acclimatization training policies		
Low	11	2.9
Moderate	49	12.8
High	323	84.3
Mean = 9, S.D. = 1.5, Min = 0, Max = 10		
The availability of supportive resources for heat acclimatization training		
Low	38	9.9
Moderate	55	14.4
High	290	75.7
Mean = 10.5, S.D. = 2, Min = 0, Max = 12		

Table 3 Factors associated with heat acclimatization among new conscripts.

Factors	Heat acclimatization	
	Crude OR (95% CI)	AOR (95% CI)
Individual Factors		
Body Mass Index (kg/m²)		
< 23 (normal)	1	1
23.00–27.99 (overweight, risk level 1)	.299 (.120–.747)**	.271 (.102–.719)*
28.00–29.99 (obese, risk level 2)	.997 (.502–1.981)	.745 (.289–1.919)
≥ 30 (severely obese)	.749 (.461–1.747)	.606 (.252–1.46)
Participation in HPPM program		
Did not participate	1	-
Participated	1.274 (.756–2.147)	-
Level of heat acclimatization knowledge		
Low	1	1
Moderate	1.224 (.469–3.196)	4.054 (1.263–13.014)*
High	1.67 (.657–4.24)	3.910 (1.197–12.773)*
Interpersonal Factors		
Perceived support from peers		
Low	1	1
High	1.556 (.92–2.63)	2.654 (1.318–5.343)**
Perceived support from military instructors		
Low	1	1
High	.848 (.484–1.485)	.368 (.168–.804)*
Environmental factors		
Ambient temperature (°C)		
≥ 29.6 °C	1	1
< 29.6 °C	.578 (.344–.972)*	3.186 (1.625–6.243)*
Relative humidity (%)		
≥ 60.0 %	1	1
< 60.0 %	1.698 (.921–3.132)	4.081 (1.577–10.560)*

*p < 0.05, **p < 0.01, ***p < 0.001, AOR: Adjusted Odds Ratio, CI: Confidence Interval

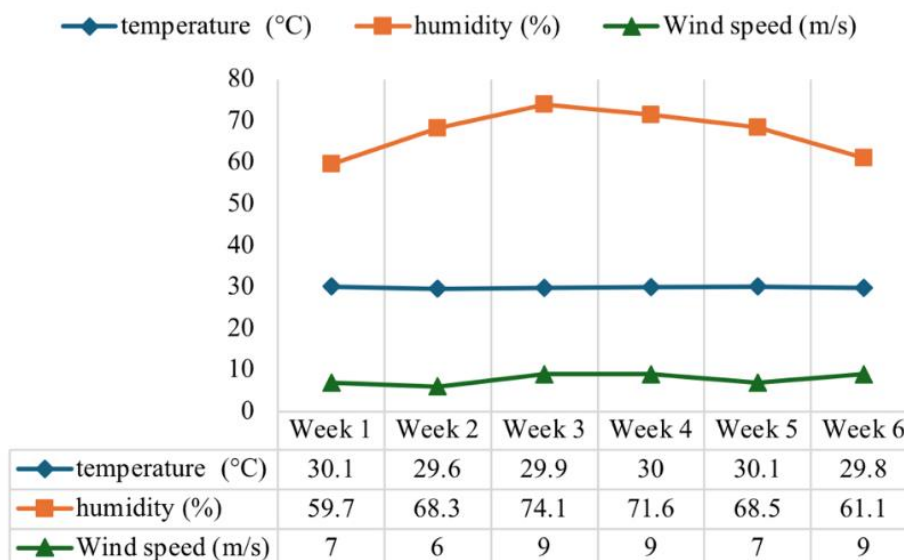


Figure 1 Environmental conditions during training across study period.

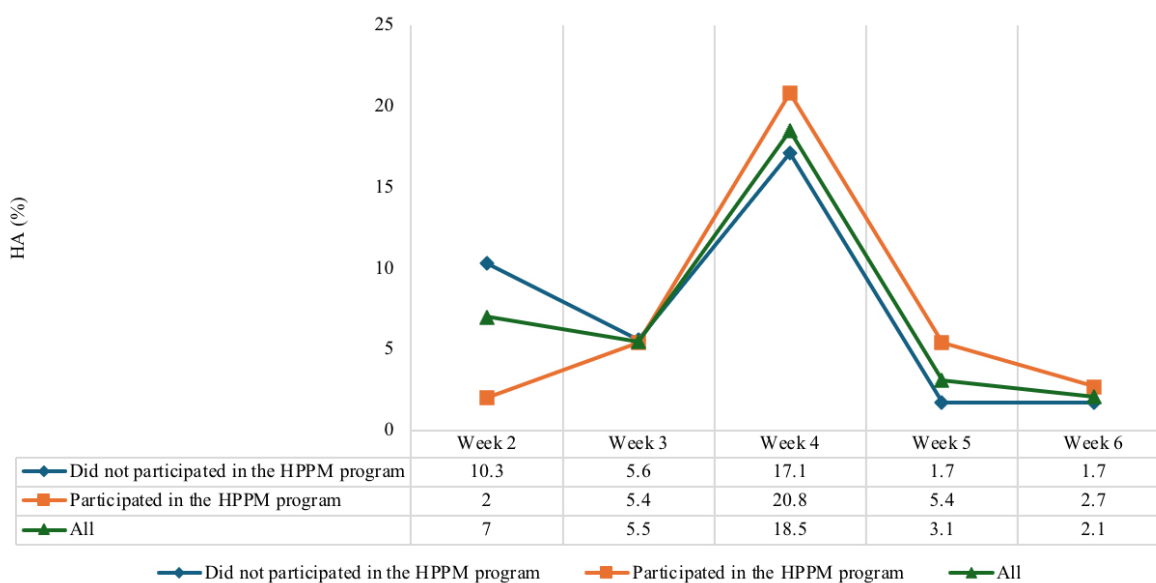


Figure 2 Proportion of new conscripts achieving full heat acclimatization by week, stratified by HPPM program participation.

Discussion

Heat acclimatization is a critical physiological process for preventing heat-related illness among military personnel, particularly in tropical environments. Previous studies among military recruits have demonstrated that acclimatization typically develops within 7–14 days, with progressive improvements in thermoregulation and cardiovascular efficiency^(1,3,4). However, evidence among Thai conscripts remains limited, particularly regarding contextual and behavioral determinants. This study aimed to evaluate heat acclimatization and identify factors associated with successful adaptation among new conscripts in Bangkok. The primary outcome was the proportion of new conscripts achieving complete heat acclimatization, while secondary outcomes included factors associated with acclimatization, including participation in the Health Promotion and Preventive Medicine (HPPM) exercise program.

In this study, only 18.5% of conscripts achieved full heat acclimatization by week 4, which is lower than that reported in some previous studies conducted in military populations^(7,16). This discrepancy may be explained by differences in environmental conditions, training intensity, and definitions of acclimatization. Notably, this study applied a stringent definition requiring simultaneous improvement in skin temperature, heart rate, and sweat rate, which may have resulted in a lower observed prevalence. Consistent with prior research, physiological adaptation—particularly reductions in heat storage and body temperature—was most evident between weeks 1 and 4⁽¹⁷⁾. This pattern reflects well-established mechanisms of heat acclimatization, including plasma volume expansion, improved cardiovascular stability, earlier onset of sweating, and increased sweat rate, which enhance heat dissipation and reduce thermal strain^(3,4). These findings align with studies in both military and occupational settings, although the magnitude and timing of adaptation may vary depending on environmental stress and individual characteristics.

Participation in the HPPM program was associated with a more favorable trend in heat acclimatization, particularly in later weeks of training. This may be explained by the structured nature of the program, which incorporates progressive overload, scheduled rest, hydration management, and supervision. These components likely promote gradual physiological adaptation, reduce excessive heat strain, and support recovery, thereby enhancing both the development and maintenance of acclimatization. Similar findings have been reported in structured heat acclimatization programs, which demonstrate improved thermoregulatory efficiency and reduced risk of heat-related illness^(18,19). The sustained advantage observed in the

HPPM group suggests that targeted interventions may be particularly beneficial for high-risk individuals, such as those with elevated BMI.

Several individual and contextual factors were significantly associated with heat acclimatization. Higher BMI was negatively associated with successful adaptation, consistent with previous studies in military populations^(20,21). Increased adiposity may impair heat dissipation due to reduced heat conduction and lower sweating efficiency. In contrast, higher levels of knowledge and strong peer support were positively associated with acclimatization, highlighting the importance of behavioral and social determinants. Interestingly, higher levels of instructor support were inversely associated with acclimatization. This finding may reflect potential selection bias, whereby instructors provide greater attention and support to recruits who are struggling to adapt, rather than those who are already acclimatizing effectively. Alternatively, overly directive support may reduce autonomy and self-regulation, as suggested by Self-Determination Theory⁽²²⁾. However, this interpretation should be made with caution, as the cross-sectional nature of these variables limits causal inference.

Environmental factors, including temperature and relative humidity, were also significantly associated with acclimatization. Lower ambient temperatures and lower humidity levels were associated with better adaptation, likely due to reduced thermal strain and more efficient evaporative cooling. These findings are consistent with established physiological principles and prior studies demonstrating that high humidity impairs sweat evaporation and increases heat storage⁽²³⁾. The use of environmental monitoring systems, such as Wet Bulb Globe Temperature, is therefore essential for optimizing training conditions and minimizing heat-related risks.

This study has several strengths. It employed a prospective cohort design with repeated physiological measurements, allowing for the assessment of dynamic changes in heat acclimatization over time. The inclusion of multiple domains—individual, interpersonal, organizational, and environmental factors—provides a comprehensive understanding of determinants of acclimatization. In addition, the use of objective physiological measures enhances the validity of the findings.

However, several limitations should be acknowledged. First, the study was conducted in a specific geographic and military context, which may limit generalizability to other settings. Second, some variables, particularly behavioral and social factors, were self-reported and may be subject to recall or social desirability bias. Third, potential selection bias may have influenced the

observed association between instructor support and acclimatization. Finally, although physiological measurements were standardized, unmeasured confounding factors may still exist.

These findings have important implications for military training and occupational health. Structured programs such as the HPPM exercise program may enhance heat acclimatization, particularly among high-risk groups. Interventions that improve knowledge, promote peer support, and optimize environmental conditions should be integrated into training protocols to reduce heat-related illness and improve operational performance. Environmental factors, including temperature and relative humidity, were significantly associated with successful heat acclimatization. While temperatures $\geq 30^{\circ}\text{C}$ typically induce sufficient heat stress, physically demanding training in thick uniforms can promote adaptation even at lower temperatures.[28] In this study, lower ambient temperature was associated with a higher likelihood of acclimatization, likely because reduced thermal strain allows recruits to perform and recover more effectively, indirectly supporting physiological adaptation. Furthermore, our findings indicate that relative humidity below 60% significantly increased the likelihood of successful acclimatization. This aligns with physiological mechanisms, as drier conditions enhance evaporative cooling, reduce heat retention and physiological stress, and thereby facilitate better adaptation. In contrast, high humidity impairs sweat evaporation, increases heat storage, and raises the risk of heat-related illness. The Royal Thai Army mitigates these risks through Wet Bulb Globe Temperature monitoring and flag-based signaling to adjust training duration and rest, balancing heat exposure with recovery and minimizing injury risk⁽⁷⁾.

Conclusion

Heat acclimatization among new conscripts in this study was limited, with 18.5% achieving full adaptation by week 4 of training. The findings suggest that heat acclimatization may be influenced by multiple factors, including body mass index, knowledge, peer support, and environmental conditions. Participation in the Health Promotion and Preventive Medicine (HPPM) exercise program showed a tendency toward improved and more sustained adaptation; however, these findings should be interpreted with caution given the observational nature of the study.

Our study indicates a possible role for a comprehensive approach to heat acclimatization in new conscripts. Implementing physiological monitoring—such as body temperature, heart rate, and sweat rate—and adjusting training programs based on environmental conditions may offer a pathway to support adaptation, although the clinical significance and effectiveness of these

strategies remain to be fully established. Strengthening knowledge and peer support may also contribute to improved adaptation, but further evidence is needed.

In the context of rising global temperatures and increasing climate change–related heat exposure, these findings may have broader implications beyond military settings, particularly for outdoor occupations such as construction workers, agricultural laborers, and emergency responders. Developing adaptive training strategies and heat risk management systems may help mitigate heat-related health risks in these populations.

Future research should employ quasi-experimental or interventional designs to better evaluate the effectiveness of structured acclimatization programs, including the HPPM program. Further studies are also needed to validate physiological indicators, explore wearable technologies for real-time monitoring, and assess the long-term sustainability of heat adaptation in operational and high-risk environments.

Ethical Approval Statement

Ethical approval for this study was obtained from the Mahidol University Institutional Review Board (Certificate of Approval No. MUPH 2022-034) and the Royal Thai Army Medical Department Institutional Review Board (Certificate of Approval No. IRBRTA 1632/2022). All procedures were conducted under relevant ethical guidelines and regulations. Informed consent was obtained from all participants before data collection. Participant confidentiality was ensured through the use of anonymous data and secure data storage protocols.

Author Contributions

CT, JA, TM, KS and DK designed the research framework, defined study objectives, and integrated the Determinants of Health model into the study. CT and DK conducted field data collection during weeks 1–6 of military training, including physiological measurements and environmental monitoring. CT and TM performed statistical analysis and interpretation of differences in heat acclimatization across training weeks and BMI groups. CT drafted the manuscript, including background, methods, results, discussion, and recommendations. JA critically revised the manuscript for intellectual content, clarity, and academic rigor. JA, TM, KS and DK provided oversight of study implementation, ensured methodological rigor, and guided interpretation of results.

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Conflicts of Interest

The authors declare no conflict of interest.

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