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ORIGINAL PAPER

Distinct risk factors for exertional heat exhaustion in competitive versus recreational amateur golfers: a stratified cross-sectional study

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Abstract

Although preventing heat illness is critical in golf, risk profiles likely vary by engagement level. This study investigated whether risk factors for exertional heat exhaustion (EHE) differ between competitive and recreational golfers. We conducted a retrospective cross-sectional study targeting amateur golfers in Japan during the summers of 2024 and 2025. A stratified analysis was performed on competitive ($n=485$) and recreational ($n=259$) groups using multivariable logistic regression to identify independent risk factors. Although perceived dehydration and loss of appetite were universal risk factors ($p<0.05$), distinct risk structures emerged. In the competitive group, sleep deprivation (adjusted odds ratio [aOR] = 2.27) and mental stress (aOR = 1.66) were significant, suggesting that psychophysiological strain associated with competitive pressure may affect subjective heat tolerance. Conversely, specific associations for the recreational group included playing ≥ 11 rounds/month (aOR = 3.63) and increased consumption of jelly drinks (aOR = 2.62) and ice cream (aOR = 2.37). These behaviors likely reflect a reactive response to early thermal discomfort, indicating cumulative fatigue from unmanaged loads and a maladaptive reliance on "sensory cooling" rather than effective rehydration. These findings reveal a clear dichotomy in EHE risk factors based on participants' competitive orientation. Competitive golfers exhibit risk structures associated primarily with physiological and psychological strain, whereas recreational golfers are vulnerable due to behavioral management and preparedness deficits. Hence, effective prevention requires targeted strategies that address distinct, group-specific risks.

Keywords Competitive orientation · Cross-sectional study · Exertional heat exhaustion · Golf · Heat stress · Mental stress

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Introduction

Global climate change has increased the frequency and intensity of heatwaves, posing a significant challenge to public health and sports safety worldwide (Ebi et al. 2021). Outdoor sports participants are directly exposed to these changing climate conditions, making them particularly vulnerable to exertional heat illness. Among these sports, golf is unique due to its prolonged duration of play (often exceeding 4–5 h), the wide age range of participants including the elderly, and the necessity of playing under direct solar radiation with limited shade (Murray et al. 2018). Reports on heat-related illnesses in specific sports are often limited to high-intensity activities, yet summer golf is increasingly recognized as a cause of heatstroke-related hospitalizations and emergency transportation (McMahon et al. 2021; Miyazawa et al. 2007). Consistent with this,

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the International Golf Federation reports that playing golf under extreme heat and humidity can lead to adverse health outcomes, including heat stroke and death, despite its lower intensity relative to sports such as tennis or athletics (IGF 2023). Similarly, the risk of heatstroke in golf was classified as moderate at the 2024 Paris Olympics, highlighting the need for vigilance even at elite levels (Bandiera et al. 2024). Consequently, identifying risk factors for exertional heat exhaustion (EHE) among amateur golfers remains a critical issue for preventing severe incidents during the summer.

Previous biometeorological studies have identified environmental factors such as ambient temperature, humidity, and solar radiation as primary determinants of heat stress (Budd 2008; Parsons 2014). However, individual susceptibility to heat stress is not determined by environmental conditions alone but also physiological and lifestyle factors (Armstrong et al. 2007; Westwood et al. 2021). A systematic review has highlighted that individual risk factors, such as sleep deprivation, physical fitness levels, and recent illness, contribute to EHE susceptibility (Westwood et al. 2021). While general guidelines, such as the "Extreme Heat Guidelines" by the International Golf Federation (2023), emphasize hydration and acclimatization, these recommendations often adopt a "one-size-fits-all" approach (IGF 2023). In reality, amateur golfers comprise a heterogeneous population ranging from serious competitors to leisure players, whose motivations, playing styles, and physiological responses vary significantly.

We previously investigated the risk factors for EHE in a broad population of amateur golfers, identifying dehydration and lack of sleep as significant contributors (Nagashima et al. 2025). However, that study analyzed the population as a single cohort, potentially masking distinct risk profiles associated with different playing styles. Notably, the mode of transport during play significantly alters physiological strain; recent research has shown that walking the course—common among competitive players—elicits significantly higher core temperatures, heart rates, and metabolic demand compared to riding a golf cart (O'Donnell et al. 2025). Beyond these physiological differences, behavioral drivers also vary: competitive athletes are often highly driven and may ignore signs of physiological fatigue (Armstrong et al. 2007), whereas recreational participants may lack fundamental knowledge about proper hydration and acclimatization (Shendell et al. 2010). Thus, analyzing these groups together may obscure role-specific risks.

Therefore, the objective of this study was to identify and compare the risk factors for subjective EHE symptoms between competitive and recreational golfers. To our knowledge, this study is the first to systematically investigate health factors, lifestyle habits, dietary behaviors, and environmental factors associated with EHE-related symptoms among golfers by stratifying levels of competitive engagement. By identifying novel risk factors and the influence of psychosocial states, this study offers practical implications for both individual golfers and tournament organizers to develop prevention strategies tailored to the golfer's competitiveness.

Materials and methods

Study design and data collection

This study builds on our previous investigation of EHE among golfers (Nagashima et al. 2025). Here, we implemented a retrospective cross-sectional design targeting amateur golfers in the Kanto region, Japan, an area selected for its representative climatic conditions and high density of golf courses. Data collection was expanded from the previous study to cover two seasons. The survey was administered during the transition from September 20 to October 30, 2024 and during the same period in 2025. The dataset comprises responses from the 2024 cohort (partially reported in Nagashima et al. 2025) combined with newly collected data from the 2025 cohort to allow for a more robust stratified analysis. Recruitment methods remained consistent with our established protocol; recruitment materials were distributed at competition venues hosted by the Kanto Golf Club and the Kanto Golf Association and posted at driving ranges across the region. Participants accessed an online questionnaire via a QR code, where informed consent was obtained digitally from all respondents prior to participation. This study followed the Declaration of Helsinki guidelines, and all procedures were approved by the Ethics Committee of Musashigaoka Junior College, Japan (No. 24–2, July 12 2024).

Participants and eligibility

To ensure the study population represented active golfers capable of sustaining standard play, inclusion was limited to individuals who played a minimum of one round per month. The following exclusion criteria were established to maintain data integrity and minimize confounding factors:

1. **Incomplete or inconsistent responses**: Data underwent rigorous manual screening by researchers to verify completeness and logical consistency.
2. **Lack of informed consent**: Individuals who did not provide digital consent were excluded.
3. **Orthopedic limitations**: Participants with pre-existing musculoskeletal disorders (e.g., chronic low back pain, knee or hip osteoarthritis) that restricted playing intensity or duration were excluded to ensure that reported symptoms were primarily attributable to environmental or physiological heat stress rather than physical pain.

Stratification of competitive engagement

After eligibility screening, a key distinction of the present study from previous investigations is the stratification of participants based on competitive engagement. Unlike our previous work that analyzed the population as a whole (Nagashima et al. 2025), this study classified participants into two distinct groups to examine role-specific risks based on their self-reported participation in official competitions:

1. **Competitive group**: Golfers actively participating in official competitions organized by golf associations or clubs.
2. **Recreational group**: Golfers playing primarily for leisure and social interaction without regular entry in official competitions.

Questionnaire and measures

We implemented the structured questionnaire developed in our previous study (Nagashima et al. 2025), which reliably assessed EHE risk factors in this demographic. The survey required participants to recall their experiences during the summer months (May to September) of the respective survey year (2024 or 2025).

Definition of EHE and case categorization

Consistent with the previous study, we adopted the clinical definition established by the Japanese Association for Acute Medicine (JAAM), which considers the subjective onset of symptoms (e.g., dizziness, headache, nausea, or malaise) as the primary indicator of EHE (JAAM 2015). This differs from Western definitions such as those by the National Athletic Trainers' Association that often prioritize the inability to continue exercise or central nervous system dysfunction (e.g., collapse) (Casa et al. 2015). Here, participants were categorized into the "EHE-related symptom experienced group" (case) or the control group based on their response to the following dichotomous questionnaire item: "When playing golf in the summer (May–September), have you ever felt symptoms such as dizziness, headache, nausea, or malaise (becoming tired easily)?" Participants who selected "Yes" were assigned to the case group, whereas those who selected "No" served as the control group.

Assessment of risk factors

The questionnaire assessed four domains of potential risk factors. Variables were categorized as previously described as follows (Nagashima et al. 2025):

- **Lifestyle habits**: Including monthly round frequency (cutoff at 11 rounds, adopted from our previous study (Nagashima et al. 2025) to ensure comparability), weekly exercise frequency, and sleep environment (air conditioning use).
- **Health factors**: Seven subjective items including loss of appetite, sleep deprivation, and mental stress. Mental stress was assessed via a single dichotomous item aimed at capturing the subjective feeling of generalized psychological pressure, tension, or performance anxiety that can be associated with golfing, rather than a specific clinical psychiatric construct.
- **Eating behaviors**: Changes in the intake of eight specific items (e.g., sports drinks, supplements) compared to cooler seasons, rated on a 3-point scale (increased/usual/decreased).
- **Environmental factors**: Subjective assessment of playing conditions (e.g., high temperature, lack of wind).

Statistical analyses

The sample size was determined to ensure sufficient statistical power for the stratified analysis (competitive vs. recreational). We calculated that a minimum of approximately 200 participants per group was required to detect a medium effect size (corresponding to an odds ratio of 1.7) with a statistical power of 0.80 and a significance level of $\alpha = 0.05$. Data from two seasons were then combined to achieve a total sample size of 744, which provided adequate power to identify role-specific risk factors within each subgroup.

Statistical procedures were performed using JMP Pro v18.2.2 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics were generated, and differences between the competitive and recreational groups were assessed using Pearson's chi-square test. The primary analysis included multivariable logistic regression using the "Fit Model" platform. To elucidate the distinct risk structures for each golfer type, analyses were stratified by group (competitive vs. recreational).

Independent variables were selected based on statistical significance in the univariate analysis (chi-square test) or clinical relevance established in previous studies. Among them, loss of appetite, sleep deprivation, dehydration symptoms, accumulated fatigue, mental stress, and sports drink intake were included based on their consistent association with EHE in the literature (Nagashima et al. 2025). These selected variables were included in the models using the forced entry method. Crucially, to eliminate the potential confounding influence of baseline demographic differences between the two groups (Table 1), variables including age, sex, body weight, and underlying medical conditions were included as covariates to adjust for their effects (Westwood et al. 2021). Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) were calculated to quantify the strength of associations.

Reference categories were defined as "usual consumption" for eating behaviors and "absence" for health factors, lifestyle habits, and environmental factors. Dummy variables were initially created for "increased" and "decreased" intake in eating behaviors. However, preliminary analyses revealed no significant associations between "decreased" intake and EHE symptoms. Therefore, only the results for "increased" intake are presented to align with the study's focus on risk-enhancing behaviors. Furthermore, to statistically verify the hypothesis that psychological stress differentially impacts EHE risk depending on competitive engagement, we introduced an interaction term (mental stress × golfer type) into the logistic regression model. Statistical significance was defined as $p < 0.05$.

Results

Participant characteristics

A total of 759 responses were obtained from the survey across the two-year period. After excluding 12 respondents who did not meet the eligibility criteria (e.g., incomplete responses, lack of consent, or active orthopedic issues), an additional three respondents who did not disclose their sex were excluded because sex was a required covariate for the multivariable adjustment models. Consequently, a total of 744 participants were included in the final analysis. Based on their engagement in official competitions, 485 participants were classified into the competitive group and 259 into the recreational group.

The demographic features of these participants are summarized in Table 1. Significant differences were observed between the two groups in several baseline characteristics. The recreational group had a significantly higher proportion of males compared to the competitive group (72.2% vs. 62.9%, $p = 0.010$). Additionally, the competitive group was significantly younger ($p = 0.033$), had significantly lower body mass ($p = 0.007$), and a significantly lower prevalence of underlying medical conditions ($p = 0.030$).

Comparison of lifestyle habits, health factors, and behaviors

Table 2 compares the lifestyle habits, perceived health factors, eating behaviors, and environmental conditions between the competitive and recreational groups. Regarding lifestyle habits, the competitive group was significantly more engaged in athletic activities and maintained more favorable health behaviors, characterized by regular dietary intake and longer sleep duration. Specifically, they reported a higher frequency of monthly golf rounds (≥11 rounds: 24.1% vs. 9.7%, $p < 0.001$), higher weekly exercise frequency ($p < 0.001$), and

Table 1 Participants' demographic characteristics

Characteristics	Total ($n = 744$)	Competitive ($n = 485$)	Recreational ($n = 259$)	p-value
Sex				
Male	492 (66.1)	305 (62.9)	187 (72.2)	0.010
Female	252 (33.9)	180 (37.1)	72 (27.8)	
Age Categories (years)				
<40	146 (19.6)	109 (22.5)	37 (14.3)	0.033
40–59	359 (48.3)	222 (45.8)	137 (52.9)	
≥60	239 (32.1)	154 (31.8)	85 (32.8)	
Body Weight (kg)				
<40	2 (0.3)	2 (0.4)	0 (0.0)	0.007
40–49	54 (7.3)	37 (7.6)	17 (6.6)	
50–59	172 (23.1)	127 (26.2)	45 (17.4)	
60–69	233 (31.3)	143 (29.5)	90 (34.8)	
70–79	174 (23.4)	118 (24.3)	56 (21.6)	
80–89	85 (11.4)	49 (10.1)	36 (13.9)	
90–99	17 (2.3)	6 (1.2)	11 (4.3)	
≥100	7 (0.9)	3 (0.6)	4 (1.5)	
Underlying Conditions				
Yes	158 (21.2)	91 (18.8)	67 (25.9)	0.030
No	586 (78.8)	394 (81.2)	192 (74.1)	

Note. Categorical data are expressed as counts and percentages

The chi-squared test was used to compare differences between the competitive and recreational groups

Statistical significance was defined as $p < 0.05$

longer exercise duration per session ($p<0.001$). Furthermore, the competitive group reported a higher prevalence of sufficient sleep duration (>6 h) during the summer (47.0% vs. 31.3%, $p<0.001$) and a higher frequency of consuming balanced meals ($p=0.003$) and daily breakfast ($p<0.001$).

Significant differences were also observed in dietary strategies. In the univariate analysis (Table 2), the competitive group reported a significantly higher rate of increased intake for jelly drinks (gels) (40.0% vs. 15.4%, $p<0.001$), fruits (16.5% vs. 6.9%, $p<0.001$), and dietary supplements (24.7% vs. 13.9%, $p<0.001$) compared to the recreational group. In contrast, no significant differences were observed in the environmental conditions experienced during play (e.g., high temperature, humidity) or in most subjective health symptoms, although loss of appetite tended toward significance ($p=0.061$).

Factors associated with EHE-related symptoms

The factors associated with EHE-related symptoms are stratified by golfer type and detailed in Table 3, and the aORs are visualized in Fig. 1. Perceived dehydration symptoms were identified as a strong risk factor for EHE-related symptoms in both the competitive (aOR=3.90, 95% CI 2.46–6.18, $p<0.001$) and recreational groups (aOR=4.73, 95% CI 2.27–9.84, $p<0.001$). Loss of appetite was also a significant risk factor for both groups (competitive: aOR=2.76, 95% CI 1.72–4.45, $p<0.001$; recreational: aOR=2.30, 95% CI 1.09–4.87, $p=0.030$).

Distinct risk profiles were observed between groups. In the competitive group, sleep deprivation (aOR=2.27, 95% CI 1.39–3.73, $p=0.001$) and mental stress (aOR=1.66, 95% CI 1.01–2.77, $p=0.045$) were significantly associated with the onset of EHE-related symptoms. In contrast, for the recreational

Table 2 Factor comparison between competitive and recreational golfers

Variables	Total ($n=744$)	Competitive ($n=485$)	Recreational ($n=259$)	p-value
Health factors				
Loss of appetite	322 (43.3)	222 (45.8)	100 (38.6)	0.061
Sleep deprivation	449 (60.3)	296 (61.0)	153 (59.1)	0.603
Poor physical condition	160 (21.5)	112 (23.1)	48 (18.5)	0.150
Hangover	124 (16.7)	82 (16.9)	42 (16.2)	0.811
Dehydration symptoms	345 (46.4)	227 (46.8)	118 (45.6)	0.751
Accumulated fatigue	611 (82.1)	400 (82.5)	211 (81.5)	0.732
Mental stress	447 (60.1)	301 (62.1)	146 (56.4)	0.136
Lifestyle habits				
Average monthly rounds (≥11 times)	142 (19.1)	117 (24.1)	25 (9.7)	<0.001
Weekly exercise frequency (high)	562 (75.5)	401 (82.7)	161 (62.2)	<0.001
Exercise duration (long)	575 (77.3)	393 (81.0)	182 (70.3)	<0.001
Average sleep duration (long)	309 (41.5)	228 (47.0)	81 (31.3)	<0.001
Air conditioner use (yes)	695 (93.4)	455 (93.8)	240 (92.7)	0.551
Balanced meals (3 times/day)	212 (28.5)	156 (32.2)	56 (21.6)	0.003
Breakfast consumption (daily)	599 (80.5)	408 (84.1)	191 (73.7)	<0.001
Eating behaviors				
Sports drinks	558 (75.0)	368 (75.9)	190 (73.4)	0.443
Jelly drinks (gels)	234 (31.5)	194 (40.0)	40 (15.4)	<0.001
Milk/Dairy products	43 (5.8)	32 (6.6)	11 (4.2)	0.197
Fruits	98 (13.2)	80 (16.5)	18 (6.9)	<0.001
Pickled plums (umeboshi)	192 (25.8)	135 (27.8)	57 (22.0)	0.086
Ice creams/Sherbets	293 (39.4)	203 (41.9)	90 (34.7)	0.060
Salt tablets	445 (59.8)	293 (60.4)	152 (58.7)	0.647
Dietary supplements	156 (21.0)	120 (24.7)	36 (13.9)	<0.001
Environmental factors				
High ambient temperature	723 (97.2)	474 (97.7)	249 (96.1)	0.218
High humidity	719 (96.6)	473 (97.5)	246 (95.0)	0.065
Strong sunlight	723 (97.2)	473 (97.5)	250 (96.5)	0.428
No wind	716 (96.2)	467 (96.3)	249 (96.1)	0.916
Clothing discomfort	531 (71.4)	349 (71.9)	182 (70.3)	0.630
Short break duration	262 (35.2)	173 (35.7)	89 (34.4)	0.725

Note. Categorical data are expressed as counts and percentages

The chi-squared test was used to compare differences between the competitive and recreational groups

Statistical significance was defined as $p<0.05$

group, playing 11 or more rounds per month (aOR = 3.63, 95% CI 1.10–11.81, $p = 0.034$) was a significant risk factor. Regarding eating behaviors, increased consumption of jelly drinks (gels) (aOR = 2.62, 95% CI 1.01–6.81, $p = 0.048$) and ice cream/sherbet (aOR = 2.37, 95% CI 1.07–5.24, $p = 0.033$) were identified as significant risk factors specific to this group.

Interaction analysis

To further examine the role of mental stress, we included an interaction term in the model (mental stress × golfer type), which tended toward statistical significance depending on golfer type ($p = 0.070$). This finding suggests that the impact of mental stress on EHE risk may be more pronounced among competitive golfers compared to recreational golfers.

Discussion

To our knowledge, this is the first study to investigate the risk factors associated with EHE among amateur golfers by stratifying participants based on their competitiveness. Notably, the risk structure for EHE differs depending on the golfer type, even when exposed to similar environmental conditions. Although perceived dehydration and loss of appetite were strong common risk factors across groups, distinct role-specific risks emerged. Specifically, mental stress and sleep deprivation were risk factors specific to the competitive group. This finding aligns with the systematic review by Westwood et al. (2021), who identified sleep deprivation and recent illness as consistent individual risk factors for EHE across various populations. In contrast, high frequency of play and increased consumption of jelly drinks and ice cream/sherbet were risk factors specific to the recreational group.

Moreover, the interaction analysis indicated a tendency ($p = 0.070$) for mental stress to have a stronger impact on EHE risk in competitive golfers. These results suggest that EHE prevention strategies in biometeorological contexts should address not only physical acclimatization and hydration but also psychological management tailored to the golfer's level of engagement.

Our results confirmed that perceived dehydration and loss of appetite are universal risk factors for EHE among amateur golfers, regardless of their competitive level. This

Table 3 Multivariable logistic regression analysis of factors associated with heat exhaustion by group

Variables	Competitive group aOR (95% CI)	Competitive *P*-value	Recreational group aOR (95% CI)	Recreational *P*-value
Health factors				
Loss of appetite	2.76 (1.72–4.45)	< 0.001	2.30 (1.09–4.87)	0.030
Sleep deprivation	2.27 (1.39–3.73)	0.001	1.00 (0.46–2.18)	0.993
Dehydration symptoms	3.90 (2.46–6.18)	< 0.001	4.73 (2.27–9.84)	< 0.001
Accumulated fatigue	0.74 (0.39–1.41)	0.361	2.15 (0.72–6.38)	0.168
Mental stress†	1.66 (1.01–2.77)	0.045	0.74 (0.36–1.50)	0.398
Lifestyle habits				
Average monthly rounds (≥ 11 times)	1.31 (0.77–2.21)	0.317	3.63 (1.10–11.81)	0.034
Weekly exercise frequency (High)	0.75 (0.35–1.64)	0.470	0.96 (0.40–2.31)	0.935
Exercise duration (Long)	1.31 (0.63–2.76)	0.470	1.16 (0.46–2.93)	0.750
Average sleep duration (Long)	0.97 (0.60–1.59)	0.915	0.87 (0.41–1.85)	0.723
Balanced meals (3 times/day)	0.84 (0.52–1.36)	0.589	1.63 (0.68–3.93)	0.273
Breakfast consumption (Daily)	1.18 (0.62–2.22)	0.693	0.65 (0.29–1.46)	0.260
Eating behaviors (High intake)				
Sports drinks	1.39 (0.77–2.52)	0.276	0.72 (0.29–1.81)	0.487
Jelly drinks (gels)	0.95 (0.55–1.63)	0.848	2.62 (1.01–6.81)	0.048
Fruits	0.99 (0.53–1.84)	0.966	1.36 (0.39–4.72)	0.628
Ice creams/Sherbets	0.76 (0.46–1.25)	0.282	2.37 (1.07–5.24)	0.033
Dietary supplements	1.03 (0.59–1.79)	0.911	1.76 (0.63–4.89)	0.278
Environmental conditions				
High humidity	2.11 (0.38–11.7)	0.394	0.35 (0.09–1.36)	0.129

Note: *aOR* adjusted odds ratios (aOR)

CI 95% confidence intervals (CI)

Models were adjusted fully adjusted for sex, age, body mass, and underlying diseases to eliminate potential confounding effects

The reference categories were set as "usual consumption" for eating behaviors and "absence" for health factors, lifestyle habits, and environmental factors

Statistical significance was defined as $p < 0.05$. "Decreased" intake was included in the analysis but showed no significant associations and was omitted from this table

† The interaction term (Mental stress × Golfer type) showed a tendency toward significance ($p = 0.070$), suggesting the impact of mental stress on EHE may differ between competitive and recreational golfers

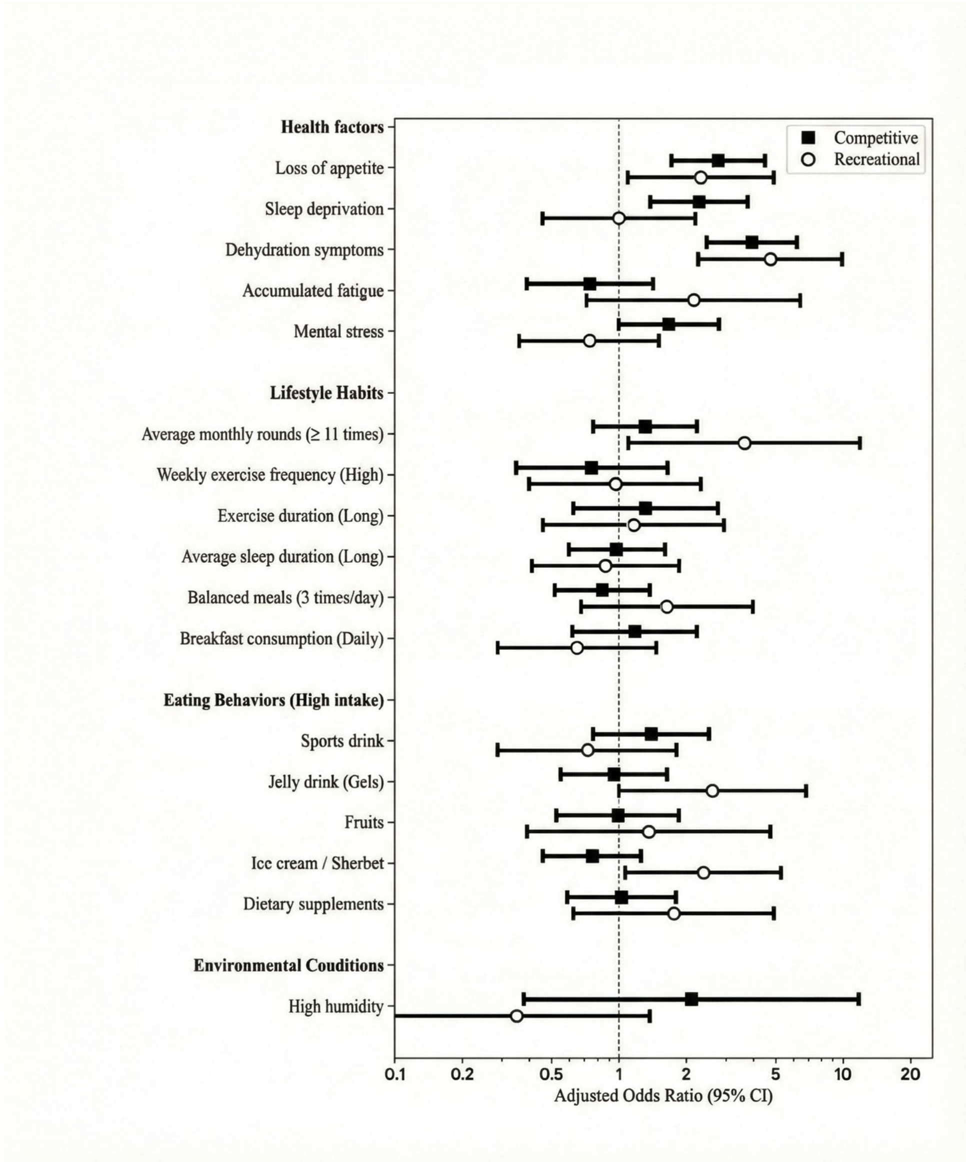

Fig. 1 Forest plot of adjusted odds ratios for factors associated with EHE-related symptoms, stratified by golfer type. Closed squares (■) and open circles (○) represent the competitive and recreational groups, respectively. Error bars indicate 95% confidence intervals. Note: Data for "decreased" intake are not shown as no significant associations were found. Logistic regression models were adjusted for sex, age, body mass, and underlying diseases. Abbreviations: EHE, exertional heat exhaustion; aOR, adjusted odds ratio; CI, confidence interval

finding is consistent with our previous study on the general golfer population (Nagashima et al. 2025) and other studies involving athletes in endurance sports (Armstrong et al. 2007; Périard et al. 2017). Given that golf involves prolonged exposure to outdoor thermal stress, relying on subjective thirst is problematic because dehydration is often advanced by the time subjective symptoms appear (Cheuvront and Kenefick 2014; Greenleaf 1992). Furthermore, loss of appetite, which may reflect heat-related malaise or gastrointestinal distress caused by splanchnic ischemia (reduced blood flow to the gut) (Costa et al. 2017; Périard et al. 2021), can lead to insufficient energy and electrolyte intake, thereby reducing heat tolerance and exacerbating symptoms. Therefore, maintaining adequate hydration and nutritional intake remains the fundamental pillar of EHE prevention for all golfers exposed to hot environments.

A novel finding of the present study is that mental stress is a significant risk factor in the competitive group. In our previous report (Nagashima et al. 2025), mental stress was found to be a risk factor for the overall population; however, the current stratified analysis reveals that this is primarily observed in competitive golfers. Interestingly, competitive golfers practiced better lifestyle habits compared to the recreational group, including longer sleep duration, more frequent exercise, and regular intake of balanced meals. Despite these favorable health behaviors and potential heat acclimatization through frequent play, mental stress was nevertheless significantly associated with elevated EHE risk. This apparent paradox suggests that the psychological pressure associated with competitions—such as performance anxiety, tension, and the need for sustained concentration—may impose an additional physiological load. It is well documented that mental fatigue can impair physical endurance while increasing perceived exertion (Marcora et al. 2009). Furthermore, psychological stress has been suggested to influence autonomic and thermoregulatory responses under heat stress conditions (Oka 2015; Périard et al. 2017), which might exacerbate subjective heat vulnerability during competitive play. The interaction observed ($p = 0.070$) further supports this hypothesis, implying that the physiological consequences of stress may differ qualitatively between those playing leisurely and those playing competitively.

In the recreational group, specific risk factors included a high frequency of play (≥11 rounds per month) and increased consumption of jelly drinks and ice cream. Notably, although the competitive group played more frequently on average, high frequency was not a risk factor for them. It is well established that high aerobic fitness and heat acclimatization confer physiological protection against heat stress (Sawka et al. 2011). In contrast, recreational golfers likely lack these adaptations; therefore, engaging in frequent rounds likely exceeds their recovery capacity. Our previous study identified accumulated fatigue as a potent risk factor for EHE in the general golfer population (Nagashima et al. 2025); the present finding extends this by suggesting that "high frequency" acts as a behavioral proxy among recreational players for this dangerous accumulation of fatigue. The possibility of reverse causality must be considered in the association with jelly drinks and ice cream; therefore, these variables should be interpreted as behavioral manifestations or direct consequences of heat stress rather than pre-existing baseline risk factors. The increased consumption of these items may simply reflect a behavioral response to thermal discomfort or early fatigue. When recreational golfers begin to experience early symptoms of heat strain, they may preferentially seek "sensory cooling" and palatability through cold, sweet items as a coping mechanism, a process driven by behavioral thermoregulation (Schlader et al. 2011). However, relying on these hypertonic items often provides only perceptual relief without effectively lowering core temperature or restoring fluid and electrolyte balance compared to water or sports drinks (Maughan and Leiper 1999; Jay and Morris 2018). Thus, the high intake of ice cream and gels in this group is likely a behavioral indicator of underlying heat strain and an insufficient cooling strategy. The robustness of this finding was supported by the fact that ice cream consumption already showed marginal significance in the univariate analysis ($p = 0.060$).

Our findings in amateur golfers largely support this dichotomy. Although golf is a lower-intensity sport compared to marathon running, the identification of mental stress and sleep deprivation as risk factors in our competitive group parallels the high physiological and psychological strain observed in elite athletes, for whom psychological stress is known to impair physical recovery and immunity (Stults-Kolehmainen and Sinha 2014). Conversely, the risk factors identified in our recreational group, such as excessive round frequency and reactive consumption of jelly drinks and ice cream, may reflect the issues of behavioral management and lack of preparedness often cited in recreational populations.

Specifically, the association between playing 11 or more rounds per month and EHE symptoms suggests that accumulated fatigue from frequent exposure to heat without adequate recovery or physical conditioning may increase susceptibility to EHE in recreational players. Additionally, the association with consumption of jelly drinks and ice cream likely reflects the maladaptive reactive strategy discussed above. Previous studies suggest that reactive intake strategies (e.g., drinking to thirst) are often insufficient for preventing dehydration and performance decrements in hot environments compared to planned intake (Kenefick 2018). This reliance on reactive strategies likely stems from a fundamental lack of knowledge on heat illness prevention and proper hydration strategies, consistent with findings in other recreational cohorts (Shendell et al. 2010; O'Neal et al. 2011). Therefore, the observed risk could be attributed to inappropriate timing and physiological state at ingestion rather than the products themselves, highlighting the need for nutritional education that targets recreational golfers.

The findings of this study emphasize the importance of targeted prevention strategies rather than a "one-size-fits-all" approach. For competitive golfers, prevention protocols should extend beyond on-course hydration to include off-course conditioning, specifically sleep hygiene and stress management. Coaches and organizers should be aware that psychological pressure can exacerbate physiological strain; therefore, adequate rest and psychological relaxation off the course should be prioritized. Strategies to optimize sleep quality and facilitate recovery are needed to counteract the psychological and physiological strain associated with high competitive stress (Bird 2013; Halson 2014).

Conversely, for recreational golfers, golf courses and associations should educate players on the specific behavioral risks identified in this study, as organizational policy and education are proven cornerstones of heat illness prevention (Stoecklin-Marois et al. 2013). It should be emphasized that relying on jelly drinks or ice cream provides only temporary sensory relief and cannot replace the physiological rehydration provided by sports drinks, which are essential for fluid retention and electrolyte restoration (Sawka et al. 2007). Furthermore, it should be noted that frequent play (e.g., 11 or more rounds per month) may lead to accumulated fatigue, which could significantly increase susceptibility to EHE. Just as competitive athletes strictly manage their training loads to prevent injury (Soligard et al. 2016), recreational players should monitor their play frequency and ensure adequate recovery days to prevent silent accumulation of heat strain. By tailoring interventions to these distinct risk profiles, safety guidelines can be made more effective and relevant for the diverse population of amateur golfers.

This study has several limitations. First, due to its retrospective cross-sectional design, we cannot establish strict causality between the identified risk factors and EHE symptoms. For instance, it remains unclear whether mental stress directly increases physiological susceptibility or if individuals prone to heat strain perceive higher stress levels. To establish clearer causal links, future research should implement prospective cohort designs that monitor golfers throughout a season. Second, there may be recall bias, as data were collected via self-administered questionnaires at the end of the summer season. The accuracy of reporting specific quantitative details—such as precise fluid intake volumes, exact sleep duration, or the timing of nutritional intake—may have been compromised by the time lag. This potential inaccuracy could introduce non-differential misclassification (random error), which generally biases results toward the null, leading to an underestimation of true associations (Coughlin 1990). Conversely, differential recall bias cannot be ruled out; participants who experienced distinct EHE symptoms may have recalled their negative conditions (e.g., mental stress or lack of sleep) more vividly or critically than asymptomatic controls, potentially leading to an overestimation of certain risk factors. Mental stress was evaluated using a single self-reported item rather than a validated, multi-item psychological assessment tool (e.g., the State-Trait Anxiety Inventory or the Perceived Stress Scale). While this enabled rapid assessment that was suitable for a large-scale field survey, it limited the precision and construct validity of the measurements. Future studies should employ established psychological scales to more accurately quantify the specific dimensions and severity of mental stress. Additionally, while self-reported regular exercise habits were included in the models as a proxy for physical activity, baseline physiological fitness levels (e.g., VO^2max), a known independent factor for heat tolerance, was not objectively measured. Third, the categorization of round frequency (≥11 rounds/month) was adopted based on our previous research targeting the general golfer population. Given that competitive golfers generally maintain a higher baseline frequency of play, this threshold may have insufficiently captured "excessive" volume for this specific subgroup. To address this potential ceiling effect, future investigations should analyze round frequency as a continuous variable or establish higher categorical thresholds (e.g., ≥15 or 20 rounds/month) to reveal dose-response relationships. Moreover, quantifying cumulative physical load using objective metrics (e.g., GPS tracking or heart rate monitoring) would provide a more precise assessment of overuse risk. Fourth, the diagnosis of EHE was based on subjective symptoms rather than physiological measurements. It should be noted that the diagnostic criteria for heat illness differ between Japan and Western countries. In Japan, clinical guidelines emphasize a symptom-based severity classification to facilitate rapid on-site triage (JAAM 2015), whereas international definitions often define core temperature thresholds (Bouchama and Knochel 2002). Although the JAAM 2015 guidelines classify heat illness into three severity levels (Grades I–III), the symptom-based classification for early stages (Grades I–II) remains central to prevention strategies. Consequently, milder cases may be captured by our symptom-driven definition than by studies enforcing strict physiological criteria, though our findings are nevertheless highly relevant for public health interventions in mass-participation sports to prevent progression to severe heat stroke. Future research incorporating wearable technology to measure real-time physiological metrics would help bridge the gap between subjective symptoms and physiological strain (Buller et al. 2013; Notley et al. 2018). Fifth, although we stratified participants by competitive engagement, the sample was recruited primarily from specific organizations in the Kanto region, restricting the generalizability of our findings. Multi-center studies across diverse climatic regions including non-affiliated recreational golfers are needed to validate the universality of these risk profiles. Finally, while we assessed subjective environmental factors (e.g., perceived high temperature and humidity, as shown in Table 2), objective biometeorological data for each specific round were not individually linked. Furthermore, critical circumstantial factors—such as the time of day when the games were played (e.g., morning vs. afternoon), total play duration, and the availability of shade—were not captured. The lack of specific temporal and meteorological conditions limits our ability to evaluate how perceived heat stress and EHE incidence may vary across different seasonal or environmental contexts. Golf courses possess unique microclimates (e.g., variations in solar radiation and wind speed due to topography and vegetation) that regional weather station data may not fully capture (Vanos et al. 2010). Future research should include on-site biometeorological monitoring combined with detailed play-time tracking to elucidate the interaction between microclimates and individual physiological responses.

Conclusions

This study demonstrates that while environmental heat stress is a prerequisite for EHE, the specific risk factors vary significantly according to the golfer's competitive orientation. Competitive golfers are more vulnerable to psychophysiological strain, specifically mental stress and sleep deprivation, underscoring the necessity of off-course recovery strategies to potentially mitigate psychological strain and facilitate recovery. In contrast, EHE symptoms in recreational golfers were associated with excessive play and an inappropriate reliance on sensory cooling products (e.g., jelly drinks and ice cream), which may reflect a fundamental gap in knowledge on exertion management and physiological rehydration. These findings highlight that effective EHE prevention in golf requires a paradigm shift from a "one-size-fits-all" approach to targeted interventions; stress management and sleep hygiene should be prioritized among competitive athletes, whereas recreational players should be educated on managing playing frequency and proper hydration.

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Data availability The datasets generated and/or analyzed during this study are not publicly available because our ethical approval did not include the use of these data by other researchers. The materials pertinent to this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Musashigaoka Junior College, Japan (No. 24–2, July 12, 2024) and the Kanto Golf Association Golf Promotion Committee Medical Department Meeting.

Consent to participate Informed consent was obtained from all individual participants included in the study.

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