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Core Body Temperatures in Collegiate Marching Band Artists During Rehearsals and Performances

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Context: To our knowledge, no researchers have investigated thermoregulatory responses and exertional heat illness (EHI) risk factors in marching band (MB) artists performing physical activity in high environmental temperatures.

Objective: To examine core temperature (T_c) and EHI risk factors in MB artists.

Design: Descriptive epidemiology study.

Setting: Three rehearsals and 2 football games for 2 National Collegiate Athletic Association Division I institution's MBs.

Patients or Other Participants: Nineteen volunteers (females = 13, males = 6; age = 20.5 ± 0.9 years, height = 165.1 ± 7.1 cm, mass = 75.0 ± 19.1 kg) completed the study.

Main Outcome Measure(s): We measured T_c, wet bulb globe temperature, and relative humidity preactivity, during activity, and postactivity. Other variables were activity time and intensity, body surface area, hydration characteristics (fluid volume, sweat rate, urine specific gravity, percentage of body mass loss), and medical history (eg, previous EHI, medications). The statistical analysis consisted of descriptive information (mean ± standard deviation), comparative analyses that determined differences within days, and correlations that identified variables significantly associated with T_c.

Results: The mean time for rehearsals was 102.8 ± 19.8 minutes and for games was 260.5 ± 47.7 minutes. Mean maximum T_c was 39.1 ± 1.1°C for games and 38.4 ± 0.7°C for rehearsals; the highest T_c (41.2°C) occurred during a game. Fluid consumption did not match sweat rates ($P < .001$). Participants reported to games in a hypohydrated state 63.6% of the time. The maximum T_c correlated with the maximum wet bulb globe temperature ($r = 0.618$, $P < .001$) and was higher in individuals using mental health medications ($r_{pb} = -0.254$, $P = .022$) and females ($r_{pb} = 0.330$, $P = .002$). Body surface area ($r = -0.449$, $P < .001$) and instrument mass ($r = -0.479$, $P < .001$) were negatively correlated with T_c.

Conclusions: Marching band artists experienced high T_c during activity and should have access to athletic trainers who can implement EHI-prevention and -management strategies.

Key Words: exertional heat illness, thermoregulation, performing arts, environment

Key Points

- During football season rehearsals and game days, marching band artists demonstrated high core temperatures and exhibited several risk factors for exertional heat illness.
- Athletic trainers and band administrators should work with student health, athletics, and other institutional partners to develop prevention and management strategies for exertional heat illness to ensure that marching band artists receive appropriate medical care.

Marching band (MB) is a popular activity among high school and collegiate students. Some MBs may have only 10 members, whereas larger institutions and elite performing groups (ie, Drum Corps International) can range from 100 to more than 300 members. Marching band artists face many of the same physical activity demands, risks, and injuries as traditional student-athletes.[1] However, unlike collegiate student-athletes who have access to multiple sports medicine providers (athletic trainers [ATs], physicians, strength and conditioning specialists, nutritionists, etc), collegiate MB artists are often considered part of the general student body. It is common for band directors or other nonmedical personnel to be responsible for recognizing and referring MB artists with a medical concern to student health, a stadium first-aid station during games, or other community health care facilities. Musculoskeletal injuries are prevalent in MB artists and attributed to the physical movements during a show (eg, running or high-step marching) and carrying instruments,[2,3] but musculoskeletal injuries are not the only health care concern common to student-athletes and MB artists.

Similar to fall-sport student-athletes (eg, football, soccer), MB artists complete preseason activity at the beginning of August, which includes rehearsing for football performances (pregame and half time) outdoors for several hours a day in high heat and humidity.[1] Preseason is the most dangerous time for fall-sport student-athletes to experience exertional heat illness (EHI), especially exertional heat stroke. In an epidemiologic study[4] of 25 National Collegiate Athletic Association sports, student-athletes experienced 232 EHI events over 5 years. Most EHIs occurred during preseason (64.7%) and practices (72.8%) and were associated with football (75%).[4] To our knowledge, no researchers have documented core body temperature (T_c) among MB artists, and little scholarly evidence exists on EHI occurrence among MB artists. Most studies[1,5] of MB members that examined injuries or illnesses were retrospective, used self-reported data at the end of a season, or combined heat illnesses with other nonmusculoskeletal illnesses. Heat distress accounted for 6% to 8% of health clinic visits during a high school band camp in August.[2] In unpublished data from our research group, 50.6% (611/1207) of collegiate MB artists indicated previously experiencing EHI associated with MB activities. News stories[6–11] have demonstrated that hundreds of MB artists were hospitalized due to EHI, including exertional heat stroke. Despite the lack of scientific evidence, MB artists not only have similar physical and environmental demands as student-athletes, but they also have other risk factors that predispose them to EHIs.

Based on known risk factors in other populations[12–14] and anecdotal experience, MB artists' EHI risks may include a lack of knowledge about proper hydration and nutrition; not gradually increasing exercise duration and intensity; a lack of heat acclimatization; poor physical conditioning; alcohol and medication use; preexisting medical conditions; and sleep deprivation, immune disturbances, or both perpetuated by the stress associated with managing academics, practice times, and travel. Similar to football players who wear heavy protective equipment, traditional MB performance uniforms are often heavy, cover the arms and legs, and include plastic hats without ventilation.[5] Football players who wore full uniforms experienced less time to exhaustion and significantly higher T_c than those not wearing uniforms,[15] so we can presume that MB uniforms and equipment (eg, drums, sousaphones) trap sweat against the skin and inhibit evaporative cooling, causing heat to be retained and T_c to increase.

The author[16] of a study on musculoskeletal injury and sudden illness rates suggested that MBs would benefit from the care of ATs. This was further supported by a National Athletic Trainers' Association (NATA) guideline encouraging collaboration between band personnel and ATs to reduce the incidence of injuries or illnesses.[17] We sought to provide additional support for MB artists to have access to ATs, due to the AT's ability to prevent, recognize, and manage patients with emergent conditions such as exertional heat stroke. Evidence on physiological responses and EHI risk factors will also support MB-specific heat policies and procedures. Our primary purpose was to assess T_c among MB artists during rehearsals and football game performances. Secondly, we sought to identify specific EHI risk factors among MB artists and determine how these may influence T_c.

METHODS

We used a cross-sectional study design. The primary dependent variable was T_c assessed before, during, and after the rehearsal or game. Other physiological outcome variables were heart rate (HR), percentage change in body mass (%BM), urine specific gravity (Usg), fluid volume (Fvol), sweat rate, and perceived thirst. Based on the NATA position statement on EHIs,[12] we selected several intrinsic and extrinsic risk factors to examine in our population, including previous EHI, environment, physical activity time and intensity, ground surface, previous night's sleep, medication use, and current general illness.

Participants

Participants were recruited from 2 National Collegiate Athletic Association Division I institutions' MBs (MB1 and MB2). A total of 19 MB artists completed the study (10 from MB1, 9 from MB2; age = 20.5 ± 0.9 years): 13 females (height = 161.8 ± 5.5 cm, mass = 72.5 ± 16.7 kg) and 6 males (height = 172.5 ± 3.6 cm, mass = 80.4 ± 24.4 kg). To be included, recruits had to be at least 18 years old and active in the university's MB during the fall 2018 season. Individuals were excluded if they had a swallowing, gastrointestinal, or other medical disorder that prevented them from ingesting the T_c sensor. The study was approved by the primary investigators' institutional review boards, and all participants read and signed an informed consent form.

Measurements and Instrumentation

Anthropometrics. Height, mass, body fat percentage, and body surface area (BSA) were obtained. Height was measured using a stadiometer height board (ShorrBoards; Shorr Productions LLC, Olney, MD). Mass and body fat percentage were measured using a body composition scale (model SC 331S; Tanita Corp of America, Inc, Arlington Heights, IL). We calculated BSA using the equation of Du Bois and Du Bois.[18] On 1 day, participants were weighed with their instruments to determine instrument mass.

Core Temperature. To assess thermoregulatory strain, T_c (°C) was monitored continuously and recorded every 15 minutes throughout exercise using ingestible thermistors (CorTemp; HQ, Inc, Palmetto, FL). Participants ingested the pill approximately 6 hours before data collection to ensure that the sensor reached the large intestine at the appropriate time.

Hydration. Hydration status was characterized by %BM and Usg. Body mass was measured preactivity and postactivity. Participants voided urine before being weighed with minimal clothing (eg, shorts and T-shirt, no shoes), and mass was adjusted by 0.5 kg for clothing. During the postactivity weighing, participants toweled off sweat before stepping on the scale. Urine was obtained preactivity and postactivity. Participants urinated into a specimen cup, and Usg was measured using a refractometer (MB1: model PEN-PRO; Atago Co, Ltd, Tokyo, Japan; MB2: model REF 312; Atago Co Ltd).

To maintain the participants' normal hydration behaviors, we did not provide them with individual bottles or fluids. For rehearsals, participants brought their own containers with their preferred amount and type of fluid. For football

games, the institution's MB provided fluids. We weighed each person's container to determine Fvol (g) consumption. If a participant needed to urinate after the preactivity weighing and before activity ended, he or she did so in a designated urine volume container, and we measured total urine volume using a graduated cylinder (mL). We calculated sweat rate (L/h) using

$$\frac{\text{Preactivity Body Mass (kg)} - \text{Postactivity Body Mass (kg)} + \text{Fluid Volume (L)} - \text{Urine Volume (L)}}{\text{Activity Time (h)}}.$$

Perceived thirst was measured using a 9-point thirst scale. Verbal anchors ranged from 1 (*not thirsty at all*) to 5 (*moderately thirsty*) to 9 (*very, very thirsty*).[14] Participants rated thirst preactivity and postactivity.

Environment. Wet bulb globe temperature (WBGT, °C) and percentage of relative humidity (RH) were continuously measured and recorded every 15 minutes using a thermal environmental monitor (model 3000HS; Kestrel Instruments, Boothwyn, PA). We recorded the ground surface (ie, turf, pavement, natural grass) each day.

Pre-Activity Questionnaire. To enable us to identify potential EHI risk factors before each rehearsal or performance, participants completed a 24-hour recall of medication and supplement use; sleep quantity; and any signs or symptoms of illness.

Activity and HR

Activity watches (model M200; Polar Electro, Inc, Lake Success, NY) continuously monitored HR. We programmed each watch with the participant's dominant hand, height, mass, date of birth, and sex according to the manufacturer's instructions. On data-collection days, participants wore the watches during the rehearsal or performance. At the end of data collection, we synchronized watches to the Polar Flow Web service and downloaded the data to determine the maximum HR during the rehearsal or performance and estimated maximum oxygen consumption ($\dot{V}O_2$max).

We recorded physical activity and duration in minutes. Activities were categorized as one of the following: (1) stretching or general warmup, (2) standing without instrument, (3) standing with instrument, (4) marching without instrument, (5) marching with instrument, (6) high-step marching without instrument, (7) high-step marching with instrument, and (8) rest or water break. Each coded activity intensity was based on the compendium of physical activities.[19] We then calculated average metabolic equivalents (METs) for each rehearsal and game.

Procedures

During an information session, recruits reviewed the study components and were informed of the risks and benefits. Those who consented to participate completed the health history questionnaire so that we could identify previous medical illness or injury (eg, gastrointestinal or metabolic disorders, EHI history), current medications and supplements, menstrual regularity, age, education level, sex, ethnicity, heat-acclimatization status, years of MB experience, and MB primary instrument. We measured participants' height and mass and familiarized them with the thirst scale and preactivity questionnaire. The day before rehearsal or game data collection, we gave participants specific oral and written instructions on how and when to ingest the T_c sensor. Participants received their activity watches with instructions on when and how to wear them.

Data were collected at each institution on 5 days: 3 outdoor rehearsals during the school year and 2 home game football days. Rehearsal data collection took place during August and September. All football game data collection occurred in September. For each football game, the bands rehearsed in the morning; we only measured environment, activity, and hydration during morning rehearsals. Participants reported 30 minutes early for preactivity measures and surveys. During activity, they maintained their typical hydration and activity habits. We recorded T_c, HR, and environment every 15 minutes. During the rehearsal or game, an investigator continuously tracked activity; all urine was collected in the participant's designated container, and we tracked Fvol consumed. Postactivity measures and surveys were recorded after the rehearsal or performance.

Statistical Analysis

We used SPSS (version 26; IBM Corp, Armonk, NY) for all analyses. The significance level was set at $P < .05$. We calculated descriptive statistics (mean, SD, and maximum) for all variables. The primary dependent variable was T_c. Because of varying rehearsal and game times, we could not compare T_c and HR at multiple timepoints (ie, every 15 minutes). We determined mean T_c and HR at preactivity and postactivity and identified each person's maximum T_c and HR during activity to determine a mean maximum T_c and HR for each rehearsal and game day. Boxplots were used to identify extreme outliers, and subsequently, we removed 1 participant's T_c rehearsal data for day 3. Pearson correlations were computed to assess the relationship between maximum T_c and each of the following variables: maximum WBGT, maximum HR, $\dot{V}O_2$max, mass, BSA, Usg, %BM, METs, physical activity time, and instrument mass. We used Pearson partial correlations to determine the relationship between maximum T_c and select variables (eg, WBGT, HR) while controlling for sex, $\dot{V}O_2$max, BSA, activity time, and instrument mass. Point biserial correlations were generated to examine associations between T_c and sex, medication use, and current illness. We described the correlation strength (weak, moderate, or strong) based on the Cohen guidelines.[20] We used paired-samples *t* tests to identify differences from before rehearsal or game to after rehearsal or game for T_c, HR, and Usg and between Fvol and sweat rate. To control for BM, Fvol was corrected to milliliters per kilogram. Chi-square analysis was performed to evaluate associations for sleep, medication use, and current illness between rehearsals and games. Finally, we conducted 1-way analyses of variance to characterize differences between MB1 and MB2 for anthropometrics, environments, physical activity time, and METs.

RESULTS

A total of 22 participants began the study; we withdrew 2 because they could not swallow the T_c sensor, leaving 20.

Table 1. Participants' Demographics

Characteristic	MB Participants		
	Total (N = 19)	1 (n = 10)	2 (n = 9)
	Mean ± SD		
Age, y	20.5 ± 0.9	20.7 ± 0.7	20.3 ± 1.1
Height, cm	165.1 ± 7.1	167.2 ± 5.8	162.8 ± 7.9
Mass, kg[a]	75.0 ± 19.1	85.1 ± 21.4	63.7 ± 5.9
Body fat, %	27.7 ± 11.9	30.1 ± 14.0	25.2 ± 9.9
Body surface area, m^2[b]	1.81 ± 0.19	1.93 ± 0.19	1.68 ± 0.74
$\dot{V}O_2$max, $mL \cdot kg^{-1} \cdot min^{-1}$[c]	40.8 ± 10.2	39.3 ± 10.2	42.5 ± 7.5
	No.		
Sex			
Male	6	5	1
Female	13	5	8
Ethnicity			
White	17	8	9
Black or African American	2	2	0
Education level			
Senior	13	8	5
Junior	2	1	1
Sophomore	4	1	3
Marching experience, y[d]			
≤4	1	0	1
5–6	4	1	3
7–8	9	5	4
≥9	4	3	1
Primary instrument			
Baritone	2	2	0
Clarinet	2	0	2
Drumline	3	3	0
Piccolo	5	1	4
Saxophone	3	1	2
Sousaphone	3	3	0
Trumpet	1	0	1

Abbreviations: MB, marching band; $\dot{V}O_2$max, maximum oxygen consumption.

[a] Higher for MB1 than MB2 ($F_{18,1} = 8.4$, $P = .010$).
[b] Higher for MB1 than MB2 ($F_{18,1} = 13.6$, $P = .002$).
[c] Estimated from physical activity watch.
[d] n = 18 due to missing information sheet.

We excluded 1 participant's data from analysis because the individual had an indoor rehearsal day due to weather and scheduling. Therefore, the data of 19 participants were analyzed. Demographics are presented in Table 1. No differences were found in age, height, or body fat percentage between the groups. However, mass and BSA were greater for MB1. Participants were predominately upperclassmen, whose experience and instruments varied. Estimated $\dot{V}O_2$max was not different between the MBs. We examined sex to classify participants' aerobic fitness.[21] Males had a higher $\dot{V}O_2$max (49.8 ± 12.1 $mL \cdot kg^{-1} \cdot min^{-1}$), indicating good aerobic fitness,[21] than females (37.1 ± 6.9 $ml \cdot kg^{-1} \cdot min^{-1}$; $F_{1,15} = 7.8$; $P = .014$), who had fair aerobic fitness.[21]

Physiological Measures

Mean preactivity, postactivity, and maximum T_c and HR for rehearsals and games are shown in Table 2. We observed no T_c difference from pregame to postgame, but T_c increased from prerehearsal to postrehearsal. Five individuals in MB2 experienced $T_c > 40°C$ (without central nervous system dysfunction) for >60 minutes during games. The highest maximum T_c during a game was 41.2°C and during a rehearsal was 40.6°C. Mean changes in T_c throughout each rehearsal and game by MB1 and MB2 are provided in the Figure. Heart rate increased from preactivity to postactivity for both rehearsals and games (Table 2).

Hydration status, sweat rate, Fvol, and thirst measures are reported in Table 3. Prerehearsal Usg was lower than the postrehearsal value. No difference was apparent in Usg from preactivity to postactivity for games or morning game-day rehearsals. Defining *hypohydrated* as Usg ≥ 1.025,[22] we classified individuals as either hypohydrated or euhydrated. Participants arrived hypohydrated at morning game-day rehearsals 40.5% of the time and at pregames 63.6% of the time. More often (76.4% of the time), they presented to rehearsals euhydrated. Fluid consumption was less than the sweat rate during rehearsals ($t_{40} = 7.0$), games ($t_{33} = 8.1$), and morning rehearsals ($t_{33} = 5.2$; $P < .001$). Thirst increased from prerehearsal to postrehearsal ($t_{52} = -5.1$, $P < .001$) but was not different from preactivity to postactivity for morning game-day rehearsals or games.

Risk Factors for EHI

Three participants reported they did not believe they were heat acclimatized. However, these individuals completed 8 to 14 days of band camp and 2 weeks of regular rehearsals before data collection, suggesting that they were indeed acclimatized. Twelve participants regularly exercised outside of MB activities. Mean BSA was higher in MB1 participants (Table 1); among these, 3 had BSAs > 2.0 m^2. Two of these (1 male, 1 female) stated they exercised regularly; both played sousaphone (the second heaviest instrument at approximately 13.4 kg) and had the highest body fat percentage (>45%) and lowest estimated $\dot{V}O_2$max (<30 $mL \cdot kg^{-1} \cdot min^{-1}$). Three participants described experiencing a previous EHI; all 3 cases were exertional heat exhaustion and occurred 1 to 4 years before fall 2018. Two of the people with a previous EHI (both female) were in MB2, played woodwind instruments (piccolo and clarinet),

Table 2. Core Temperature and Heart Rate (Mean ± SD) During Rehearsals and Games

Event	Average Core Temperature, °C			Average Heart Rate, beats/min		
	Preactivity	Postactivity	Maximum	Preactivity	Postactivity	Maximum
Rehearsals	37.8 ± 0.7[a]	38.3 ± 0.7	38.4 ± 0.7	89.5 ± 14.0[b]	118.9 ± 21.9	159.6 ± 21.2
Games	38.4 ± 1.2	38.7 ± 1.1	39.1 ± 1.1	85.9 ± 12.3[c]	123.6 ± 17.3	174.1 ± 13.5

[a] Lower than postrehearsal ($t_{47} = -6.2$, $P < .001$).
[b] Lower than postrehearsal ($t_{51} = -10.7$, $P < .001$).
[c] Lower than postgame ($t_{25} = -9.6$, $P < .001$).

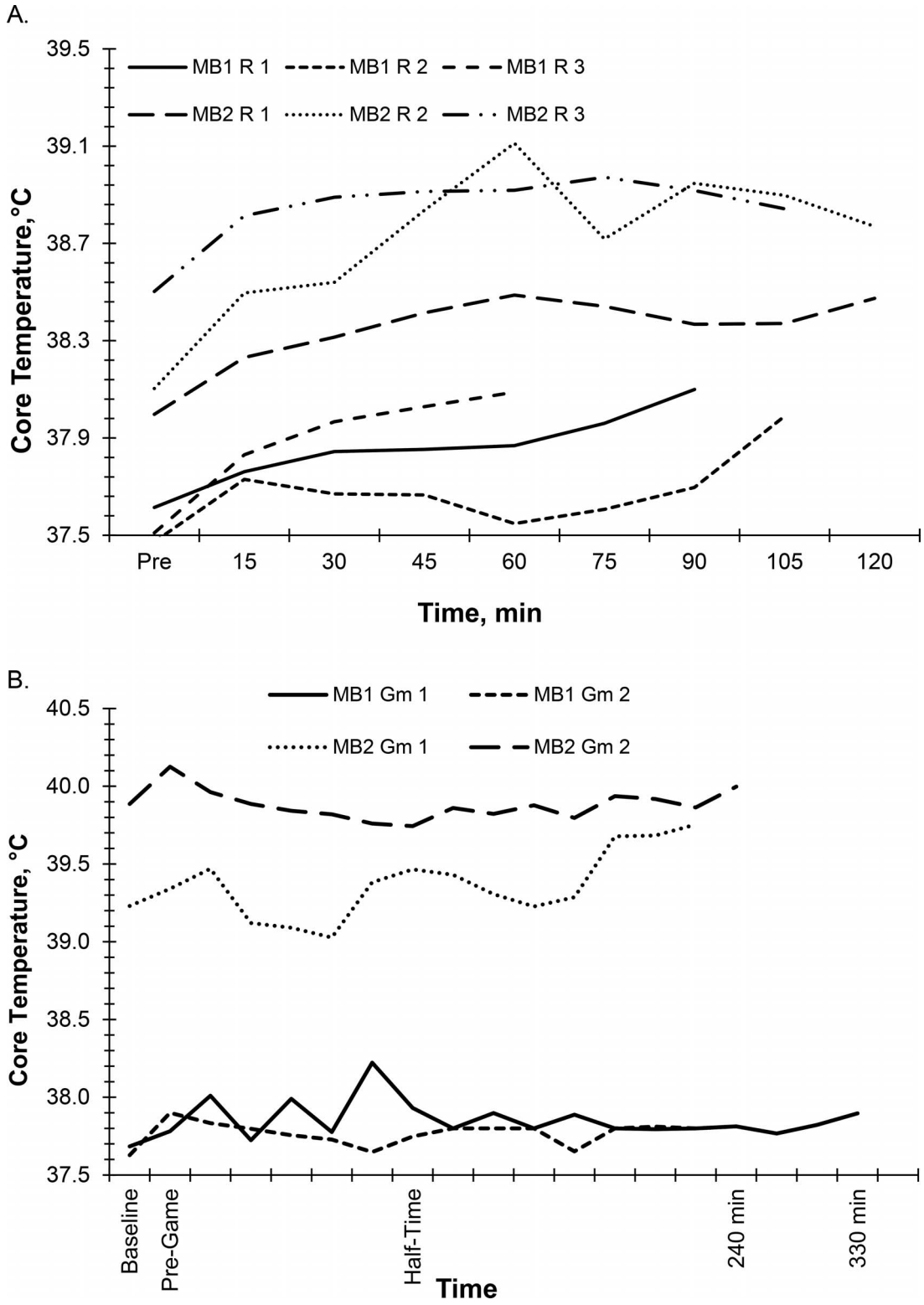

Figure 1. Mean core temperature throughout A) Rehearsals and B) Games for each marching band. Baseline on game-day is 2 hours before kickoff before all pep-rallies and other activities. Abbreviations: R, rehearsal; Gm, game.

and regularly experienced T_c >39.5°C during rehearsals and >40°C during games, including the highest T_c (41.2°C).

Each band's rehearsal and game WBGT range, activity time, mean METs, and number of breaks during activity are provided in Table 4. For comparison, we used regional guidelines[23] to indicate the recommended activity based on WBGT measures. Both bands were in category 3.[23] Environmental measures were not different between institutions. Mean WBGT for rehearsals was 28.8°C ± 5.2°C, for morning game-day rehearsals was 25.6°C ± 10.1°C, and for games was 32.7°C ± 9.9°C. Mean RH

Table 3. Hydration Characteristics for Rehearsals and Game Days (Mean ± SD)

Variable	Rehearsals	Morning Game-Day Rehearsals	Games
Urine specific gravity			
Preactivity	1.018 ± 0.009[a]	1.023 ± 0.006	1.024 ± 0.009
Postactivity	1.023 ± 0.007	1.024 ± 0.008	1.021 ± 0.011
Body mass loss, %	–0.4 ± 0.6	–0.2 ± 0.6	–0.9 ± 2.0
Fluid volume, L·h^{-1}	0.5 ± 0.2[b]	0.3 ± 0.3[b]	0.4 ± 0.2[b]
Fluid volume, mL·kg^{-1} of body mass	9.4 ± 7.8	6.8 ± 7.1	29.5 ± 12.5
Sweat rate, L·h^{-1}	0.7 ± 0.3	0.4 ± 0.3	0.7 ± 0.3
Thirst			
Preactivity	3 ± 1	3 ± 2	4 ± 2
Postactivity	5 ± 2[c]	4 ± 2	4 ± 2

[a] Lower than postrehearsal ($P = .001$).
[b] Less than sweat rate ($P < .001$).
[c] Greater than prerehearsals ($P < .001$).

during rehearsals was 61.2% ± 21.8%, during morning game rehearsals was 77.4% ± 16.7% and during games was 55.8% ± 12.1%. Mean rehearsal time was 102.8 ± 19.8 minutes and was longer for MB2 than MB1 (116.3 ± 15.3 minutes versus 87.5 ± 11.4 minutes; $F_{1,47} = 54.5$, $P < .001$). Mean game time was 260.5 ± 47.7 minutes and was longer for MB1 (282.6 ± 46.2 minutes) than MB2 (234.2 ± 35.3 minutes; $F_{1,33} = 11.8$, $P = .002$). For morning game-day rehearsals, mean METs (3.3 ± 0.4) were higher than for rehearsals (3.0 ± 0.3; $P < .001$) and games (3.0 ± 0.5; $P = .004$). Mean METs differed between bands: MB1 was greater than MB2 during rehearsals (3.2 ± 0.3 versus 2.7 ± 0.3; $F_{1,52} = 51.9$, $P < .001$). However, MB2 averaged greater METs during morning game-day rehearsals (3.5 ± 0.6 versus 3.2 ± 0.2; $F_{1,37} = 7.7$, $P = .009$).

Table 5. Pearson and Point Biserial Correlations for Maximum Core Temperature

Variable	Maximum Core Temperature	
	R Value	*P* Value
Sex	0.330	.002
$\dot{V}O_2$max	0.028	.813
Body surface area	−0.449	.000
Body mass	−0.347	.002
Maximum heart rate	0.042	.728
Urine specific gravity		
Preactivity	−0.300	.008
Postactivity	0.144	.203
Percentage of body mass loss	0.048	.674
Any medications	−0.353	.001
Mental health medications	−0.254	.022
Maximum wet bulb globe temperature	0.618	.000
Average metabolic equivalents	−0.111	.357
Activity minutes	0.291	.008
Instrument mass	−0.479	.000

Abbreviation: $\dot{V}O_2$max, maximum oxygen consumption.

Correlation and point biserial correlation results are listed in Table 5. Maximum T_c did not significantly correlate with $\dot{V}O_2$max, postactivity Usg, %BM, METs, or HR. We identified a strong correlation between T_c and WBGT that persisted when adjusted for METs ($r_{partial} = 0.617$, $P < .001$) and decreased slightly when activity time ($r_{partial} = 0.577$, $P < .001$) and instrument mass ($r_{partial} = 0.552$, $P < .001$) were controlled. The weak association between T_c and activity minutes decreased and was no longer significant when we adjusted for WBGT ($r_{partial} = 0.112$, $P = .324$). We found moderate negative correlations for T_c with BSA and mass. When WBGT was adjusted, T_c and BSA remained significantly correlated but decreased ($r_{partial} = –0.292$, $P = .008$). Maximum T_c was negatively

Table 4. Environmental Conditions, Ground Surface, Activity Time, Metabolic Equivalents, and Work-Rest Amounts for All Activity Days

Marching Band Event	WBGT Range, °C	Ground Surface	Metabolic Equivalents, Mean	Activity Time, min	Rest Time, min	Water Breaks	Rest, min·h^{-1}	Recommended Activity Guidelines Based on Maximum WBGT[a]
1								
Rehearsal 1	28.3–32.4	Turf	3.2	69	9	1	9	20 min rest/h, 1 h max
Rehearsal 2	26.2–28.9	Turf	3.3[b]	85[b]	9	1	7[b]	≥12 min over 3 breaks/h
Rehearsal 3	28.2–32.1	Turf	3.1	97	13	2	9	≥16 min over 4 breaks/h, 2 h maximum
Rehearsal game 1	22.0–22.3	Turf	3.0	138	14	2	7	≥9 min over 3 breaks/h
Game 1	23.1–36.2	Grass	3.2	330	76[c]	NA[d]		No activity
Rehearsal game 2	14.8–22.7	Turf	3.3	102	7	1	4	≥9 min over 3 breaks/h
Game 2	18.8–27.7	Grass	3.1	240	NA[c]	NA[d]	NA[c]	≥9 min over 3 breaks/h
2								
Rehearsal 1	27.4–40.1	Pavement	2.8	118	14	4	8	No activity
Rehearsal 2	31.9–43.7	Pavement	3.1	135	22	3	12	No activity
Rehearsal 3	19.2–20.7	Pavement	2.3	98	7	1	5	≥9 min over 3 breaks/h
Rehearsal game 1	27.9–42.8	Turf	3.0	159	25	3	11	No activity
Game 1	27.9–42.9	Turf	3.5	265	23	NA[d]	6	No activity
Rehearsal game 2	20.7–22.7	Turf	4.1	88	5	1	4	Minimum 9 min over 3 breaks/h
Game 2	42.5–51.0	Turf	2.1	220	39[c]	NA[d]	13	No activity

Abbreviations: NA, not applicable; WBGT, wet bulb globe temperature.
[a] Using regional guidelines, both bands were at category 3.[22] The WBGT ranged within days, but we provide the recommended activity guidelines based on the maximum WBGT for that activity time.
[b] Drumline rehearsed an additional 15 min.
[c] Due to weather (extreme heat or lightning delays), multiple people were under the stands during portions of games; rest min·h^{-1} could not be calculated for marching band 1 games.
[d] Participants were provided water in the stands and able to drink throughout the game.

correlated with preactivity Usg; this relationship increased when activity time was controlled ($r_{partial} = -0.427$, $P < .001$) and decreased when WBGT was adjusted ($r_{partial} = -0.286$, $P = .012$). Sex significantly correlated with T_c, with females being higher than males (38.9 ± 1.0°C versus 38.2 ± 0.7°C). The moderate negative correlation between T_c and instrument mass decreased slightly when WBGT was controlled ($r_{partial} = -0.367$, $P = .001$).

Based on the NATA position statement on EHIs,[12] we examined associations for individuals taking specific medications known to alter thermoregulation. Three participants took mental health medications daily. Other common medications taken occasionally included antibiotics, nonsteroidal anti-inflammatories, and cold and asthma medications. Maximum T_c correlated with the use of any medication and specifically mental health medication (Table 5). Maximum T_c was higher among individuals who were taking regular medications (39.1 ± 1.0°C) than among those who were not (38.4 ± 0.8°C). Similarly, individuals who were taking mental health medications experienced higher T_c (39.3 ± 1.1°C) than those who were not (38.6 ± 0.9°C).

To examine any associations between rehearsals and games for medication and current illness, we violated the assumption for expected cell frequency counts using the χ^2 analysis. Hours of sleep were significantly associated with rehearsals or games ($\chi^2 = 16.3$, $P < .001$). When participants reported <5 hours of sleep the night before, this occurred more often for games than for rehearsals (73.1% of the time versus 26.9%). In the same way, more individuals reported receiving below-average sleep hours for games compared with rehearsals (61.8% versus 38.2%, $\chi^2 = 12.8$, $P = .002$).

DISCUSSION

We sought to assess T_c in MB artists and determine the presence of EHI risk factors. During rehearsals and performances, MB artists experienced high T_c similar to temperatures observed among collegiate and professional football players (range = 37.2–40.7°C)[14,24–27] and collegiate cross-country runners (38.5–39.5°C).[24] We also identified that MB artists had multiple EHI risk factors and that those who were less physically fit (with larger BSA or mass) or carrying heavier instruments could not be assumed to be at the highest risk. Several other intrinsic variables appeared to affect T_c in this population. Being female and using mental health medications resulted in higher T_c. Generally, females have lower $\dot{V}O_2$max than males, and we observed this in our population. Less aerobic fitness may explain the higher T_c during activity,[28] but $\dot{V}O_2$max did not correlate with T_c in our participants. The 2 individuals with previous EHI who experienced the highest T_c were female. We cannot determine which risk factor had the greatest effect on T_c, but our results suggested that females exhibited several risk factors that likely contributed to high T_c.

The MB2 participants averaged higher estimated $\dot{V}O_2$max, lower BSA, and less weight and carried lighter instruments, yet their T_c was generally higher during rehearsals and games compared with MB1 individuals. This was likely due to the environment. Although not a statistically significant finding, MB2 members experienced higher WBGT, which was strongly correlated with T_c even when we adjusted for other factors, such as activity time and METs. We did not expect to find a lower T_c among MB artists with a higher BSA, considering that higher BSA and mass have been associated with greater heat storage.[29,30] This difference may be partially explained by activity intensity (ie, METs). Different sections and even individuals within a section may not move as much as others during a performance. For example, the sousaphone players may have less distance to cover and, therefore, experience less activity intensity and metabolic heat production. In contrast, some piccolo players may be required to perform at high intensity if the drill requires them to cover more yards than others in their section. Subsequently, a great deal of variability in the physical strain may be present within the band and within the section that the person may not be conditioned to perform.

As in any setting, certain EHI risk factors can be modified and others cannot. Colleges, particularly members of the Power 5 conferences, cannot alter football game times, as these are often dictated by television. Also, marching bands have no control over game field surfaces and may lack control over practice field settings. In general, our participants' T_c values were highest at the beginning of the game and throughout the pregame show, which is likely due to the long game-day schedule before kickoff. As an example, morning rehearsal for an 11:00 AM game may run from 6:00 to 9:00 AM, followed by a short 30-minute break before 1 hour of pep rallies and other performances for fans. By the time pregame begins, some MB artists have been in full uniform, playing outdoors for several hours, without access to water or shade.

Many MB artists arrived at rehearsals and games hypohydrated, a finding that was similar to results in traditional athletic settings[31,32] and a recent investigation among Japanese collegiate MB artists.[33] The limited water breaks or rest time during rehearsals and, for MB2, bringing their own fluids likely explains why MB members did not match their sweat rates during rehearsals. Even though they had ready access to water during games (the band supplies water bottles and coolers), they did not consume enough fluids to match their sweat loss. This fluid deficit is reflected in the greater game-day %BM loss. Although MB artists averaged <2% loss, several members lost 2% to 3%, and 2 MB1 members (both in the drumline with lean builds and similar sweat rates) experienced >4% loss during games. It is important to educate MB individuals about hydrating throughout the day so as to arrive at activity euhydrated and, particularly for those who lose more than 2% during an activity, how to replenish fluid losses afterward.

When we compared activity and rest time with recommended guidelines based on WBGT (Table 4), 2 rehearsals and 3 games occurred during black conditions (≥33.4°C). The MB2's game field was turf, which corresponded to the highest recorded WBGT on all data-collection days (game 2 maximum = 51°C). The rehearsal surface was pavement, which also corresponded to WBGT measures exceeding 43°C. On only 1 occasion, MB1's morning game 1 rehearsal, did rest time meet the recommendation. For 5 out of 10 rehearsals, only 1 break was allowed for the entire rehearsal time. Water breaks are important not only for rehydrating but also to permit the artists' T_c values to decrease. The inadequate rest time based on the environmental conditions may have led to higher T_c throughout rehearsals, particularly

for MB2. Guidelines for modifying activity due to extreme weather are predominately based on football data, and some aspects could be easily incorporated to reduce risks. For instance, when WBGT exceeds 27.8°C, multiple rest breaks could be incorporated, in the shade if possible, to allow individuals time to cool down. Another consideration is the time of day when rehearsal takes place. The MB1 rehearsal began at 5:00 PM, whereas MB2 started at 3:45 PM, when it was presumably hotter. For MB2, rehearsals 1 and 2 both started in black conditions but cooled during the session. Moving rehearsal time to later in the day could decrease the heat exposure and minimize the EHI risk. Other activity modifications may not be as easily applied to MB, particularly when the individuals responsible for implementing preventive measures are band directors. Specific MB guidelines could address the maximum intensity of a rehearsal—eg, standing or learning drills with no instruments or not playing versus full-speed drill runs while playing. Although football players would never play a game without their full equipment, some MBs have alternative uniforms for extreme environmental conditions, whereas others wear full uniforms to maintain their show appearance. Overall, specific MB activity-modification guidelines, including preseason heat-acclimatization recommendations, could help align expectations across the country and the occurrence of EHIs in MB artists.

Uniforms may have played a role in participants' T_c. However, our limited game-day data did not allow us to determine the extent to which uniforms may have affected T_c. Both bands in our study wore traditional game-day uniforms made of wool-blend bibs and jackets, plastic hats, and cotton-blend gloves. Some bands have a summer uniform option: members may wear shorts and either a T-shirt or polo shirt at certain environmental temperatures. The MB2 had a summer uniform that was worn during game 1. Even in this alternate uniform, MB artists experienced extremely high T_c, suggesting that it was being driven by other factors. The institution's policy at the time dictated that summer uniforms were only allowed for 1 game. As it turned out, the second game was hotter, and MB2 members were required to wear full uniforms. Though MB2's 6:00 AM rehearsal for game 2 took place under cool conditions, it averaged the highest METs of all days, and many participants presented hypohydrated with less than average sleep the previous night. The combination of sleep loss, fatigue, hypohydration, full uniforms, turf, and high WBGT during the entire game resulted in not only study participants experiencing high T_c but many nonstudy participant band members seeking shade and treatment for exertional heat exhaustion at the first-aid station.

Limitations and Future Research

Our investigation was limited in that we only assessed 2 Division I MBs. Style and movement vary greatly within a performance depending on the institution and traditions. Our results are applicable to bands with a corps marching style and traditional uniforms that are located in hot, humid geographic areas. Our findings may not be applicable to bands with different styles, who wear auxiliary (color guard or dance) uniforms, or who are located in cooler parts of the country. One game for MB1 was delayed due to extreme weather that required members to seek shelter under the stadium. The delay may have altered the results, as participants were able to rest, which would have lowered T_c and allowed more time for hydration. The MB1 rehearsals were shorter and occurred later in the day than for MB2, which may explain the generally lower T_c in MB1. Our sample size and study design prevented us from determining associations between T_c and certain risk factors (eg, previous EHI, ground surface, sleep, sex). Finally, MB1 had an AT providing medical coverage, while MB2 did not. The preventive EHI strategies implemented by ATs and adopted by MB1 may have led to artists being more cognizant about proper hydration, nutrition, and sleep or being more aware of early EHI signs and more willing to seek care earlier, or both.

Future researchers should examine skin temperature along with T_c to determine the effects of wearing different types of band uniforms on sweating and thermoregulation. The physiological responses and risks for various instrument sections may differ. Some sections of the band may move more than others during a drill, carry different loads, and require different playing techniques that may demand various levels of energy. Certain band sections, particularly the drumline, may rehearse outside for longer periods than others, potentially increasing their exposure and risk. More investigation at different levels (high school, small colleges, elite, and military MBs) and on different marching styles (traditional, high step) is needed. Continuing to examine physiological responses, EHI prevalence rates, and different environmental temperatures will allow for the development of more specific MB activity-modification guidelines. Finally, more research is needed on patient outcomes and best practices among MBs who have access to ATs.

CONCLUSIONS

Our MB artists experienced high T_c during football rehearsals and games and exhibited several EHI risk factors. Performing physical activity in a hot, humid environment for several hours a day on ground surfaces that radiate heat, using medications that alter thermoregulation, and inadequate sleep can all increase T_c and ultimately the EHI risk. Implementing heat policies while taking into consideration the unique aspects of game-day performances may be challenging. In the absence of ATs, EHI prevention, recognition, and treatment are at the discretion of band directors, student leaders, or other nonmedical personnel. We suggest that ATs and band administrators work together along with student health and athletic personnel and other institutional partners to develop specific EHI-prevention and -management strategies that use best practices and ensure that MB artists receive appropriate medical care. Recommendations include requiring preparticipation examinations to identify at-risk individuals, creating guidelines to modify rehearsal time and intensity in extreme environments, providing ample shade and rest breaks, considering alternate game-day uniforms during extreme conditions, and establishing a management protocol in the event of an MB member with exertional heat stroke.

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