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Body Temperature in Sedentary Adults During Moderate Exercise: No Effect from Exercise the Day Before

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ORIGINAL RESEARCH

Body Temperature in Sedentary Adults During Moderate Exercise: No Effect from Exercise the Day Before

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McLELLAN TM, RHIND SG, BELL DG. *Body temperature in sedentary adults during moderate exercise: no effect from exercise the day before.* **Aviat Space Environ Med 2002; 73:1167–75.**

Background: Epidemiological findings show a continued presence of exertional heat injury during military basic recruit training. Current guidelines do not consider the carry-over effects of prior exercise or exposure to high ambient temperatures on the risk of succumbing to heat illness. ***Hypothesis:*** From the epidemiological evidence we hypothesized that both prior exercise and exposure to hot environments on the day before would increase the core temperature response during exercise the next day. ***Methods:*** Seven sedentary and non heat-acclimated men and women each performed eight randomized exposures involving treadmill walking for a maximum of 2 h every 2 wk. Two separate control trials at a wet bulb globe temperature (WBGT) of 22.5°C and 26.5°C consisted of exercise during the morning only. Six experimental trials involved successive days of exercise with trials on the second day at either a WBGT of 22.5°C or 26.5°C. All of the experimental trials involved walking during the first morning at a WBGT of 22.5°C. Further, four of these trials included additional exercise in the afternoon at either a WBGT of 22.5°C (two trials) or 29.5°C (two trials). ***Results:*** There was no impact of prior exercise on the day preceding the tests at either WBGT for any of the dependent measures. Rectal temperatures increased to 38.0°C at the WBGT of 22.5°C and to 38.5°C for trials at 26.5°C. There were also no carry-over effects from exercise conducted during the preceding afternoon. ***Conclusions:*** Under situations where individuals are well hydrated, rested, and free of injury, illness, and drug use, repeated exercise bouts on successive days do not alter the thermoregulatory response to exercise.

Keywords: rectal temperature, skin temperature, heart rate, basic training, heat injury.

PRESENTLY, both the Canadian and U.S. military have guidelines in place to minimize the risk of heat stress in personnel (16). Factors such as dehydration (27), illness (3,4), sleep deprivation (7,26), and injury from prior exercise (21) may all be involved in increasing the risk to exertional heat illness.

Recent epidemiological findings from the U.S. Marine recruit training center in Parris Island, SC, which span a 10-yr period, have revealed a small (less than 1% of personnel) but continued presence of cases of exertional heat illness (16). The findings also showed that despite curtailing exercise marches to the cool morning hours where wet bulb globe temperature (WBGT) levels would be well below 26°C, personnel were still experiencing problems. Further analyses revealed that both the activity and WBGT level on the preceding day influenced the outcome on the following day. Current military guidelines do not consider the effects of prior exercise or prior heat exposure on the risk of succumbing to heat illness. Montain et al. (21) reported that core temperature was elevated during treadmill walking for up to 7 h following a bout of lower body eccentric exercise for heat acclimated and moderately active men and women. However, it is presently unknown whether this impairment in temperature regulation would be greater or last longer for previously sedentary or inactive subjects. It is also unknown whether prior exercise that does not result in the same inflammatory response as was observed following the eccentric exercise used by Montain et al. (21) would affect the core temperature response to a similar extent. Thus, carry-over effects of prior exercise or exposure to high ambient temperatures or a combination of both appear to increase the incidence of exertional heat illness. This same group of researchers reported that those individuals who were less fit and more overweight had an eight-fold greater risk of experiencing symptoms related to exertional heat illness (11). The U.S. National Weather Service also defines a heat wave in terms of cumulative exposure of two or more consecutive days to a heat index above 40.5°C (15) implying at least in principle that there is some basis to a carry-over effect as a factor in heat injury.

It was the purpose of the present investigation to examine whether the current military guidelines on the prevention of heat stress should be modified to include the influence of prior exercise and exposure to hot environments. Based on the epidemiological evidence provided by Kark et al. (16) it was hypothesized that both prior exercise and exposure to hot environments on the day before exercise heat-stress would predispose individuals to a higher core temperature response during exercise the next day.

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METHODS

Subjects

Following approval from the institute's human ethics committee, seven non heat-acclimatized and sedentary subjects (four men and three women) volunteered to participate in the study. Mean values (±SD) for age, weight, height, Dubois body surface area, body fat percentage, and $\dot{V}O_{2peak}$ were 25.6 ± 6.0 yr, 76.1 ± 18.4 kg, 1.74 ± 0.13 m, 1.90 ± 0.29 m^2, 18.2 ± 4.8%, and 3.20 ± 1.05 $L \cdot min^{-1}$ or 42.1 ± 4.9 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. They were informed of all details of the experimental procedures and the associated risks and discomforts. After a medical examination to ensure that there were no medical contraindications to their participation in the experiment, each subject gave informed consent prior to the first day of data collection.

Determination of peak aerobic power ($\dot{V}O_{2peak}$)

$\dot{V}O_{2peak}$ was determined on a motor-driven treadmill using open-circuit spirometry (19) before the series of experiments in the climatic chamber. Following 2 min of running at a self-selected pace, the treadmill grade was increased $1\% \cdot min^{-1}$ until subjects were running at a 10% grade. If necessary, increases in treadmill speed of $0.22\ m \cdot s^{-1}$ and grade of 1% were alternated each minute until the subject could no longer continue. $\dot{V}O_{2peak}$ was defined as the highest oxygen consumption ($\dot{V}O_2$) observed during the incremental test. Heart rate (HR) was monitored throughout the incremental test from a telemetry unit (Polar Electro PE3000, Stamford, CT). The heart rate value recorded at the end of the exercise test was defined as the individual's peak value (HR_{peak}).

Experimental Design

All subjects performed eight experimental sessions in random order separated by a minimum of 10 d with the majority of trials being performed on a biweekly basis for a given subject. The following items were worn during each trial: underwear (and bra for the women), T-shirt, shorts, socks, lightweight cotton combat jacket and pants, and jogging shoes. Two of the trials represented the control trials at either a WBGT of 26.5°C (35°C dry bulb, 35% relative humidity, vapor pressure of 2.0 kPa) ($CONT_{(26.5)}$) or the lower WBGT of 22.5°C (30°C dry bulb, 35% relative humidity, vapor pressure of 1.5 kPa) ($CONT_{(22.5)}$) with wind speeds less than $0.1\ m \cdot s^{-1}$. $CONT_{(26.5)}$ is within the range where guidelines would initially recommend the implementation of work and rest schedules for Canadian Forces personnel; whereas $CONT_{(22.5)}$ would not be associated with any restrictions during training. The exercise consisted of 2 h of treadmill walking at $6\ km \cdot h^{-1}$ with a 2% grade for the men and $5\ km \cdot h^{-1}$ with a 6% grade for the women. The speed of walking for the men was the speed required to complete the recruit-training 13 km march in the maximum allowed time of 2 h 10 min. Rather than encumber the subjects with the required additional 11 kg of ammunition, canteen, rifle and helmet, the grade of the treadmill was increased to 2% to increase the metabolic rate. Initially the female subjects found it very difficult to walk at $6\ km \cdot h^{-1}$. Thus, to maintain an equivalent metabolic demand to the men, their speed of walking was decreased and the grade of the treadmill was increased.

TABLE I. A DESCRIPTION OF THE WBGT CONDITIONS AND TREADMILL EXERCISE DURATIONS FOR THE EXPERIMENTAL TRIALS OVER TWO SUCCESSIVE DAYS (DAYS 1 AND 2) OF TESTING.

	Day 1 (D1)		Day 2 (D2)
Experimental Trial	AM	PM	AM
${}_{(22.5)}D1/D2_{(22.5)}$	2 h at 22.5°C	None	2 h at 22.5°C
${}_{(22.5)}D1/D2_{(26.5)}$	2 h at 22.5°C	None	2 h at 26.5°C
${}_{(22.5)}D1_{(22.5)}/D2_{(22.5)}$	2 h at 22.5°C	1 h at 22.5°C	2 h at 22.5°C
${}_{(22.5)}D1_{(22.5)}/D2_{(26.5)}$	2 h at 22.5°C	1 h at 22.5°C	2 h at 26.5°C
${}_{(22.5)}D1_{(29.5)}/D2_{(22.5)}$	2 h at 22.5°C	1 h at 29.5°C	2 h at 22.5°C
${}_{(22.5)}D1_{(29.5)}/D2_{(26.5)}$	2 h at 22.5°C	1 h at 29.5°C	2 h at 26.5°C

The remaining six trials examined the impact of prior exercise on the day preceding a repeat of the conditions representing the control trials. Thus, all of these six trials involved exercise on two successive days (D1, D2) with half of the trials involving 2 h of exercise at a WBGT of 22.5°C on the second morning ($D2_{(22.5)}$) and half involving exposure to a WBGT of 26.5°C on the second morning ($D2_{(26.5)}$). Further, all of these trials involved at least 2 h of walking at a WBGT of 22.5°C in the morning of the first day to simulate basic physical training during the cooler early morning hours (${}_{(22.5)}D1$). In addition, four of these sessions also involved 1 h of exercise in the afternoon of the first day with two sessions at a WBGT of 22.5°C ($D1_{(22.5)}$) and two at a much warmer WBGT of 29.5°C (38.5°C dry bulb, 35% relative humidity, vapor pressure of 2.4 kPa) ($D1_{(29.5)}$). These afternoon exercise bouts were included to simulate additional physical training that might normally occur during the basic training. The exposure to the higher WBGT during this exercise period was used to test whether these conditions might have a carry-over effect on temperature regulation the next day. All of the exercise during these trials involved the same treadmill speed and grade that was used during the control trials. A summary description of the exercise durations and the WBGT for the six experimental trials is presented in **Table I**.

All experiments were conducted in the fall and winter months. As mentioned previously trials were separated by approximately 2 wk to lessen the influence of heat acclimation and a change in aerobic fitness on the thermoregulatory response (1). Women were tested throughout their menstrual cycle. Since the treatment order was randomized menstrual cycle effects on temperature regulation were minimized (32). Subjects were also asked to avoid alcohol for a 24 h period and caffeine for a 12 h period preceding each trial.

Each session continued for a maximum of 2 h or until rectal temperature (T_{re}) reached 40.0°C, heart rate remained at or above 95% of HR_{peak} for 3 min, nausea or dizziness precluded further exercise, the subject asked to be removed from the chamber, or the investigator removed the subject from the chamber. The men consumed 300 ml and the women 200 ml of water immediately prior to beginning the exercise session each morning and every 30 min during the exercise session. The temperature of the water approximated body temperature to minimize the heat-sink effect that a bolus of cold water would have on core temperature. Warm water was provided ad libitum during the 1-h exercise bouts in the afternoon. Subjects also performed a familiarization trial that involved 2 h of exercise at a WBGT of 26.5°C. This session was performed 2 wk prior to the first experimental condition. Subjects were asked to keep a dietary record for the 2 d prior to this familiarization session and then replicate this diet prior to the experimental trials.

Dressing and Weighing Procedures

Subject preparation, insertion of the rectal thermistor, and placement of skin thermistors have been detailed previously (1,19). On entering the chamber, the subject's thermistors and rectal thermistor monitoring cables were connected to a computerized data acquistion system (Hewlett-Packard 3497A control unit, 236-9000 computer, and 2934A printer) and the exercise began. Mean values over 1-min periods for T_{re} and skin temperature were recorded and printed by the data acquisition system. A seven-point weighted mean skin temperature ($\bar{T}_{sk}$) (14) was subsequently calculated. HR was recorded every 5 min from the display on the telemetry receiver (Polar® CE0537). After the completion of each trial, dressed weight was recorded within 1 min after exit from the chamber and nude weight was recorded following a subsequent short undressing procedure.

Differences in nude and dressed weights before and after each trial were corrected for respiratory and metabolic weight loss (see below). The rate of sweat production was calculated as the difference between the corrected pre-trial and post-trial nude weights, divided by exercise time that was defined as the difference in time between removal from and entry into the environmental chamber. Evaporative sweat loss was calculated from the differences in pre- and post-trial corrected dressed weights. Although the dripping of sweat from the clothing, face and hands was minimal our calculation of evaporative sweat loss does not account for any of this lost sweat.

Gas Exchange Analyses

During each trial, open-circuit spirometry was used to determine expired minute ventilation and oxygen consumption ($\dot{V}O_2$) using a 2-min average obtained every 15 min. Respiratory water loss was calculated using the VO_2 measured during the trial and the equation presented by Mitchell et al. (20). Metabolic weight loss was calculated from $\dot{V}O_2$ and the respiratory exchange ratio using the equation described by Snellen (31).

Ratings of Perceived Exertion and Thermal Comfort

Following the gas exchange measurement, subjects were asked to provide a rating of perceived exertion (RPE) between 6 and 20 for the whole body (6) and a rating of thermal comfort (TC) between 1 (so cold I am helpless) and 13 (so hot I am sick and nauseated) for the whole body (10).

Blood Sampling

At the same time for each trial, prior to beginning the dressing procedure for the morning sessions, but after the insertion of the rectal thermistor, a 5 ml venous blood sample was taken while the subject was in the supine position and the serum was later analyzed for osmolality (Advance Micro Osmometer, Model 3300, Advanced Instruments Inc., Norwood, MA).

Statistical Analyses

Data are presented as mean values and the standard deviation of the mean. An analysis of variance (ANOVA) was performed using the data from the tests conducted on the second morning of successive exercise days and the control trial performed at the same WBGT. A one-factor (trial) repeated measures ANOVA was used to evaluate any differences among these sessions for osmolality, sweat production, sweat evaporation, and exercise time. All subjects completed at least 100 min of exercise at the WBGT of 22.5°C and 75 min at the higher WBGT of 26.5°C. As a result, a two-factor (trial and time) repeated measures ANOVA was performed on the data set for all subjects to 100 min and to 75 min for the lower and higher WBGTs, respectively, for evaluating the changes in RPE, TC, $\dot{V}O_2$, HR, T_{re}, and $\bar{T}_{sk}$ during the exercise. It was not the intent of this study to compare responses between the different WBGTs. However, to examine whether the current military guidelines indeed demarcate different degrees of thermal stress, HR, T_{re}, and $\bar{T}_{sk}$ responses were compared over 75 min of exercise between the control days at the WBGT of 22.5°C and 26.5°C. In addition, the HR and T_{re} responses were compared during the 60 min of exercise in the afternoon of D1 for the WBGT of 22.5°C and 29.5°C. When a significant F-ratio was obtained, a Newman-Keuls post-hoc analysis was used to isolate differences among treatment means. For all statistical analyses, the 0.05 level of significance was used.

RESULTS

Indices of Hydration Status

Nude body weights and osmolality were not different among the trials, thus indicating that hydration status was similar prior to initiating the heat exposures.

Indices of Heat Strain

Metabolic rate: There was no difference in VO_2 among the trials conducted at either a WBGT of 22.5°C or 26.5°C. However, at the former WBGT, values did show a small but significant increase from $1.41 \pm 0.30\ L \cdot min^{-1}$ to $1.47 \pm 0.35\ L \cdot min^{-1}$ from the beginning to 90 min into the heat stress trials, respectively. Similarly, at the higher WBGT of 26.5°C, VO_2 increased significantly from $1.40 \pm 0.31\ L \cdot min^{-1}$ at the beginning to $1.49 \pm 0.33\ L \cdot min^{-1}$ after 75 min of exercise. These values throughout the exercise trials averaged 45.2 ± 7.1%

TABLE II. RATES OF SWEAT PRODUCTION AND EVAPORATION DURING THE HEAT-STRESS TRIALS.*

	22.5°C				26.5°C			
		Day 2 Response				Day 2 Response		
	CONT	$_{(22.5)}$D1	$_{(22.5)}$D1$_{(22.5)}$	$_{(22.5)}$D1$_{(29.5)}$	CONT	$_{(22.5)}$D1	$_{(22.5)}$D1$_{(22.5)}$	$_{(22.5)}$D1$_{(29.5)}$
Sweat Rate ($kg \cdot m^{-2} \cdot h^{-1}$)	0.33 (0.07)	0.31 (0.06)	0.33 (0.09)	0.31 (0.05)	0.39 (0.08)	0.38 (0.07)	0.40 (0.07)	0.39 (0.08)
Rate of Sweat Evaporation ($kg \cdot m^{-2} \cdot h^{-1}$)	0.26 (0.06)	0.25 (0.04)	0.24 (0.04)	0.25 (0.03)	0.26 (0.06)	0.28 (0.04)	0.28 (0.06)	0.27 (0.07)

* The trials were conducted at a WBGT of 22.5°C and 26.5°C for the single-day control (CONT) sessions and day 2 of two successive days of exercise with the first day (D1) exposure in the morning at a WBGT of 22.5°C ($_{(22.5)}$D1) and afternoon sessions on D1 at either a WBGT of 22.5°C (D1$_{(22.5)}$) or 29.5°C (D1$_{(29.5)}$)
Values are means (SD) for n = 7

$\dot{V}O_{2peak}$ and ranged from 35.7% to 59.0% $\dot{V}O_{2peak}$ for these subjects.

Rates of sweat production and evaporation: The rates of sweat production and evaporation are presented in **Table II.** Prior exercise during the morning only or during both the morning and afternoon of D1 had no influence on either the sweat rate or the rate of sweat evaporation during exercise conducted in the morning of D2 at either WBGT. Sweat rates were higher during the control test at the WBGT of 26.5°C. At the higher skin temperatures (see the following section) these elevated sweat rates would have maintained the vapor pressure gradient and evaporative potential comparable with the control trial at the WBGT of 22.5°C.

Heart rate: **Fig.** 1A and B presents the changes in heart rate (HR) throughout the trials at the WBGT of 22.5°C and 26.5°C, respectively. There was no impact of prior exercise conducted during the morning and/or afternoon on the day preceding the tests at either WBGT. Values increased significantly throughout the heat stress trials at 22.5°C WBGT from 115.6 ± 14.0 bpm after 5 min of exercise to 131.3 ± 16.6 bpm after 100 min of exercise. During the trials at a WBGT of 26.5°C, HR increased significantly from 118.3 ± 15.1 bpm after 5 min to 140.5 ± 18.5 bpm following 75 min of exercise. Heart rates were not significantly different ($p < 0.08$) after 75 min of exercise between the control days at the WBGT of 22.5°C and 26.5°C.

HR responses during the morning of D1 at a WBGT of 22.5°C were similar to the responses noted above and presented in Fig. 1A for CONT$_{(22.5)}$ and the D2$_{(22.5)}$ trials. During the afternoon of D1 at the WBGT of 22.5°C, HR increased to 132.7 ± 12.2 bpm following 60 min of exercise. During D1$_{(29.5)}$, HR increased to significantly higher values of 164.1 ± 14.9 bpm at the end of this 1-h exercise session.

Rectal temperature: As shown in **Fig.** 2A and B, exercise on the day before also had no impact on the T_{re} response during exercise at either WBGT. Core temperature increased significantly throughout the trials with values reaching 37.9 ± 0.3°C after 100 min of exercise at a WBGT of 22.5°C and 38.2 ± 0.3°C after 75 min at a WBGT of 26.5°C. The increase in T_{re} was significantly greater at the WBGT of 26.5°C compared with 22.5°C after 75 min of exercise. The T_{re} response during $_{(22.5)}$D1 was not different from the trials conducted on D2 at the same WBGT. During the 1 h of exercise on the afternoon of D1, the increase in T_{re} to 38.0 ± 0.1°C during D1$_{(22.5)}$ was significantly less than the increase to 38.6 ± 0.3°C during D1$_{(29.5)}$.

Mean skin temperature: **Fig.** 3A and B presents the $\bar{T}_{sk}$ response during the trials at the WBGT of 22.5°C and 26.5°C, respectively. Prior exercise during the morning only or during both the morning and afternoon of D1 had no effect on $\bar{T}_{sk}$ throughout the trials at either WBGT. Values increased significantly over time reaching 33.9 ± 1.2°C and 35.1 ± 0.9°C during the trials at the WBGT of 22.5°C and 26.5°C, respectively. The increase in $\bar{T}_{sk}$ after 75 min of exercise was significantly greater during the WBGT trial at 26.5°C. The $\bar{T}_{sk}$ response during $_{(22.5)}$D1 was not different from the response shown in Fig. 3A during CONT$_{(22.5)}$ or during trials conducted at the same WBGT on D2.

Ratings of thermal comfort and perceived exertion: Prior exercise on the day before had no effect on the ratings of TC or RPE during exercise at either WBGT. At the WBGT of 22.5°C, TC increased significantly from 8.1 ± 0.9 after 15 min of walking to 8.9 ± 0.9 after 90 min of exercise. RPE also increased significantly over this time period from 11.0 ± 1.9 to 12.7 ± 2.3. At the higher WBGT of 26.5°C, TC increased significantly from 8.3 ± 0.8 after 15 min of exercise to 9.4 ± 1.2 after 75 min of walking. Over this same time period RPE also increased significantly from 11.0 ± 2.2 to 13.5 ± 3.1.

Exercise time: **Table III** presents the exercise time for the trials and the final T_{re}. Prior exercise on day 1 of the protocol had no influence on either of these dependent measures on day 2. During the trials conducted at the WBGT of 22.5°C one subject complained of leg fatigue and failed to complete the 2 h of walking during the $_{(22.5)}$D1$_{(22.5)}$/ D2$_{(22.5)}$, and $_{(22.5)}$D1$_{(29.5)}$/ D2$_{(22.5)}$ trials. At the higher WBGT of 26.5°C, eight trials were terminated prior to 120 min of exercise because of fatigue (n = 4), difficulty breathing (n = 2), nausea (n = 1), and dizziness (n = 1). Only three of the seven subjects completed 2 h of exercise during all of the trials at this higher WBGT.

DISCUSSION

The findings from the present study have revealed that in hydrated and rested subjects, prior moderate intensity exercise during the morning or during both the morning and afternoon of the day before does not

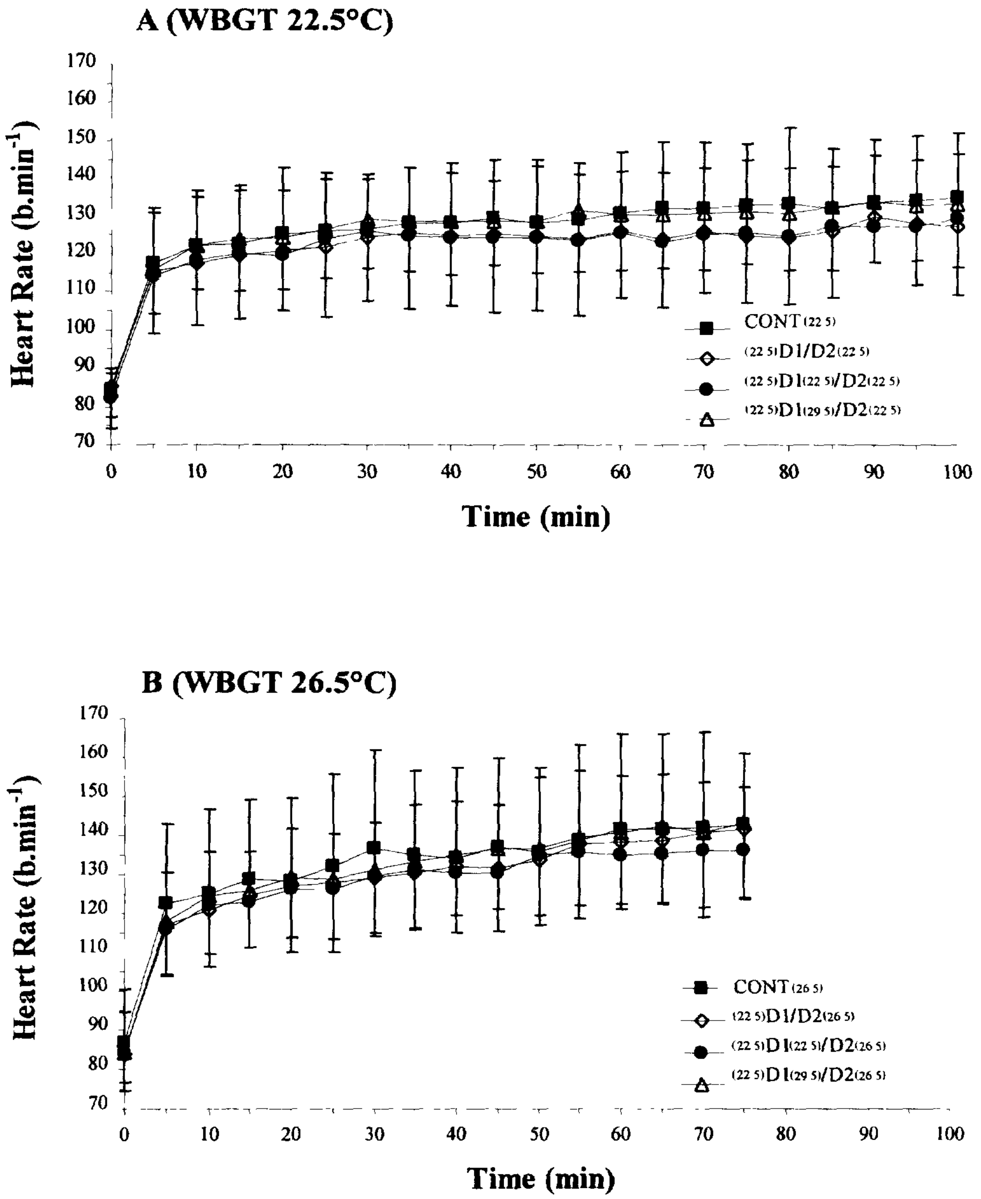

Fig. 1. Changes in heart rate during the heat-stress trials at a WBGT of 22.5°C (A) and 26.5°C (B) for the single-day control (CONT) sessions and the second day of successive days of exercise (D1, D2) with the first day exposure in the morning at a WBGT of 22.5°C ($_{(22.5)}$D1) and afternoon sessions on D1 at either a WBGT of 22.5°C (D1$_{(22.5)}$) or 29.5°C (D1$_{(29.5)}$). Values are mean ± SD for n = 7

impact on the thermoregulatory response during the same moderate intensity exercise the next morning. These findings were consistent for exercise at a WBGT that would not be associated with restrictions of duty for Canadian and U.S. military personnel as well as for a WBGT that represents the lowest temperature where work and rest schedules are to be implemented. Further, there was no evidence of any carry-over effects if the exercise during the afternoon of the first day was performed at a higher WBGT that normally would be associated with curtailed activity levels. One important conclusion from the present work would be the support of the statement that the present guidelines for implementing work and rest schedules at different WBGT levels, which do not make any adjustments for carry-over, are adequate. For hydrated and well-rested individuals there is no need to take into consideration heat exposure and/or moderate intensity exercise on the previous day. We believe this statement could be applied to the majority of military personnel in these environmental conditions since our subjects were sedentary and had an increased body fat percentage that, in theory, would place them at an increased risk of succumbing to exertional heat illness (11). However, for more prolonged or repeated exposure to heat and heavy exercise, and/or a more severely stressed population, it may still be appropriate to give some consideration to potential carry-over effects.

It must be remembered, however, that our subjects were properly hydrated, rested and free of injury, disease, or drugs, which are factors that could alone, or in combination, influence the thermoregulatory response to exercise in the heat (3,4,7,8,21,26,27). The demands of basic training may increase the risk of personnel becoming sleep deprived and injured from the amount of physical training incorporated into the program, especially for those that were previously sedentary and unaccustomed to regular exercise. Further, failure of

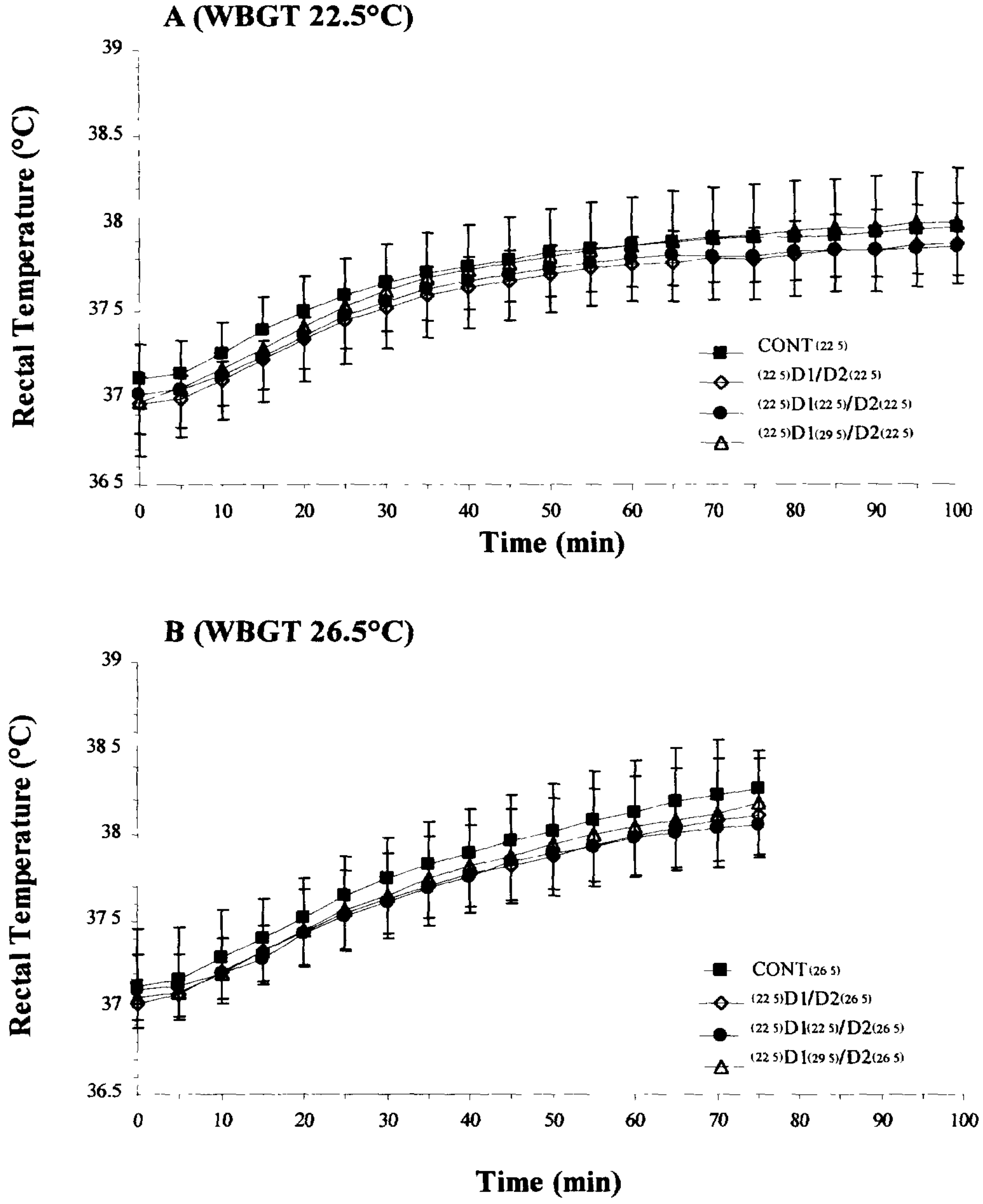

Fig. 2. Changes in rectal temperature during the heat-stress trials at a WBGT of 22.5°C (A) and 26.5°C (B) for the single-day control (CONT) sessions and the second day of successive days of exercise (D1, D2) with the first day exposure in the morning at a WBGT of 22.5°C ($_{(22.5)}$D1) and afternoon sessions on D1 at either a WBGT of 22.5°C (D1$_{(22.5)}$) or 29.5°C (D1$_{(29.5)}$). Values are mean ± SD for n = 7.

training officers to adhere to rehydration guidelines during physical training would place recruits at an increased risk to thermoregulatory problems (27). Finally the peer-pressure that recruits may feel while trying to successfully complete a 13 km loaded march, for example, or while trying to perform as well as a more fit counterpart may motivate these less fit individuals to continue to exercise under conditions when they would otherwise stop. According to Epstein et al. (9) most cases of exertional heat stroke occur in young, highly motivated healthy individuals.

The findings from the present study are limited to two successive days of exercise. Whether subjects would have experienced greater increases in core temperature during exercise on a third successive day (or more) is not known. However, it is clear that adaptation to daily regular exercise is rapid with changes occurring in as few as 3 d (12,13) and that adaptations that occur with heat acclimatization also begin within 3–4 days of repeated heat exposure (22). Further, Armstrong et al. (2) reported that the signs and symptoms of heat exhaustion occurred more frequently during the first 4 d of an 8-d heat acclimation program. Thus, it is more likely that problems with exertional heat illness during basic training would occur during the initial days of increased physical activity. As the training continues, recruits should increase their aerobic fitness and become more heat acclimated, which are factors that normally lessen (but not eliminate) their risk to heat injury (8,22). Additionally, recent epidemiological evidence has indicated that hospitalization for exertional heat illness during subsequent military service is uncommon following an initial episode during basic training (23).

One should also be cognizant that the present findings cannot necessarily be extrapolated to repeated bouts of exercise at higher intensities. The workrate in the present study was selected to simulate the marching pace required to complete a 13 km march in the maxi-

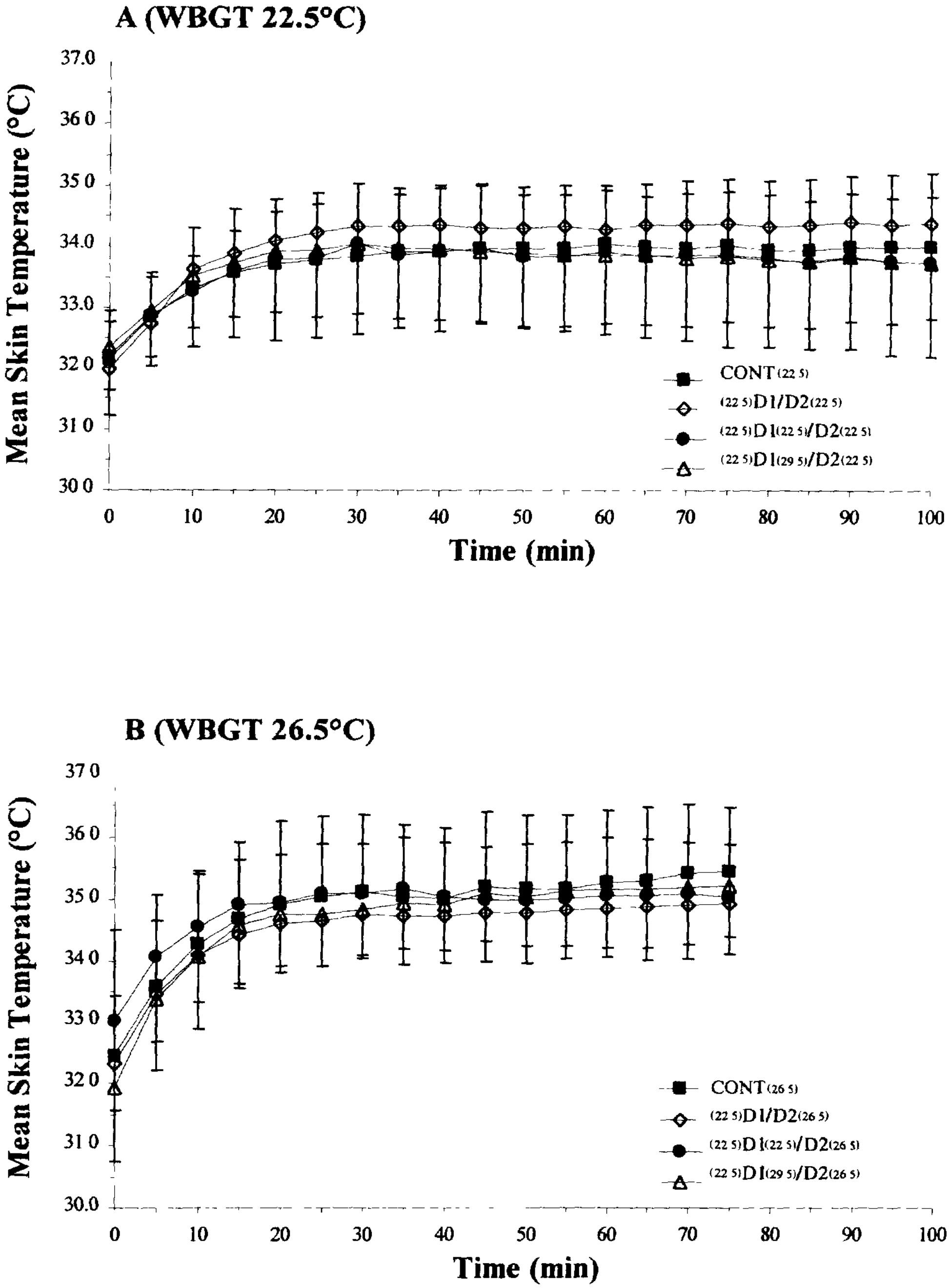

Fig. 3. Changes in mean skin temperature during the heat-stress trials at a WBGT of 22.5°C (A) and 26.5°C (B) for the single-day control (CONT) sessions and the second day of successive days of exercise (D1, D2) with the first day exposure in the morning at a WBGT of 22.5°C ($_{(22.5)}$D1) and afternoon sessions on D1 at either a WBGT of 22.5°C (D1$_{(22.5)}$) or 29.5°C (D1$_{(29.5)}$). Values are mean ± SD for n = 7.

TABLE III. EXERCISE TIMES AND FINAL RECTAL TEMPERATURES (TRE) DURING THE HEAT-STRESS TRIALS.*

	22.5°C				26.5°C			
		Day 2 Response				Day 2 Response		
	CONT	$_{(22.5)}$D1	$_{(22.5)}$D1$_{(22.5)}$	$_{(22.5)}$D1$_{(29.5)}$	CONT	$_{(22.5)}$D1	$_{(22.5)}$D1$_{(22.5)}$	$_{(22.5)}$D1$_{(29.5)}$
Exercise Time	120	120	117	119	107	111	110	107
(min)	(0)	(0)	(8)	(2)	(22)	(16)	(18)	(21)
Final T_{re}	38.0	37.9	37.9	38.0	38.5	38.3	38.2	38.3
(°C)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.5)	(0.3)

* The trials were conducted at a WBGT of 22.5°C and 26.5°C for the single-day control (CONT) sessions and day 2 of two successive days of exercise with the first day (D1) exposure in the morning at a WBGT of 22.5°C ($_{(22.5)}$D1) and afternoon sessions on D1 at either a WBGT of 22.5°C (D1$_{(22.5)}$) or 29.5°C (D1$_{(29.5)}$).
Values are means (SD) for n = 7.

mum allowed time of 2 h 10 min during basic training for the Canadian Forces. The relative exercise intensity associated with the walking pace approximated 45% VO_{2max} for our subjects and the increase in T_{re} to around 38.5°C (see Table III) at the WBGT of 26.5°C would indicate only a moderate degree of heat stress. Since core temperature response during exercise is determined more by relative rather than absolute exercise intensity (25) either asking the present subjects to simulate the completion of the 13 km march in less than 2 h 10 min or studying subjects with a lower aerobic fitness would have increased the relative exercise intensity and resultant increase in core temperature. Clearly we cannot be certain that under these potential situations that prior exercise would not affect the thermoregulatory response to subsequent exercise the next morning.

The use of the WBGT index, as proposed by Yaglou and Minard (34), to establish guidelines assumes an equivalent heat stress regardless of the infinite combinations of dry bulb, wet bulb, and black globe temperatures that could produce a given WBGT. In an elegant study, Shapiro et al. (28,29) showed that heat acclimated men with varied fitness levels had a higher heart rate and a greater T_{re} increase and body heat storage during 2 h of exercise in humid heat compared with dry heat at equivalent WBGT levels around 34°C. However, similar findings were not evident for a group of heat acclimated women (28). Ramanathan and Belding (24) also reported greater thermal strain during treadmill walking for 2 h during warm-humid conditions but they only studied three subjects. Others have reported greater heat strain in hot-dry compared with hot-wet conditions during 60 min of exercise at a WBGT of 32°C regardless of gender (17); whereas no difference in heat strain has been observed in hot-dry and warm-humid conditions at a WBGT of 28°C during prolonged exercise at 30% VO_{2max} (30). Thus, it would appear that thermal strain during exposure to hot-dry or hot-wet environments may not be similar even though the measured WBGT is equivalent. It should be remembered, therefore, that our findings in the present study are applicable for intensities of exercise and environmental conditions that result in moderate heat stress with an increase in T_{re} to approximately 38.5°C.

The small number of subjects that could be recruited for this study lowered the power of the experimental design to approximately 0.3 for the dependent measure of T_{re}. Thus, there might be concern of a Type II error in the acceptance of the null hypothesis. However, the difference between the treatment and error variances was quite small and post-hoc analyses revealed that approximately 125 subjects would have to be tested to increase the power to 0.8. It is important to realize that both subject numbers as well as the difference between the treatment and error variance influence the power of the experimental design (18). One of the advantages of a repeated-measures design is to lower the within-subject error variance. Thus, the fact that 125 subjects would be needed in this repeated-measures design to increase the power to 0.8 attests to the lack of a significant treatment affect.

In conclusion, this study has shown that moderate intensity exercise during the morning or during both the morning and afternoon on the day before does not impact the heart rate and core temperature responses during the same moderate intensity exercise the next morning. This conclusion was consistent for a WBGT that would be associated with the initial implementation of work and rest schedules for military training as well as for a lower WBGT that would not be associated normally with any restrictions of duty. Thus, under situations where individuals are well hydrated, rested, and free of injury, illness, and drug use, repeated moderate intensity exercise bouts on successive days do not alter the thermoregulatory response to exercise and would not appear to place anyone at an increased risk to exertional heat injury.

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