Temperature Regulation during Intermittent Exercise with Progressive Dehydration

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Abstract Effects of dehydration (3% of initial body weight) on temperature regulation were investigated in 5 men during intermittent exercise of 4 h duration at a dry air temperature of 34°C. Relative mechanical work load was 50% of the subject’s steady state heart rate, which was 170 beats·min⁻¹. During rehydration from the 70th min to the end of the exercise, the subjects drank, every 10 min in equal portions, an amount of water (20°C) totaling up to 80% of the body weight loss recorded during dehydration runs. Continuous measurements were made of rectal (Tre) and mean skin (Tsk) temperatures and of whole body weight loss. Chest sweating rate (msw) was measured from a capsule located under a local thermal clamp (36°C). Blood samples were obtained during rest periods and after the 1st and the 4th hour of exercise. Compared to dehydration runs, water intake did not always cause an increase of msw while body temperatures always decreased. Dehydration resulted in a decrease in plasma volume and in increases of plasma osmolality, [Na⁺] and [K⁺]. Water intake induced a thermoregulatory response whose intensity largely differs from one body area to another. The change in the slope of the relation of msw to Tre features a decrease in the sensitivity of the thermoregulatory system with dehydration. The whole body water loss is significantly correlated with the change in plasma volume and body temperatures (Tre, Tsk). This suggests that the reduced sweating response observed during dehydration can be related to plasma hypovolemia.

Key words: intermittent exercise, dehydration, sweat rate, local skin temperatures, plasma constituents.

Experimental evidence supports the finding that continuous exercise in the heat leading to 2–3% dehydration of body weight results in a sweat rate decline and a body temperature rise, when compared to that observed during the hydrated state.

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253
A similar finding has been reported by Ekblom et al. (1970) during intermittent exercise (1% dehydration of the body weight). However, for similar experimental conditions, Gosselin (1947), Strydom et al. (1966), and Claremont et al. (1976) found no change in the sweat rate. From these data it can be assumed that lower levels of dehydration (2–3%) promote individual differences in the sweating response during dehydration-rehydration experiments performed on exercising men since with higher levels of dehydration (4–8%), a sweat rate decline is always described (Senay, 1968; Strydom and Holdsworth, 1968; Sawka et al., 1983). This reduced sweating rate has been related to plasma hypovolemia (Nadel et al., 1980; Fortney et al., 1981) or to an increase in plasma osmolality (Senay, 1968; Greenleaf and Castle, 1971; Nielsen, 1974; Sawka et al., 1985).

The discrepancies between the results showing and those not showing an increase in sweating rate with fluid intake may also be related to differences between the body areas from which the sweat gland activity is recorded. As demonstrated by Senay and Christensen (1965) through analysis of local skin temperature responses, fluid intake triggers the sweating reflex over the body surface. The duration and intensity of the sweating responses differ from one body area to another. The observations of Fortney et al. (1981) also suggest that the reduction in sweating rate observed during iso-osmotic hypovolemia occurred only in skin areas located over inactive muscles (chest and arm) while this effect is masked over contracting muscles (calf). Until now, little attention has been paid to regional skin temperature responses which can give information on regional sudomotor changes following water ingestion. The aim of the present study was to investigate how thermoregulatory responses are affected by progressive dehydration (3% of body weight) and rehydration during intermittent exercise in a dry, warm environment. The plasma constituents were taken into account in order to determine their interactions with thermoregulatory responses. The present study was also an attempt at a more complete description of interregional local skin temperature responses and of interindividual differences in the sweating response occurring during progressive dehydration and rehydration experiments.

MATERIALS AND METHODS

Experimental procedure. Five healthy fit non-acclimatized male subjects, whose characteristics are described in Table 1, volunteered for the experiments. They were informed of the protocol and gave their written consent to participation. During the experiment, the subject wore shorts and tennis shoes, and sat on a bicycle ergometer attached to a scale. After a resting period of 30 min in a thermoneutral environment at air ($T_a$) and wall ($T_w$) temperatures of 28°C, dew-point temperature ($T_{dp}$) of 10°C and air velocity ($V_a$) of 0.3 m·s$^{-1}$, the subject performed intermittent exercise for a period of 4 h. Relative mechanical work load was 50% of the subject’s steady state heart rate which would be 170 beats·min$^{-1}$. Pedaling
frequency was fixed at 60 rpm.

At the onset of exercise, $\dot{V}_a$ was increased to 0.6 m s\(^{-1}\) while $T_a$ and $T_w$ were raised to 34°C, and $T_{\text{op}}$ remained unchanged. Durations of work-rest cycles were 4 repetitions of 25 min work and 5 min rest for the first 2 h of heat exposure followed by 4 repetitions of 20 min work and 10 min rest for the second 2 h.

The experiments were carried out in 2 separate series; the first without fluid intake (dehydration), and the second with spring water intake (rehydration). The mineral composition of the replacement water is given in Table 2. During rehydration runs, from the 70th minute to the end of heat exposure, the subject drank, in successive equal portions, an amount of water totaling up to 80% of the body weight loss previously measured during the dehydration experiments. The temperature of the ingested water was 20°C. Every 10 min an amount equal to 1/18 of the total amount to be ingested was given to the subject.

Experiments on a single subject were scheduled at a 6-day interval to avoid muscular training and heat acclimation. All the experiments were performed in the morning (7.30–12.30 h), to minimize variability due to the circadian rhythm. On the evening before heat exposure, subjects ate a standard meal and slept in the

### Table 1. Physical characteristics, oxygen uptake, initial blood volume, and body weight losses of the five subjects.

<table>
<thead>
<tr>
<th>Subj.</th>
<th>Age (yr)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>$A_D$ (m(^2))</th>
<th>$W$ (watts)</th>
<th>$\dot{V}_{O_2}$ (ml·min(^{-1})·kg(^{-1}))</th>
<th>$\Delta W_i$ (%)</th>
<th>$V$ (l)</th>
<th>$BV_o$ (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>1.79</td>
<td>68</td>
<td>1.86</td>
<td>76</td>
<td>15.4</td>
<td>15.2</td>
<td>-3.2</td>
<td>-0.6</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>1.80</td>
<td>67</td>
<td>1.85</td>
<td>82</td>
<td>15.2</td>
<td>16.2</td>
<td>-2.9</td>
<td>-0.5</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>1.78</td>
<td>72</td>
<td>1.89</td>
<td>73</td>
<td>14.0</td>
<td>14.8</td>
<td>-2.8</td>
<td>-0.6</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>1.86</td>
<td>87</td>
<td>2.12</td>
<td>103</td>
<td>19.1</td>
<td>17.4</td>
<td>-2.9</td>
<td>-0.4</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>1.76</td>
<td>71</td>
<td>1.86</td>
<td>93</td>
<td>18.1</td>
<td>18.4</td>
<td>-3.5</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

$W =$ mechanical relative work load; $D, R =$ dehydration and rehydration runs, respectively; $V =$ volume drunk; $BV_o =$ initial body weight volume calculated from Allen et al.'s equation (1956); $\Delta W_i =$ body weight loss expressed in terms of % from initial body weight; $\dot{V}_{O_2} =$ mean value of oxygen uptake measured after the 1st and 2nd hour of exercise; $W_i =$ initial mean body weight measured before each experimental test; $A_D =$ Dubois area.

### Table 2. Mineral composition of ingested spring water.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>0.52</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.50</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.35</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.13</td>
</tr>
<tr>
<td>Chloride</td>
<td>0.21</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.03</td>
</tr>
<tr>
<td>Sulfate</td>
<td>0.14</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>1.04</td>
</tr>
</tbody>
</table>

All values are in milliequivalents per liter of water.
laboratory under the experimenter's supervision, to insure that all the subjects underwent the same regimen. The change in base-line body weight measured before each experimental test did not exceed 0.4 kg.

**Measurements of physiological variables.** Expired air was collected by the open circuit technique in a Douglas bag: the expired air volume was measured by a spirometer and oxygen uptake \( (\dot{V}_{O_2}) \) was determined by an oxygen analyzer (Beckman Model E2) after 1 and 2 h of exercise. Mean values of \( \dot{V}_{O_2} \) are indicated in Table 1.

During the experiment, venous blood samples (15 ml) were drawn with an indwelling needle which had been inserted into the antecubital vein at 7.30 h. Blood samples were taken at the end of the resting period (8.30 h), and after 1 and 4 h of exercise. The attached tubing was back-flushed with 1 ml of heparinized saline solution after each manipulation.

The following physiological data were monitored digitally every minute throughout the experiment:
- Ten local skin temperatures from thermistors were placed on the skin surface of the forehead, left scapular region, right pectoral region, left upper abdominal quadrant, right lumbar region, left forearm, left hand dorsum, right foot dorsum, right calf, and right thigh. The mean skin temperature \( (T_{sk}) \) was calculated by using the weighing area factors of HARDY and DUBOIS (1938);
- Rectal temperature \( (T_{re}) \) from a thermistor placed at a depth of 11 cm beyond the anal sphincter;
- Whole body weight loss from a recording scale \( (\pm 1 \text{ g accuracy}) \);
- Local sweating rate \( (m_{sw}) \) from a highly ventilated \( (\text{constant flow} = 5 \text{l min}^{-1}) \) capsule with a 12 cm\(^2\) surface area was placed on the right side of the chest: sweating rate \( (m_{sw}) \) was estimated by the dew-point hygrometer technique. Continuous \( m_{sw} \) records were integrated over 1 min-periods. The target level of the local skin temperature under the capsule \( (T_{sa}) \) was fixed at 36°C. The local skin temperature, under the capsule was continuously monitored by 2 thermistors (KTY 11 2A). Average local skin temperature \( (T_{sa}) \) was kept as constant as possible \( (\pm 0.5°C) \) by means of a servosystem acting on the temperature of the air flowing through the capsule.

Accuracy of all temperature readings was 0.05°C in absolute level and \( \pm 0.01°C \) in variation.

Changes in plasma volume \( (\Delta PV) \) was assessed by triplicate determinations from changes both in the hematocrit and in hemoglobin concentrations (DILL and COSTILL, 1974). \( \Delta PV \) was expressed in terms of percent change from the value measured at the end of the resting period. Plasma osmolality was measured in duplicate by the freezing-point depression technique. Serum \([Na^+]\) and \([K^+]\) were assayed by flame photometry. Plasma protein \( (PP) \) was measured by WEICHSELBAUM’s method (1946).

**Calculations.** Blood volume \( (BV) \) was estimated from the equation of ALLEN et al. (1956) and the absolute value of plasma volume \( (PV) \) was calculated from \( BV \)
and blood hematocrit. Changes in plasma constituents during exercise were expressed by differences between the 1st and the 4th hour of exercise. The 1st hour was considered as the reference point since no fluid had yet been given to the subjects in any of the trials. Statistical analyses were performed on these calculated changes.

The sweating response rate in relation to body temperature was analyzed only for sweat on the chest area where the local skin temperature could be kept constant.

The interaction between thermoregulatory response and plasma constituents was analyzed using the body weight recording as parameter for whole body water loss. Whole body water loss measured during the 1st and the 4th hour of exercise was adjusted for the body surface area. The analyses were done on mean values of hourly whole body sweating rates.

Mean body temperature decreases ($\Delta T_b$) due to the cooling of the body by the ingested water were calculated from the following equation:

$$\Delta T_b = V \times \Delta T \times 4.18 / W_t \times 3.5$$

where: $V =$ volume drunk, kg; $\Delta T =$ difference between mean body temperature $(0.9 T_{re} + 0.1 \bar{T}_{sk})$ recorded before drinking and the temperature of the drink (20°C); $W_t =$ body mass, kg; 3.5 = specific heat of body tissue, kJ·kg$^{-1}$·°C$^{-1}$; and 4.18 = conversion factor from kcal to kJ.

Statistical analysis. Dependent Student’s t-tests were used for the statistical analysis of the individual data. The difference in the regression coefficients of the $\dot{m}_{sw}$ vs. $T_{re}$ relationships between the dehydration and the rehydration runs were analyzed using the procedure of Yates (1938).

The existing relationship between mean whole body sweating rate and other variables (body temperatures and plasma constituents) was studied using the analysis of covariance (1 V procedure from BMDP). The mean whole body sweating rate was taken as the dependent variable, time (hour 1 or 4) was taken as the independent categorical (factor) variable, and body temperatures (rectal, $T_{re}$, and mean skin temperature, $\bar{T}_{sk}$) and plasma constituents (plasma osmolality, PO, and plasma volume, PV) were assumed to be metric independent variables (covariates). After adjusting for factors, i.e. after removing time-related effects, the relationship between the dependent and the independent variables was studied using linear multiple regression analysis. On the first run, all of the above independent variables were introduced into the regression equation. Then, not-significant covariates were removed and the regression coefficients hereafter presented were obtained.

$p < 0.05$ was accepted as statistically significant. $p < 0.10$ was also given when the tested effect was of practical importance.

RESULTS

Data reported in Table 1 show that during the dehydration runs the subjects lost $3.1 \pm 0.1\%$ (1 S.D.) of their initial body weights. No differences in oxygen
uptake were observed between the 2 series of experiments.

The time courses of local ($m_{sw}$) and whole body sweat rates were similar during the dehydration and the water intake experiments. The mean whole body sweat rates were 341 ± 43 (1 S.D.) g·h⁻¹·m⁻² in dehydration runs and 349 ± 41 g·h⁻¹·m⁻² in rehydration runs while $m_{sw}$ were 1.05 ± 0.33 mg·min⁻¹·cm⁻² and 1.05 ± 0.18 mg·min⁻¹·cm⁻², respectively. In the dehydration runs, rectal ($T_{re}$) and mean skin ($T_{sk}$) temperatures showed overall ascending trends with time (induced by the work periods). In the hydrated state from the 1st hour of exercise to the end of the experiment, body temperatures were lower than those simultaneously reached in the dehydrated state. There were decreases of $T_{re}$ (−0.5°C) and of $T_{sk}$ (−0.4°C) with water intake. As expected with the law of the conservation of energy, these body temperature decreases can be explained, in part, by the amount of heat taken from the body core to warm up the ingested water. No true steady state with respect to body temperature was ever attained either in the dehydration or in the rehydration runs.

Plasma constituents

Plasma constituents measured at the end of the resting period are shown in Table 3. From these data it can be assumed that there are no marked interindividual differences in initial plasma constituents between the 2 experimental tests.

Table 4 shows the values of the plasma constituents and of the percent change in plasma volume ($\Delta PV$) calculated in the 2 series of experiments, after the 1st and the 4th hour of exercise. After the 1st hour of exercise without drinking in the 2 experimental tests, comparable values of PO were observed for all the subjects (286–301 mOsm·kg⁻¹), despite large interindividual differences in $\Delta PV$ (0.32 to −5.03%). An increase in PO, ($\Delta$PO) was observed with water deprivation from the 1st and the 4th hour of exercise ($t(4) = 4.365; p < 0.01$). An important point to remember is that
Table 4. Plasma constituents measured at the 1st and the 4th hour of exercise for the 5 subjects.

<table>
<thead>
<tr>
<th>Subj.</th>
<th>ΔPV</th>
<th>PO</th>
<th>[K⁺]</th>
<th>[Na⁺]</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>R</td>
<td>H1</td>
<td>H4</td>
<td>D</td>
</tr>
<tr>
<td>1</td>
<td>-5.03</td>
<td>-11.37</td>
<td>-0.53</td>
<td>+2.50</td>
<td>290</td>
</tr>
<tr>
<td>A</td>
<td>-6.34</td>
<td>+3.03</td>
<td>+16</td>
<td>-7</td>
<td>4.30</td>
</tr>
<tr>
<td>2</td>
<td>-1.72</td>
<td>-4.73</td>
<td>+0.32</td>
<td>-1.84</td>
<td>287</td>
</tr>
<tr>
<td>A</td>
<td>-3.01</td>
<td>-2.16</td>
<td>+11</td>
<td>-2</td>
<td>4.10</td>
</tr>
<tr>
<td>3</td>
<td>-1.35</td>
<td>-1.77</td>
<td>-1.85</td>
<td>+0.37</td>
<td>292</td>
</tr>
<tr>
<td>A</td>
<td>-0.42</td>
<td>+2.22</td>
<td>+13</td>
<td>-15</td>
<td>4.10</td>
</tr>
<tr>
<td>4</td>
<td>-1.22</td>
<td>-4.30</td>
<td>-0.05</td>
<td>+3.06</td>
<td>295</td>
</tr>
<tr>
<td>A</td>
<td>-3.08</td>
<td>+3.11</td>
<td>+1</td>
<td>-7</td>
<td>4.10</td>
</tr>
<tr>
<td>5</td>
<td>-1.89</td>
<td>-3.99</td>
<td>-4.29</td>
<td>+2.15</td>
<td>286</td>
</tr>
<tr>
<td>A</td>
<td>-2.10</td>
<td>+6.44</td>
<td>+1</td>
<td>-10</td>
<td>4.30</td>
</tr>
</tbody>
</table>

Δ, R = dehydration and rehydration runs, respectively; Δ = difference between 4th (H4) and 1st (H1) hour values; ΔPV = plasma volume change %; PO = osmolality in milliosmols per kilogram of plasma; K⁺ and Na⁺ concentrations in milliequivalents per liter of plasma; PP = plasma proteins in g.
during dehydration, subjects 4 and 5 seemed to maintain their plasma osmolalities ($\Delta$PO = +1 mOsm $\cdot$ kg$^{-1}$) while subjects 1–3 showed greater increases (+5–16 mOsm $\cdot$ kg$^{-1}$).

Except for subject 2, [K$^+$] was elevated during the dehydration runs while in [Na$^+$] the response was highly variable. Compared to water intake, dehydration runs induced an increase in $\Delta$[K$^+$] ($t_{(4)} = 5.582$; $p < 0.001$) and $\Delta$[Na$^+$] ($t_{(4)} = 3.833$; $p < 0.02$). During dehydration the total plasma protein levels increased. Compared to dehydration, there were no significant changes in total plasma protein masses ($\Delta$PP) after water intake. The data also showed that during dehydration the percent change in plasma volume decreased while during water intake this value increased. Statistical analysis showed that compared to water ingestion, dehydration significantly decreased the percent change in plasma volume $\Delta$(APV) ($t_{(4)} = 3.343$; $p < 0.05$) recorded between the 1st and the 4th hour of exercise.

Chest sweating rate and body temperature

The individual relationships obtained between $m_{sw}$ and $T_{re}$ during the exercise period are shown in Fig. 1. The transient phases of exercise and recovery periods were not considered in order to avoid possible effects of the rates of changes of $T_{sk}$ and $T_{re}$ in the $m_{sw}$ response. The first 20 min following drinking were also excluded to avoid the outburst of sweating following, in some occasions, the first ingestion of water. This outburst of local sweating appearing without any consistent changes in body temperature was probably due to a reflex following fluid ingestion. Each point corresponds to a mean value of $m_{sw}$ averaged over $T_{re}$ intervals of 0.10°C. No significant difference (paired $t$-test) appeared in the levels of local skin temperature under the capsule between the dehydration and the rehydration runs. Except for subject 2, the slopes of $m_{sw}$ vs. $T_{re}$ relationship decreased with dehydration. These decreases were significant in 2 out of the 5 subjects. The slopes averaged 0.39 ± 0.12 (1 S.D.) mg·min$^{-1}$·cm$^{-2}$·°C$^{-1}$ during the dehydration tests and 0.80 ± 0.32 mg·min$^{-1}$·cm$^{-2}$·°C$^{-1}$ during the rehydration ones.

Whole body sweating rate and plasma constituents

Using the analysis of covariance, time-related effects were removed and the relationship between mean whole body sweating rate and plasma constituents were analyzed by multiple linear regression. The following results were obtained:

a) No significant correlation ($F_{1,15} = 0.13$) was found between the sweating response and plasma osmolality after adjusting for other covariates;

b) The following regression coefficients $b$ (means ± 1 S.E.) of mean whole body sweating rate (g·min$^{-1}$·m$^{-2}$) vs. body temperature ($T_{re}$, $T_{sk}$, °C) and plasma volume (PV, l) were obtained:

$$b (T_{re}) = 0.930 \pm 0.288 \quad F_{1,15} = 9.5 \quad p < 0.01;$$

$$b (T_{sk}) = -0.576 \pm 0.159 \quad F_{1,15} = 11.7 \quad p < 0.001;$$

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Fig. 1. Local sweating rate ($m_{sw}$) plotted against corresponding rectal temperature ($T_{re}$) during dehydration (○) and rehydration (●) runs for each subject. Values of the slopes of the regressive lines for the dehydration ($a_D$) and the rehydration runs ($a_R$) are also indicated. The statistical analysis ($t$-values) of differences between slopes $a_D$ and $a_R$ are indicated. For each line mean skin temperature values (in °C) are noted in parenthesis. Symbols *, ** indicate the statistical significance of the differences between the two relationships ($p<0.05$, $p<0.01$, respectively); NS = not significant.
Local skin temperatures

The local skin temperatures ($T_{sl}$) of the different parts of the body are plotted against time in Fig. 2. In view of the responses of individual local skin temperatures,
the subjects were divided into 2 groups (S1–3; S4–5) in which the data were analyzed separately. In each group, the responses of the different local skin temperatures were so similar that averaging did not alter any significant detail of the individual data. During the dehydration runs, except for the forehead skin temperature, there was an upward trend in the function of time for all the local skin temperatures. The trend was greater for group (S4–5) than for group (S1–3).

After water ingestion, $T_{sl}$ responses may be varied in different areas. A drop of $T_{sl}$ was observed on the foot and the hand dorsum while on other body areas, $T_{sl}$ was stable (forehead, thigh and calf) or increased gradually (forearm and trunk).

The effect of water intake on local skin temperature responses was more pronounced for S4–5 than for S1–3. This was predominantly noted on $T_{sl}$ of the foot and hand dorsum of subjects 4–5, showing marked downward trends with time. It can also be pointed out that, for these 2 subjects, $T_{sl}$ levels of foot and hand dorsum were below the environmental temperature (34°C).

DISCUSSION

Results show that during prolonged intermittent exercise, compared to rehydration (Table 4), dehydration induces a plasma concentration with increases in serum $A[K^+]$ and $A[Na^+]$. These features are still debated in the literature. $[K^+]$ usually shows a nominal relationship ($r=0.20$ to $0.40$) with dehydration. Only $[Na^+]$ has been consistently shown to be strongly ($r=0.65$) related to dehydration. During dehydration an increased amount of $[K^+]$ was found by many authors in experiments performed on a bicycle ergometer with a constant relative work load (van Beaumont et al., 1973; Costill and Fink, 1974) as well as on resting subjects (Costill and Fink, 1974; Ohira et al., 1981) while Whiting et al. (1984) found no modification of the serum $K^+$ concentration in marathon runners. As for $[Na^+]$, the data of the present study confirm those of Whiting et al. (1984) and of Costill and Fink (1974) who observed an increase in the serum $Na^+$ concentration during dehydration, in opposition to authors showing that the $Na^+$ concentration was unaffected (Ohira et al., 1981) or decreased (van Beaumont et al., 1973).

It is worth mentioning that, during the dehydration runs, compared to subjects 4 and 5, the other 3 subjects were unable to maintain their plasma osmolalities despite the fact that they exercised at lower absolute work loads. There were no apparent interindividual differences in plasma constituents to account for the discrepancy in osmolality responses.

The change in osmolality observed in the present study cannot be accounted for by the sum of changes of $[Na^+]$, $[K^+]$, and protein concentrations. A similar result has been reported by Gaebelein and Senay (1980). During exercise it would seem that osmotically active particles other than those measured here, such as lactate and pyruvate may also play a role.

This study failed to demonstrate any systematic increase in the sweating rate with water ingestion. For subjects 4–5, after water ingestion, the local skin
temperatures ($T_{an}$) of different parts of the body showed marked decreases. The rehydration effect on $T_{an}$ was particularly strong on the extremities (hand and foot dorsum). For these body parts, the decrease of $T_{an}$ below the environmental temperature of 34°C can be taken as featuring an increase in evaporative skin cooling. These observations indicate that the increase in the sweating rate was not restricted to the chest and was particularly strong on the extremities of these two subjects. Water intake induces a thermoregulatory response which differs strongly from one body area to another. Thus, the body area from which the sweating response is measured can be at the origin of the discrepancy between the results showing and those not showing an increase in sweating rate with rehydration. Under water intake, an increase in the sensitivity of the thermoregulatory system was observed. This increase was significant in 2 out of the 5 subjects. This observation is consistent with the results reported by Fortney et al. (1981) during hypovolemia induced by diuretics but disagrees with the statements of Doris and Baker (1981) and of Turleiska-Stelmasiak (1974) who concluded that, in animals, dehydration results in a rise of the hypothalamic temperature threshold for evaporation. However, it is difficult to compare the mode of thermoregulation between these studies since the different experimental protocols do not induce similar thermal or blood constituent equilibriums.

The observation showing that during water ingestion body temperatures always fell while there was no systematic increase in the sweating rate could be attributed to the drink temperature which contributes to body cooling. The decreases in mean body temperature ($\Delta T_b$) related to the amount of heat taken from the body core to warm up the ingested water were calculated from Eq. (1). The individual values of $\Delta T_b$ are not very different: $-0.57^\circ$C for S1; $-0.51^\circ$C for S2; $-0.48^\circ$C for S3; $-0.61^\circ$C for S4, and $-0.50^\circ$C for S5. From this, it seems difficult to explain the wide interindividual differences observed in the sweating response from the temperature of the ingested water only.

The data found from the covariance analysis show that during physical exercise the whole body sweating rate is mainly correlated with plasma volume, and rectal and mean skin temperatures. As it has already been shown (Nadel et al., 1980; Fortney et al., 1981), reduced plasma volume is associated with a lower ability to sweat. The effect of hypovolemia on the sweating response could be explained from neural pathways located between atrial stretch receptors and the hypothalamus through which changes in receptor activity, depending on the cardiac filling pressure, could directly modify the sensitivity of the hypothalamic thermoregulatory center (Gauer et al., 1970). In the present study a negative partial regression coefficient between the sweating response and $T_{sk}$ was found. It is unwise to admit an inhibitory effect of $T_{sk}$ on sweating. Rather, it may be assumed that exercise first induces an increase in $T_{re}$ and then increases the sweating rate which in turn determines a drop in $T_{sk}$.

In conclusion, the results show that the sweating response is correlated with the change in plasma volume. The large interindividual differences observed in the
sweating responses can not be simply explained by those changes in the plasma constituents or in the thermophysiological variables. A nonthermal effect due to interindividual difference in psychic excitement accompanying changes in work load (MIYAGAWA et al., 1985) can not be ruled out.

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