Acute Effects of Exercise or Sauna on Appetite in Obese and Nonobese Men

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Westerterp-Plantenga, M. S., C. R. T. Verwegen, M. J. W. Ijdeema, N. E. G. Wijckmans and W. H. M. Saris. Acute effects of exercise or sauna on appetite in obese and nonobese men. Physiol Behav 62(6) 1345–1354, 1997.—To study the effect of exercise on appetite in men, hunger, thirst, taste perception, energy intake, and macronutrient choice were assessed in relation to exercise and to sauna; the latter was done to correct for dehydration and rise in body temperature. Since exercise is used to prevent and cure obesity, subjects included obese as well as nonobese men. Thirty subjects (25 ± 7 years, BMI 22.8 ± 1.6 and 28.5 ± 1.9) were given twice, in random order before and after 2 h of cycling at 60% of W\textsubscript{max}, 2 h of sauna, or 2 h of rest. an ample choice from solid and liquid almost single-macronutrient food items and a taste perception test with solutions of sucrose, citric acid, NaCl, quinine, a mixture of these, and a carbohydrate electrolyte solution. After cycling as well as after sauna, in comparison to after rest, subjects lost 3 ± 0.5% of body mass, while thirst, fluid intake, perception of sweet at relatively low concentrations, and percentage of energy coming from carbohydrate increased significantly. Only after cycling compared to after rest did perception of bitterness at a low concentration increase and hunger and energy intake decrease. We conclude that exercise induced a short-term reduction in hunger and energy intake, whereas exercise and sauna induced a short-term increase in taste perception of sweet at the lower concentration, while macronutrient preference of carbohydrate increased. © 1997 Elsevier Science Inc.

EXERCISE is considered as contributing to the prevention of cure of obesity, by preventing a positive energy balance and by having a positive effect on body composition (12). Rising et al. (24) suggested that obesity is associated with low physical activity, and because physical activity is one of the most variable components of energy expenditure, addition of exercise to the daily programs of the obese might have favorable effects. By increasing exercise, higher rates of energy expenditure can be achieved, and when energy intake does not change, increased energy expenditure might result in a negative energy balance.

The question remains whether possible compensation by type and amount of food intake after exercise would reduce the intended effect. Altered food intake has been suggested as compensatory adaptation for the extra energy deficit from the addition of exercise (10). Moreover, exercise has been reported to increase, have no effect on, or decrease food intake (34,35,39). Several studies in humans, i.e., in lean men (13,20,31), in obese men (8), and in obese women (39,40), have shown stable energy intake after 30–60 min of exercise, without differences between obese and normal weight subjects. Other studies indicate that exercise induced anorexia, which is characterized by a brief suppression of hunger, accompanied by a delay in the onset of eating (17,18,23,33).

The decrease of food intake 15 min after exercise was shown to be due to severity of exercise, as a dose response relationship (18). The increase in food intake was shown when the meal was given 50, 60, or 75 min after finishing cycling (18,33–37). In this respect, it has also been suggested that exercise (29) or exercise-induced anorexia (36,37) results in a change in macronutrient preference.

Verger et al. reported a relative increase of carbohydrate consumption with a limited food choice after exercise (36) and a relative increase of protein consumption with a wide range of foods to choose from after exercise (37). In the first study, the food choice was limited (36), and a choice for fat or protein could not be specific due to the mixed protein/fat food items. In the second study, an ample choice of food items was offered, including fat and carbohydrate specificity, but little protein specificity (37), while from this study protein preference was reported.

King et al. (17) reported no effect of exercise on possible macronutrient preference, but gave a limited food choice, in which only carbohydrate specificity was present.

Therefore, it would be difficult to conclude from these studies whether after exercise a preference for a macronutrient would exist, since it was hardly possible to choose or avoid protein (17,36,37) or fat (17,36). Moreover, taste perception or a possible change in taste perception may have played a role, which was not assessed in the studies mentioned. Some studies suggest that there may be sensory differences in individuals that are not usually taken into account (2–5). Especially with respect to exercise, it has been observed that acoustic and physiological stress can change taste perception or hedonic rating and that athletes sometimes complain about changes in gustatory sensation of drinks, such as a carbohydrate electrolyte solution, during exercise (30). In this context, the observations by Saris et al. (30), who reported a change in taste.

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perception during and after endurance exercise, may be of relevance. They showed, during exercise, an increase in taste perception for bitter but not for sweet, sour, and salt in a mixture in which the four basic tastes were equally dominant (30). Since exercise induces a dehydration of 2–3% of body mass during 2 h of cycling at 60% of \( W_{\text{max}} \) and an increase in body temperature, a change in food preference may also be caused by dehydration and hyperthermia (29,41).

Until now, the effects of exercise on appetite in terms of taste perception, food and macronutrient preference, hunger, and energy intake have not been assessed in relation to each other. In this study, we hypothesized that dehydration (and also hyperthermia) might be related to a change in food preference and therefore possibly a change in macronutrient preference. To address our hypothesis that exercise per se alters energy intake, food preference, and taste perception, tests were run before and after exercise as well as before and after ‘rest.’ To assess the possible role of dehydration induced by the exercise, similar tests were administered before and after a similar weight loss induced by sauna. To address the hypothesis that nutrient intake after exercise is not altered in obese subjects, the same protocol was performed in obese and nonobese subjects. For these subjects, it is of special relevance to estimate whether by increasing exercise increased energy expenditure results in a negative energy balance without a possible energy intake compensation.

METHODS

Subjects

Subjects were recruited from Maastricht University by means of an article in the University weekly newspaper. Because more than the required number of men responded, which allowed selection after screening for health (no high blood pressure, no diabetes mellitus, no use of medicines, no other diseases), for body mass index (for the nonobese, 20–25 kg/m\(^2\); for the obese, >25 kg/m\(^2\) (12) and for age (19–35 years), and less than the required number of women responded, the study was executed with men. Thirty healthy untrained men participated in the studies: 10 obese and 10 nonobese men executed the first protocol (cycling versus rest); 10 nonobese men executed the second protocol (sauna versus rest). The subject characteristics (mean ± SD) were as follows: for the nonobese subjects, age 25 ± 7, body mass index 22.8 ± 1.6; for the obese subjects, age 25 ± 6, body mass index 28.5 ± 1.9. The subjects were fully informed on the study and gave their written informed consent. The study was approved by the Medical Ethical Committee.

Procedure

Protocol 1. Each subject (n = 20) came to the laboratory eight times during 8 consecutive weeks on a fixed day of the week at 0930 hours 2 h after his own—each time identical—subject-specific breakfast to execute randomly one of the following procedures. Four times the subjects performed 2 h of submaximal exercise on a bicycle ergometer at 60% of their individual \( W_{\text{max}} \), which (60%) was on average (±SD) 211 ± 27.9 W for the lean men and 144 ± 19.2 W for the obese men (vide infra). Room temperature was 19°C. Four other times the subjects spent 2 h reading or studying while sitting in a chair; room temperature was 22°C. During cycling as well as during studying, subjects were offered 250 mL of water from the start onward (which they drank completely) to prevent severe dehydration during cycling and to run the same protocol during rest. Each time before and immediately after 2 h of cycling or rest, body weights of the subjects were measured. Two times before and 10 min after 2 h of cycling and two times before and 10 min after 2 h of studying, the taste perception test as described below was executed. Two times before and 10 min after 2 h of cycling and two times before and 10 min after 2 h of studying, the subjects were offered a buffet-style meal as described below. After each session, subjects were asked to rate how comfortable they had been in terms of general well-being to determine whether the data were being collected under circumstances that were relatively acceptable to the subjects.

Protocol 2. Each subject (n = 10), nonobese and with sauna experience, came to the laboratory eight times during 8 consecutive weeks on a fixed day of the week at 0930 hours 2 h after his own—each time identical—subject-specific breakfast. In random order, the following activities were executed. Four times the subjects were transported to the sauna. They were allowed to stay in the sauna for 2 h, during which they had to spend three 20-min periods at 80°C. When they were not in the sauna itself, they were sitting in a small swimming pool or bubble bath. The sauna duration was chosen to achieve the same magnitude of dehydration as during the 2 h of cycling of Protocol 1. Spending three 20-min periods at 80°C during 2 h in the sauna was based on experience with respect to required weight loss. Four other times the subjects spent 2 h reading or studying while sitting in a chair; room temperature was 22°C. During sauna as well as during studying, subjects were offered 250 mL of water from the start onward (which they drank completely) to prevent severe dehydration during sauna and to run the same protocol during rest. Each time before and immediately after 2 h in the sauna or rest, body weights of the subjects were measured.

Tests similar to those in Protocol 1 were done: Two times before and 10 min after 2 h in the sauna and two times before and 10 min after 2 h of studying, the taste perception test as described below was executed. Two times before and 10 min after 2 h in the sauna and two times before and 10 min after 2 h of studying the subjects were offered a buffet-style meal as described below. After each session, subjects were asked to rate how comfortable they had been in terms of general well-being to determine whether the data were being collected under circumstances that were relatively acceptable to the subjects.

Maximal Exercise Test

Before Protocol 1 (cycling versus rest) started, the subjects’ maximal work load (\( W_{\text{max}} \)) was measured during an individual incremental exercise test using the bicycle ergometer (19). Subjects started the bicycle test with 5 min of cycling at 40 W. After 5 min, the workload was increased by 40 W to 80 W for 4 min. After this 9-min warm-up period, the workload was increased every minute by 20 W for the normal weight subjects and by 10 W for the obese subjects till exhaustion. The maximal workload was calculated using the total time cycled. For the last 1-min period, the fraction of this minute that was cycled was divided by 60 (seconds) and multiplied by 20 W (for normal weight subjects) or by 10 W (for obese subjects). This fraction was added to the amount of work performed to obtain the maximal workload (19). The oxygen uptake during the test was measured continuously using a computerized open system (Oxycon Beta, Mijnhardt, Bunnik, The Netherlands). This test was carried out at a room temperature of 19°C.

Tests of Taste Perception

Before the start of both protocols (cycling versus rest and sauna versus rest), for each subject the rate of taste perception of a range of five concentrations of sweet (sucrose: 0, 25, 50, 75, and 100 g/liter), bitter (quinine sulfate: 0, 12.5, 25, 50, and 75 mg/liter), salt (sodiumchloride: 0, 2.5, 5.0, 7.5, and 10.0 g/liter), and sour (citric
acid: 0, 0.5, 1.0, 1.5, and 2.0 g/liter) solutions was determined following the method described by Bartoshuk (2,4).

To be able to compare our data with those reported by Saris et al. (30), a taste perception test was also performed with mixtures of these solutions in which each of the tastes was almost equally dominant to the subject. The composition of the mixture was 12.5 g/liter sucrose, 0.625 g/liter NaCl, 0.375 g/liter citric acid, and 18.75 mg/liter quinine sulfate. For each subject, it appeared that these were the lowest concentrations of which the taste was recognized in the mixture.

Finally, to be able to relate our data to the perception of the carbohydrate electrolyte solution (CES), a taste perception test was done with this drink. Carbohydrate electrolyte solution, a sport drink, consists of 125 kJ, 6.9 g of carbohydrate, 100 mg of vitamin C, and 0.6 mg of vitamin B.

The procedure for the taste perception test was as follows: The complete ranges were offered twice, with 2 h in between (to mimic the prospective experimental situation), during which no solid or liquid consumption was allowed, except a glass of water. The drinks were offered in random order with respect to concentrations, with water offered alternating with each drink to prevent comparison of the taste with the saliva solution in the mouth (2); it was not allowed to ingest the drinks. The order in which the different series of tastes were offered was constant: sweet series, salty series, sour series, bitter series, mixture, and CES. Room temperature was 22°C during each of the tests.

Subjects were asked to indicate the taste (sweet, salt, sour, or bitter) to rate the perceived intensity (how sweet/salty/sour/bitter do you find the drink?) on 100-mm visual analog scales (VAS) with the anchor “very weak” and “very strong” and to rate the hedonic value of the drink on 100-mm VAS with the anchors “not nice” and “very nice.” This had to be done for the 20 single-taste concentrations, for the mixture, and for the CES. It is this complete taste perception procedure that was repeated each time when it is mentioned in the text as a “taste perception test.”

Tests of Macronutrient Preference

The macronutrient choices were made from buffet-style meals with an ample choice of almost single-macronutrient solid and fluid food items, with a carbohydrate specificity of at least 98% of energy, a fat specificity of at least 90% of energy, and a protein specificity of 44–90% of energy (Table 1). Each time each meal had to be rated on a 100-mm VAS with respect to hedonic value. Before and after each meal, hunger, thirst, and satiety were rated. From each meal, energy intake and macronutrient composition were calculated.

Data Analysis

Rates of hunger, thirst, satiety, comfort, the perceived taste intensities, and hedonic values of each drink, energy intake divided over solid and fluid energy intake, macronutrient intake, and body weight were averaged per time point over the two identical occasions per subject and subsequently per group of subjects (N = 10). When the groups of subjects, i.e., the obese and the nonobese, did not show significantly different results, the data were taken together (N = 20). Results from cycling versus rest were compared to those from sauna versus rest using ANOVA.

RESULTS

Body mass index differed significantly between the obese and the nonobese (Mann–Whitney U-test, p < 0.01). %Wmax was also significantly different between the obese (240 ± 38 W) and the nonobese subjects (351 ± 49 W) [F(2, 20) = 16.12; p < 0.01].

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Carbohydrate</th>
<th>% Protein</th>
<th>% Fat</th>
<th>Energy Content (kJ/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosehip jam</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>1021</td>
</tr>
<tr>
<td>Honey</td>
<td>99.7</td>
<td>0.3</td>
<td>0</td>
<td>1343</td>
</tr>
<tr>
<td>Potatoes</td>
<td>84</td>
<td>16</td>
<td>0</td>
<td>320</td>
</tr>
<tr>
<td>White bread</td>
<td>84</td>
<td>12.8</td>
<td>3.2</td>
<td>1086</td>
</tr>
<tr>
<td>Grape juice</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>301</td>
</tr>
<tr>
<td>Apple juice</td>
<td>98.7</td>
<td>1.1</td>
<td>0</td>
<td>155</td>
</tr>
<tr>
<td>Tummy</td>
<td>0</td>
<td>90.6</td>
<td>9.4</td>
<td>488</td>
</tr>
<tr>
<td>Smoked beef</td>
<td>1.6</td>
<td>61.0</td>
<td>37.4</td>
<td>638</td>
</tr>
<tr>
<td>Lean yoghurt</td>
<td>48.7</td>
<td>49.3</td>
<td>2.0</td>
<td>138</td>
</tr>
<tr>
<td>Buttermilk</td>
<td>40.5</td>
<td>44.1</td>
<td>15.4</td>
<td>131</td>
</tr>
<tr>
<td>Butter</td>
<td>0</td>
<td>0.5</td>
<td>99.5</td>
<td>3186</td>
</tr>
<tr>
<td>French spread</td>
<td>1</td>
<td>8.6</td>
<td>90.4</td>
<td>1766</td>
</tr>
<tr>
<td>Cheese</td>
<td>1.2</td>
<td>0.6</td>
<td>98.2</td>
<td>3120</td>
</tr>
<tr>
<td>Cucumber salad with mayonnaise</td>
<td>0.5</td>
<td>99.5</td>
<td>3186</td>
<td></td>
</tr>
<tr>
<td>Fatty broth</td>
<td>0</td>
<td>0.5</td>
<td>99.5</td>
<td>3186</td>
</tr>
<tr>
<td>Pumpernickel</td>
<td>81.9</td>
<td>13.1</td>
<td>5.0</td>
<td>1390</td>
</tr>
</tbody>
</table>

VO2max (mL kg⁻¹ min⁻¹) was 58.4 ± 1.6 in the obese and 71.8 ± 1.9 in the nonobese subjects.

There were no significant differences between the results of the obese and the nonobese subjects with respect to how comfortable the subjects felt, body weight change, taste perception, hedonic values of the drinks, energy intake from solid and liquid food intake, macronutrient composition of food intake, hedonic ratings of the buffet-style meals, and hunger and thirst ratings, so the data of these groups were taken together.

During rest, the subjects felt very comfortable (92; range 88–100); during sauna, they felt extremely comfortable (95; range 91–100); and during cycling, they felt just comfortable (71; range 60–79). There were no differences between sauna and rest; during cycling, the subjects felt less comfortable than during rest [F(1, 19) = 4.37; p < 0.01].

After rest, body weight did not differ significantly from before rest: ±0.13 kg or 2 ±0.1%. Body weight changed significantly from before to after cycling (−1.86 kg; range −1.55 to −2.06 kg, [F(1, 19) = 21.49; p < 0.001] or 3 ± 0.5%) and from before to after sauna (−1.82 kg; range −1.53 to −2.04 kg, [F(1, 19) = 15.7; p < 0.001], 3 ± 0.4%). Body weight change, especially during cycling, cannot be completely attributed to dehydration. The part of the drop that is due to utilization of glycogen stores was calculated based on 60% of VO2max during 2 h body weight, and the assumption of an RQ = 0.85 (16,22). This yielded on average for the obese and for the lean subjects a weight loss of 86.4 g over 2 h.

The rate of taste perception of each concentration of the single-taste drinks did not differ between before and after rest respectively before cycling or before sauna (Fig. 1–4). Also, rate of perception of salt or sour at any concentration did not change in any of the situations measured. After cycling, rate of taste perception of the 50 g/liter sucrose solution was significantly increased compared to after rest [F(3, 76) = 10.18; p = 0.0001]. Rate of taste perception of the 25 mg/liter quinine sulfate solution was also increased compared to after rest [F(3, 76) = 11.82; p = 0.0001]. After sauna, rate of taste perception of the 50 g/liter sucrose solution was not significantly increased compared to after rest [F(3, 76) = 0.001].
FIG. 1. Rate of taste perception (100-mm VAS) in relation to a range of sucrose concentrations: $p < 0.01$ after cycling or sauna compared to after rest.

FIG. 2. Rate of taste perception in relation to a range of quinine sulfate concentrations: $p < 0.001$ after cycling compared to after rest.
solution was also significantly increased \( F(3, 36) = 44.9; p = 0.0001 \) compared to after rest. Rates of taste perception at the higher concentrations did not differ between any of the time points.

Perception of the four tastes individually in the mixture did not differ significantly from before to after rest or from before to after sauna, or from before rest to before cycling or sauna (Table 4).

FIG. 4. Rate of taste perception in relation to a range of citric acid concentrations.
TABLE 2
TASTE PERCEPTION OF THE MIXTURE ON 100-mm VAS WITH ANCHORS “VERY WEAK” AND “VERY STRONG” FOR TWO SETS OF EXPERIMENTAL COMPARISONS: (1) BEFORE AND AFTER CYCLING VERSUS BEFORE AND AFTER REST AND (2) BEFORE AND AFTER SAUNA VERSUS BEFORE AND AFTER REST

<table>
<thead>
<tr>
<th>Situation</th>
<th>Sweet</th>
<th>Salt</th>
<th>Sour</th>
<th>Bitter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Rest</td>
<td>34 ± 12</td>
<td>32 ± 11</td>
<td>20 ± 12</td>
<td>20 ± 10</td>
</tr>
<tr>
<td>Cycling</td>
<td>32 ± 12</td>
<td>44 ± 11</td>
<td>19 ± 11</td>
<td>22 ± 13</td>
</tr>
<tr>
<td>Rest</td>
<td>46 ± 8</td>
<td>56 ± 7</td>
<td>35 ± 10</td>
<td>26 ± 6</td>
</tr>
<tr>
<td>Sauna</td>
<td>41 ± 6</td>
<td>40 ± 7</td>
<td>17 ± 6</td>
<td>15 ± 5</td>
</tr>
</tbody>
</table>

* p < 0.001, compared to before cycling and compared to after rest.

After cycling, only rate of taste perception for bitter in the mixture was significantly increased compared to after rest [F(3, 76) = 102.34; p = 0.0001], Table 2. In the carbohydrate electrolyte solution, rate of taste perception for sweet had increased from before to after cycling [F(3, 76) = 98.27; p = 0.0001] as well as from before to after sauna [F(3, 36) = 47.49; p = 0.0001], both compared to after rest (Table 3). For the whole group, no differences in hedonic ratings were found for any of the drinks between before rest, cycling or sauna, or between before and after rest, before and after cycling or before and after sauna (Table 4). Comparing the different drinks, the hedonic value of the carbohydrate electrolyte solution was significantly higher than those of any of the other solutions [F(1, 29) = 74.3; p < 0.001], and the hedonic value of the sweet solution was significantly higher than those of the other single-taste solutions or of the mixture [F(1, 29) = 23.5; p < 0.01] (Table 4).

Energy intake appeared to be reduced before cycling compared to before rest [F(3, 76) = 116.57; p < 0.001] and after cycling [F(3, 76) = 118.12; p < 0.001] compared to after rest (Table 5). No significant differences were observed with respect to energy intake before sauna compared to before rest or after sauna compared to after rest.

Energy percentage from solid respectively liquid food did not differ between before cycling or before rest respectively before sauna or before rest. Energy percentage from liquid food intake was significantly increased after cycling compared to after rest [F(3, 76) = 115.67; p < 0.001] as well as after sauna compared to after rest [F(3, 36) = 52.32; p < 0.001] (Table 5).

With respect to macronutrient composition of food intake, no statistically significant differences were found between the situations before rest and before cycling or before rest and before sauna. Also the macronutrient compositions of food intake before and after rest did not differ significantly from each other. Macronutrient composition, however, differed after cycling compared to after rest [F(3, 76) = 36.86; p < 0.01] as well as after sauna compared to after rest [F(3, 36) = 47.92; p < 0.01] (Table 5). In both cases, energy percentage from carbohydrate increased and energy percentage from fat decreased. Hedonic values did not show any differences with respect to before rest or cycling or sauna and with respect to before compared to after cycling, or rest, or sauna (Table 5).

After cycling, but not after sauna, hunger was significantly suppressed [F(3, 76) = 88.36; p < 0.01] compared to after rest (Fig. 5). Satiety ratings were not significantly different between cycling and rest or between sauna and rest (Fig. 6). Thirst was significantly increased after cycling [F(3, 76) = 193.13; p = 0.0001] as well as after sauna [F(3, 36) = 94.36; p = 0.0001] compared to after rest (Fig. 7).

DISCUSSION
In general, comfort ratings representing general physical well-being, in which hunger, thirst, body temperature, and exhaustion could play a role, were sufficiently high to judge the situations as being acceptable to the subjects. In none of the observations was there any difference between the obese and nonobese groups of subjects, so the conclusions with respect to cycling versus rest apply to both groups.

TABLE 3
TASTE PERCEPTION OF THE CARBOHYDRATE ELECTROLYTE SOLUTION ON 100-mm VAS WITH ANCHORS “VERY WEAK” AND “VERY STRONG” FOR TWO SETS OF EXPERIMENTAL COMPARISONS: (1) BEFORE AND AFTER CYCLING VERSUS BEFORE AND AFTER REST AND (2) BEFORE AND AFTER SAUNA VERSUS BEFORE AND AFTER REST

<table>
<thead>
<tr>
<th>Situation</th>
<th>Sweet</th>
<th>Salt</th>
<th>Sour</th>
<th>Bitter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Rest</td>
<td>60 ± 4</td>
<td>61 ± 3</td>
<td>10 ± 7</td>
<td>11 ± 8</td>
</tr>
<tr>
<td>Cycling</td>
<td>61 ± 4</td>
<td>68 ± 3*</td>
<td>11 ± 5</td>
<td>12 ± 6</td>
</tr>
<tr>
<td>Rest</td>
<td>60 ± 4</td>
<td>61 ± 4</td>
<td>12 ± 5</td>
<td>10 ± 5</td>
</tr>
<tr>
<td>Sauna</td>
<td>62 ± 3</td>
<td>71 ± 4*</td>
<td>11 ± 7</td>
<td>12 ± 7</td>
</tr>
</tbody>
</table>

* p < 0.001, compared to before cycling respectively before sauna and compared to after rest.
### TABLE 4

<table>
<thead>
<tr>
<th>Situation</th>
<th>Sweet</th>
<th>Salt</th>
<th>Sour</th>
<th>Bitter</th>
<th>Mixture</th>
<th>CES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Rest</td>
<td>60 ± 16</td>
<td>61 ± 17</td>
<td>27 ± 9</td>
<td>29 ± 4</td>
<td>45 ± 14</td>
<td>48 ± 13</td>
</tr>
<tr>
<td>Cycling</td>
<td>62 ± 17</td>
<td>78 ± 16</td>
<td>28 ± 7</td>
<td>18 ± 6</td>
<td>47 ± 14</td>
<td>58 ± 13</td>
</tr>
<tr>
<td>Rest</td>
<td>63 ± 13</td>
<td>67 ± 12</td>
<td>10 ± 9</td>
<td>3 ± 3</td>
<td>60 ± 8</td>
<td>65 ± 9</td>
</tr>
<tr>
<td>Sauna</td>
<td>76 ± 11</td>
<td>69 ± 9</td>
<td>17 ± 8</td>
<td>7 ± 6</td>
<td>58 ± 10</td>
<td>62 ± 8</td>
</tr>
</tbody>
</table>

After exercise, i.e., 2 h of cycling at 60% \( W_{max} \), a change in appetite was observed, which consisted of a change in hunger, thirst, macronutrient preference, energy intake, and taste perception at relatively low concentrations of sucrose (50 g/liter) and quinine sulfate (25 mg/liter). No change in taste perception at the higher concentrations was observed.

With respect to a change in taste perception, this study confirms the results reported by Saris et al. (30) regarding the perception of bitter in low concentrations, but we also observed a difference regarding the perception of sweet in low concentrations in single-taste drinks. With respect to the range of concentrations offered, this study is in agreement with one of the models described by Bartoshuk (2), which suggests that rate of taste perception at lower concentrations might be sensitive to interventions but rate of perception at higher concentrations might not change.

The significant increase in rate of taste perception of the lower concentrations of sucrose and/or quinine sulfate in the simple solutions, in the mixture, and in the carbohydrate electrolyte solution after exercise compared to after rest might be of little significance, since a change of perception at a low concentration might hardly have any influence, which is confirmed by the observation that hedonic rating did not change. A change of perception without a change of hedonic rating has been observed before, where perception had changed with age but hedonic rating had remained the same (6).

Thus the observed change in perception might not be related to the increased macronutrient preference for carbohydrate, since the sweet carbohydrate food items offered were judged to be sweeter than the 50 g/liter sucrose solution and the neutral carbohydrate food items offered were not sweet. On closer inspection of the data, no significant food selection occurred between sweet and neutral carbohydrates. The bread and the crackers were consumed as basis for the jam, honey, tuna, beef, butter, and cheese whereas the potatoes were consumed together with the cucumber salad.

Taste perception appears to be independent of sensory-specific appetite (27). After exercise, a significant reduction of hunger and of energy intake was observed. Moreover, a significant increase of thirst and a relative increase of liquid intake, together with a significantly lower energy intake from solid foods, was seen. Also before cycling energy intake was reduced compared to after rest, probably in anticipation of the expected activity to perform. Finally, a shift in macronutrient selection after cycling was seen toward a relatively higher carbohydrate intake at the expense of fat. Both observations are of importance in the perspective of exercise to cure obesity, i.e., to improve weight maintenance after weight reduction, since at least these confirm that exercise does not increase energy intake in the obese as well as in the nonobese in the short term. The suppressed hunger feelings after exercise compared to after rest which we observed were also reported by King et al. (17) and Katch et al. (15), whereas Thompson et al. (33) reported both relatively suppressed hunger feelings and increased fluid intake after exercise. With respect to macronutrient preference, energy intake from carbohydrates was significantly increased at the expense of energy intake from fat after exercise compared to

### TABLE 5

<table>
<thead>
<tr>
<th>Situation</th>
<th>Energy Intake (MJ)</th>
<th>% Solid/Liquid Food</th>
<th>CHOP/F</th>
<th>Hedonic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Rest</td>
<td>3.1 ± 0.2</td>
<td>3.1 ± 0.3</td>
<td>70/30</td>
<td>70/30</td>
</tr>
<tr>
<td>Cycling</td>
<td>1.0 ± 0.1</td>
<td>2.3 ± 0.2*</td>
<td>69/31</td>
<td>30/70**</td>
</tr>
<tr>
<td>Rest</td>
<td>1.7 ± 0.3</td>
<td>2.6 ± 0.4</td>
<td>55/45</td>
<td>72/28</td>
</tr>
<tr>
<td>Sauna</td>
<td>2.3 ± 0.6</td>
<td>2.9 ± 0.5</td>
<td>55/45</td>
<td>45/55*</td>
</tr>
</tbody>
</table>

* \( p < 0.01 \) versus after rest.

** \( p < 0.001 \) versus after rest.
FIG. 5. Rates of hunger before and after the meal before rest, cycling, and sauna and before and after the meal after rest, sauna, and cycling.

FIG. 6. Rates of satiety before and after the meal before rest, cycling, and sauna and before and after the meal after rest, sauna, or cycling.
after rest, which is also reported by Thompson et al. (33) and by Verger et al. (36) but which is not in line with later observations by Verger et al. (37), who reported an increase in percentage of energy from protein 30 min after the end of the exercise session. This difference in observations might be due to the time in between the end of the exercise session and the start of the meal, which was in our situation only 10 min, and to the possibility of macronutrient specificity offered during the different buffets.

Since dehydration and hyperthermia occur during exercise (29,41), the same parameters related to appetite were assessed during sauna, which also yields dehydration and hyperthermia (41). Comparison of these two interventions are of interest since a comparable dehydration level and hyperthermia during the sauna trial is not accompanied with a temporally considerable energy turnover. Hyperthermia was not measured in these experiments, unfortunately, but as suggested from the literature (41), it was likely to occur. The following effects on appetite that were observed after exercise were noticed after sauna as well.

With respect to taste perception, a change in rate of perception of the lower concentration of the single sweet solution was also observed after sauna compared to after rest, but not of the bitter solution. Perceptions of higher concentrations were unaltered. Thirst and fluid intake were also significantly increased, together with a significantly lower energy intake from solid foods. Energy intake from carbohydrates was significantly increased too and energy intake from fat was significantly decreased after sauna compared to after rest as well. However, hunger was not reduced significantly after sauna, nor was energy intake in comparison to after rest.

The changes in appetite being present after sauna as well as after exercise were thirst and macronutrient preference, which might be due to dehydration and hyperthermia. Increased thirst and increased liquid intake have previously been suggested to be due to dehydration (9,11,14,21,23,24,28,32). The change in macronutrient preference might be due to dehydration and thirst also. On closer inspection of the data, it appeared that this preference was achieved by decreasing consumption of tunny, smoked beef, butter, French spread cheese, cucumber salad with mayonnaise, and fatty broth, so that a decrease of fat and of protein intake occurred. Obviously, in a situation in which the subject is dehydrated and thirsty, the jam, honey, juices, yoghurt, and buttermilk were relatively easier to ingest. In this respect it would be necessary to unconfound preferences for macronutrient and for other sensory aspects like taste and texture. Probably, the possibility to drink mineral water would have shown the relative preference for something liquid more clearly, without including that the drink was in fact a carbohydrate, fat, or protein solution. However, the lady who served the visitors in the sauna restaurant informed us that the regular sauna visitors almost all either took a sport drink called AA, after sauna, which is a carbohydrate electrolyte solution, or a bitter lemon.

Changes in appetite in terms of reduced hunger and reduced energy intake which occurred after cycling but not after sauna might be due to an increased sympathetic nervous system activity during exercise that may be enhanced to overcome a temporary energy deficiency (1). Increased sympathetic nervous system activity during exercise may also reduce motility of the intestinal tract, which may lead to anorexia. Moreover, changes associated
with metabolism during exercise also may influence hunger, such as altering blood glucose, free fatty acids, and insulin levels.

We conclude that the acute effects of exercise on appetite, consisting of a short-term reduction in hunger and in energy intake, an increase in thirst and in fluid intake, a change in rate of taste perception for sweet and bitter at low concentrations, and a macronutrient preference in favor of carbohydrate, seem to be partly related to each other. Thirst, due to dehydration, is likely to have caused increased fluid intake after exercise as well as after sauna. Reduced hunger and reduced energy intake might be due to an increased sympathetic nervous system activity during exercise that may be enhanced to overcome a temporary energy deficiency. The observed change in rate of taste perception is unlikely to have contributed to the macronutrient preference for carbohydrate. The change in macronutrient preference might be due to dehydration and thirst, a situation in which food items are chosen with such sensory aspects that they are easy to ingest. Further research is needed to unconfound preferences for macronutrients and for sensory aspects of foods in different circumstances. In the perspective of obesity, we may conclude that exercise does not increase food intake in the short term and that the switch to a relative increase of carbohydrate intake at the expense of fat might be of importance in the perspective of weight maintenance after weight reduction (22).

REFERENCES