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1 **The impact of 16-h heat exposure on appetite and food reward in adults**

2

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25 **Abstract** ¹

26

27 Heat exposure is thought to reduce energy intake (EI) but studies are sparse and results not
28 always concordant. The aim of this study was to examine whether a 16-h exposure to 32°C leads
29 to reduced EI compared to a control session (22°C) and whether modifications in appetite
30 sensations or food reward are implied. Sixteen healthy, lean, and active participants (9 women
31 and 7 men, 25±5 yo, body mass index: 22.0±2.4 kg.m⁻²) were passively exposed to two different
32 thermal temperatures from 4:00 pm to 8:00 am under controlled conditions. Hunger and thirst
33 scores were regularly assessed using visual analogue scales. A fixed dinner meal (3670±255 kJ)
34 was consumed at 7:30 pm and an ad libitum breakfast buffet (20 foods/drinks varying in
35 temperature, fat, and carbohydrate content) at 7:30 am. Components of reward (explicit liking
36 [EL] and implicit wanting [EI]) for fat and sweet properties of food were assessed before each
37 meal using the Leeds Food Preference Questionnaire (LFPQ). *Ad libitum* EI at breakfast did not
38 differ between sessions (2319±1108 vs 2329±1141 kJ, in 22 and 32°C sessions, respectively;
39 $p=0.955$). While thirst scores were higher in the 32 than the 22°C session ($p<0.001$), hunger
40 scores did not differ ($p=0.580$). EL and IW for high fat foods relative to low fat foods were
41 decreased in 32 compared to 22°C before dinner and breakfast ($p<0.001$ for all). Although EI and
42 hunger were not affected by a 16-h exposure to heat, modifications in food reward suggested a
43 reduction in the preference of high-fat foods. Future research should investigate whether
44 reduced EI in response to heat exposure is due to spontaneous selection of low-fat foods rather
45 than altered appetite sensations.

46

47 **Keywords:** LFPQ, hot conditions, thermal exposure, appetite, energy balance, hunger

Abbreviations

CAS: composite appetite score

EB : energy balance

EE: energy expenditure

EI: energy intake

EL: explicit liking

IW: implicit wanting

LFPQ : Leeds Food Preference Questionnaire

RH: relative humidity

VAS: visual analogue scale

48 1. Introduction

49 Athletes and military personnel are regularly exposed to energy deficits due to inadequate levels
50 of energy intake (EI) compared to their high levels of energy expenditure (EE) (Charlot, 2021;
51 Heydenreich, Kayser, Schutz, & Melzer, 2017; Logue et al., 2020; Tassone & Baker, 2017; Tharion
52 et al., 2005). If sustained, this state may have direct deleterious consequences on their cognitive
53 (Giles et al., 2019; O'Leary, Wardle, & Greeves, 2020) and physical (Murphy, Carrigan, Philip
54 Karl, Pasiakos, & Margolis, 2018; O'Leary et al., 2020) performances. Seasonal scheduling and
55 localization of competitions may impose athletes to train/compete in the heat during a
56 significant duration (de Korte, Bongers, Hopman, & Eijsvogels, 2021; Racinais, Casa, Brocherie, &
57 Ihsan, 2019). For their part, militaries are often deployed in war zones characterized by a hot
58 climate (Ashworth, Cotter, & Kilding, 2020; Parsons, Stacey, & Woods, 2019). During acute heat
59 exposures (< than 8 h), EI was found to be reduced in some studies compared to a
60 thermoneutral control session (Shorten, Wallman, & Guelfi, 2009; Wasse, King, Stensel, &
61 Sunderland, 2013; Zakrzewski-Fruer, Horsfall, Cottrill, & Hough, 2021). Given that EE is
62 unaltered or even slightly increased due to an rise in ventilation and sweat gland activity in this
63 thermal environment (Ocobock, 2016; Valencia, McNeill, Brockway, & Smith, 1992), energy
64 balance (EB; EI *minus* EE) is very likely to be negative during heat exposures. These decreases
65 were sometimes accompanied by reductions in appetite (assessment of hunger scores) (Kojima,
66 Sasaki, Tsuchiya, & Goto, 2015; Wasse et al., 2013) and increases in the plasma levels of
67 anorexigenic hormones such as peptide YY (Shorten et al., 2009; Zakrzewski-Fruer et al., 2021).
68 These results imply that heat exposures may potentially worsen the already frequent and large
69 states of energy deficiency.

70 To date, these effects remain uncertain since the literature is sparse and some studies have
71 reported no modifications in appetitive responses (Ahmed et al., 2019; Faure et al., 2016). The
72 main reason for this lack of consistency is very likely the considerable variability of the protocols
73 (duration of exposure, choice of temperature, presence of physical exercise sessions, test meals,
74 clothing...) (Charlot, Faure, & Antoine-Jonville, 2017; Millet et al., 2021). Although a recent meta-
75 analysis found a slight heat-induced anorexia (Millet et al., 2021), further studies are required to
76 help draw more solid conclusions on the effects of heat exposure on appetite and EI. Particularly,
77 studies in which heat exposure is applied during a prolonged period (> 8 h) and during
78 sedentary conditions are required in order to eliminate the biases induced by physical exercise.
79 Food reward has been shown to strongly influence food choices and EI in both laboratory and
80 free-living settings (Dalton & Finlayson, 2014; French et al., 2014). However, food reward is
81 rarely assessed in extreme environments (Charlot et al., 2021; Karl et al., 2018) and never to our
82 knowledge during heat exposure. The construct of food reward and its sub-components of liking
83 and wanting may help elucidate the heat-induced anorexia that is often observed.

84 The aim of this study was therefore to assess the effects of 16-h passive heat exposure on EI
85 assessed during an *ad libitum* breakfast and associated changes in appetite and food reward. It
86 was hypothesized that heat exposure would exert an anorexigenic effect reflected by a decrease
87 in hunger scores, and/or a decrease in liking and wanting for high fat foods, both resulting in
88 lower EI.

89

90 **2. Materials and methods**

91 **2.1. Design**

92 Participants took part in four 16-h sessions separated by ~2 weeks in a climatic apartment (four
93 bedrooms, a living-room with a kitchen and a bathroom with a shower and a toilet) in which
94 ambient temperature was fixed at 22 or 32 °C (two sessions in each temperature). The measured
95 ambient temperatures were 22.5 ± 0.7 °C and 32.3 ± 0.6 °C, respectively. Relative humidity was
96 fixed at $\sim 40 \pm 5\%$. Four groups of 4 participants were composed and this composition remained
97 similar during the study. The session order was randomly allocated and counterbalanced for the
98 4 groups. Just before 4:00 pm, participants arrived and were fitted with devices for continuous
99 measurements of heart rate, skin temperature, and ingestion of a thermal pill. Dressed in
100 standardized clothes (short sleeves tee-shirt made of cotton, shorts made of polyester, socks
101 made of cotton, and synthetic sandals), the participants remained in the apartment until the next
102 morning (8:30 am). At 7:30pm, a dinner (pasta, yoghurt, and chocolate bar) served in
103 standardized quantity was consumed. At 9:30pm, they went to bed and were woken up at
104 7:00am. At 7:30 am, an *ad libitum* breakfast buffet was served with a large selection of foods and
105 drinks. Breakfast EI was calculated from the weighed quantity consumed. Food reward using the
106 LFPQ was assessed just before the dinner and the breakfast. Subjective appetite and thermal
107 sensations were assessed throughout the sessions using visual analog scale (VAS). Fluid and
108 food intake and fluid loss (urine and sweat) were directly measured or calculated during the
109 sessions. The first session at each temperature was treated as a familiarization session. The
110 second session at each thermal condition was treated for analysis (~1 month apart). The
111 procedure is presented in Figure 1.

112

113 **2.2. Participants**

114 Sixteen healthy, young, lean, and active participants (9 women and 7 men) were recruited from
115 the Institut de Recherche Biomédicale des Armées (age: 25 ± 5 yo; body mass: 64.6 ± 9.5 kg,
116 height: 171 ± 7 cm, and body mass index: 22.0 ± 2.4 kg.m⁻²). Inclusion criteria were restraint
117 score < 2 based on the Three-Factor Eating Questionnaire-R18 (Karlsson, Persson, Sjöström, &
118 Sullivan, 2000), regularly consuming at least 3 meals per day including breakfast, and have a
119 sleep score < 5 based on the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, &

120 Kupfer, 1989). They were also not eligible if they had been exposed to a hot climate (> 3
121 consecutive days, mean temperature > 30 °C) in the last 6 months before the study to ensure
122 that participants were not considered heat acclimated. Given that this study was realized in
123 spring 2021, they were not exposed to temperature above 20 °C in the 6 previous months.
124 Female participants who used contraceptive medication and had irregular menstrual cycle
125 (absence of regular cycle for at least 3 consecutive months) were excluded. Female participants
126 had to realize the two sessions that were considered for analysis at the same phase of their
127 menstrual cycle since core temperature regulation (Baker, Sibozza, & Fuller, 2020), appetite and
128 EI (Asarian & Geary, 2013) fluctuated during the menstrual cycle higher. The second session was
129 therefore planned approximately 30 days (29 ± 4 d) after the first one. This study was conducted
130 according to the guidelines laid down in the Declaration of Helsinki and all procedures were
131 approved by the French National Ethics Committee Sud Méditerranée n°2 (2021-A01238-33).
132 Written informed consent was obtained from all participants who received financial
133 remuneration for study completion.

134

135 **2.3. Measurements**

136 *2.3.1. Energy intake*

137 Participants were asked to eat the same breakfast at the same hour (depending on their habits)
138 before each session. Since all the participants worked on site, they were instructed to eat at the
139 mess at the same hour (between 11:30am and 12:30pm) and eat the same kind of meals (one
140 salad, one main dish with meat or fish and pasta or rice on the side, one portion of cheese, one
141 yoghurt, and one fruit). They were also instructed to drink at least 5 glasses of water (~ 1 L) on
142 this day to avoid disparities in the hydration level and to not perform physical activities on the
143 day and day before the study.

144 Dinner was composed of a main dish (carbonara, salmon, cheese, or meat balls pasta, Grande
145 Box, Lustucru®, ~360 g), a yoghurt (Vanilla, Chocolate, Lemon, or Coconut Yoghourt, Yaourt
146 Gourmand, Mamie Nova®, 125 g) and a bar of milk chocolate (Milka®, 17 g). Participants chose
147 the recipes/ flavor of the first two items during a screening visit. During the first session, the full
148 portions were served but participants could choose to not finish them knowing that the same
149 quantities would be served during the remaining sessions with the obligation to finish them.
150 Thus, food, quantities, and therefore EI was fixed during this meal. Two subjects chose to eat 2
151 yoghurts and two others ate only half of the chocolate bar. Mean EI of the meal was 3670 ± 255
152 kJ with a CHO/Fat/Protein distribution of $51 \pm 2\%$, $37 \pm 2\%$, and $13 \pm 1\%$.

153 A breakfast buffet was served ad libitum. It was composed of a selection of drinks, savory and
154 sweet and/or high-fat and low-fat foods, and extras/toppings. The details are presented in Table
155 1. The buffet was prepared outside the climatic apartment in a room at ~22°C. Some items were

156 served at room temperature (~ 22°C). Other were served cold (~ 4°C) and some were served hot
 157 (~ 50°C). Pre-tests revealed that the gustatory properties of some items were impaired after 20-
 158 30 min in a room at 32 °C. To avoid this deterioration, the buffet was set on two large tables in a
 159 temperate room (20-24 °C) outside the climatic apartment. These tables were then moved just
 160 before 7:30 am in order that participants may choose drinks and foods with similar gustatory
 161 properties in both thermal conditions. Each item was served in large quantities (see Table 1).
 162 Participants were informed that they were allowed to freely serve themselves and that they
 163 were not forced to finish their dish. They served themselves using specific cutlery and placed
 164 each item in specific disposable dishes (small plates, bowl, cup, or goblet). An investigator then
 165 weighed (Mettler Toledo, Columbus, OH, USA, accuracy: 0,1g) each dish with the served portion.
 166 The same dish with remaining foods and drinks were weighed after breakfast. The difference
 167 between before and after the breakfast corresponded to the consumed quantities. They were
 168 allowed to serve themselves three times in total. If available food portions decreased by
 169 approximately 50% of the starting portion, investigators refilled the concerned items to ensure
 170 that served portions were similar between participants. They were previously informed that
 171 food selection and EI were assessed since it was impossible to totally conceal the weighing
 172 procedure. This latter phase was however done the most quick and discrete possible: after they
 173 served themselves, they had to leave their tray on a table in the main room and returned to their
 174 respective room. The weighing lasted less than 30 seconds and their tray was then handed over
 175 to the participants. Finally, all the procedure (food selection and eating) was done entirely
 176 separately in order to avoid the well-known social facilitation of eating (Ruddock, Brunstrom,
 177 Vartanian, & Higgs, 2019). Before the beginning of the breakfast, participants remained in their
 178 room with their door shut. They were invited one at the time to serve themselves at the buffet
 179 and to eat alone in their room. The participants therefore never crossed during the whole
 180 breakfast.

181

182 **Table 1 – Composition of foods and drinks served in the *ad libitum* breakfast buffet**

Item	Brand	Served portion	Energy content (kJ/100 g)	CHO (g/ 100g)	Fat (g/100 g)	Protein (g/100 g)
Drinks						
Milk*	Auchan	1000 mL	196	4.8	1.6	3.3
Orange juice*	Tropicana	1000 mL	162	8.9	0.0	0.8
Grape juice*	Auchan	1000 mL	295	16	0.5	0.5
Sweet foods						
Applesauce*	Andros	1000 g	343	20.0	0.1	0.3
White cheese*	Auchan	1000 g	459	2.9	7.8	7.0
Corn flakes**	Kellog's	500 g	1568	87.0	0.6	4.5
Bread**	Heudebert	8 9-g slices	1679	73.0	7.3	11.0
Toast**	Harry's	8 25-g slices	1090	48.5	4.3	7.0
Chocolate cake**	Ker Cadélaç	8 30-g cakes	1812	45.7	25.5	5.3
Extra/topping						
Strawberry jam*	Bonne Maman	100 g	997	59.0	0.1	0.4
Chocolate spread**	Rigoni di Asiago	100 g	2242	54.0	32.0	8.1
Honey**	Lune de Miel	100 g	1365	80.0	0.5	0.5
Cacao powder**	Nesquick	100 g	1540	78.9	3.6	5.1

Butter*	Auchan	8 portions of 12,5 g	3033	0.6	80.0	0.8
Savory foods						
Salami*	Herta	8 10-g slices	1818	1.0	39.0	20.0
Cheese*	Leerdamer	8 25-g slices	1471	0.1	27.5	26.0
Cooked ham*	Herta	8 42.5 slices	437	0.5	2.5	20.0
Mini-sausages***	Auchan	300 g	920	1.3	19.0	11.0
Hard-boiled eggs**	Matines	8 eggs	594	0.5	9.8	13.0
White beans***	Auchan	500 g	303	12	0.5	5.0

183 */**/** The items were served cold/at room temperature/hot.

184

185 2.3.2. Subjective ratings

186 Appetite, thirst, and thermal assessments (thermal sensation, discomfort and preference) were
187 assessed 7 times during each session. Appetite was separated into four different perceptions:
188 hunger, desire to eat, fullness, and prospective consumption. Appetite and liking were assessed
189 on 100 mm VAS presented on paper preceded by the following questions: “How hungry do you
190 feel?”; “How strong is your desire to eat something?”; “How full do you feel?”; and “What
191 quantity of food would you be able to eat?”. These scales were anchored with “not at all” and
192 “extremely” at the left and right ends, respectively. The distance from the extreme left to the
193 participant’s vertical dash represented the rating score, expressed in cm. The composite appetite
194 score (CAS), reflecting the responses to the four VAS questions, was included in the study as a
195 summary measure of appetite. CAS was calculated using the following formula: $CAS = ((100 -$
196 $desire\ to\ eat) + (100 - fullness) + hunger + prospective\ consumption)/4$ (Anderson, Catherine,
197 Woodend, & Wolever, 2002). These scales have been shown to have a good level of reliability
198 and reproducibility, and a certain level of predictive validity (Stubbs et al., 2000). Thirst was also
199 assessed at the same time points as appetite sensations. After dinner, liking of the food items
200 was assessed using a VAS preceded by the question: “Did you like this food item?”. The self-
201 selected portion size was also assessed for each item by the question “What amount of food
202 would have been ideal?” These scales were anchored with “0% of the served portion” and
203 “200% of the served portion” at the left and right ends, respectively.

204 Thermal sensation (“How do you perceive your thermal environment?”) was determined with
205 the ASHRAE 7-pt scale (from -3, cold, to 3) and thermal comfort (“How do you perceive your
206 thermal environment?”) using a VAS with “very uncomfortable” and “very comfortable” at the
207 left and right ends, respectively. Thermal preference (“What would you prefer at the moment?”) was
208 assessed using a 5-point NICOL scale (from 2, prefer much cooler to +2, prefer much
209 warmer) (Humphreys, Nicol, & Raja, 2007).

210 Fatigue and sleep quality were assessed at 7:15am using a VAS preceded by the questions: “Do
211 you feel tired?” and “Were you satisfied of this night?”, respectively, with “not at all” and
212 “extremely” at the left and right ends, respectively.

213

214 2.3.3. Food reward

215 Food reward for fat and sweet dimensions of foods was assessed using the Leeds Food
216 Preference Questionnaire (LFPQ) (Finlayson, King, & Blundell, 2008; Finlayson, King, & Blundell,
217 2007; Oustric et al., 2020). Briefly, liking and IW for 4 categories of food: high-fat-sweet, high-
218 fat-savory, low-fat-sweet and low-fat-savory were assessed using a computerized task. Explicit
219 liking (EL) was measured using 100-pt VAS for which participants had to answer to the question
220 “How pleasant would it be to taste this food now?” with “not at all” and “extremely” at the left
221 and right ends, respectively. Food images (n = 16) appeared individually on the screen in a
222 randomized order. IW was assessed using a forced-choice procedure. Every image of each of the
223 4 food categories was compared to every other image of the 3 other categories (96 pairs in
224 total). Participants were instructed to respond as quickly as they could to indicate which food
225 they most wanted to eat at that moment. The IW score is therefore a combination of reaction
226 time and frequency of selection (Oustric et al., 2020). EL and IW can be summarised as “appeal”
227 scores (called “appeal bias” in the LFPQ) for fat or sweet foods. Mean savoury scores may be
228 subtracted from the mean sweet score to provide a “Taste appeal” score. The same procedure
229 may be applied to high fat relative to low fat foods for the “Fat appeal” score.

230

231 *2.3.4. Temperatures and heart rate*

232 Upon their arrival in the apartment, participants ingested a capsule containing a temperature
233 sensor (BodyCap, e-Celsius, Caen, France). The capsule is equipped with a memory chip which
234 allows storage of data in case of loss of connection and communicates with a monitor that
235 remains with the participants during the whole session. The system was shown to accurately
236 represent fast changes in water temperature (Bongers, Daanen, Bogerd, Hopman, & Eijsvogels,
237 2018) and was judged reliable to assess core (Bogerd et al., 2018; Travers, Nichols, Farooq,
238 Racinais, & Periard, 2016) temperature. Given the timing of ingestion, we acknowledge that first
239 measurements (between 1 to 3 h) reflect gastric temperatures.

240 Participants were also equipped with three cutaneous sensors. The mean of each measurement
241 was calculated to determine skin temperature. Then body temperature ($[\text{skin temperature} +$
242 $\text{core temperature}]/2$) was calculated.

243 Finally, a heart chest strap was fitted (Polar H10, Polar, Kempele, Finland) communicating with a
244 watch (Polar RC3, Polar, Kempele, Finland) to measure heart rate. The mean was calculated for
245 3 periods (before the night: 4:00 pm to 10:00 pm; night: 10:00 pm to 7:00 am; morning: 7:00 am
246 to 8:00 am).

247

248 *2.3.5. Body mass modifications*

249 Body mass was assessed three times (4:00 am, 9:30 pm, and 7:15 am). Food weight was
250 controlled (dinner) or accurately assessed (breakfast) and was therefore easily determined.

251 Fluid intake was measured using weighing of water bottles. Participants were given cool (~4°C)
252 500-mL water bottles that were replaced at the beginning of each of these three periods (before
253 dinner: 4:00 pm to 7:30 pm; dinner and after: 7:30 pm to 10:00 pm: night until breakfast: 9:30
254 pm to 7:15 am). Their participant code was clearly written on their bottles and they were
255 instructed to consume as much volume as they desired. If a bottle was finished before the end of
256 the period, supplementary bottles were available in a fridge.

257 To assess urine loss, a scale was placed very close to toilets. Participants had to weigh
258 themselves before and after urination and to indicate their participant code and the hour on a
259 record. The correct filling of the records were frequently checked with participants to ensure
260 that no weighing were forgotten.

261 Finally sweat loss was calculated using all the aforementioned measurements, considering that
262 water loss through respiration was negligible (food and water intake – body mass modification –
263 urine loss).

264

265 *2.3.6. Hydration level*

266 Urine was collected to assess hydration level. Urine specific gravity of the collected urine was
267 immediately measured with an automated dipstick analyzer (Clinitek Status+ Analyzer, Siemens,
268 Munich, Germany) using a Multistix10SG (Siemens, Munich, Germany). Values < 1.013 indicate
269 euhydration (Perrier, Bottin, Vecchio, & Lemetais, 2017), whereas values > 1.020 reflect
270 hypohydration (Logan-Sprenger & Spriet, 2013).

271

272 **2.4. Statistical analyses**

273 A priori power analysis for EI based on a recent meta-analysis (Millet et al., 2021) selecting
274 conventional α (0.05) and $1-\beta$ (0.80) levels observed that at least twelve participants were
275 required. All variables were checked for normality using a Shapiro-Wilk test followed by
276 skewness and kurtosis. In case of absence of normality, logarithmic transformation was
277 performed. If this transformation did not correct data normality, nonparametric tests were used.
278 In the case of repeated measurements, mixed-model repeated-measures ANOVA were used.
279 Thus, appetite and thirst-related VAS scores were compared using a 2x7 ANOVA (temperature
280 effect: 22 vs 32°C and time effect: 4:00 pm, 6:00 pm, 7:30 pm, 8:00 pm, 9:30 pm, 7:15 am, and
281 8:00 am). A 2x2 ANOVA was used to compare EL and IW Taste and Fat Appeal scores
282 (temperature effect: 22 vs 32°C and meal effect: dinner vs breakfast). When the sphericity
283 assumption was violated (Mauchly's test), a Greenhouse-Geisser correction was used. *Post hoc*
284 analyses were performed using Bonferroni's tests. The effect of ambient temperature was
285 assessed using Student t-tests or Wilcoxon rank-sum tests for the remainder of the
286 measurements. The differences were also examined using Cohen's effect size (ES): > 0.2 (small),

287 > 0.5 (moderate), and > 0.8 (large) (Cohen, 1988). Data are presented as the means \pm SD.
 288 Significance was determined as $p < 0.05$. Analyses were performed using Jamovi software (1.2.9
 289 version, the Jamovi project; retrieved from <https://www.jamovi.org>).

290

291 **3. Results**

292 **3.1. Breakfast energy intake**

293 EI (Figure 2A and 2B) and macronutrient composition of the meal (in g or % of total EI; Figure
 294 2A and 2C, respectively) were not different between the sessions ($p > 0.411$, $d < 0.21$). Analysis
 295 of individual variability using graphs shows that results were very heterogeneous with 7
 296 individuals increasing and 9 decreasing their EI during the 32 compared to the 22°C session.
 297 Moreover participants' intake for specific items of the buffet was also not different (data not
 298 shown). Figure 2D presents the participants' food and drink selection during this meal. They
 299 selected 5.8 ± 2.3 and 5.1 ± 2.1 items during the 22 and 32°C sessions, respectively ($p = 0.102$, d
 300 $= 0.32$).

301

302 **3.2. Appetite and dinner palatability**

303 No temperature effect was found for hunger score ($p = 0.580$) and CAS ($p = 0.380$). However,
 304 thirst was significantly higher in the 32 than the 22°C session ($p < 0.001$, $d = 0.66$).

305 At the dinner, palatability for pasta ($p = 0.317$, $d = 0.26$), yoghurt ($p = 0.135$, $d = 0.14$), and
 306 chocolate ($p = 0.090$, $d = 0.45$) were not significantly different between sessions (Table 2).
 307 Similarly, self-selected portion size was not different for pasta ($p = 0.706$, $d = 0.21$) and yoghurt
 308 ($p = 0.061$, $d = 0.14$), but was lower in the 32 than 22°C session for chocolate ($p = 0.044$, $d =$
 309 0.60).

310 **Table 2 -Subjective assessment of dinner with fixed quantities**

	22 °C	32°C
	Palatability (/10)	
Pasta	6.1 \pm 1.9	5.6 \pm 1.8
Yoghurt	7.2 \pm 2.0	7.0 \pm 2.0
Chocolate	7.4 \pm 2.3	6.5 \pm 2.7
	Self-selected portion size (%)	
Pasta	128 \pm 38	122 \pm 33
Yoghurt	119 \pm 38	107 \pm 22
Chocolate	107 \pm 44	90 \pm 48*

311 *different from 22°C ($p < 0.05$)

312

313 **3.3. Food reward**

314 A temperature effect was found in both EL ($p < 0.001$, $d = 0.56$, Figure 3A) and IW ($p < 0.001$, $d =$
 315 0.77 , Figure 3B) for high fat relative to low fat foods (fat appeal). Analysis of individual
 316 variability using graphs shows that among the 16 participants, a contradictory increase in the fat
 317 appeal score before dinner was observed in 6 and 4 participants for EL and IW, respectively.

318 This decreased to 2 and 1 before breakfast indicating that results were more homogeneous
319 before breakfast than before dinner.

320 A meal effect was found for sweet relative to savoury foods (taste appeal) in both EL ($p < 0.001$,
321 $d = 2.58$, Figure 3C) and IW ($p < 0.001$, $d = 3.72$, Figure 3D), responses being higher before
322 breakfast than before dinner. Finally, a meal*temperature interaction in taste appeal score in IW
323 only ($p = 0.029$). Post hoc tests revealed no further meaningful differences.

324

325 ***3.4. Heat-related perceptive and physiological modifications***

326 Core, skin, and body temperatures and heart rate were all higher in the 32 than the 22°C session
327 ($p < 0.001$ for all, $d = 1.03, 2.40, 2.03$, and 1.14 , respectively; Table 3).

328 Water intake ($p < 0.001$, $d = 3.06$), total intake ($p < 0.001$, $d = 3.33$), sweat loss ($p < 0.001$, $d =$
329 2.86), and total loss ($p < 0.001$, $d = 2.89$) were higher in the 32 than the 22°C session while urine
330 loss ($p = 0.041$, $d = 0.56$) and body mass modifications ($p = 0.012$, $d = 0.72$) were lower (Table 3)

331 Thermal sensation ($p < 0.001$, $d = 3.44$) and discomfort ($p < 0.001$, $d = 1.67$) were higher and
332 thermal preference lower ($p < 0.001$, $d = 3.30$) in the 32 than the 22°C session (Table 3).

333 Sleep duration reduction in the 32 than the 22°C session was not significant ($p = 0.084$) and
334 sleep analysis revealed only slight modifications in the 32 than the 22°C session. However, this
335 analysis was not the primary objective of the article and will not be presented. Fatigue at the
336 morning was not different between sessions and sleep quality was assessed lower in the 32 than
337 the 22°C session ($p = 0.004$, $d = 1.46$).

338 **Table 3 – Thermal-related perceptive and physiological markers**

	22 °C	32°C
Core Temperature (°C)	36.7 ± 0.3	37.0 ± 0.3***
Skin Temperature (°C)	34.7 ± 0.6	35.9 ± 0.4 ***
Body Temperature (°C)	35.7 ± 0.4	36.4 ± 0.3***
Heart Rate (bpm)	65.9 ± 6.1	73.0 ± 6.3***
Δ Body mass (kg)	0.38 ± 0.40	-0.05 ± 0.50*
Food intake (kg)	1.00 ± 0.26	1.05 ± 0.27
Water intake (kg)	0.60 ± 0.31	1.50 ± 0.50***
Total intake (kg)	1.60 ± 0.38	2.55 ± 0.53***
Urine loss (kg)	0.91 ± 0.33	0.79 ± 0.32*
Sweat loss (kg)	0.30 ± 0.18	1.81 ± 0.64***
Total loss (kg)	1.21 ± 0.44	2.60 ± 0.66***
Thermal sensation (-3 ;+3)	-0.49 ± 0.55	1.44 ± 0.49***
Thermal discomfort (/10)	3.7 ± 1.9	6.3 ± 1.1**
Thermal preference (-2 ; +2)	0.34 ± 0.37	-0.93 ± 0.40***
Sleep duration (min)	478 ± 26	456 ± 62
Fatigue score (/10)	3.77 ± 2.00	4.84 ± 2.37
Sleep quality (/10)	6.99 ± 2.11	3.82 ± 2.23**

339 Different from 22°C (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)

340 USG was found slightly lower at 4:00 pm in the 32 than the 22°C session (1.020 ± 0.006 vs 1.024
 341 ± 0.005 , respectively; $p = 0.036$, $d = 0.72$). USG were found similar between 32 and 22°C sessions
 342 at 9:30 pm (1.019 ± 0.006 vs 1.019 ± 0.004 , respectively; $p = 1.000$) and 7:15 am (1.026 ± 0.006
 343 vs 1.027 ± 0.007 , respectively; $p = 0.270$).

344

345 4. Discussion

346

347 The aim of this study was to assess the impact of heat exposure on hunger sensations and EI and
 348 its impact on food reward before two different meals (dinner and breakfast) during a long
 349 sedentary period (16 h). Contrary to our hypothesis, heat exposure did not modify appetite or *ad*
 350 *libitum* breakfast EI and only very slightly impacted subjective assessments (palatability and
 351 self-selected portion size) of the fixed dinner meal. However, liking and wanting for high-fat
 352 foods relative to low fat foods were decreased before both meals.

353

354 Several studies have reported modifications of appetite and EI during or after heat exposure.
 355 Subjective hunger was found diminished just after (Kojima et al., 2015) and up to 2 h (Wasse et
 356 al., 2013) after an exercise session in the heat compared to a thermoneutral condition. In a
 357 recent study (Zakrzewski-Fruer et al., 2021) with a design similar to this study (sedentary 4-h
 358 exposure at 30 °C compared to 20 °C), appetite scores were decreased during the whole
 359 exposure. *Ad libitum* EI at lunch was found to decrease by $1189 \text{ kJ} \pm 1219 \text{ kJ}$ in the same study.
 360 Concordant results were found after an exercise session using two consecutive cold buffet-style
 361 meals ($-1400 \pm 2345 \text{ kJ}$ at 30 compared to 20°C, $p = 0.08$ (Wasse et al., 2013)) and a buffet-type
 362 breakfast (EI increased after an exercise session at 25°C compared to a rest session at 25 °C but
 363 not after the same exercise at 36 °C (Shorten et al., 2009)). Although effects were less

364 pronounced in other studies (Ahmed et al., 2019; Faure et al., 2016; Laursen et al., 2017), a
365 recent meta-analysis (Millet et al., 2021) highlighted a very likely anorexigenic effect of heat
366 independently of performing an exercise session. Real-life condition studies are very rare but
367 results from a recent one (Zheng, Li, & Wang, 2019) suggested blunted levels of hunger on hot
368 days (34-36 °C) compared to milder ones (28-30 °C). Although this study was designed to focus
369 on the effects of heat exposure in removing or limiting numerous biases (no physical exercise,
370 standard and similar clothing, and *ad libitum* water intake), hunger scores and EI during an *ad*
371 *libitum* buffet breakfast were not influenced by the thermal environment therefore contradicting
372 results from the aforementioned studies. This lack of effect remains to understand and explain
373 especially when a very similar study (Zakrzewski-Fruer et al., 2021) found a strong and
374 homogenous response during exposure to heat.

375

376 The main explanation we can offer for the discrepancy in findings is related to the nature of the
377 test meal. Zakrzewski-Fruer et al (Zakrzewski-Fruer et al., 2021) selected an *ad libitum* pasta
378 dish served at lunch after 4 h of heat exposure (30 °C vs 20 °C). In the present study, a buffet
379 breakfast containing foods and drinks varying in temperature (served cold, at ambient
380 temperature, or hot), fat content (from low to high-fat), and taste (savory or sweet) was
381 retained. This choice was made for two main reasons: 1) this procedure has been shown reliable
382 and reproducible (Chaput et al., 2016; McNeil, Riou, Razmjou, Cadieux, & Doucet, 2012; Thivel,
383 Genin, Mathieu, Pereira, & Metz, 2016), 2) the variety of items partially reproduced the variety of
384 the food list used in the LFPQ allowing therefore observation of similar responses between
385 actual intake and LFPQ responses (Dalton, Blundell, & Finlayson, 2013; Kapoor et al., 2021).
386 Moreover, since we only considered the measurements realized during the second session of
387 both thermal conditions, we theoretically removed the likely over-consumption and selection of
388 different items at each session for the purpose of variety (Stubbs, Johnstone, Mazlan, Mbaiwa, &
389 Ferris, 2001). This choice did not lead to modifications of EI when exposed to heat and only
390 induced slight differences in food selection between thermal conditions indicating that
391 participants mostly ate the same kind of items. These observations are only partially surprising.
392 Indeed, contrary to other meals, breakfast composition characterized by strong habits. In a
393 survey realized in 771 Irish adults, only 17% modified the composition of their breakfast each
394 day (Gibney & Uzhova, 2019). Moreover, specifically in France, a large majority of children and
395 adults (~90%) consumed a breakfast with a high content in carbohydrates (Gibney et al., 2018;
396 Lopicard, Maillot, Vieux, Viltard, & Bonnet, 2017). Thus, even with a buffet theoretically allowing
397 the choice of items with different fat and carbohydrates content, it cannot be excluded that this
398 usual high level of carbohydrates intake may conceal the expression of modifications of
399 preferences for the different items. In these conditions, EI would have required very strong

400 modulators to be affected, and an increase of 10 °C was probably not sufficient to change these
401 strong habits.

402

403 Two other hypotheses surrounding the choice of the buffet breakfast were: 1) low hunger
404 scores, and 2) the duration between the end of the meal and the end of the study. Concerning the
405 former point, we did not expect such low hunger scores (~ 4 cm on a 10-cm scale) since we
406 respected participants' habits in terms of sleep duration, sleep usual awakening time, and delay
407 between awakening and breakfast initiation and since we recruited habitual breakfast eaters.
408 Amongst the 16 participants, only two ate their breakfast with hunger scores higher than 5 cm
409 and most of them probably ate in the absence of hunger. Studies in which hunger is assessed
410 before breakfast generally report hunger scores twice the levels in the present study (6-8 cm)
411 (Robert A. Corney, Horina, Sunderland, & James, 2015; McNeil et al., 2017; Radcliffe et al., 2021;
412 Thomas, Higgins, Bessesen, McNair, & Cornier, 2015; Zakrzewski-Fruer et al., 2021). However,
413 analysis of these protocols revealed a 60 to 90 min delay between the awakening and the VAS
414 filling allowing hunger to grow. In a study in which hunger scores were assessed at 7:30 am, 30
415 min after awakening, 3 to 4-cm response were reported indicating that the hunger scores in the
416 present study were not unusual. Nevertheless, this could participate to the lack of expression of
417 environmental effect on subjective scales, hidden by a certain cognitive inertia classically
418 described for all subjective assessments during the 15 to 60 minutes following awakening
419 (Hilditch & McHill, 2019). In these conditions of low hunger VAS, the observation of a reduction
420 in EI is less likely. Concerning the second hypothesis, one recent study highlighted an effect of
421 the defined postprandial delay on breakfast EI. It was found that EI was lower when participants
422 knew that they could leave the laboratory as soon as the 30-min period allocated to eat elapsed
423 compared to an imposed 1 or 3-h stay after (Palmer, Irwin, McCartney, Cox, & Desbrow, 2021).
424 Participants were obliged to remain in their rooms until 8:15 am (45 min after the beginning of
425 the meal). They were then allowed to remove equipment and to take a shower. Considering the
426 results of this study, which was not published when the present study was designed, it is
427 possible that participants have rushed to leave the unit, altering their food intake. It is difficult to
428 weigh the importance of this possible explanation, but it is quite reasonable to think that the
429 procedure used in the present study at least partly blunted food/drink choice and intake.

430

431 An effect of heat exposure on food reward was examined for the first time in the present study. It
432 has already been used in extreme environments such as cold (Charlot et al., 2021) or hypoxia
433 (Aeberli et al., 2013; Karl et al., 2018) but never in a laboratory context with a control condition.
434 In the present study, a clear heat-induced decrease of liking and wanting for high-fat foods
435 (decrease in the fat appeal score for EL and IW) was found before each meal (dinner and

436 breakfast) suggesting that being acutely exposed to heat may potentially reduce the selection of
437 high-fat foods in favor of lower fat ones. Moreover, this response was found in the large majority
438 of participants (~90% before breakfast) reflecting its robustness. However, these specific
439 modifications of food reward were not accompanied by coherent modifications of food choice or
440 EI contrary to previous studies linking LFPQ responses and actual choices (Dalton et al., 2013)
441 or self-reported preference for fat taste and high-fat food intake (Chmurzynska et al., 2021). As
442 explained earlier, the modalities of the *ad libitum* test meal selected for this study were possibly
443 not the best option to objectify these modifications in food reward. Moreover, one might argue
444 that, despite being able to choose foods with different fat content, participants did not correctly
445 identify the fatness of proposed foods blurring therefore the associations between the responses
446 during the LFPQ and the choices made during the buffet. Interestingly, subjective assessment of
447 the three imposed items during the dinner showed that chocolate bar, the item with the highest
448 relative fat content, was the one that was the most depreciated in the 32 vs 22 °C session. It
449 remains hypothetical since these foods were not specifically chosen to observe such
450 relationships but it supports the link between heat exposure and preference for high-fat foods.
451 Studies assessing the direct influence of acute the direct influence of acute or long heat exposure
452 on food choice is almost non-existent. Studies on seasonal variations indicate that EI is higher in
453 winter than summer (Stelmach-Mardas et al., 2016) probably through modifications in food
454 choice (fruits and vegetables, cereals dairy). However, these changes were likely influenced by
455 their availability (pre or post-harvest) and effects of heat are therefore hypothetical.

456
457 No effect of the temperature in the taste appeal score (liking or wanting for savory over sweet
458 items) was observed in this study. This may be contradictory with some articles suggesting a
459 link between between hydration level, exercise-induced salt loss, and/or thirst sensation and the
460 preference for salt (Leshem, Abutbul, & Eilon, 1999; Takamata, Mack, Gillen, & Nadel, 1994). It
461 was indeed hypothesized that sodium loss in sweat may increase desire for salt and savory foods
462 and drinks in order to prevent more loss and to maintain osmoregulation. However, this
463 mechanism is contradicted by several studies in which sodium loss did not induce excess salt
464 appetite (Carroll et al., 2019; Leshem, 2009). The present results rather support the last
465 hypothesis. The effect of heat exposure on other dimensions of food would be interesting to
466 assess starting with the temperature of the served foods. Indeed, it is now well demonstrated
467 that oral temperature sensing in the mouth may influence ingestive acceptance (Lemon, 2021)
468 and that cold drinks but also cold foods may be perceived as more pleasant in the heat (Burdon,
469 Johnson, Chapman, & O'Connor, 2012) through higher ability to satiate thirst (Eccles, Du-Plessis,
470 Dommels, & Wilkinson, 2013). Other dimensions such as the texture, the color, and/or the taste
471 are interconnected with food/drink temperature since these dimensions may be influenced by

472 the coldness/warmth of ingested items or influence the perception of the served temperature
473 (Labbe et al., 2009; Motoki, Saito, Nouchi, & Sugiura, 2020; Suzuki et al., 2017).

474

475 Assessing appetite and food intake is a complex task (Gibbons, Hopkins, Beaulieu, Oustric, &
476 Blundell, 2019) requiring making choices during the design of the protocol (Gregersen et al.,
477 2008; Horner, Byrne, & King, 2014; Laan, Leidy, Lim, & Campbell, 2010; Thivel et al., 2016) that
478 may lead to limited conclusions. Adding the thermal matter into this field necessarily adds
479 supplemental limitations. As explained in this recent meta-analysis (Millet et al., 2021), no
480 consensus exists in the adequate modalities of thermal exposure (temperature, humidity,
481 duration of exposure, clothing, water intake management). The choices made may be therefore
482 somewhat arbitrary and may influence the obtained results. In this article, a lot of effort was
483 made to ensure that ambient temperature was the only difference between sessions. Clothing
484 activities and hydration status were similar. We found that heat-related physiological (core, skin,
485 and body temperatures, HR, sweat loss) and subjective markers (thermal discomfort, sensation,
486 and preference) were strongly impacted by the exposure to 32 °C compare to 22 °C. These
487 differences, although not surprising since similar studies (Faure et al., 2016; Zakrzewski-Fruer
488 et al., 2021) indicate that the exposure to 32°C induced very large and concordant differences in
489 physiological and subjective thermal markers. Moreover, although providing them free access to
490 cool water during and between the meals to avoid imposing them large amounts of water that
491 may be felt as uncomfortable as others (Wasse et al., 2013), water loss was replaced by ad
492 libitum water intake leading to neutral water balance. Participants were therefore at worse
493 slightly less hydrated in the 32 than the 22 °C. Since, severe dehydration (between -1 and -3% of
494 body mass) does not appear to modify EI (Carroll et al., 2019; Robert Anthony Corney,
495 Sunderland, & James, 2015) even during a semi-solid breakfast (Robert A. Corney et al., 2015),
496 heat-induced perturbations in water balance were not certainly considered a bias in the present
497 study. Another potential limitation of this study would the influence of heat on sleep duration
498 and quality that may be altered during heat exposure (Libert et al., 1991; Okamoto-Mizuno &
499 Mizuno, 2012; Zheng et al., 2019). Only marginal alterations of sleep architecture (data not
500 shown), duration, and fatigue score were reported in this study. This result is crucial in the
501 context of the present study since sleep restriction may modify EI (Radcliffe et al., 2021;
502 Soltanieh, Solgi, Ansari, Santos, & Abbasi, 2021) and food reward (McNeil et al., 2017), However,
503 these perturbations seem observable with less than 6-h sleep (Soltanieh et al., 2021) and/or if
504 sustained over several days (Calvin et al., 2013). Milder sleep deprivation/perturbation as in the
505 present study was generally not associated with EI modifications (Morrison et al., 2021). It was
506 concluded that all measurements related to food intake were unlikely to be influenced by heat-
507 induced sleep-alterations. Finally, a slight effect of differences in menstrual cycle may exist.

508 Indeed it has been clearly showed that EI is higher during the luteal than the midfollicular and
509 the periovulatory phases (Asarian & Geary, 2013). Study constraints (4 participants per group,
510 and 2-d inertia of temperature modifications in the apartment) impeded us to plan the sessions
511 in the same phase for each female participant. However, at the exception of one participant that
512 realized both sessions in different phases (luteal then periovulatory phases), the eight other
513 were in the same phase (5 in luteal, 2 in the early-follicular, and 1 in the midfollicular phase). It
514 is therefore possible that results for women may have been slightly altered.

515

516 **5. Conclusions**

517

518 In this study, 16-h passive exposure to heat (32 °C, 40 % RH) modified food reward with a
519 decrease in liking and wanting for high fat relative to low fat foods in comparison to a
520 thermoneutral condition (22 °C, 40% RH). Surprisingly, hunger feelings were not modified
521 during the whole exposure and the absence of modifications in actual food choice or EI during an
522 *ad libitum* breakfast buffet did not reflect the changes in food reward. Although these apparent
523 contradictory results remain to be understood, the lower preference for high-fat foods may
524 explain the heat-induced decrease in EI observed in previous studies indicating that acute EI
525 modifications are not necessarily driven by hunger modifications but could be altered by reward
526 value of energy dense foods. The effects of a longer exposure with several successive meals and
527 the analysis of food reward for other dimensions (such as temperature and texture) that may be
528 impacted by ambient temperature should be assessed to better identify the effects of heat
529 exposure on appetite. Moreover, the effect of gender on heat-induced modifications of EI and
530 food reward deserved to be specifically assessed since men and women are known to differently
531 experience similar thermal environments (Karjalainen, 2007). This was not the primary aim of
532 this study and it lacked of statistical power to realize adequate analyses.

533

534

535 **Ethical statement**

536 This study was conducted according to the guidelines laid down in the Declaration of Helsinki
537 and all procedures were approved by the French National Ethics Committee Sud Méditerranée
538 n°2 (2021-A01238-33). Written informed consent was obtained from all participants who
539 received financial remuneration for study completion.

540

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544

545 **Conflict of interest**

546 No potential conflicts of interest relevant to this article were reported.

547

548 **Authors contribution**

549 KC and JM designed the study. KC, JM, FP, PVB, JM, FS, PETD, and investigators group realized the
550 experiment and collected the data. KC and JM processed data and conducted the statistical
551 analyses. Laboratoire graphique (KC) designed the figures. KC drafted the initial manuscript. All
552 authors reviewed and revised the manuscript, approved the final manuscript as submitted, and
553 agree to be accountable for all aspects of the work.

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556

557 **Data availability statement**

558 The datasets generated and analyzed during the current study are available from the
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560 **References**

- 561 Aeberli, I., Erb, A., Spliethoff, K., Meier, D., Gotze, O., Fruhauf, H., . . . Lutz, T. A. (2013). Disturbed
562 eating at high altitude: influence of food preferences, acute mountain sickness and
563 satiation hormones. *Eur J Nutr*, *52*(2), 625-635. doi: 10.1007/s00394-012-0366-9
- 564 Ahmed, M., Mandic, I., Lou, W., Goodman, L., Jacobs, I., & L'Abbe, M. R. (2019). Comparison of
565 dietary intakes of Canadian Armed Forces personnel consuming field rations in acute
566 hot, cold, and temperate conditions with standardized infantry activities. *Mil Med Res*,
567 *6*(1), 26. doi: 10.1186/s40779-019-0216-7
- 568 Anderson, G. H., Catherine, N. L., Woodend, D. M., & Wolever, T. M. (2002). Inverse association
569 between the effect of carbohydrates on blood glucose and subsequent short-term food
570 intake in young men. *Am J Clin Nutr*, *76*(5), 1023-1030. doi: 10.1093/ajcn/76.5.1023
- 571 Asarian, L., & Geary, N. (2013). Sex differences in the physiology of eating. *Am J Physiol Regul*
572 *Integr Comp Physiol*, *305*(11), R1215-1267. doi: 10.1152/ajpregu.00446.2012
- 573 Ashworth, E. T., Cotter, J. D., & Kilding, A. E. (2020). Methods for improving thermal tolerance in
574 military personnel prior to deployment. *Mil Med Res*, *7*(1), 58. doi: 10.1186/s40779-020-
575 00287-z
- 576 Baker, F. C., Sibozza, F., & Fuller, A. (2020). Temperature regulation in women: Effects of the
577 menstrual cycle. *Temperature (Austin)*, *7*(3), 226-262. doi:
578 10.1080/23328940.2020.1735927
- 579 Bogerd, C. P., Velt, K. B., Annaheim, S., Bongers, C., Eijsvogels, T. M. H., & Daanen, H. A. M. (2018).
580 Comparison of two telemetric intestinal temperature devices with rectal temperature
581 during exercise. *Physiol Meas*, *39*(3), 03NT01. doi: 10.1088/1361-6579/aaad52
- 582 Bongers, C., Daanen, H. A. M., Bogerd, C. P., Hopman, M. T. E., & Eijsvogels, T. M. H. (2018).
583 Validity, Reliability, and Inertia of Four Different Temperature Capsule Systems. *Med Sci*
584 *Sports Exerc*, *50*(1), 169-175. doi: 10.1249/MSS.0000000000001403
- 585 Burdon, C. A., Johnson, N. A., Chapman, P. G., & O'Connor, H. T. (2012). Influence of beverage
586 temperature on palatability and fluid ingestion during endurance exercise: a systematic
587 review. *International journal of sport nutrition and exercise metabolism*, *22*(3), 199-211.
- 588 Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh
589 Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry*
590 *Res*, *28*(2), 193-213. doi: 10.1016/0165-1781(89)90047-4
- 591 Calvin, A. D., Carter, R. E., Adachi, T., Macedo, P. G., Albuquerque, F. N., van der Walt, C., . . .
592 Somers, V. K. (2013). Effects of experimental sleep restriction on caloric intake and
593 activity energy expenditure. *Chest*, *144*(1), 79-86. doi: 10.1378/chest.12-2829
- 594 Carroll, H. A., Templeman, I., Chen, Y. C., Edinburgh, R., Burch, E. K., Jewitt, J. T., . . . Betts, J. A.
595 (2019). Hydration status affects thirst and salt preference but not energy intake or
596 postprandial ghrelin in healthy adults: A randomised crossover trial. *Physiol Behav*, *212*,
597 112725. doi: 10.1016/j.physbeh.2019.112725
- 598 Chaput, J. P., Jomphe-Tremblay, S., Lafreniere, J., Patterson, S., McNeil, J., & Ferraro, Z. M. (2016).
599 Reliability of a food menu to measure energy and macronutrient intake in adolescents.
600 *Eur J Clin Nutr*, *70*(1), 104-108. doi: 10.1038/ejcn.2015.116
- 601 Charlot, K. (2021). Negative energy balance during military training: The role of contextual
602 limitations. *Appetite*, *164*, 105263. doi: 10.1016/j.appet.2021.105263
- 603 Charlot, K., Chapelot, D., Siracusa, J., Lavoue, C., Colin, P., Oustric, P., . . . Bourrilhon, C. (2021). An
604 augmented food strategy leads to complete energy compensation during a 15-day
605 military training expedition in the cold. *Physiol Rep*, *9*(11), e14591. doi:
606 10.14814/phy2.14591
- 607 Charlot, K., Faure, C., & Antoine-Jonville, S. (2017). Influence of Hot and Cold Environments on
608 the Regulation of Energy Balance Following a Single Exercise Session: A Mini-Review.
609 *Nutrients*, *9*(6). doi: 10.3390/nu9060592
- 610 Chmurzynska, A., Młodzik-Czyżewska, M. A., Malinowska, A. M., Radziejewska, A., Mikolajczyk-
611 Stecyna, J., Bulczak, E., & Wiebe, D. J. (2021). Greater self-reported preference for fat

612 taste and lower fat restraint are associated with more frequent intake of high-fat food.
613 *Appetite*, 159, 105053. doi: 10.1016/j.appet.2020.105053

614 Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale (NJ):
615 Lawrence Erlbaum Associates., 567 p-567 p.

616 Corney, R. A., Horina, A., Sunderland, C., & James, L. J. (2015). Effect of hydration status and fluid
617 availability on ad-libitum energy intake of a semi-solid breakfast. *Appetite*, 91, 399-404.
618 doi: 10.1016/j.appet.2015.04.075

619 Corney, R. A., Sunderland, C., & James, L. J. (2015). The effect of hydration status on appetite and
620 energy intake. *Journal of Sports Sciences*, 33(8), 761-768. doi:
621 10.1080/02640414.2014.962578

622 Dalton, M., Blundell, J., & Finlayson, G. S. (2013). Examination of food reward and energy intake
623 under laboratory and free-living conditions in a trait binge eating subtype of obesity.
624 *Front Psychol*, 4, 757. doi: 10.3389/fpsyg.2013.00757

625 Dalton, M., & Finlayson, G. (2014). Psychobiological examination of liking and wanting for fat and
626 sweet taste in trait binge eating females. *Physiol Behav*, 136, 128-134. doi:
627 10.1016/j.physbeh.2014.03.019

628 de Korte, J. Q., Bongers, C., Hopman, M. T. E., & Eijvogels, T. M. H. (2021). Exercise Performance
629 and Thermoregulatory Responses of Elite Athletes Exercising in the Heat: Outcomes of
630 the Thermo Tokyo Study. *Sports Med*, 51(11), 2423-2436. doi: 10.1007/s40279-021-
631 01530-w

632 Eccles, R., Du-Plessis, L., Dommels, Y., & Wilkinson, J. E. (2013). Cold pleasure. Why we like ice
633 drinks, ice-lollies and ice cream. *Appetite*, 71, 357-360. doi: 10.1016/j.appet.2013.09.011

634 Faure, C., Charlot, K., Henri, S., Hardy-Dessources, M. D., Hue, O., & Antoine-Jonville, S. (2016).
635 Effect of heat exposure and exercise on food intake regulation: A randomized crossover
636 study in young healthy men. *Metabolism*, 65(10), 1541-1549. doi:
637 10.1016/j.metabol.2016.07.004

638 Finlayson, G., King, N., & Blundell, J. (2008). The role of implicit wanting in relation to explicit
639 liking and wanting for food: implications for appetite control. *Appetite*, 50(1), 120-127.
640 doi: 10.1016/j.appet.2007.06.007

641 Finlayson, G., King, N., & Blundell, J. E. (2007). Is it possible to dissociate 'liking' and 'wanting' for
642 foods in humans? A novel experimental procedure. *Physiol Behav*, 90(1), 36-42. doi:
643 10.1016/j.physbeh.2006.08.020

644 French, S. A., Mitchell, N. R., Wolfson, J., Finlayson, G., Blundell, J. E., & Jeffery, R. W. (2014).
645 Questionnaire and laboratory measures of eating behavior. Associations with energy
646 intake and BMI in a community sample of working adults. *Appetite*, 72, 50-58. doi:
647 10.1016/j.appet.2013.09.020

648 Gibbons, C., Hopkins, M., Beaulieu, K., Oustric, P., & Blundell, J. E. (2019). Issues in Measuring and
649 Interpreting Human Appetite (Satiety/Satiation) and Its Contribution to Obesity. *Curr*
650 *Obes Rep*, 8(2), 77-87. doi: 10.1007/s13679-019-00340-6

651 Gibney, M. J., Barr, S. I., Bellisle, F., Drewnowski, A., Fagt, S., Hopkins, S., . . . Masset, G. (2018).
652 Towards an Evidence-Based Recommendation for a Balanced Breakfast-A Proposal from
653 the International Breakfast Research Initiative. *Nutrients*, 10(10). doi:
654 10.3390/nu10101540

655 Gibney, M. J., & Uzhova, I. (2019). Breakfast: Shaping Guidelines for Food and Nutrient Patterns.
656 *Nestle Nutr Inst Workshop Ser*, 91, 133-142. doi: 10.1159/000493705

657 Giles, G. E., Mahoney, C. R., Caruso, C., Bukhari, A. S., Smith, T. J., Pasiakos, S. M., . . . Lieberman, H.
658 R. (2019). Two days of calorie deprivation impairs high level cognitive processes, mood,
659 and self-reported exertion during aerobic exercise: A randomized double-blind, placebo-
660 controlled study. *Brain Cogn*, 132, 33-40. doi: 10.1016/j.bandc.2019.02.003

661 Gregersen, N. T., Flint, A., Bitz, C., Blundell, J. E., Raben, A., & Astrup, A. (2008). Reproducibility
662 and power of ad libitum energy intake assessed by repeated single meals. *Am J Clin Nutr*,
663 87(5), 1277-1281. doi: 10.1093/ajcn/87.5.1277

664 Heydenreich, J., Kayser, B., Schutz, Y., & Melzer, K. (2017). Total Energy Expenditure, Energy
665 Intake, and Body Composition in Endurance Athletes Across the Training Season: A
666 Systematic Review. *Sports Med Open*, 3(1), 8. doi: 10.1186/s40798-017-0076-1
667 Hilditch, C. J., & McHill, A. W. (2019). Sleep inertia: current insights. *Nat Sci Sleep*, 11, 155-165.
668 doi: 10.2147/NSS.S188911
669 Horner, K. M., Byrne, N. M., & King, N. A. (2014). Reproducibility of subjective appetite ratings
670 and ad libitum test meal energy intake in overweight and obese males. *Appetite*, 81C,
671 116-122. doi: 10.1016/j.appet.2014.06.025
672 Humphreys, M. A., Nicol, J. F., & Raja, I. A. (2007). Field Studies of Indoor Thermal Comfort and
673 the Progress of the Adaptive Approach. *Advances in Building Energy Research*, 1, 55 - 88.
674 Kapoor, N., Al Najim, W., Menezes, C., Price, R. K., O'Boyle, C., Bodnar, Z., . . . le Roux, C. W. (2021).
675 A Comparison of Total Food Intake at a Personalised Buffet in People with Obesity,
676 before and 24 Months after Roux-en-Y-Gastric Bypass Surgery. *Nutrients*, 13(11). doi:
677 10.3390/nu13113873
678 Karjalainen, S. (2007). Gender differences in thermal comfort and use of thermostats in everyday
679 thermal environments. *Building and Environment*, 42(4), 1594-1603. doi:
680 10.1016/j.buildenv.2006.01.009
681 Karl, J. P., Cole, R. E., Berryman, C. E., Finlayson, G., Radcliffe, P. N., Kominsky, M. T., . . . Pasiakos, S.
682 M. (2018). Appetite Suppression and Altered Food Preferences Coincide with Changes in
683 Appetite-Mediating Hormones During Energy Deficit at High Altitude, But Are Not
684 Affected by Protein Intake. *High Alt Med Biol*, 19(2), 156-169. doi:
685 10.1089/ham.2017.0155
686 Karlsson, J., Persson, L. O., Sjöström, L., & Sullivan, M. (2000). Psychometric properties and factor
687 structure of the Three-Factor Eating Questionnaire (TFEQ) in obese men and women.
688 Results from the Swedish Obese Subjects (SOS) study. *Int J Obes Relat Metab Disor*,
689 24(12), 1715-1725.
690 Kojima, C., Sasaki, H., Tsuchiya, Y., & Goto, K. (2015). The influence of environmental
691 temperature on appetite-related hormonal responses. *Journal of physiological*
692 *anthropology*, 34(1), 22-22. doi: 10.1186/s40101-015-0059-1
693 Laan, D. J., Leidy, H. J., Lim, E., & Campbell, W. W. (2010). Effects and reproducibility of aerobic
694 and resistance exercise on appetite and energy intake in young, physically active adults.
695 *Appl Physiol Nutr Metab*, 35(6), 842-847. doi: 10.1139/H10-072
696 Labbe, D., Almiron-Roig, E., Hudry, J., Leathwood, P., Schifferstein, H. N., & Martin, N. (2009).
697 Sensory basis of refreshing perception: role of psychophysiological factors and food
698 experience. *Physiol Behav*, 98(1-2), 1-9. doi: 10.1016/j.physbeh.2009.04.007
699 Laursen, T. L., Zak, R. B., Shute, R. J., Heesch, M. W. S., Dinan, N. E., Bubak, M. P., . . . Slivka, D. R.
700 (2017). Leptin, adiponectin, and ghrelin responses to endurance exercise in different
701 ambient conditions. *Temperature (Austin)*, 4(2), 166-175. doi:
702 10.1080/23328940.2017.1294235
703 Lemon, C. H. (2021). Tasting temperature: neural and behavioral responses to thermal
704 stimulation of oral mucosa. *Curr Opin Physiol*, 20, 16-22. doi:
705 10.1016/j.cophys.2020.12.005
706 Lepicard, E. M., Maillot, M., Vieux, F., Viltard, M., & Bonnet, F. (2017). Quantitative and qualitative
707 analysis of breakfast nutritional composition in French schoolchildren aged 9-11 years. *J*
708 *Hum Nutr Diet*, 30(2), 151-158. doi: 10.1111/jhn.12412
709 Leshem, M. (2009). The excess salt appetite of humans is not due to sodium loss in adulthood.
710 *Physiol Behav*, 98(3), 331-337. doi: 10.1016/j.physbeh.2009.06.009
711 Leshem, M., Abutbul, A., & Eilon, R. (1999). Exercise increases the preference for salt in humans.
712 *Appetite*, 32(2), 251-260. doi: 10.1006/appe.1999.0228
713 Libert, J. P., Bach, V., Johnson, L. C., Ehrhart, J., Wittersheim, G., & Keller, D. (1991). Relative and
714 combined effects of heat and noise exposure on sleep in humans. *Sleep*, 14(1), 24-31. doi:
715 10.1093/sleep/14.1.24

716 Logan-Sprenger, H. M., & Spriet, L. L. (2013). The acute effects of fluid intake on urine specific
717 gravity and fluid retention in a mildly dehydrated state. *J Strength Cond Res*, 27(4), 1002-
718 1008. doi: 10.1519/JSC.0b013e31826052c7

719 Logue, D. M., Madigan, S. M., Melin, A., Delahunt, E., Heinen, M., Donnell, S. M., & Corish, C. A.
720 (2020). Low Energy Availability in Athletes 2020: An Updated Narrative Review of
721 Prevalence, Risk, Within-Day Energy Balance, Knowledge, and Impact on Sports
722 Performance. *Nutrients*, 12(3). doi: 10.3390/nu12030835

723 McNeil, J., Forest, G., Hintze, L. J., Brunet, J. F., Finlayson, G., Blundell, J. E., & Doucet, E. (2017).
724 The effects of partial sleep restriction and altered sleep timing on appetite and food
725 reward. *Appetite*, 109, 48-56. doi: 10.1016/j.appet.2016.11.020

726 McNeil, J., Riou, M. E., Razmjou, S., Cadieux, S., & Doucet, E. (2012). Reproducibility of a food
727 menu to measure energy and macronutrient intakes in a laboratory and under real-life
728 conditions. *Br J Nutr*, 108(7), 1316-1324. doi: 10.1017/S0007114511006672

729 Millet, J., Siracusa, J., Tardo-Dino, P. E., Thivel, D., Koulmann, N., Malgoyre, A., & Charlot, K.
730 (2021). Effects of Acute Heat and Cold Exposures at Rest or during Exercise on
731 Subsequent Energy Intake: A Systematic Review and Meta-Analysis. *Nutrients*, 13(10).
732 doi: 10.3390/nu13103424

733 Morrison, S., Galland, B. C., Haszard, J. J., Jackson, R., McIntosh, D. R., Beebe, D. W., . . . Taylor, R. W.
734 (2021). Eating in the absence of hunger in children with mild sleep loss: a randomized
735 crossover trial with learning effects. *Am J Clin Nutr*, 114(4), 1428-1437. doi:
736 10.1093/ajcn/nqab203

737 Motoki, K., Saito, T., Nouchi, R., & Sugiura, M. (2020). Cross-Modal Correspondences Between
738 Temperature and Taste Attributes. *Front Psychol*, 11, 571852. doi:
739 10.3389/fpsyg.2020.571852

740 Murphy, N. E., Carrigan, C. T., Philip Karl, J., Pasiakos, S. M., & Margolis, L. M. (2018). Threshold of
741 Energy Deficit and Lower-Body Performance Declines in Military Personnel: A Meta-
742 Regression. *Sports Med*, 48(9), 2169-2178. doi: 10.1007/s40279-018-0945-x

743 O'Leary, T. J., Wardle, S. L., & Greeves, J. P. (2020). Energy Deficiency in Soldiers: The Risk of the
744 Athlete Triad and Relative Energy Deficiency in Sport Syndromes in the Military. *Front*
745 *Nutr*, 7, 142. doi: 10.3389/fnut.2020.00142

746 Ocobock, C. (2016). Human energy expenditure, allocation, and interactions in natural
747 temperate, hot, and cold environments. *Am J Phys Anthropol*, 161(4), 667-675. doi:
748 10.1002/ajpa.23071

749 Okamoto-Mizuno, K., & Mizuno, K. (2012). Effects of thermal environment on sleep and circadian
750 rhythm. *J Physiol Anthropol*, 31, 14. doi: 10.1186/1880-6805-31-14

751 Oustric, P., Thivel, D., Dalton, M., Beaulieu, K., Gibbons, C., Hopkins, M., . . . Finlayson, G. (2020).
752 Measuring food preference and reward: Application and cross-cultural adaptation of the
753 Leeds Food Preference Questionnaire in human experimental research. *Food Quality &*
754 *Preference*, 80. doi: <https://doi.org/10.1016/j.foodqual.2019.103824>

755 Palmer, B., Irwin, C., McCartney, D., Cox, G. R., & Desbrow, B. (2021). The impact of post-prandial
756 delay periods on ad libitum consumption of a laboratory breakfast meal. *Appl Physiol*
757 *Nutr Metab*, 46(10), 1290-1297. doi: 10.1139/apnm-2020-0801

758 Parsons, I. T., Stacey, M. J., & Woods, D. R. (2019). Heat Adaptation in Military Personnel:
759 Mitigating Risk, Maximizing Performance. *Front Physiol*, 10, 1485. doi:
760 10.3389/fphys.2019.01485

761 Perrier, E. T., Bottin, J. H., Vecchio, M., & Lemetais, G. (2017). Criterion values for urine-specific
762 gravity and urine color representing adequate water intake in healthy adults. *Eur J Clin*
763 *Nutr*, 71(4), 561-563. doi: 10.1038/ejcn.2016.269

764 Racinais, S., Casa, D., Brocherie, F., & Ihsan, M. (2019). Translating Science Into Practice: The
765 Perspective of the Doha 2019 IAAF World Championships in the Heat. *Front Sports Act*
766 *Living*, 1, 39. doi: 10.3389/fspor.2019.00039

767 Radcliffe, P. N., Whitney, C. C., Fagnant, H. S., Wilson, M. A., Finlayson, G., Smith, T. J., & Karl, J. P.
768 (2021). Severe sleep restriction suppresses appetite independent of effects on appetite

769 regulating hormones in healthy young men without obesity. *Physiol Behav*, 237, 113438.
770 doi: 10.1016/j.physbeh.2021.113438

771 Ruddock, H. K., Brunstrom, J. M., Vartanian, L. R., & Higgs, S. (2019). A systematic review and
772 meta-analysis of the social facilitation of eating. *Am J Clin Nutr*, 110(4), 842-861. doi:
773 10.1093/ajcn/nqz155

774 Shorten, A. L., Wallman, K. E., & Guelfi, K. J. (2009). Acute effect of environmental temperature
775 during exercise on subsequent energy intake in active men. *The American journal of*
776 *clinical nutrition*, 90(5), 1215-1221. doi: 10.3945/ajcn.2009.28162

777 Soltanieh, S., Solgi, S., Ansari, M., Santos, H. O., & Abbasi, B. (2021). Effect of sleep duration on
778 dietary intake, desire to eat, measures of food intake and metabolic hormones: A
779 systematic review of clinical trials. *Clin Nutr ESPEN*, 45, 55-65. doi:
780 10.1016/j.clnesp.2021.07.029

781 Stelmach-Mardas, M., Kleiser, C., Uzhova, I., Penalvo, J. L., La Torre, G., Palys, W., . . . Boeing, H.
782 (2016). Seasonality of food groups and total energy intake: a systematic review and
783 meta-analysis. *Eur J Clin Nutr*, 70(6), 700-708. doi: 10.1038/ejcn.2015.224

784 Stubbs, R. J., Hughes, D. A., Johnstone, A. M., Rowley, E., Reid, C., Elia, M., . . . Blundell, J. E. (2000).
785 The use of visual analogue scales to assess motivation to eat in human subjects: a review
786 of their reliability and validity with an evaluation of new hand-held computerized
787 systems for temporal tracking of appetite ratings. *Br J Nutr*, 84(4), 405-415.

788 Stubbs, R. J., Johnstone, A. M., Mazlan, N., Mbaiwa, S. E., & Ferris, S. (2001). Effect of altering the
789 variety of sensorially distinct foods, of the same macronutrient content, on food intake
790 and body weight in men. *Eur J Clin Nutr*, 55(1), 19-28. doi: 10.1038/sj.ejcn.1601117

791 Suzuki, M., Kimura, R., Kido, Y., Inoue, T., Moritani, T., & Nagai, N. (2017). Color of hot soup
792 modulates postprandial satiety, thermal sensation, and body temperature in young
793 women. *Appetite*, 114, 209-216. doi: 10.1016/j.appet.2017.03.041

794 Takamata, A., Mack, G. W., Gillen, C. M., & Nadel, E. R. (1994). Sodium appetite, thirst, and body
795 fluid regulation in humans during rehydration without sodium replacement. *Am J*
796 *Physiol*, 266(5 Pt 2), R1493-1502. doi: 10.1152/ajpregu.1994.266.5.R1493

797 Tassone, E. C., & Baker, B. A. (2017). Body weight and body composition changes during military
798 training and deployment involving the use of combat rations: a systematic literature
799 review. *Br J Nutr*, 117(6), 897-910. doi: 10.1017/S0007114517000630

800 Tharion, W. J., Lieberman, H. R., Montain, S. J., Young, A. J., Baker-Fulco, C. J., Delany, J. P., & Hoyt,
801 R. W. (2005). Energy requirements of military personnel. *Appetite*, 44(1), 47-65. doi:
802 10.1016/j.appet.2003.11.010

803 Thivel, D., Genin, P. M., Mathieu, M. E., Pereira, B., & Metz, L. (2016). Reproducibility of an in-
804 laboratory test meal to assess ad libitum energy intake in adolescents with obesity.
805 *Appetite*, 105, 129-133. doi: 10.1016/j.appet.2016.05.028

806 Thomas, E. A., Higgins, J., Bessesen, D. H., McNair, B., & Cornier, M. A. (2015). Usual breakfast
807 eating habits affect response to breakfast skipping in overweight women. *Obesity (Silver*
808 *Spring)*, 23(4), 750-759. doi: 10.1002/oby.21049

809 Travers, G. J., Nichols, D. S., Farooq, A., Racinais, S., & Periard, J. D. (2016). Validation of an
810 ingestible temperature data logging and telemetry system during exercise in the heat.
811 *Temperature (Austin)*, 3(2), 208-219. doi: 10.1080/23328940.2016.1171281

812 Valencia, M. E., McNeill, G., Brockway, J. M., & Smith, J. S. (1992). The effect of environmental
813 temperature and humidity on 24 h energy expenditure in men. *Br J Nutr*, 68(2), 319-327.
814 doi: 10.1079/bjn19920091

815 Wasse, L. K., King, J. A., Stensel, D. J., & Sunderland, C. (2013). Effect of ambient temperature
816 during acute aerobic exercise on short-term appetite, energy intake, and plasma acylated
817 ghrelin in recreationally active males. *Applied Physiology, Nutrition, and Metabolism*,
818 38(8), 905-909. doi: 10.1139/apnm-2013-0008

819 Zakrzewski-Fruer, J. K., Horsfall, R. N., Cottrill, D., & Hough, J. (2021). Acute exposure to a hot
820 ambient temperature reduces energy intake but does not affect gut hormones in men
821 during rest. *Br J Nutr*, 125(8), 951-959. doi: 10.1017/S0007114520002792

822 Zheng, G., Li, K., & Wang, Y. (2019). The Effects of High-Temperature Weather on Human Sleep
823 Quality and Appetite. *Int J Environ Res Public Health*, 16(2). doi:
824 10.3390/ijerph16020270

825 **Figure legends**

826

827 **Figure 1 - Study protocol.** RH = relative humidity, LFPQ = Leeds Food Preference
828 Questionnaire.

829

830 **Figure 2 - Absolute (A) and relative (C) macronutrient macronutrient intake, energy**
831 **intake (B) and the amount of consumed items (D) at the ad libitum breakfast-buffet.** For
832 Figures A and C, each bar indicates individual data ranged by total energy intake and relative
833 carbohydrate intake, respectively. Horizontal lines indicate the mean for each macronutrient.
834 For Figure B, bars indicate the means and the grey lines the individual values. For Figure D, grey
835 bars indicated the number of items that were selected in both conditions by the same
836 participants. Blue and red bars exceeding the grey bar indicated the number of items that were
837 only selected in 22 and 32°C sessions, respectively. PRO = protein, CHO = carbohydrates.

838

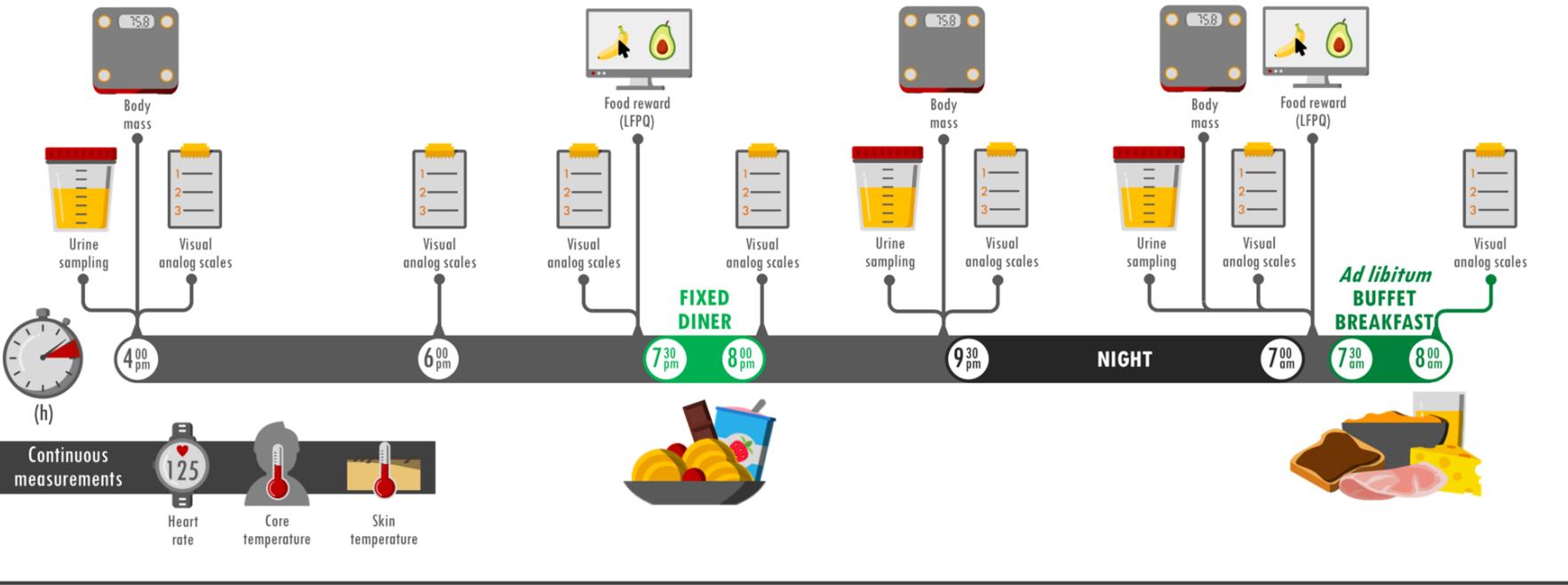
839 **Figure 3 - Hunger (A) and thirst (B) scores during the whole exposure.** Means \pm SD. 0 h =
840 16:00 pm. Grey bars symbolizes meals and black bar the sleep period. *** different from 22°C
841 session ($p < 0.001$).

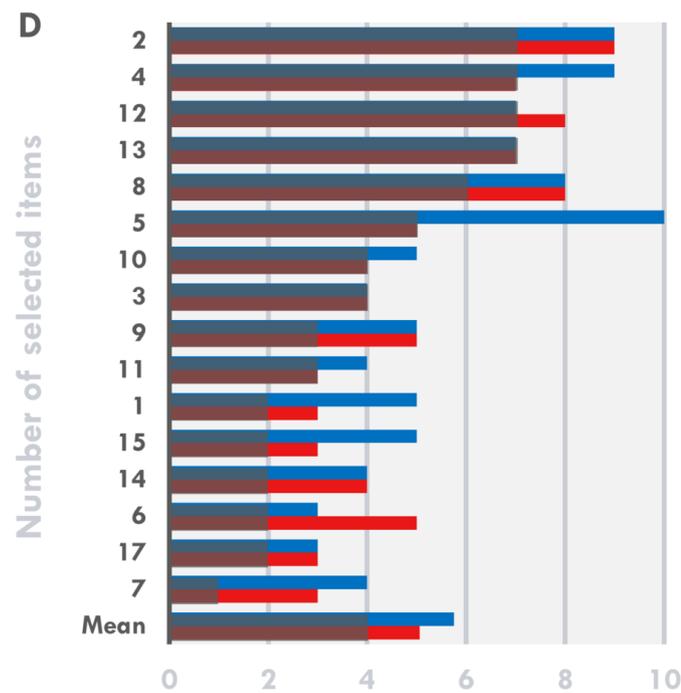
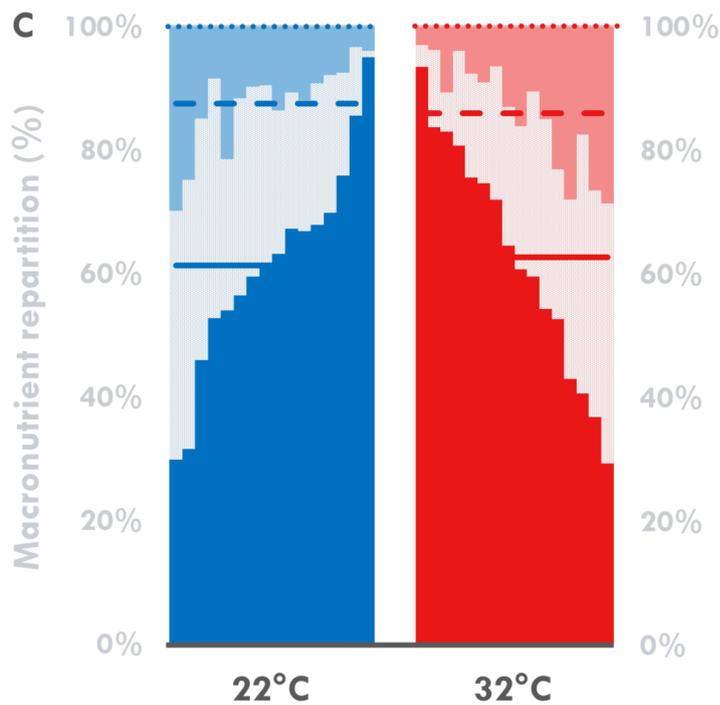
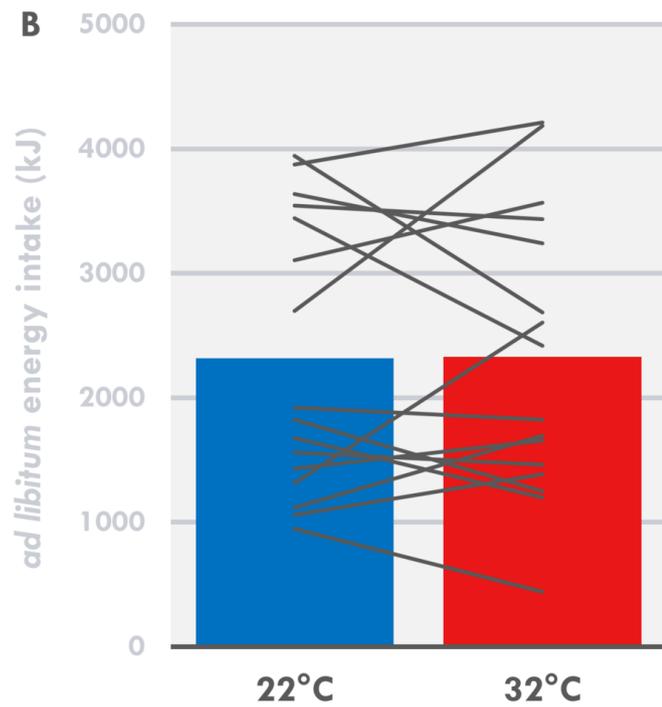
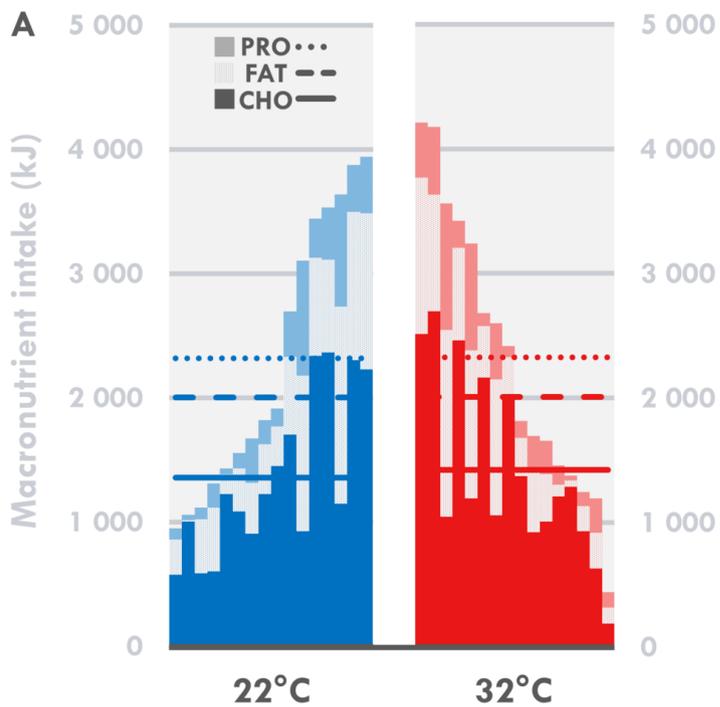
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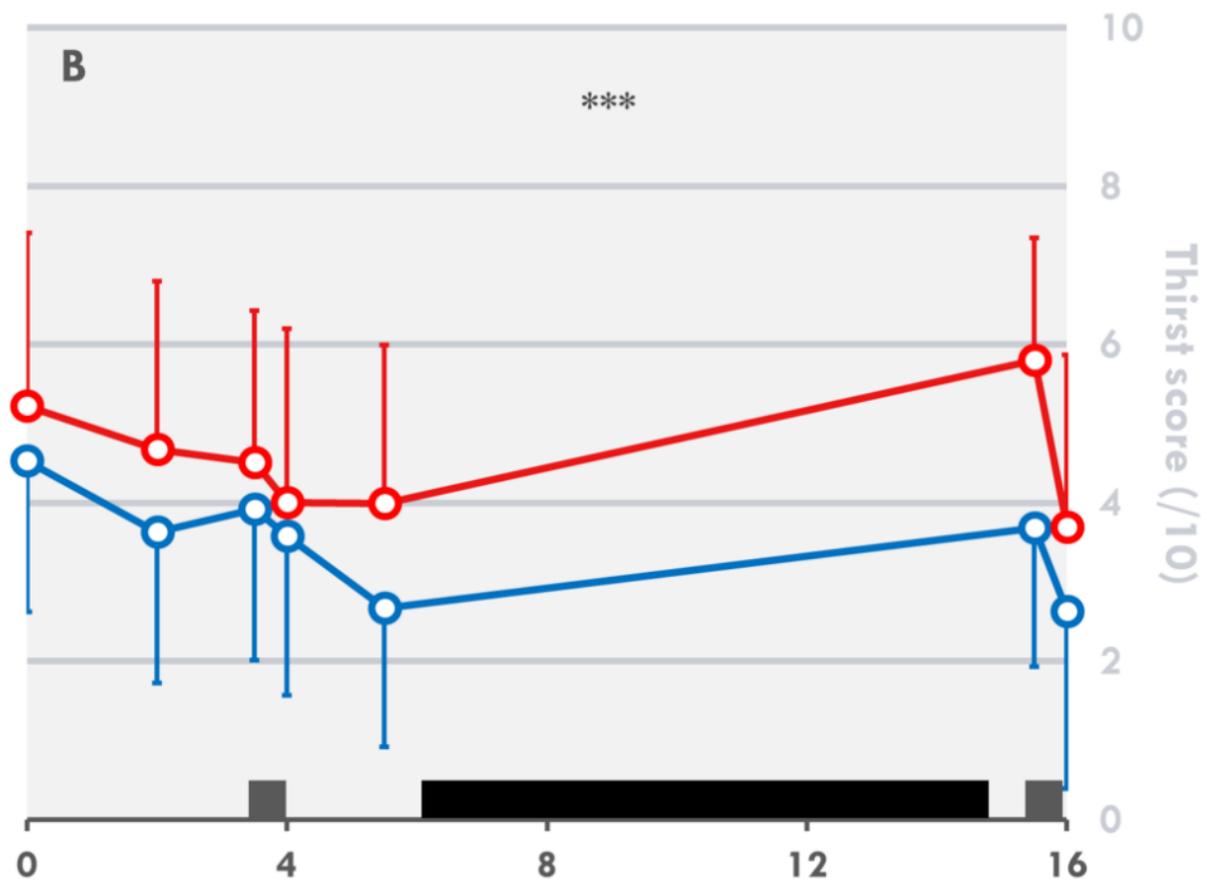
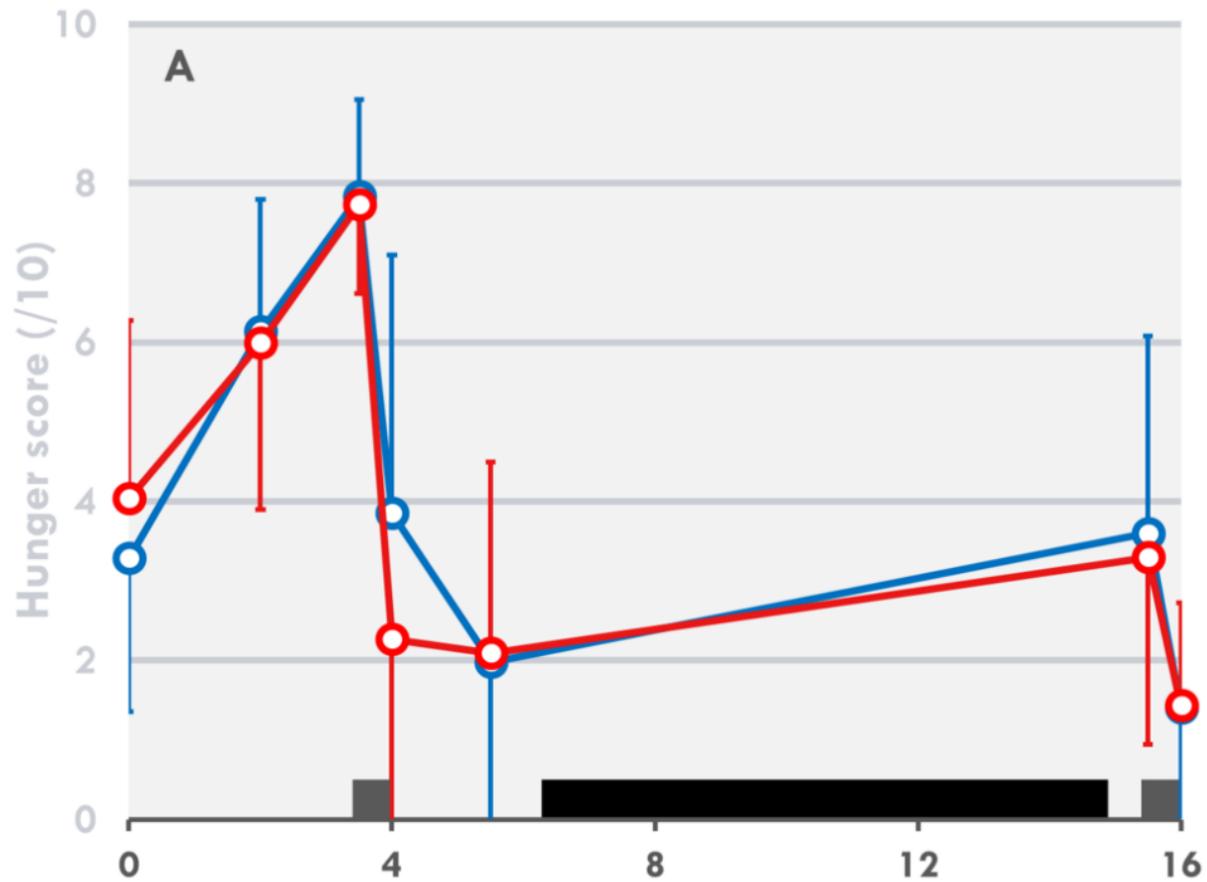
843 **Figure 4 - Fat and Taste appeal scores before dinner and breakfast.** Values for explicit
844 liking (A and C, respectively) and implicit wanting (B and D, respectively). The bars indicates the
845 means and the grey lines the individual values. ***different from 22°C session ($p < 0.001$);
846 $\alpha\alpha\alpha$ different from the dinner ($p < 0.001$).

22 °C
40% RH vs 32 °C
40% RH

4 participants per session
1 month between sessions



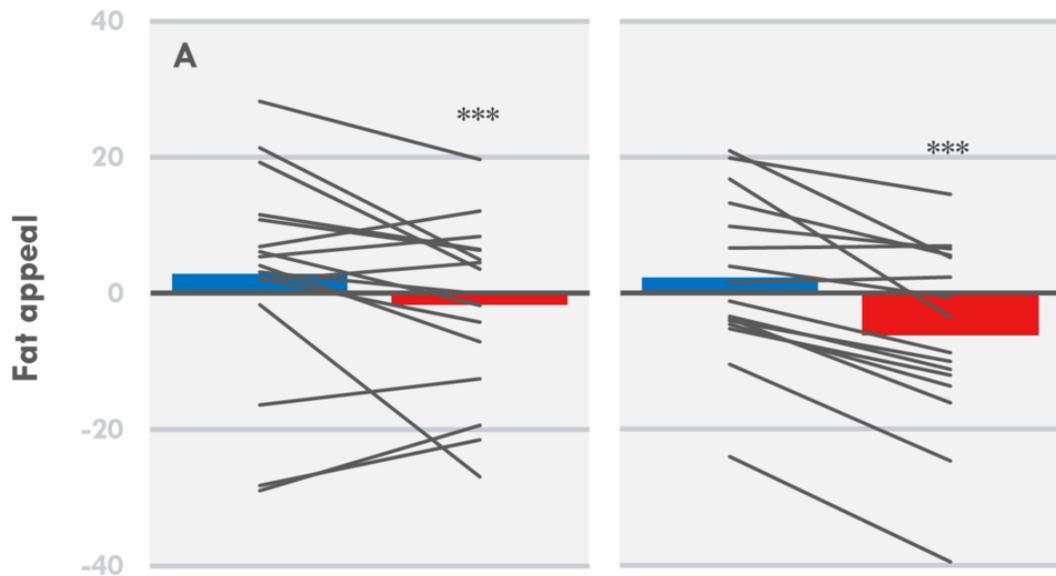




Explicit liking

Before dinner

Before breakfast



Implicit wanting

Before dinner

Before breakfast

