



Applied nutritional investigation

Single bout of low-intensity exercise produces modestly favorable changes in glycemic and lipidemic profiles after ingestion of non-isoglucidic breakfasts



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ABSTRACT

Objectives: The aim of this study was to investigate the acute effects of low-intensity exercise on the postprandial hormonal and metabolic milieu induced by breakfast consumption.

Methods: Exercise began 100 min after the initiation of breakfast consumption and consisted of cycling at 40% of maximum oxygen uptake for 20 min. Three different breakfasts were used to elicit the postprandial state: B1 = skimmed milk (125 mL) and 30g corn flakes; B2 = skimmed milk (220 mL), 200 g apple, 30 g cocoa cream-filled sponge cake; B3 = skimmed milk (125 mL), 50 g bread, 150 g apple, and 15 g hazelnut and cocoa spread. Nineteen young healthy participants (8 M/11 F; body mass index 22.7 ± 0.5 kg/m²; age 31 ± 0.7 y) consumed the three breakfasts, as well as an oral glucose load (50-g oral glucose tolerance test), under either resting or exercise conditions, in a randomized-crossover fashion. Blood glucose, insulinemia, ghrelinemia, lipidemia, and satiety were measured throughout the studies. To evaluate the metabolic effects of exercise, the changes that glucose, insulin, ghrelin, free fatty acid exhibited in the interval 90 to 120 min were analyzed with a two-way repeated measures analysis of variance (factor 1: type of oral test; factor 2: resting/exercise condition).

Results: No interaction between the two factors was found for any of the examined variables. Light exercise produced a modest, significant decrease in blood glucose levels ($P = 0.004$) and a modest, significant increase in free fatty acid levels ($P = 0.002$) with respect to the resting condition.

Conclusions: These findings suggest that short, mild exercise has beneficial effects on postprandial metabolism and this may have direct bearing on the issue of counteracting the epidemic rising of sedentary lifestyle of the general population.

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Introduction

Physical inactivity has been identified as the fourth leading risk factor for global mortality causing an estimated 3.2 million deaths [1]. Indeed, sedentary lifestyle has been emerging as a major concern in present-day societies, leading to health-related problems such as obesity and chronic-degenerative metabolic diseases. In particular, obesity has become one of the most challenging medical problems of the 21st century [2–4].

Although several factors (genes, psychology, environment, lifestyle) there is an interplay of in the etiopathogenic picture leading to obesity, a common underlying “obesogenic” trait is a positive energy balance. Recent studies highlight the primary role exerted by lifestyle over the genetic signature, indicating that alterations in gene expression observed in obese individuals are not due to their genetic background, but are primarily associated with environment and lifestyle [5].

Healthy lifestyles embrace salutary habits like dynamic daily living and appropriate eating behaviors [2,6,7]. Multiplying chances of being physically active throughout the day is an effective and strongly recommended strategy to accumulate beneficial levels of physical activity for anyone. Modalities of exercise that are time-efficient and, at the same time, capable of producing

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Table 1
Anthropometrical and clinical characteristics of the study participants

	Mean \pm SEM
Sex (M/F)	8/11
Age (y)	31 \pm 0.7
Weight (kg)	68.1 \pm 3.3
Height (m)	1.73 \pm 0.01
BMI (kg/m ²)	22.7 \pm 0.5
Fasting glucose* (mmol/L)	4.66 \pm 0.07
2-h glucose [†] (mmol/L)	5.05 \pm 0.27

BMI, body mass index; SEM, standard error of the mean.

*Measured before 50-g oral glucose tolerance test, under resting conditions.

[†]Measured 2 h after 50-g oral glucose tolerance test, under resting conditions.

significant health benefits, are highly recommended. For example, older adults should perform aerobic activity in bouts of ≥ 10 min duration [8]. Likewise, children and young people ages 5 to 17 y should accumulate ≥ 60 min of moderate to vigorous intensity activity, daily [9]. In the context of family, school, and community activities, adolescents should exploit any opportunity for planned or recreational exercise to improve cardiorespiratory, muscular fitness, and metabolic health.

Along with these World Health Organization recommendations, proper eating behaviors, including eating breakfast on a regular basis, are equally critical for maintaining normal body weight and metabolic health biomarkers. In this scenario, more attention has been given to specific nutrients, and to their effects on physiological or pathophysiological events [1,10–12].

We previously studied the hormonal and metabolic responses as well as the sense of satiety determined by several commercial isoglucidic snacks, showing different patterns among them [13]. Specifically, some snack foods administered in equivalent glucidic loads elicited favorable postprandial glycemic profile accompanied by an evident suppression of plasma ghrelin concentration. In another recent study, similar breakfast types determined different hormonal and metabolic responses, which in turn resulted in being linearly related to peculiar neurofunctional responses [14].

In the present study, we investigated the acute effects of exercise on the postprandial hormonal and metabolic milieu induced by breakfast consumption. Given that lack of time and elevated exercise intensity can become critical barriers to exercise compliance, we tested the effectiveness of a short, low-intensity exercise session performed in the postabsorptive state after breakfast consumption. The timing and type of exercise were chosen to

reproduce a real-life setting. Given that glycemic peaks are usually concurrent to gastric fullness—a feeling poorly compatible and tolerable with performing physical activity—exercise began 100 min after the initiation of breakfast consumption and consisted in cycling at low intensity for 20 min. Three different breakfasts were used to elicit the postprandial state. The three breakfasts were non-isoglucidic and represented three types of commonly consumed breakfasts in Mediterranean countries [15]. Nineteen young healthy men and women underwent the three breakfasts and an oral glucose load (50-g oral glucose tolerance test [OGTT]), under either resting or exercise conditions, in random order. Blood glucose, insulinemia, ghrelinemia, lipidemia, and satiety were measured throughout the studies.

Material and methods

Selection criteria

Nineteen healthy volunteers (8 M/11 F, age 31 \pm 0.7 y, body mass index 20.8 \pm 0.5 kg/m²) on a stable diet, with normal glucose tolerance and no dyslipidemia (according to American Diabetes Association and Adult Treatment Panel III-National Cholesterol Education Program guidelines, respectively) were recruited for this study (Table 1).

Ethical approval was obtained from the Ethical Committee of the Università degli Studi di Milano (Milano, Italy). All participants signed a written informed consent before participation, according to the Declaration of Helsinki. All procedures used complied with the Good Clinical Practice principles.

Research design

This study was carried out in a randomized-crossover fashion at San Raffaele Hospital (Milano, Italy). During the preliminary examination, blood was withdrawn from 30 individuals for the measurement of basal lipid profile (total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides). All individuals received a standard 75-g OGTT to assess eligibility for the study. The 19 participants matching the inclusion criteria completed two experimental trials: resting and exercise. During the resting trial, all participants underwent an OGTT (50-g: A) and three breakfast tolerance tests (one for each breakfast tested: B1 = 125 mL skimmed milk and 30 g corn flakes; B2 = 220 mL skimmed milk, 200 g apple, and 30 g cocoa cream-filled sponge cake; B3 = 125 mL skimmed milk, 50 g bread, 150 g apple, and 15 g hazelnut and cocoa spread). In the exercise trial, 100 min after ingestion of one of the glucose/meals, participants cycled for 20 min at 40% of maximum oxygen uptake (VO₂ max; Fig. 1). The dependent variables examined were the changes that glucose, insulin, ghrelin, and free fatty acid (FFA) exhibited in the interval 90 to 120 min. Our hypothesis was that participants would experience greater changes in metabolite concentrations when exercise was administered than in the resting condition.

Participants were admitted to hospital at 0830 to 0900 h after overnight fasting (~12 h). An indwelling catheter was inserted in an antecubital arm vein and

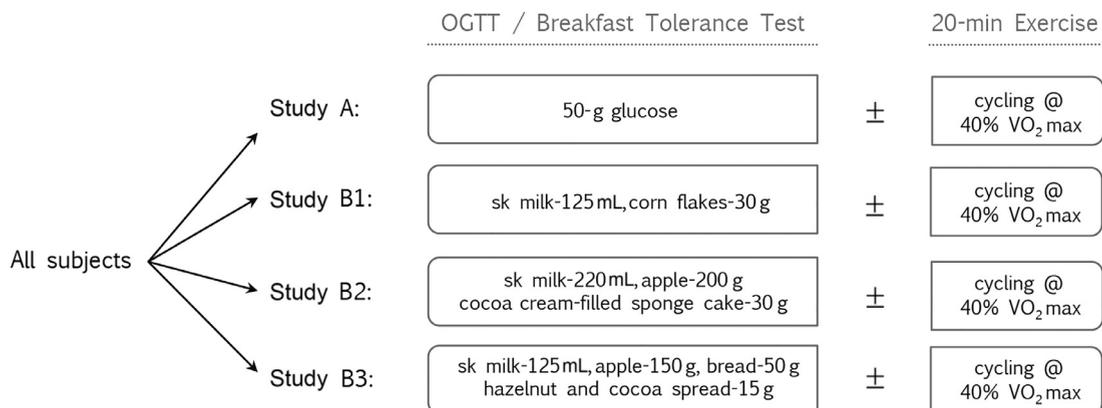


Fig. 1. Flowchart of the study. All participants underwent studies A, B1, B2, B3, twice. In the first trial, they remained under resting conditions, whereas in the second trial they cycled at 40% of VO₂ max (maximum oxygen uptake in the interval 100 to 120 min after glucose/breakfast ingestion).

Table 2
Oral loads nutritional facts

Nutritional facts	Breakfasts			
	Glucose A	B1	B2	B3
Energy (kcal)	190	170.5	329.2	350.5
(kJ)	795.5	724.8	1 389.2	1 481.2
Glycemic index	100	68	36	37
Glycemic load	50	22	17	12
Protein (g)	0	6.2	11	9
Carbohydrate (g)	50	31.5	51.8	61.4
Sugars (g)	50	8.5	44.9	35.1
Fat (g)	0	2.2	9.5	8.3
Saturated fats (g)	0	1.4	4.7	3
Monounsaturated (g)	0	0.35	0.57	0.52
Polyunsaturated (g)	0	0.13	0.17	0.60
Fiber (g)	0	1.14	5.58	8.7
Vitamin A (μ g)	0	148.2	28.6	16.2
Vitamin B ₃ niacin (mg)	0	7.39	0.31	2.44
Vitamin C (mg)	0	7.85	11.4	8.4
Vitamin B ₂ riboflavin (mg)	0	0.98	0.39	0.37
Sodium (mg)	0	348.1	267.2	402.9
Calcium (mg)	0	146.2	303.2	496
Potassium (mg)	0	212.4	546.2	412.7
Iron (mg)	0	8.76	0.35	2.69

Participants consumed each portion on different test days

the participants consumed the glucose load (A) or the three breakfasts (B1, B2, B3). The entire study lasted for 9 experimental days (1 d for eligibility, 4 d for resting trial, 4 d for exercise trial).

Breakfast tolerance tests

Nutritional composition of the breakfasts is presented in Table 2. Breakfast 1 (B1) was composed of 125 mL of skimmed milk (1.8% fat) and 30 g of cereals (corn flakes); breakfast 2 (B2) was composed of 220 mL of skimmed milk (1.8% fat), 200 g of a green apple, and 30 g of cocoa cream-filled sponge cake; breakfast 3 (B3) was composed of 125 mL skimmed milk (1.8% fat), 50 g of white bread (hard "durum" wheat), 150 g of a green apple, and 15 g of hazelnut and cocoa spread. Breakfasts or 50-g glucose load (A) were consumed in a randomized order on separate days ~2 weeks apart to ascertain lipidemia, plasma glucose, and plasma hormone profile. Either breakfasts or glucose (dissolved in an aqueous solution) were administered at ~0900 h and consumed completely within 10 min, in front of the physician. Blood samples were collected at -15 and 0 min; thereafter the participants received either a breakfast test meal or 50 g of glucose. Hence, additional blood samples were obtained at 15, 30, 45, 60, 75, 90, 120 min after ingestion.

Meal tests were selected as very popular combination of breakfasts from the large-scale Italian foodstuff market. In detail, we evaluated three combinations exemplified by Italian recommended daily dietary intake—Levels of Reference Assumption of Nutrients and Energy (LARN; featured by the Italian Society of Human Nutrition [SINU], and the Italian National Institute for Research on Food and Nutrition [INRAN]) according to a daily dietary intake of 2000 kcal. These combinations envisaged nutritional composition of three types of breakfasts commonly consumed in Mediterranean countries. For each breakfast, the specific nutrient content was calculated and compared with optimal dietary intake and ratios provided by LARN [15]. Italian guidelines on healthy nutrition recommend introducing 15% to 20% of the total daily calorie intake during the first meal of the day. Thus, the three breakfasts ranged from 8.5% (B1) to 16% (B2) and 18% (B3) of an optimal daily intake.

Exercise protocol

Participants filled in the Baecke's exercise activity questionnaire [16] to ensure they all could be considered "sedentary." They reported no differences in physical

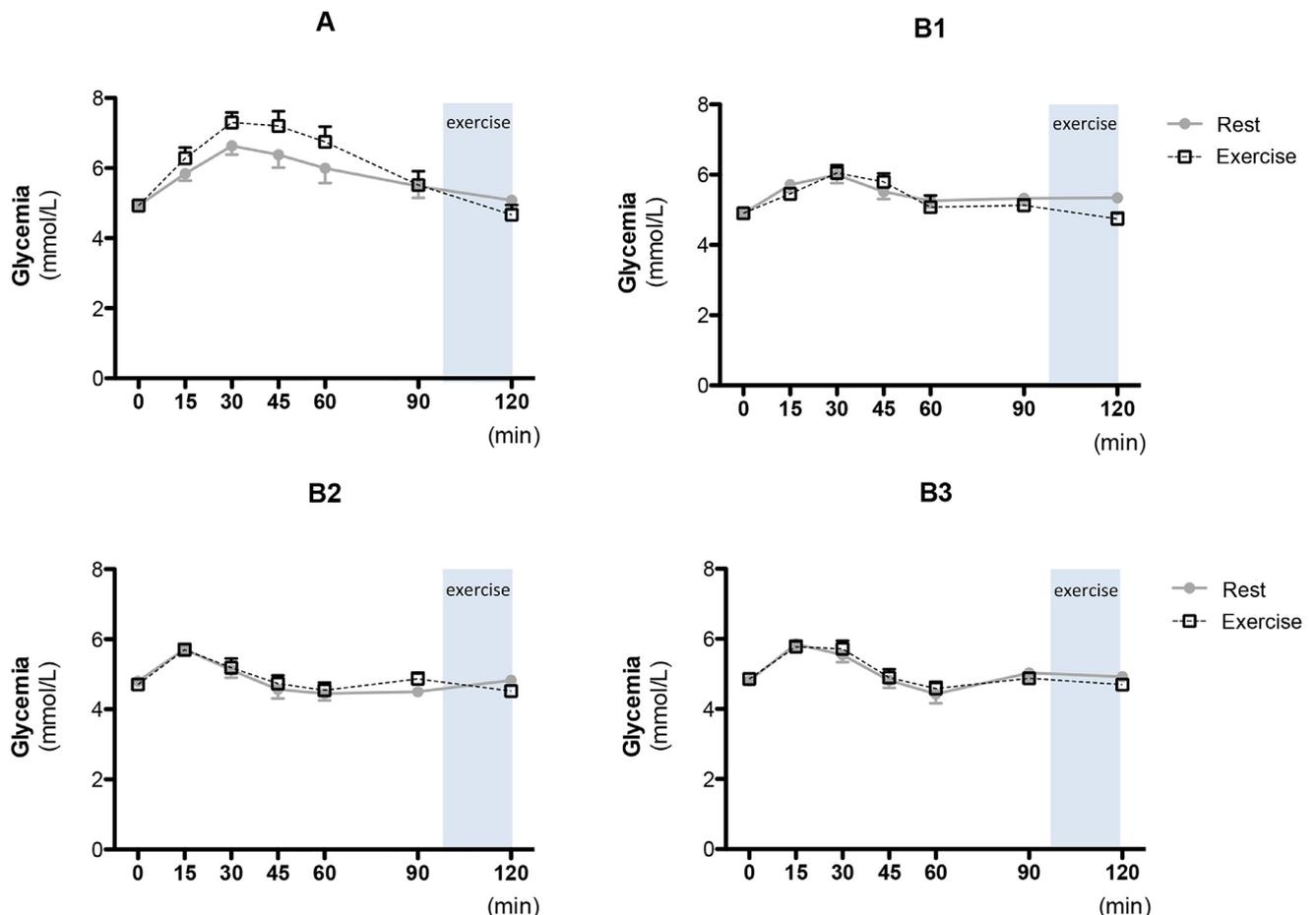


Fig. 2. Panels show the time courses of plasma glucose concentrations after oral loads A, B1, B2, and B3, in resting (gray continuous line) and exercise (black dotted line) conditions. Physical exercise significantly decreased the final glucose concentration (Δ 120–90) after ingestion of all loads with respect to the resting condition (two-way repeated measures ANOVA, $P = 0.004$). ANOVA, analysis of variance.

activity level before each test day. They also were asked to maintain their habitual dietary intake throughout the entire duration of the study. A submaximal incremental cycle-ergometer was performed to assess the maximal aerobic power (VO_2 max), as previously described [17].

In the exercise trial, when 100 min were elapsed from the glucose/breakfast ingestion, participants cycled for 20 min on an Ergoline cycle-ergometer (Sensor Medics Italia, Milano Italy) at 40% of VO_2 max.

Analytical methods

The total amount of blood for each glucose/breakfast test was about 22.5 mL and was withdrawn through an indwelling catheter inserted in each participant's antecubital arm vein. All samples were kept in ice. Plasma was prepared by centrifugation at 4°C within 1.5 h from sampling. Plasma glucose was measured at the bedside with a glucose analyzer (Beckman Instruments, Fullerton, CA, USA). Aliquots of blood for measurement of plasma insulin and ghrelin were collected in test tubes containing EDTA. All plasma and serum aliquots were frozen at -60°C for later analysis.

Each specimen was measured in duplicate. Free insulin was dosed by a highly specific two-site monoclonal antibody-based immunosorbent assay (enzyme-linked immunosorbent assay; Dako Diagnostics, Cambridgeshire, UK). Ghrelin concentration was measured through an enzymatic immunoassay method (LINCO Research Inc., St. Charles, MO, USA). Standard lipid profile and FFAs were measured through the immunoenzymatic technique as previously described [18].

Satiety

A 100-mm linear visual analog scale (VAS) was used to assess the volunteers' subjective feelings of satiety [19]. Participants were instructed to rate both their fullness and hunger at 0, 30, 60, 90, and 120 min from the load assumption by making a single vertical mark on a scale ranging from the most negative to the most positive score (e.g., from *not hungry* to *hungry*). The satiety scores were then plotted against time for each experiment. Participants also scored palatability of loads.

Statistical analysis

All participants underwent all of the scenarios, for which there were two within-group independent variables, one with four conditions (a glucose load and three different breakfasts) and the other with two conditions (resting/exercise). To evaluate the metabolic effects of exercise, four metabolic variables (i.e., the dependent variables) were examined. They were the changes that glucose, insulin, ghrelin, and FFA exhibited in the interval 90 to 120 min. The data analysis was conducted using a two-way analysis of variance (ANOVA) with repeated measures on both factors. Briefly, the ANOVA procedure considered each metabolic variable to be dependent on two within-subject factors: The type of load and the resting or exercise condition. One purpose of the ANOVA analysis was to establish whether the modality of change of the metabolic variable between the resting and the exercise condition was dependent on the load type. In the so-called profile plot—a graphical representation that usually accompanies a two-way ANOVA—this would be visualized as four non-parallel lines connecting the levels of the metabolic variable measured in the two occasions (resting/exercise). To single out the individual effects of the load and exercise, we considered whether such interaction was significant. A preliminary analysis showed that such interaction between load and exercise was not significant for any of the four metabolic variables. Thus, the main effect of exercise per se was tested by evaluating the differences in the metabolic variable measured during the resting and exercise conditions collapsed across the loads (i.e., regardless of the loads). The level of significance of this comparison was found in the within-subjects table provided by the two-way ANOVA.

To evaluate the effects of exercise on the 2-h satiety score (an interval variable), a two-way ANOVA with repeated measures on both factors (i.e., load type and resting/exercise condition) was carried out. The ANOVA procedure followed the same rationale as the one outlined for the assessment of the effect of exercise on the metabolic variables.

All data were reported as mean and standard error of the mean (SEM). $P < 0.05$ was considered statistically significant. Analyses were carried out with SPSS version 22 (IBM Corp., Armonk, NY, USA), Excel 2011 (Microsoft, Redmond, WA, USA), and GraphPad Prism 7 (San Diego, CA, USA).

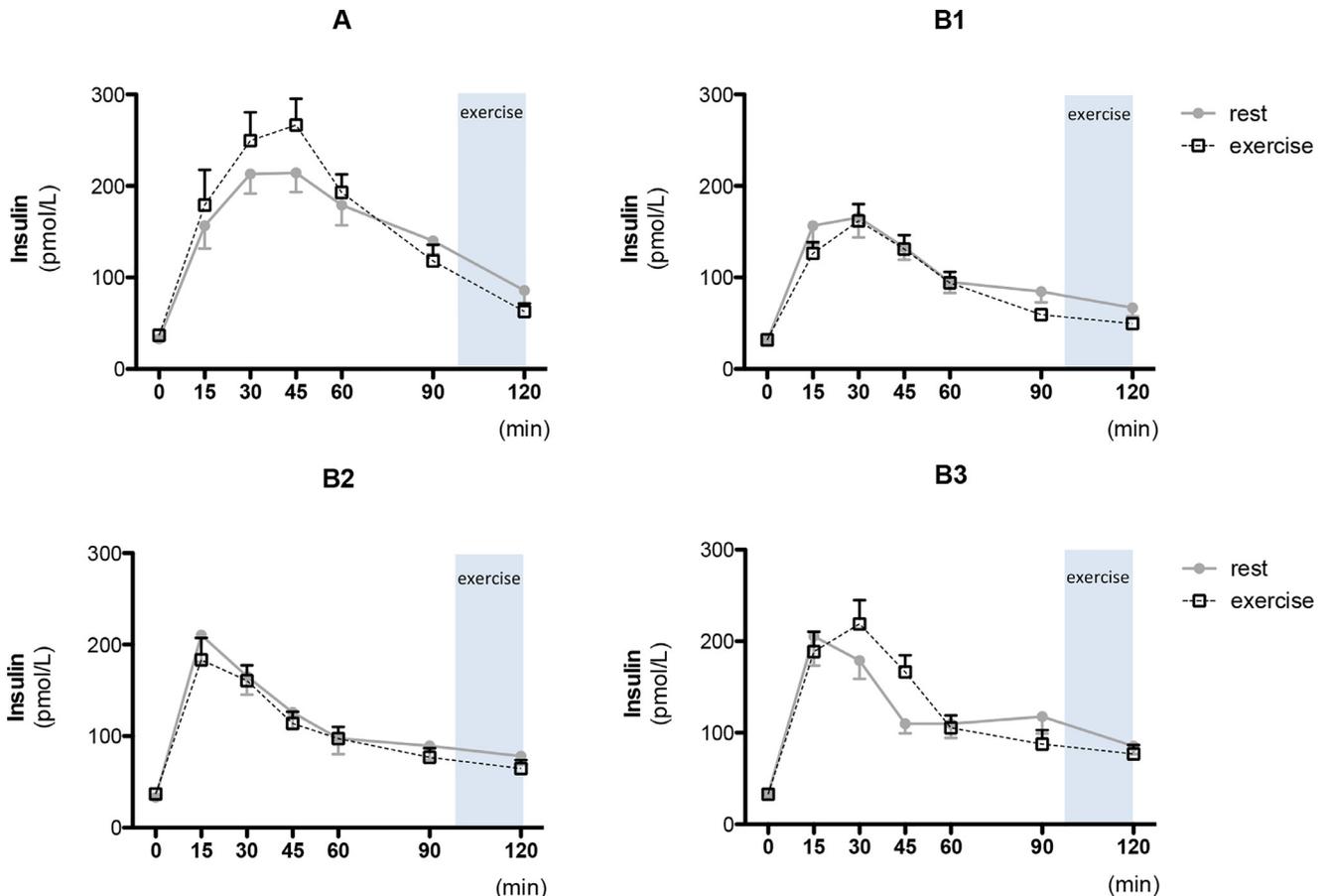


Fig. 3. Panels show the time courses of plasma insulin concentrations after oral loads A, B1, B2, and B3, in resting (gray continuous line) and exercise (black dotted line) conditions. Exercise did not produce any significant change on the final insulin concentration ($\Delta 120-90$) after ingestion of all loads with respect to the resting condition.

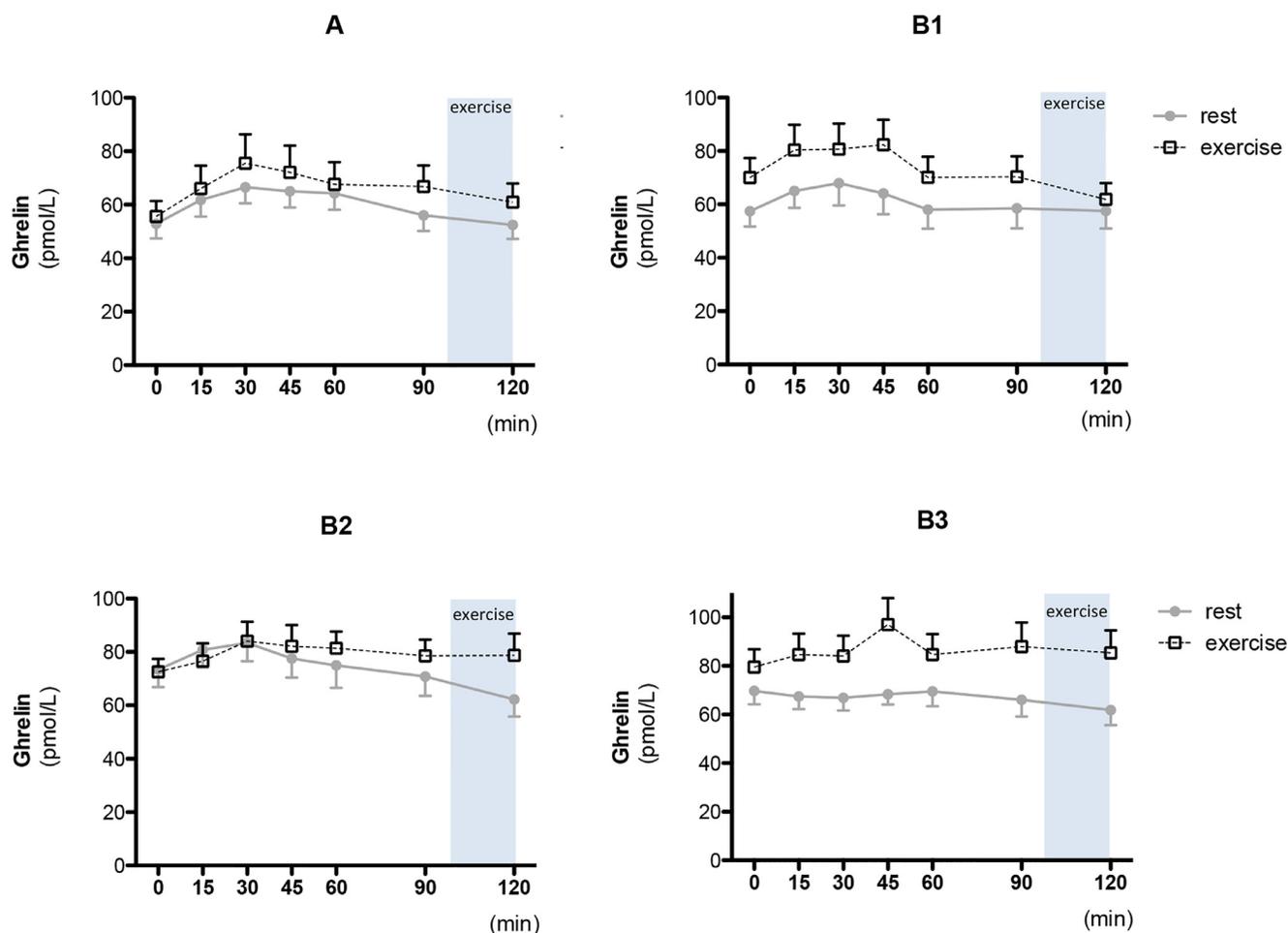


Fig. 4. Panels show the time courses of plasma ghrelin concentrations after oral loads A, B1, B2, and B3, in resting (gray continuous line) and exercise (black dotted line) conditions. Exercise did not produce any significant change on the final ghrelin concentration ($\Delta 120-90$) after ingestion of all loads with respect to the resting condition.

Results

Metabolic effects of exercise

The time courses of glucose, insulin, ghrelin, and FFA concentrations after the four oral loads under either resting or exercise conditions are shown in [Figures 2–5](#).

[Table 3](#) shows the values of the changes that glucose, insulin, ghrelin, and FFA exhibited in the interval 90 to 120 min, as well as the results of the two-way ANOVA for repeated measures with the associated *P*-values. As anticipated in the statistical analysis section, no significant interaction was found between load and exercise for any of the four metabolic variables. As for the effect of exercise per se, this resulted statistically significant for glucose and FFA. The profile plots provided by the two-way ANOVA for glucose and FFA are reported in [Figure 6](#).

The main effect of exercise on glucose was characterized by $F = 11.1$, $P = 0.004$, $\eta^2 = 0.38$. The overall size of the effect of exercise on glucose concentration was medium according to Cohen's effect size ($d = 0.47$). In particular, after ingestion of 50-g glucose, exercise determined a 15% decrease in blood glucose (from 5.49 mmol/L at 90 min to 4.66 mmol/L at 120 min) whereas, in resting conditions, glycemia dropped by 7% (from 5.43 mmol/L at 90 min to 5.05 mmol/L at 120 min). After ingestion of B1, light cycling determined an approximate 8%

decrease in glycemia from 90 to 120 min, whereas in resting conditions, blood glucose remained almost stable (-1%) from 90 to 120 min. After ingestion of B2, exercise induced a 7% glycaemic decrease from 90 to 120 min, whereas in resting conditions, blood glucose rose by $\sim 5\%$ from 90 to 120 min. After ingestion of B3, exercise reduced glycemia by 3.5% from 90 to 120 min, whereas in resting conditions, the end of the experiment was accompanied by a glycaemic reduction of 2% from 90 to 120 min.

The main effect of exercise on FFA was characterized by $F = 12.7$, $P = 0.002$, $\eta^2 = 0.41$. The overall size of the effect of exercise on FFA concentration was medium according to Cohen's effect size ($d = 0.52$). In particular, after ingestion of 50-g glucose, exercise determined an increase of plasma levels of FFA by 20% from 90 to 120 min, whereas in resting conditions, FFA concentration remained identical from 90 to 120 min. After ingestion of B1, exercise induced a 122% increase in circulating levels of FFA from 90 to 120 min, whereas FFA increased by $\sim 22\%$ under resting conditions, from 90 to 120 min. After ingestion of B2, exercise augmented circulating levels of FFA by 100% from 90 to 120 min, whereas under resting conditions FFA remained stable within the same considered interval. After ingestion of B3, exercise induced an increase of plasma levels of FFA by 40% from 90 to 120 min, whereas under resting conditions, FFA concentration dropped by 23% from 90 to 120 min.

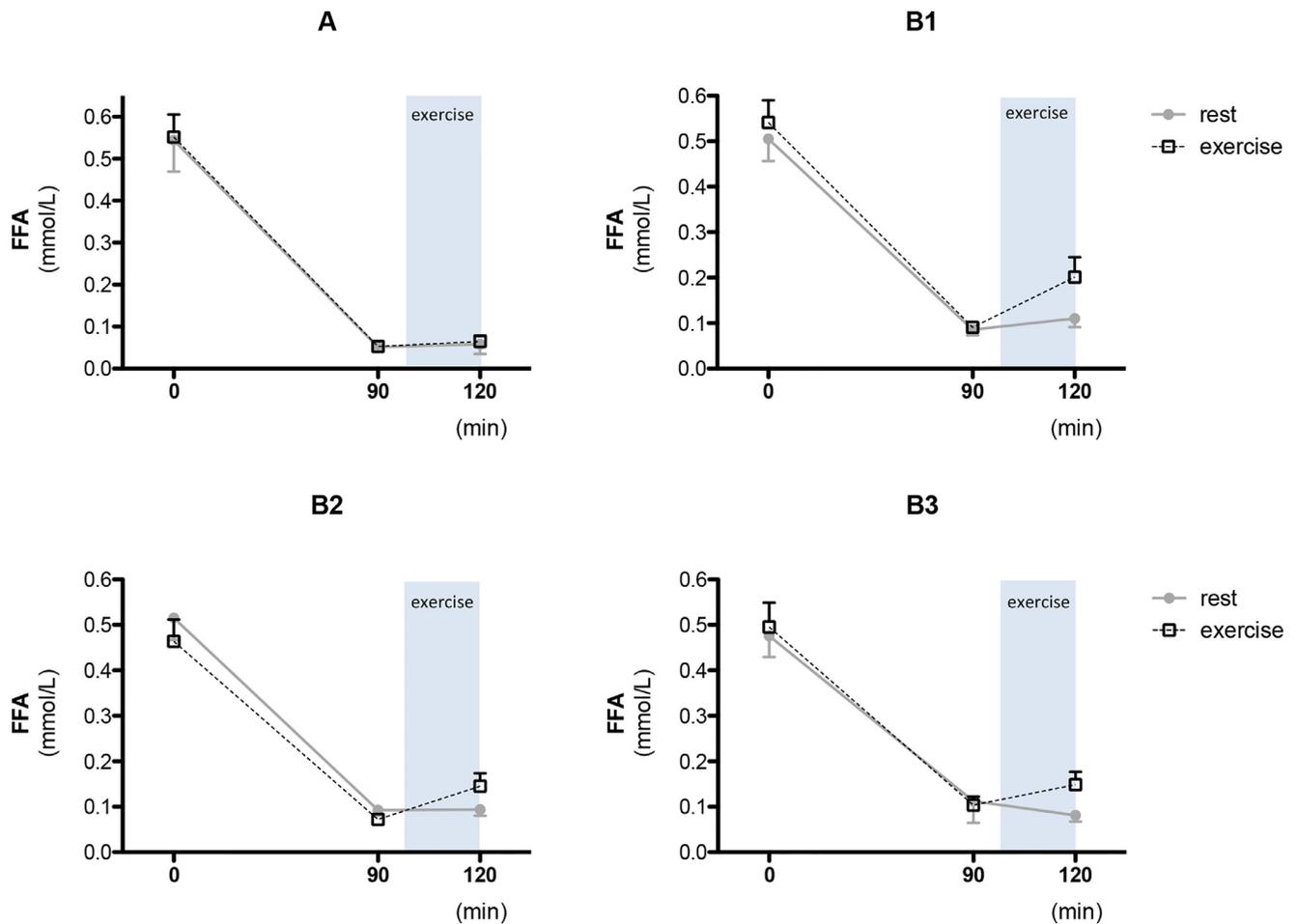


Fig. 5. Panels show the time courses of plasma FFA concentrations after oral loads A, B1, B2, and B3, in resting (gray continuous line) and exercise (black dotted line) conditions. Physical exercise significantly increased the final FFA concentration ($\Delta 120-90$) after ingestion of all loads with respect to the resting condition (two-way repeated measures ANOVA, $P = 0.002$). ANOVA, analysis of variance; FFA, free fatty acid.

Table 3

Metabolic and hormonal responses after loads in resting and exercise conditions

	Glucose				Breakfast			
	A		B1		B2		B3	
	Rest	Exercise	Rest	Exercise	Rest	Exercise	Rest	Exercise
$\Delta(120-90)$ ghrelin (pmol/L)	-3.63 ± 4.13	-5.87 ± 5.38	-0.99 ± 3.86	-8.51 ± 4	-8.57 ± 5.08	-0.51 ± 6.06	-1.51 ± 4.42	-2.60 ± 5.44
$\Delta(120-90)$ glucose (mmol/L)	-0.40 ± 0.23	-0.85 ± 0.27	0.01 ± 0.12	-0.38 ± 0.12	0.32 ± 0.09	-0.34 ± 0.19	-0.11 ± 0.18	-0.18 ± 0.18
$\Delta(120-90)$ insulin (pmol/L)	-54.2 ± 14.6	-55 ± 16	-17.7 ± 13.2	-9.77 ± 5.01	-11.4 ± 10.9	-12.2 ± 9	-32.3 ± 15.8	-10.9 ± 11.2
$\Delta(120-90)$ FFA (mmol/L)	0.007 ± 0.018	0.011 ± 0.014	0.024 ± 0.014	0.110 ± 0.043	-0.0009 ± 0.0103	0.077 ± 0.023	-0.031 ± 0.0469	0.044 ± 0.015

Two-way repeated measures ANOVA revealed no interaction between the type of oral test and physical activity. Exercise significantly decreased the final glucose concentration ($\Delta 120-90$ glucose, $*P = 0.004$), and increased the final FFA concentration ($\Delta 120-90$ FFA, $*P = 0.002$).

Effects of exercise on satiety

The final (2-h) satiety score (arbitrary unit) measured after glucose or breakfast consumption, under either resting or exercise conditions is shown in Figure 7. The two-way ANOVA for repeated measures showed no significant interaction between load and exercise, thus indicating that the effect of exercise on the satiety score did not depend on the type of load. As for the main effect of exercise per se, this did not achieve the statistical significance ($P = 0.06$).

Discussion

In the present study, we investigated the effects of a short session of light exercise after ingestion of a 50-g glucose load and three mixed breakfasts on hormonal and metabolic responses in young healthy adults. Specifically, plasma glucose, insulinemia, ghrelinemia, FFA, and satiety were evaluated. We found that light exercise produced a modest decrease in blood glucose levels and a modest increase in FFA levels with respect to the resting condition.

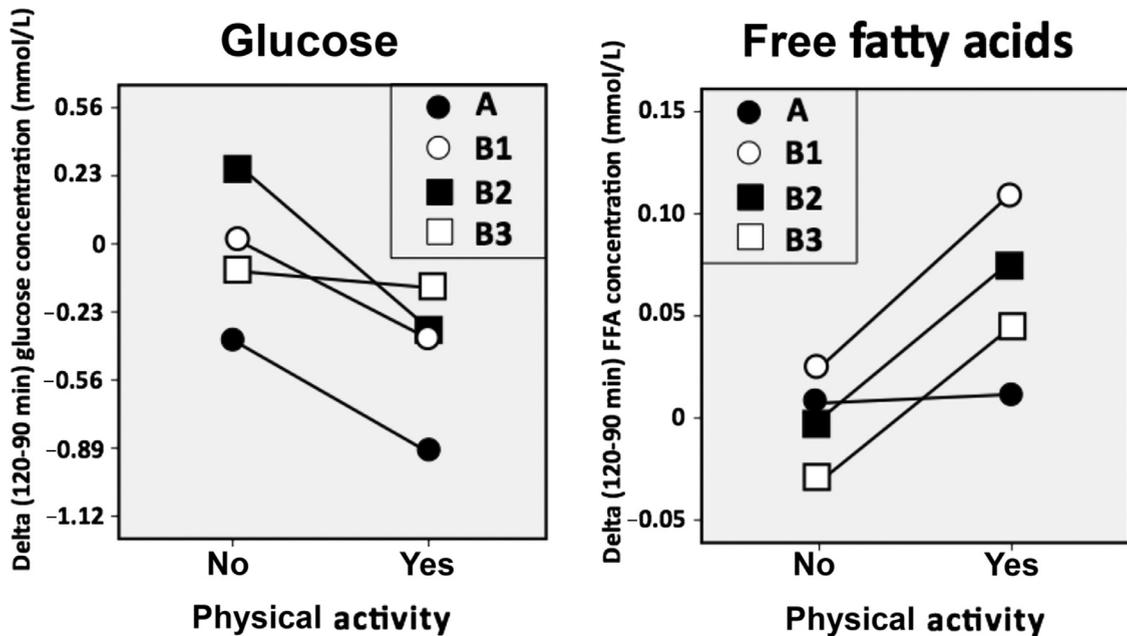


Fig. 6. The profile plots provided by the two-way repeated measures ANOVA for glucose (left panel) and FFA (right panel) changes during the interval 90 to 120 min. No significant interaction between load and exercise was found, thus indicating that the impact of exercise on either glucose or FFA did not depend on the type of load. The main effects of exercise per se on glucose and FFA were both significant ($P=0.004$, and $P=0.002$, respectively). ANOVA, analysis of variance; FFA, free fatty acid.

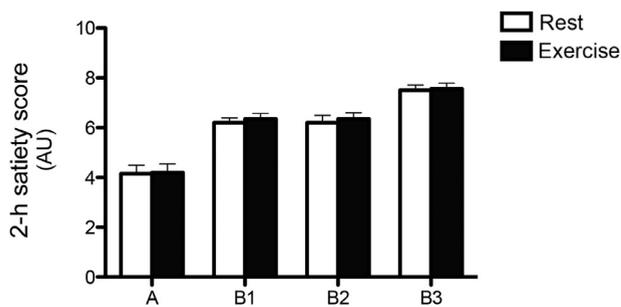


Fig. 7. Final (2-h) satiety score (AU) measured after glucose (A) or breakfast consumption (B1–B3) under either resting or exercise conditions. The two-way ANOVA for repeated measures showed no significant interaction between load and exercise. Also the main effect of exercise per se did not achieve the statistical significance ($P=0.06$). ANOVA, analysis of variance; AU, arbitrary unit.

On average, light cycling determined an 8% glucose-lowering effect in the 90 to 120 min interval after meal ingestion, whereas glycemia remained quite stable in the same interval at rest. The extent by which exercise lowered blood glucose (3.5–15%) is consistent with that ascertained in literature [20]. While in the fasted state, aerobic exercise can acutely increase glucose uptake up to two- to fivefold through insulin-independent mechanisms [21], in the fed state (500-kcal breakfast), 1-h cycling at 65% of maximal heart rate may lower glycemia by 15% in the 90 to 120 min interval after the meal ingestion [20]. In the present study, with a lower caloric content, lesser duration, and an intensity as low as 40% VO_2 max, cycling was capable to demonstrate an analogous decrease in blood glucose with respect to resting conditions. Generally, in healthy individuals, in the fasted state, during moderate-intensity aerobic exercise blood glucose does not change because the rise in peripheral glucose uptake is balanced by an equal rise in hepatic glucose production [22]. This is not the case if exercise is prolonged, depleting glycogen stores. In the fed state, when

exercise is preceded by carbohydrate intake, glucose concentrations may vary substantially because of the postprandial glycemic increase and subsequent fall because of the combined effect of hyperinsulinemia and augmented glucose uptake for use as an energy substrate in muscle contractile activity [23]. In addition, higher insulin concentrations caused by a meal may decrease fat oxidation during exercise in the fed state [23]. However, this did not apply to the present study, likely because the insulin antilipolytic effect was finishing at the end of the experiment. On the contrary, the lipolysis-driven rate at 120 min exceeded the FFA utilization rate in the muscles, with a subsequent rise in the plasma concentrations.

Physical exercise favors glucose uptake by the activation of intracellular signals merging in the phosphorylation of AMPK-inase, an enzyme that is a central sensor of the cell, responding to a variety of physiological stimuli [24,25]. Such a result may indicate that, in daily living activities, being physically active in the morning might be effective in reducing blood glucose no matter the quality and quantity of food ingested at breakfast. This is also true when exercise is performed for a period of time as short as 20 min, and above all, even if exercise is performed with an intensity as low as 40% of the VO_2 max. This finding is relevant as postmeal hyperglycemic peaks have been correlated to higher incidence of cardiovascular events in the long distance run [26]. Thus, the assumption of meals producing less hyperglycemic bursts or associated with physical activity may be of value in the prevention of cardiovascular episodes.

Another finding of this study was that a short session of light exercise was capable of increasing the final FFA concentration ($\Delta 120-90$), thus confirming the beneficial lipolytic effect of an acute bout of low-intensity cycling. On average, exercise increased the circulating levels of FFA by 90%, in the time course 90 to 120 min after the ingestion of the three breakfasts, whereas FFA did not change in the same interval during resting conditions. This might be of relevance, considering that increased fat utilization may inhibit ghrelin release, therefore playing an indirect role on appetite regulation.

Conclusions

The results of the present study indicate that a short, low-intensity exercise session performed in the postabsorptive state after breakfast consumption produces a modestly beneficial effect on glucose and FFA metabolism with respect to the resting condition. A single bout of physical exercise determined a decrease of plasma glucose and an increase of plasma FFA levels, thus speeding up the resumption of the hormonal and metabolic milieu to the premeal condition. This may have health benefits, especially in the long run, by alleviating the burden of sugars and fats on the body. The results highlighted the importance of performing any level of physical activity, even of light intensity and short duration, in front of as primary to addressing the epidemic rise of sedentary lifestyle in the general population.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nut.2018.06.005.

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