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# Accumulating exercise and postprandial health in adolescents

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ABSTRACT

*Purpose.* To examine the influence of exercise intensity on postprandial health outcomes in adolescents when exercise is accumulated throughout the day.

*Methods.* 19 adolescents (9 male, 13.7 ± 0.4 years old) completed three 1-day trials in a randomised order: (1) rest (CON); or four bouts of (2) 2 × 1 min cycling at 90% peak power with 75 s recovery (high-intensity interval exercise; HIIE); or (3) cycling at 90% of the gas exchange threshold (moderate-intensity exercise; MIE), which was work-matched to HIIE. Each bout was separated by 2 hours. Participants consumed a high fat milkshake for breakfast and lunch. Postprandial triacylglycerol (TAG), glucose, systolic blood pressure (SBP) and fat oxidation were assessed throughout the day.

*Results.* There was no effect of trial on total area under the curve (TAUC) for TAG ($P = 0.87$). TAUC-glucose was lower in HIIE compared to CON ($P = 0.03$, $ES = 0.42$) and MIE ($P = 0.04$, $ES = 0.41$), with no difference between MIE and CON ($P = 0.89$, $ES = 0.04$). Postprandial SBP was lower in HIIE compared to CON ($P = 0.04$, $ES = 0.50$) and MIE ($P = 0.04$, $ES = 0.40$), but not different between MIE and CON ($P = 0.52$, $ES = 0.11$). Resting fat oxidation was increased in HIIE compared to CON ($P = 0.01$, $ES = 0.74$) and MIE ($P = 0.05$, $ES = 0.51$), with no difference between MIE and CON ($P = 0.37$, $ES = 0.24$).

*Conclusion.* Neither exercise trial attenuated postprandial lipaemia. However, accumulating brief bouts of HIIE, but not MIE, reduced postprandial plasma glucose and SBP, and increased resting fat oxidation in adolescent boys and girls. The intensity of accumulated exercise may therefore have important implications for health outcomes in youth.



## 1. Introduction

Repeat exposure to elevated postprandial plasma triacylglycerol (TAG) and glucose concentrations has been implicated in the pathogenesis of type two diabetes [1] and atherosclerosis [2], which have their origins in youth [3,4]. Elevated non-fasting plasma TAG, glucose, and systolic blood pressure (SBP) in adolescence are independently associated with fatty streaks in

*Abbreviations:* CVD, Cardiovascular disease; EE, Energy expenditure; ES, Effect size; GET, Gas exchange threshold; HFM, High fat meal; HIIE, High-intensity interval exercise; IAUC, Incremental area under the curve; MIE, Moderate-intensity exercise; PACES, Physical activity enjoyment scale; PPL, Postprandial lipaemia; REE, Resting energy expenditure; SBP, Systolic blood pressure; TAG, Triacylglycerol; $\dot{V}O_{2\,max}$, Maximal oxygen uptake.

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the coronary arteries and future cardiovascular risk [5–7]. Furthermore, postprandial hypertension has been purported as a novel risk factor for atherosclerosis in adults [8]. Considering that most of the day may be spent in the postprandial state, it is important to identify feasible interventions to modulate these risks factors for cardiovascular disease in youth.

We have recently demonstrated that a single bout of exercise (~30 min) can improve postprandial health outcomes in adolescents in an intensity-dependent manner [9]. However, it is known that adolescents rarely sustain exercise for longer than 10 min [10]. Therefore it is important to address whether accumulating short bouts of exercise over the course of the day can favourably modulate postprandial health in this group.

It has been demonstrated that performing brief (3–10 min) bouts of low to moderate intensity exercise throughout the day may reduce postprandial plasma TAG to the same extent [11], or greater than [12], an equivalent volume of continuous exercise in adults. Similar exercise patterns have also been shown to lower SBP in normotensive adults [11]. Accumulating moderate-intensity exercise (MIE) the day before a high fat meal has been shown to lower postprandial plasma glucose and TAG concentrations, and improve endothelial function in adolescent boys [13]. However, the timing of the exercise stimulus in relation to a high fat meal is known to effect the subsequent lipaemia [14], and no study with adolescents has addressed the impact of exercise accumulated on the same day as the test meal, or if the intensity of accumulated exercise influences the postprandial response. The latter point is important to consider as there is evidence showing that performing high-intensity exercise is superior than MIE at modifying cardiometabolic risk factors in youth [15,16], even when the total amount of high-intensity exercise performed is small (~4 min) [17].

Given the above, the purpose of this investigation was to test the hypothesis that accumulating short bouts of work matched high-intensity interval exercise (HIIE) and MIE would improve parameters of postprandial health in youth (e.g. plasma glucose and TAG, blood pressure and lipid oxidation), but the benefits would be superior in HIIE compared to MIE. The present study also builds on our earlier work by identifying whether comparable benefits are achievable when the same exercise stimulus is accumulated in smaller bouts rather than performed in a single session [9].

## 2. Methods

### 2.1. *Participants*

Twenty one 13 to 14-year-old adolescents (11 boys) initially volunteered to take part in this study. Participant assent and parental consent were provided before participation in the project, which was approved by the institutional ethics committee (reference number 2012/391). Exclusion criteria included any contraindications to exercise, the presence of disease or musculoskeletal injury and the use of any medication or substance known to influence carbohydrate or fat metabolism. These criteria precluded two boys from taking part (diagnosed asthma $n = 1$; use of medication $n = 1$), thus only 19 adolescents (9 boys) completed this investigation.

### 2.2. *Experimental Protocol*

This study required four visits to the laboratory over a period of three weeks, each separated by at least 4 days, and incorporated a within measures design. All exercise tests were performed using an electronically braked cycle ergometer (Lode Excallibur Sport, Groningen, The Netherlands).

#### 2.2.1. *Visit 1: Maximal Oxygen Uptake ($\dot{V}O_{2\ max}$) and Gas Exchange Threshold (GET) Determination*

Body mass and stature were measured to the nearest 0.1 kg and 0.01 m respectively. Body mass index (BMI) was interpreted using established cut points for this population [18]. Percentage body fat was estimated using triceps and subscapular skinfold thickness according to Slaughter *et al.* [19] and pubertal status was determined by a self-assessment of secondary sexual characteristics of pubic hair development [20].

Participants were habituated to exercise on the cycle ergometer before completing a validated combined ramp and supramaximal test to exhaustion to establish $\dot{V}O_{2\ max}$ [21]. Pulmonary $\dot{V}O_2$ was monitored throughout (Coretex Metalyzer III B, Leipzig, Germany) and the GET was identified as the disproportionate increase in carbon dioxide production ($\dot{V}CO_2$) relative to $\dot{V}O_2$ and an increase in expired ventilation ($\dot{V}E/\dot{V}O_2$ with no increase in $\dot{V}E/\dot{V}CO_2$. $\dot{V}O_{2\ max}$ was determined as the highest 10 second average in $\dot{V}O_2$ elicited either during the ramp test or supramaximal bout. Aerobic fitness was interpreted using current thresholds for metabolic health [22].

#### 2.2.2. *Visits 2–4: Experimental Trials*

A schematic of each trial is provided in Fig. 1. Following an ~12 h overnight fast, participants arrived at the laboratory at 07:45 and rested for 10 min before providing a fasting capillary blood sample for plasma glucose and TAG concentrations. At 08:00 SBP was recorded after spending ~10 min in a seated position using an automated inflation cuff (Dinamap Carescape V100, GE Healthcare). Resting metabolic rate (RMR) was then assessed via indirect calorimetry (Cortex Metalyzer 3B, Leipzig, Germany) for 15 min in order to determine total resting energy expenditure (REE) and substrate oxidation (lipid and carbohydrate) in accordance with our earlier work [9,23]. These measures were repeated 45 min after the cessation of each exercise bout or rest.

On three separate occasions, approximately one week apart, participants completed in a randomised order: (1) two, 1 minute intervals at 90% of the peak power determined from the ramp test, separated by 75 s at 20 W (HIIE); (2) ~6 min of cycling at 90% GET (MIE); or (3) remained seated and watched films in the laboratory (control; CON). The exercise bouts were repeated four times, each separated by two hours (see Fig. 1). A warm up and cool down of 75 s at 20 W was included for each HIIE and MIE. The duration of the MIE trial was calculated to match the total work performed during the HIIE bout for each participant, and the total accrued exercise stimulus matched our earlier postprandial investigation with this group [9]. Total EE and the macronutrient energetic contributions to MIE were determined using the mean exercise $\dot{V}O_2$ and respiratory exchange ratio (RER) values [24]. Protein oxidation was assumed to be negligible, and an RER >1 was taken to represent 100% carbohydrate oxidation.