Accumulating short bouts of brisk walking reduces postprandial plasma triacylglycerol concentrations and resting blood pressure in healthy young men

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ABSTRACT

Background: Physical activity recommendations promote the accumulation of aerobic activity in bouts of ≥10 min. It is important to determine whether shorter bouts of activity can influence health.

Objective: We compared the effects of accumulating ten 3-min bouts of brisk walking with those of one 30-min bout of brisk walking on postprandial plasma triacylglycerol concentrations and resting blood pressure.

Design: Fifteen healthy young men completed three 2-d trials ≥1 wk apart in a randomized, repeated-measures design. On day 1, subjects rested (no exercise) or walked briskly in either ten 3-min bouts (30 min rest between each) or one 30-min bout (gross energy expenditure: 1.10 MJ/30 min). On day 2, subjects rested and consumed high-fat test meals for breakfast and lunch.

Results: On day 2 area under the plasma triacylglycerol concentration over time curve was 16% lower on the accumulated and continuous brisk walking trials than on the control trial (5 ± SEM: 9.98 ± 0.67 compared with 9.99 ± 0.76 compared with 11.90 ± 1.02 mmol · 7h/L, respectively; P = 0.005, one-factor ANOVA). Resting systolic blood pressure was 6–7% lower throughout day 2 on the accumulated and continuous trials than on the control trial (109 ± 1 compared with 110 ± 1 compared with 117 ± 2 mm Hg, respectively; P < 0.0005).

Conclusion: Accumulating 30 min of brisk walking in short (3-min) bouts is equally effective in reducing postprandial lipemia and systolic blood pressure as one continuous 30-min bout. Am J Clin Nutr 2008;88:1225–31.

INTRODUCTION

Physical activity guidelines advise that adults should accumulate 30 min of moderate intensity aerobic (endurance) activity on ≥5 d of the week to promote and maintain health (1, 2). These guidelines also state that physical activity may be performed in bouts lasting ≥10 min. Although shorter bouts of activity may provide health benefit, these are not promoted in the guidelines because of a limited evidence base. It is important to know whether short bouts of exercise influence health because the activity patterns of many people may comprise multiple short bouts of activity accumulated throughout the day. In view of this we investigated the potential for short bouts of activity to modify 2 risk markers for cardiovascular disease (CVD): postprandial triacylglycerol concentration and resting blood pressure.

Recent studies confirm that elevated non–fasting triacylglycerol concentrations are an independent risk factor for CVD in men and women (3–5). In the Copenhagen City Heart Study the age-adjusted hazard ratio for myocardial infarction was 16.8 in women and 4.6 in men whose non–fasting triacylglycerol concentrations were ≥5.0 mmol/L compared with those whose values were <1.0 mmol/L. Those ratios were attenuated (to 5.4 and 2.4, respectively) but remained significant after multivariate adjustment for confounding factors (5). These findings are consistent with those of the US Women’s Health Study that observed a fully adjusted CVD event hazard ratio of 4.5 in participants whose non–fasting triacylglycerol concentrations were in the highest compared with the lowest tertile (3). Elevated resting blood pressure is a well-established risk factor for CVD, and it is estimated that in industrialized countries, the lifetime risk of becoming hypertensive (blood pressure > 140/90 mm Hg) exceeds 90% (6). Consequently, blood pressure guidelines now include a prehypertension category (systolic blood pressure of 120–139 mm Hg or diastolic blood pressure of 80–89 mm Hg) with the aim of encouraging lifestyle modifications to prevent further increases in blood pressure and hence CVD risk (7).

Physical activity is effective for lowering postprandial triacylglycerol concentrations (8, 9) and resting blood pressure (10, 11). Several studies have investigated the acute effect of accumulated physical activity on postprandial triacylglycerol concentrations (12–17) and resting blood pressure (16, 18, 19). Although those studies support the concept of accumulation, the mode, volume, and intensity of activity used often exceed the minimum activity guidelines for health. Therefore, we conducted a randomized controlled trial to compare the effects of accumulating ten 3-min bouts of brisk walking with those of one 30-min bout of brisk walking on postprandial plasma triacylglycerol concentrations and resting blood pressure in healthy young men. Walking was chosen because it is a popular and accessible...
activity and can be incorporated into daily activity routines with little risk of injury (20).

SUBJECTS AND METHODS

Subjects

After approval from the Loughborough University Ethics Committee, 15 healthy men aged 18–28 y volunteered to participate in this study. All subjects were recreationally active and had been weight stable (±2.5 kg) for ≥3 mo before the study. To minimize risks, the subjects were only recruited if they met the following criteria: were nonsmoking, were free of known CVD or abnormalities, were not taking any medication known to influence lipid or carbohydrate metabolism, had resting arterial blood pressure <140/90 mm/Hg, and had a body mass index (BMI; in kg/m²) <35. Mean (±SEM) values were identified for the subjects’ age (23.4 ± 0.8 y), height (178.6 ± 1.3 cm), weight (74.9 ± 2.3 kg), BMI (23.4 ± 0.6), waist circumference (80.8 ± 2.1 cm), percentage of body fat (11.2 ± 0.9%), maximal oxygen uptake (56.3 ± 2.1 mL · kg⁻¹ · min⁻¹), systolic blood pressure (114 ± 2 mm Hg), and diastolic blood pressure (68 ± 2 mm Hg).

Anthropometric measures

Height was measured to the nearest 0.1 cm with the use of a stadiometer (Seca, Hamburg, Germany), and weight was measured to the nearest 0.01 kg with the use of a balance-beam scale (Avery, Birmingham, United Kingdom). BMI was calculated. Skinfold thickness was measured at 3 sites (chest, abdomen, and thigh) on the right-hand side of the body with the use of calipers (John Bull; British Indicators, West Sussex, United Kingdom). Body density was calculated with the use of a 3-site formula (21), and percentage of body fat was then estimated with the use of the Siri equation (22). Waist circumference was determined as the widest part of the torso between the xiphoid process of the sternum and the iliac crest.

Preliminary tests

After a treadmill familiarization session, each subject was asked to walk “briskly” on a treadmill for several minutes to determine their walking speed for the main trials. Brisk walking was defined as feeling slightly out of breath while walking but still able to hold a conversation. Thereafter, subjects completed 2 preliminary exercise tests on a motorized treadmill (RUN-RACE; Technogym, Gambettola, Italy). The first of these was a 16-min submaximal treadmill test to establish the relation between oxygen uptake and treadmill speed. Subjects were given 20–30 min to recover from this test before they completed a maximum oxygen uptake treadmill test. This test involved an incremental uphill protocol at a constant speed until subjects reached volitional fatigue (23). Expired air samples were collected during both tests with the use of Douglas bags (Plyus Protection Systems, Milton Keynes, United Kingdom). Heart rate was monitored throughout both tests with the use of short-range telemetry (Polar A3; Kempele, Finland) and ratings of perceived exertion (RPEs) were assessed periodically in both tests (24). Data from the submaximal and maximal treadmill tests were used to determine the relative exercise intensity adopted by each subject at their self-selected brisk walking pace.

Main trials

Each subject completed three 2-d trials: an accumulated walking trial, a continuous walking trial, and a control trial. Two-day trials were used because skeletal muscle lipoprotein lipase activity is thought to peak >8 h after exercise (25), and this enzyme facilitates the removal of triacylglycerol from the blood (26). There was a 7-d gap between each trial, and trials were performed in a randomized design.

Day 1

On the first day of each trial, the subjects reported to the laboratory at 0900 having eaten breakfast. On arrival in the laboratory the subjects were asked to sit quietly in a chair for 20 min, and then baseline resting arterial blood pressure was measured with the use of a random-zero sphygmomanometer (Hawksley Mk II; Hawksley and Sons Ltd, Sussex, United Kingdom). For the accumulated walking trial, the subjects performed 10 3-min bouts of treadmill brisk walking throughout the day. A 30-min rest interval followed each bout. Walking speed was set at a self-selected pace as determined by the preliminary visit. Blood pressure was measured in a seated position immediately after each bout of walking. Thereafter the subjects were asked to remain seated quietly, and additional blood pressure readings were measured at 5 min and 15 min after the termination of each walking bout. Those blood pressure measurements were made at equivalent time points during the continuous walking and control trials. For the continuous walking trial, the subjects performed one 30-min bout of brisk treadmill walking in the afternoon from 1500 to 1530. For both walking trials, the exercise was completed at 1530 so that the time interval between the cessation of exercise and the consumption of the first test meal (on the following day) was the same (ie, 17 h). For the control trial, the subjects rested throughout the day in the laboratory. During each trial, the subjects consumed a packed lunch midway through the day (1200–1300). The subjects left the laboratory at ~1600, and they were instructed to consume an early evening meal and to rest for the remainder of the evening.

Day 2

On the second day of each trial, the subjects reported to the laboratory at 0800 after a 10-h overnight fast (no food or drink except water). The subjects sat in a semisupine position on a bed for 10 min after their arrival at the laboratory. A cannula (Venflon; Becton Dickinson, Helsingborg, Sweden) was then inserted into an antebrachial vein, and a baseline blood sample was collected. Five minutes after this blood sample, baseline resting blood pressure was measured in a seated position. The subjects then consumed a standardized test meal for breakfast. A clock was started when the subjects began eating, and they were required to rest (reading, watching television) in the laboratory for 7 h after the start of breakfast. A second test meal identical to the first) was consumed 3 h after the start of the first meal. Further collections of blood and measurements of blood pressure were performed at hourly intervals for 7 h after the start of breakfast. Additional blood samples were collected at 0.5, 0.75, 3.5, and 3.75 h for measurement of glucose and insulin in the immediate period after feeding.

Standardization of diet and exercise

Subjects weighed and recorded all food and drink consumed for 2 d before the first main trial. They then consumed identical
amounts of the same food and drink before each of the remaining main trials. Thus, meals were standardized across trials, including the evening meal on day 1. Subjects refrained from drinking alcohol before and during each of the main trials. In addition, subjects were asked to remain inactive on the day before day 1 of each trial and throughout the main trials (other than the exercise performed as part of the experiment). Food diaries were analyzed with the use of computerized software (COMP-EAT version 5.0; Nutrition Systems, London, United Kingdom) to determine energy intake and macronutrient content.

**Estimation of energy expenditure during walking**

Expired air samples were collected into Douglas bags (Plyus Protection Systems) for both walking trials. Samples were collected during the final minute of each 3-min bout of exercise during the accumulated walking trial and at 9–10, 19–20, and 29–30 min for the continuous walking trial. Oxygen consumption and carbon dioxide production were determined with the use of a paramagnetic oxygen analyzer and an infrared carbon dioxide analyzer, respectively (Series 1400; Servomex, Crowborough, United Kingdom). These analyzers were calibrated before analysis with the use of gases of known concentration. Expired air volumes were measured with a dry gas meter (Harvard Apparatus, Edenbridge, United Kingdom) and corrected to standard temperature and pressure dry. Oxygen consumption and carbon dioxide production values were used to calculate energy expenditure (27).

**Test meals**

The test meal consisted of white bread, cheddar cheese, butter, mayonnaise, potato crisps, whole milk, and milkshake powder. The meal was prescribed according to body mass and provided 0.69 g fat, 0.95 g carbohydrate, 0.31 g protein, and 46 kJ energy/kg body mass. The mean ± SEM macronutrient content of each test meal was 51.8 ± 1.5 g fat, 67.5 ± 2.0 g carbohydrate, and 23.3 ± 0.7 g protein, which provided 3.45 ± 0.10 MJ energy (56% fat, 33% carbohydrate, and 11% protein). Subjects were asked to consume each meal within 20 min. The time taken to consume each meal was recorded and replicated in subsequent trials. The time (mean ± SEM) taken to consume the first meal (breakfast) and the second meal (lunch) were 10.1 ± 0.8 min and 11.0 ± 1.0 min, respectively. None of the subjects reported nausea or any gastrointestinal discomfort during or after meals. The subjects consumed water ad libitum during the first trial, and the volume ingested was replicated in subsequent trials.

**Analytic methods**

Venous blood samples were collected into precooled 9-mL potassium EDTA-coated Monovette tubes (1.6 mg/mL; Sarstedt, Leicester, United Kingdom), and samples were immediately centrifuged (GS-15R Centrifuge; Beckman Coulter, Fullerton, CA) at 1968 × g for 10 min at 4 °C. After being separated, plasma was dispensed into plain microtubes and stored at −80 °C for later analysis. The plasma concentrations of triacylglycerol and glucose were determined by enzymatic, colorimetric methods (Randox Laboratories, County Antrim, United Kingdom) with the use of a centrifugal analyzer (Cobas Mira Plus; Roche Diagnostic Systems, Basel, Switzerland). Plasma insulin concentration was measured by radioimmunoassay (MP Biomedicals, Orangeburg, NY). All samples from the same subject were assayed in a single run. Accuracy and precision were monitored with the use of quality control sera (Randox Laboratories and MP Biomedicals, Orangeburg, NY). Intraassay CVs were 0.5% for triacylglycerol, 1.8% for glucose, and 7.4% for insulin. Hemoglobin concentration and hematocrit were measured at baseline on day 2 and at the end of the observation period to estimate changes in plasma volume (28).

**Statistical analysis**

Data were analyzed with the use of the SPSS software version 12.0 for WINDOWS (SPSS Inc, Chicago, IL). Areas under the curve for plasma concentrations compared with time were calculated with the use of the trapezium rule. Student’s t tests for correlated data were used to compare physiologic responses between exercise trials. One-factor analysis of variance (ANOVA) was used to examine differences among the 3 trials when repeated measures were not involved, ie, fasting plasma concentrations, area under the curve values, percentage change in plasma volume, and baseline blood pressure values. Repeated-measures 2-factor ANOVA was used to examine differences among the 3 trials over time for plasma constituents and blood pressure. When significant interactions were detected, post hoc multiple comparisons were made with the use of the Bonferroni method. Statistical significance was accepted at the 5% level. Results are presented as means ± SEMs.

**RESULTS**

**Responses to treadmill walking**

Self-selected brisk walking speed during the exercise trials was 6.8 ± 0.1 km/h. No significant differences were observed between exercise trials in estimated gross energy expenditure (accumulated walking: 1.10 ± 0.17 MJ/30 min; continuous walking: 1.10 ± 0.16 MJ/30 min), relative exercise intensity (accumulated walking: 41.4 ± 1.8% of maximum oxygen uptake; continuous walking: 42.4 ± 1.8% of maximum oxygen uptake), oxygen uptake (accumulated walking: 23.4 ± 0.7 mL·kg⁻¹·min⁻¹; continuous walking: 23.7 ± 0.7 mL·kg⁻¹·min⁻¹), or respiratory exchange ratio (accumulated walking: 0.94 ± 0.02; continuous walking: 0.97 ± 0.01). Heart rate and RPE were significantly higher on the continuous walking trial (heart rate: 131 ± 4 beats/min; RPE: 10 ± 1) than on the accumulated walking trial (heart rate: 122 ± 3 beats/min; RPE: 9 ± 0) (heart rate: P < 0.0005; RPE: P = 0.02). For comparison, heart rate on day 1 of the control trial (mean of 10 heart rate measurements collected at time points identical to those in the accumulated walking trial) was 64 ± 2 beats/min.

**Dietary data**

Energy intake for the day before the trials and for day 1 of the trials was 10.3 ± 0.9 MJ (28 ± 2% fat, 56 ± 2% carbohydrate, and 16 ± 1% protein) and 10.2 ± 0.9 MJ (27 ± 2% fat, 55 ± 2% carbohydrate, and 18 ± 1% protein), respectively.

**Plasma concentrations in the fasted state**

Fasting plasma concentrations before the test meals on day 2 of each trial are shown in Table 1. One-factor ANOVA showed that there was no difference in fasting concentrations of plasma triacylglycerol, glucose, and insulin among trials.
Plasma concentrations in the postprandial state

Changes in plasma volume during the observation periods were small and did not differ significantly among trials (accumulated walking: 0.1 ± 1.8%; continuous walking: −1.4 ± 2.0%; control: −1.8 ± 1.4%). Thus, plasma concentrations were not adjusted for changes in plasma volume.

Plasma triacylglycerol responses to the test meals on day 2 of each trial are shown in Figure 1. Two-factor ANOVA showed significant main effects of trial and time. Plasma triacylglycerol responses were lower on both walking trials than on the control trial with little difference between the accumulated and continuous walking trials. Total and incremental areas under the plasma triacylglycerol concentration over time curve compared with the time curve are shown in Table 2. Total area under the plasma triacylglycerol concentration over time curve was 16% lower on both walking trials than on the control trial. Although no significant difference was observed among trials for the incremental area under the plasma triacylglycerol concentration over time curve (P = 0.051, one-factor ANOVA), the area tended to be lower on the walking trials than on the control trial. No significant differences were observed between the walking trials for plasma triacylglycerol area under the curve values.

Plasma glucose and insulin responses on day 2 of each trial are shown in Figure 2. No differences were observed among trials

### Table 1

<table>
<thead>
<tr>
<th>Trial</th>
<th>Triacylglycerol (nmol/L)</th>
<th>Glucose (mmol/L)</th>
<th>Insulin (pmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulated walking</td>
<td>0.78 ± 0.07</td>
<td>5.07 ± 0.03</td>
<td>158.5 ± 14.0</td>
</tr>
<tr>
<td>Continuous walking</td>
<td>0.86 ± 0.05</td>
<td>5.34 ± 0.08</td>
<td>160.0 ± 11.6</td>
</tr>
<tr>
<td>Control</td>
<td>0.87 ± 0.05</td>
<td>5.20 ± 0.97</td>
<td>162.2 ± 14.4</td>
</tr>
</tbody>
</table>

All values are mean ± SEM; n = 15. Means were compared using one-factor ANOVA for the main effect of trial. Between-trial differences were not significant.

### Table 2

<table>
<thead>
<tr>
<th>Trial</th>
<th>Total triacylglycerol (nmol·7h/L)</th>
<th>Incremental triacylglycerol (nmol·7h/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulated walking</td>
<td>9.98 ± 0.67</td>
<td>4.63 ± 0.46</td>
</tr>
<tr>
<td>Continuous walking</td>
<td>9.99 ± 0.76</td>
<td>4.00 ± 0.49</td>
</tr>
<tr>
<td>Control</td>
<td>11.90 ± 1.02</td>
<td>5.64 ± 0.84</td>
</tr>
</tbody>
</table>

All values are mean ± SEM; n = 15. Means were compared using one-factor ANOVA followed by a Bonferroni multiple-comparisons test.

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**FIGURE 1.** Mean (±SEM) fasting and postprandial plasma triacylglycerol concentrations measured on day 2 during the accumulated walking (●), continuous walking (Δ), and control (■) trials (n = 15). The black rectangles indicate the times that the test meals were consumed. Data were analyzed with the use of two-factor ANOVA with repeated measures followed by a Bonferroni multiple-comparisons test. A main effect of trial was observed (P = 0.005), indicating significantly lower values on both the accumulated and continuous walking trials than on the control trial (P < 0.05 for both). A main effect of time was also observed (P < 0.0005), but the time × trial interaction effect was not significant.

**FIGURE 2.** Mean (±SEM) fasting and postprandial plasma concentrations of glucose and insulin measured on day 2 during the accumulated walking (●), continuous walking (Δ), and control (■) trials (n = 15). The black rectangles indicate the times that the test meals were consumed. Data were analyzed with the use of two-factor ANOVA with repeated measures. For both glucose and insulin, a main effect of time was observed (P < 0.0005), but between-trial and interaction effects were not significant for either variable.
for plasma concentrations of glucose and insulin, but a main effect of time was observed for both variables.

**Blood pressure responses**

Systolic and diastolic blood pressure values are shown in Table 3 and Figure 3. Baseline resting systolic and diastolic blood pressures measured on day 1 were not different among trials. Systolic blood pressure measured at the termination of each walking bout on the accumulated exercise trial was significantly elevated in comparison with equivalent time points on the other trials. In contrast 15 min after the termination of each walking bout during day 1 of the accumulated exercise trial systolic blood pressure was significantly lower than values measured at equivalent time points during the other trials. Systolic blood pressure measured throughout day 2 was significantly lower in the accumulated and continuous walking trials than in the control trial with little difference between the accumulated and continuous walking trials.

**DISCUSSION**

The main finding of this study is that multiple short (3-min) bouts of brisk walking (30 min in total) performed throughout 1 day are equally effective in lowering postprandial plasma triacylglycerol concentration and resting systolic blood pressure as one continuous 30-min brisk walk. These findings imply that the duration and pattern of activity may be unimportant for some aspects of disease prevention, provided sufficient energy is expended. This finding has important implications for persons who prefer to accumulate activity in short bouts throughout the day rather than performing all of their exercise in one episode.

We have previously shown that accumulating 30 min of running in short (3 min) bouts on a single day is equally effective in reducing postprandial plasma triacylglycerol concentrations on the following day as one continuous 30-min run in young men (15). In our previous study (15), the exercise duration was consistent with physical activity guidelines for health (1, 2). However, the total energy expenditure was high (2.0 MJ = 476 kcal) compared with the minimum expenditure (200 kcal) recommended in public health guidelines (29). In addition, the exercise intensity (70% of maximum oxygen uptake) was not applicable for many middle-aged and older persons. Thus, the present study investigated whether similar reductions in triacylglycerol could be obtained if persons walked for 30 min in a single exercise bout or accumulated 30 min of walking in short bouts. The exercise intensity (≈42% of maximum oxygen uptake) and energy expenditure (1.1 MJ = 260 kcal) used in this study are consistent with exercise recommendations for public health. The findings confirm and extend those of previous studies that support the notion that accumulated exercise is as effective as continuous

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**TABLE 3**

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) measured on days 1 and 2 of the accumulated walking, continuous walking, and control trials.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Baseline</th>
<th>After walking&lt;sup&gt;2,3&lt;/sup&gt;</th>
<th>5 min after walking&lt;sup&gt;2&lt;/sup&gt;</th>
<th>15 min after walking&lt;sup&gt;2,3&lt;/sup&gt;</th>
<th>Resting values&lt;sup&gt;3,4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP (mm Hg)</td>
<td>SBP (mm Hg)</td>
<td>SBP (mm Hg)</td>
<td>SBP (mm Hg)</td>
<td>SBP (mm Hg)</td>
</tr>
<tr>
<td>Accumulated</td>
<td>117 ± 1</td>
<td>140 ± 1&lt;sup&gt;5&lt;/sup&gt;</td>
<td>114 ± 1</td>
<td>109 ± 1&lt;sup&gt;5&lt;/sup&gt;</td>
<td>109 ± 1&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Continuous</td>
<td>114 ± 2</td>
<td>117 ± 1</td>
<td>115 ± 2</td>
<td>113 ± 2</td>
<td>110 ± 1&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>115 ± 2</td>
<td>115 ± 2</td>
<td>114 ± 1</td>
<td>114 ± 1</td>
<td>117 ± 2</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulated</td>
<td>67 ± 2</td>
<td>67 ± 2</td>
<td>67 ± 2</td>
<td>67 ± 2</td>
<td>67 ± 2</td>
</tr>
<tr>
<td>Continuous</td>
<td>68 ± 2</td>
<td>68 ± 2</td>
<td>68 ± 2</td>
<td>68 ± 2</td>
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</tr>
<tr>
<td>Control</td>
<td>67 ± 2</td>
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<td>70 ± 2</td>
</tr>
</tbody>
</table>

<sup>1</sup> All values are ñ ± SEM; n = 15. Baseline means were compared using a one-factor ANOVA. All other values were compared using a 2-factor repeated-measures ANOVA followed by a Bonferroni multiple-comparisons test.

<sup>2</sup> Mean of 10 after-walking measurements (ie, one for each bout of exercise) or mean of 10 values measured at equivalent times on the continuous walking or control trials.

<sup>3</sup> Significant main effect of trial, P < 0.0005.

<sup>4</sup> Mean of 8 measurements taken at 1-h intervals throughout day 2 (ie, 7-h average).

<sup>5</sup> Significantly different from the continuous walking and control trials, P < 0.0005.

<sup>6</sup> Significantly different from the control trial, P < 0.0005.

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**FIGURE 3.** Mean (±SEM) systolic blood pressure (SBP) and diastolic blood pressure (DBP) values on day 2 during the accumulated walking (●), continuous walking (△), and control (■) trials (n = 15). The black rectangles indicate the times that the test meals were consumed. Data were analyzed with the use of 2-factor ANOVA with repeated measures followed by a Bonferroni multiple-comparisons test. A main effect of trial was observed (P < 0.0005) for SBP, indicating lower values on both walking trials compared with the control trial (P < 0.0005 for each). A main effect of time was observed for both SBP (P = 0.003) and DBP (P = 0.004). No significant interaction effects were observed.
exercise for reducing postprandial plasma triacylglycerol concentration (13, 15). Collectively, these findings show that the duration of aerobic exercise is unimportant for lowering postprandial lipemia; ie, short and long bouts are equally effective, provided the energy expenditure is similar.

In addition to the positive changes in postprandial lipemia, our findings also show that resting systolic blood pressure is reduced to a similar extent when ten 3-min bouts of brisk walking are performed during a single day compared with one continuous 30-min bout of brisk walking. These findings are consistent with those of a previous study showing that a high volume (4.2 MJ) of running accumulated in short (6 min) bouts is effective for lowering resting blood pressure in healthy young men (16). The current findings also support the observation that an increased amount of lifestyle physical activity accumulated in a free-living setting is effective in reducing ambulatory systolic blood pressure in normotensive, prehypertensive, and hypertensive men and women (18). In contrast to the present findings, a previous study has reported a greater reduction in ambulatory blood pressure in prehypertensive middle-aged persons after the accumulation of 40 min of walking in four 10-min bouts compared with one continuous 40-min bout (19). This discrepancy may be due to differences in blood pressure measurement time points between studies because blood pressure was not measured after subjects left the laboratory on day 1 in the present study until they returned to the laboratory the next morning (a gap of ≈16 h). Nonetheless, our findings show a sustained reduction in resting systolic blood pressure up to 24 h after 30 min of brisk walking performed either continuously or intermittently. These findings are likely to have public health implications for normotensive and prehypertensive persons.

It is not possible to determine the mechanisms responsible for the changes after walking in postprandial lipemia and blood pressure in the present study. Likely mechanisms for a postexercise reduction in postprandial lipemia are an improved clearance of triacylglycerol by skeletal muscle and adipose tissue, a reduced endogenous (hepatic) production of VLDL particles, or both mechanisms (9). With respect to exercise-induced lowering of systolic blood pressure, the mechanisms responsible are not fully understood but must involve reductions in total peripheral resistance or cardiac output because these are the determinants of mean arterial pressure. Such changes may be secondary to reductions in sympathetic nervous system activity, reductions in the concentrations of the enzyme renin and the vasoconstrictor hormone angiotensin II, and possibly improvements in endothelial function (11). Whether the mechanisms differ between accumulated and continuous exercise is not known.

Our findings support the current physical activity guidelines (1, 2), and they provide evidence that health benefits arise after the accumulation of moderate intensity physical activity in short bouts, at least for postprandial triacylglycerol concentration and resting blood pressure. Such changes suggest (but do not prove) that CVD risk may be reduced in persons whose physical activity patterns are characterized by the accumulation of short bouts of physical activity throughout the course of each day. Such an activity pattern may be attractive for persons who want to improve their health through the accumulation of routine physical chores or pastimes because these activities are intermittent in nature and often involve bouts lasting <10 min. In addition, these laboratory-based findings support the findings from previous studies showing that lifestyle activity performed in free-living situations is as effective in reducing blood lipids and blood pressure as is structured exercise in overweight (30) and obese middle-aged (31) persons.

There are 2 important limitations to the present study. First, the subjects in this study were young, active men, and it is not certain that these results would apply to young, sedentary adults, middle-aged and older adults, or female subjects, although there is no reason to believe that such groups would not experience similar benefits from accumulated walking. Second, the present study used high-fat test meals to examine the effects of short bouts of activity on postprandial lipemia (56% of energy from fat, 0.69 g fat/kg body mass). Such meals are not reflective of the typical dietary fat intakes within a population [dietary fat intake averages 36% currently in the United Kingdom (32)]. Despite these limitations, the exercise mode, intensity, and duration used in the present study are realistic and attainable for virtually all adults regardless of age. In addition, dietary surveys indicate that fat intake exceeds dietary recommendations in many adults, suggesting that the fat challenge used here has some relevance (32).

In summary, the present study shows that accumulating 30 min of brisk walking in short, 3 min, bouts throughout the day is equally effective in lowering postprandial plasma triacylglycerol concentrations and resting systolic blood pressure on the following day as does one continuous 30-min bout in young men. These findings are suggestive of a role for accumulated exercise in the prevention of CVD. Additional research is required to examine whether the accumulation of short bouts of exercise is effective in lowering postprandial triacylglycerol concentrations and resting blood pressure in subjects with clinical signs and symptoms of CVD.

We thank all of the volunteers for their participation in this study. The author’s responsibilities were as follows—MM: was involved in study design and implementation, data collection and blood biochemistry, and data analysis; SFB: was involved in data collection and blood biochemistry; DJS: conceived the study, obtained the funding, and performed the venous cannulations; all authors contributed to the writing of the manuscript. None of the authors had a personal or financial conflict of interest.

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