Postprandial lipemia in young men and women of contrasting training status

SARA L. HERD, JANET E. M. LAWRENCE, DALE MALKOVA, MARIE H. MURPHY, SARABJIT MASTANA, AND ADRIANNE E. HARDMAN

1Human Muscle Metabolism Research Group, Department of Physical Education, Sports Science and Recreation Management, 3Department of Human Sciences, Loughborough University, Loughborough, Leicestershire LE11 3TU, United Kingdom; and 2Department of Sport and Exercise Sciences, University of Ulster at Jordanstown, Northern Ireland BT37 0QB

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Herd, Sara L., Janet E. M. Lawrence, Dale Malkova, Marie H. Murphy, Sarabjit Mastana, and Adrianne E. Hardman. Postprandial lipemia in young men and women of contrasting training status. J Appl Physiol 89: 2049–2056, 2000.—This study compared the postprandial triacylglycerol (TAG) response to a high-fat meal in trained and untrained normolipidemic young adults after 2 days’ abstinence from exercise. Fifty-three subjects (11 endurance-trained men, 9 endurance-trained women, 10 sprint/strength-trained men, 11 untrained men, 11 untrained women) consumed a meal (1.2 g fat, 1.1 g carbohydrate, 66 kJ per kg body mass) after a 12-h fast. Venous blood samples were obtained in the fasted state and at intervals until 6 h. Postprandial responses were the areas under the plasma or serum concentration-vs.-time curves. Neither fasting TAG concentrations nor the postprandial TAG response differed between trained and untrained subjects. The insulinemic response was 29% lower in endurance-trained men than in untrained men [mean difference –37.4 (95% confidence interval –62.9 to –22.9) μIU/ml × h, P = 0.01]. Responses of plasma glucose, serum insulin, and plasma nonesterified fatty acids were all lower for endurance-trained men than for untrained men. These findings suggest that, in young adults, no effect of training on postprandial lipemia can be detected after 60 h without exercise. The effect on postprandial insulinemia may persist for longer.

triacylglycerol; insulin; dietary fat; endurance-trained; sprint/strength-trained

CASE-CONTROL STUDIES HAVE found that a high postprandial concentration of triacylglycerol (TAG) is a strong and independent risk marker for coronary artery disease (31). The underlying reason may be that repeated daily episodes of exaggerated postprandial lipemia represent an atherogenic influence on other lipoprotein species in plasma (23). Therefore, the factors that influence postprandial lipemia are the subject of current research interest.

Levels of postprandial lipemia have been reported to be >25% lower in endurance-trained men than in sedentary controls (5, 20, 28). The clearance rate of an intravenously administered lipid emulsion, an alternative measure of TAG tolerance, has also been found to be faster in male (16, 36) and female (32) endurance athletes than in controls. One mechanism invoked to explain these findings is enhanced activity in athletes of lipoprotein lipase (LPL), located on the luminal surface of capillary endothelium. Hydrolysis by LPL is an important determinant of TAG clearance, and this broadly reflects tissue requirements for fatty acids. Enhanced LPL activity in the well-vascularized skeletal muscle of endurance athletes (24) probably facilitates high rates of fatty acid oxidation after exercise (25). Skeletal muscle can account for more than 50% of clearance of a bolus dose of Intralipid (35), so these adaptations might be functionally important.

Recent evidence questions this rationale, however, because the plasma TAG response to a fatty meal has been shown to increase markedly when athletes refrain from training for as little as 2 days (19). Although the latter study did not provide comparative data for untrained people, this suggests that mechanisms other than structural adaptations in skeletal muscle are responsible for the low levels of postprandial lipemia in athletes. A single exercise session can decrease fasting (2, 37) and postprandial (41) TAG concentrations, and so, in studies reporting enhanced fat tolerance in athletes, the effects of recent exercise may have contributed to differences from control groups because the interval between training and testing has often been as short as 24 h (3, 5, 32). Although such studies describe accurately the “real-life” situation for athletes, they cannot distinguish between long-term adaptations to training and the effects of recent exercise as factors influencing fat tolerance. One recent report concluded that training and single exercise sessions have distinct and interactive effects on fasting lipoprotein lipids (7), but there is no evidence for the postprandial state.

There are two reasons for attempting to clarify this issue: first, to increase understanding of the putative...
mechanisms, and second, because the question of whether frequent exercise in itself (irrespective of being “well-trained”) can help maintain low postprandial plasma concentrations of TAG is important in drawing up sound public health recommendations for physical activity.

The purpose of the present study was therefore to test the hypothesis that, in the absence of effects of recent exercise, postprandial lipemia is not lower in trained than in untrained people. On the basis of evidence that lipemia increased markedly in athletes who refrained from training for 2 days, with little further increase after four further inactive days (19), we asked subjects not to train during the 2 days leading up to their fat tolerance test. Women were studied as well as men because of the paucity of data in women (41, 43), who comprise half the population to whom exercise recommendations are addressed. Sprint/strength training is probably not as potent a stimulus to muscle capillarization as endurance training (27) but could influence TAG tolerance by increasing muscle mass. It is also specifically recommended as part of a well-rounded exercise program (33). For these reasons, a group of sprint/strength-trained athletes were included. We were unable to recruit sufficient numbers of women athletes in this category, so the athletes were included. We were unable to recruit sufficient numbers of women athletes in this category, so the data reported herein are only for men.

METHODS

Subjects. Fifty-three nonsmoking young adults aged 18–35 yr participated. All met the following inclusion criteria: systemic arterial blood pressure <160/90 mmHg; normolipidemic as determined from blood samples obtained during preliminary screening (total cholesterol <6.8 mmol/l, fasting TAG <2.3 mmol/l); no known cardiovascular or metabolic disease; and not taking (at the time of the study or during the previous 6 mo) drugs known to affect lipid or carbohydrate metabolism (including oral contraceptives). Subjects were volunteers recruited through advertisements placed on the campus and in the town. Individuals with high levels of body fatness (men >28%, women >33%) or extreme dietary practices (energy from fat <25% or >45%, assessed as described below) were excluded. The research was carried out in accordance with the Declaration of Helsinki and was approved by Loughborough University Ethical Advisory Committee. Some of the physical characteristics of the subjects are shown in Table 1.

Training status and exercise habits. A physical activity questionnaire was completed by all subjects to provide information describing the type, duration, and frequency of current exercise. For trained subjects, additional data were collected to describe typical training weeks, total training distance(s), level of competition, and years of training.

Four endurance-trained men competed at international level, three at national level, two at regional level, and six at club level. They had been training for 6.5 (3–17) yr. Four triathletes each training for different combinations of the three disciplines (running 16–48 km/wk, cycling 64–256 km/wk, swimming 9,000–17,000 m/wk), and one was a cyclist (200 km/wk). Two endurance-trained women competed internationally, four at national level, and three at club level. They had been training for 5 (3–14) yr and currently trained 9 (5–13) times per week. Two were runners (77 and 104 km/wk), three were triathletes (running 24–64 km/wk, cycling 32–96 km/wk, swimming 10,000–12,000 m/wk), three were biathletes each training for different combinations of the three disciplines (running 20 or 55 km/wk, cycling 160 or 240 km/wk, swimming 2,000 or 3,400 m/wk), and one was a cyclist (320 km/wk). The duration of training sessions was typically 1–1.5 h, with a maximum of 2 h of running and 3 h of cycling. Three elements were common to all regimens, i.e., long slow distance work, “tempo” or “threshold” sessions demanding sustained high-intensity effort (~80–85% maximum heart rate), and interval sessions based on multiple short efforts above race pace interspersed with slower recovery. Swimming training also included technical drills.

Five sprint/strength-trained men were sprinters and five were field event athletes. Two competed at national level, two at regional level, and six at club level. They had been training for 9 (3–17) yr and currently trained 5.5 (3–13) times per week. Sprinters typically did two weight-training sessions per week, involving three to five sets of three to five repetitions of each of five exercises at an average intensity of 80–90% of one repetition maximum. They also did plyometrics, sprint track sessions (repeated maximal efforts over 60–200 m, depending on season), technique work, and (in winter) hills. The field event athletes typically undertook three sessions of weights per week, one of plyometrics, and two or three sessions including event-specific technique work. Weights sessions involved six exercises (for example: Olympic lift, bench press, squats, Olympic pulls, abdominal exercises, 20- to 35-m sprints), with two to five sets of three to five repetitions at an average of 90% one repetition maximum.

The criteria for acceptance into the untrained group were as follows: no more than two 30-min sessions of recreational exercise per week at the time of the study or during the preceding two years and not engaged in a manual job. Four untrained subjects reported regular activity at a level less than this threshold: one man did five miles of jogging per week in two sessions and one did two sessions of trampolining; and two women did aerobics once each week.

Exercise tests. Maximal oxygen uptake was directly determined during uphill treadmill running to volitional fatigue by using standard Douglas bag techniques for trained subjects and for those untrained subjects (10 men, 7 women) who could be persuaded to undergo this test.

Fat tolerance tests. All subjects undertook to refrain from planned exercise and to perform only activities of daily living during the 2 days leading up to their oral fat tolerance test. The evening before this 2-day period, trained subjects performed an hour-long exercise session typical of their usual training regimens. The interval between training and testing was thus ~60 h. All subjects refrained from alcohol for at least 2 days before testing. Appointments to test women were made on a convenience basis and not during a particular phase of the menstrual cycle.

Subjects reported to the laboratory at 0800 after a 12-h fast during which they consumed only water. They rested for 15 min before a cannula was inserted into a forearm or antecubital vein. After a further 10 min, a baseline blood sample was obtained, and the subject then ate the test meal. This comprised whipping cream, fruit, cereal, nuts, and chocolate and was given according to body mass (i.e., 1.2 g fat, 1.1 g carbohydrate, 0.2 g protein, and 66 kJ per kg). Further blood samples were obtained 0.5 h after completion of the meal and then hourly until 6 h. The cannula was kept patent by flushing with nonheparinized saline (9 g/l). Subjects read, worked quietly, or watched television during the postprandial observation period and consumed only water (ad libi-
Table 1. Some characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
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<tbody>
<tr>
<td></td>
<td>Untrained</td>
<td>Endurance-trained</td>
</tr>
<tr>
<td>no. of subjects</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Age, yr</td>
<td>25.6 ± 4.6</td>
<td>23.8 ± 3.9</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.78 ± 0.07</td>
<td>1.75 ± 0.05</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>71.4 ± 8.2</td>
<td>68.1 ± 7.7</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>22.4 ± 2.0</td>
<td>22.3 ± 2.1</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>15.3 ± 4.2‡</td>
<td>13.7 ± 5.0</td>
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<tr>
<td>Lean body mass, kg</td>
<td>59.6 ± 6.9‡</td>
<td>58.6 ± 5.9</td>
</tr>
<tr>
<td>( \dot{V}O_{2\text{max}}, \text{ml·kg}^{-1}·\text{min}^{-1} )</td>
<td>51.3 ± 4.6‡</td>
<td>70.2 ± 8.9*</td>
</tr>
<tr>
<td>Apo E phenotype</td>
<td>three 3–3, two 4–3, one 4–4,</td>
<td>eight 3–3, one 4–4, five 3–3,</td>
</tr>
<tr>
<td></td>
<td>two 3–2, one 4–4, two 4–3</td>
<td>five 4–3</td>
</tr>
<tr>
<td></td>
<td>one 4–2, two N/A</td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± SD. BMI, body mass index; Apo E, apolipoprotein E; \( \dot{V}O_{2\text{max}} \), maximal oxygen uptake. N/A, not available. *Significantly different from untrained men or women by unpaired two-tailed \( t \)-test, \( P < 0.01 \); †significantly different from endurance-trained men by unpaired, two-tailed \( t \)-test, \( P < 0.05 \); \( \ddagger \)significantly different from endurance-trained men by unpaired, two-tailed \( t \)-test, \( P < 0.02 \); \( \ddagger\ddagger \)significantly different from endurance-trained men by unpaired, two-tailed \( t \)-test, \( P < 0.01 \); \( \ddagger\ddagger\ddagger \)significantly different from endurance-trained men by unpaired, two-tailed \( t \)-test, \( P < 0.05 \).

RESULTS

Maximal oxygen uptake values are presented in Table 1. Trained men and women possessed higher values than untrained individuals (both \( P < 0.01 \)), and endurance-trained men had significantly higher values than sprint/strength-trained men (\( P < 0.02 \)). Sprint/strength-trained men had higher body mass index than either untrained men (\( P < 0.01 \)) or endurance-trained men (\( P < 0.02 \)); their lean body mass was also greater than that of endurance-trained men (\( P < 0.02 \)) (Table 1). Mean percentage of body fat was lower (\( P < 0.01 \)) for endurance-trained women than for untrained women.

**Plasma and serum concentrations in the fasted state.** Concentrations of plasma TAG, NEFA, glucose, and serum insulin measured in the fasted state are shown in Fig. 1 and concentrations of plasma total and HDL cholesterol in Table 2. Plasma TAG concentrations were similar in all groups of men (untrained 1.03 ± 0.08 mmol/l, endurance-trained 1.09 ± 0.06 mmol/l, sprint/strength-trained 1.06 ± 0.03 mmol/l) and both groups of women (untrained 0.86 ± 0.12 mmol/l, endurance-trained 0.87 ± 0.10 mmol/l, means ± SE). Neither total nor HDL cholesterol concentration differed significantly between groups with different training status. However, endurance-trained men had a lower plasma NEFA concentration than untrained men [mean difference −0.14 (95% confidence interval −0.28–0.00 mmol/l) \( P = 0.05 \)] and a lower serum insulin concentration [mean difference −2.4 (95% confidence interval −4.4 to −0.4) µIU/ml; \( P = 0.03 \)].
intervals and corresponding $P$ values. There was no indication of a difference in postprandial lipemia between groups with different training status, either in men or in women. The responses of plasma glucose, serum insulin, and plasma NEFA were all lower for endurance-trained men than for untrained men. Peak insulin concentration was lower in endurance-trained women than in untrained women [mean difference $-14.4$ (95% confidence interval $-28.6$ to $-0.2$) μIU/ml, $P = 0.048$].

Habitual diets and diets during the day before fat tolerance testing. Information about subjects’ diets is shown in Table 4. The 3-day records showed that endurance-trained men obtained a larger proportion of energy from carbohydrate than untrained men ($P < 0.01$), with a smaller proportion from fat ($P < 0.01$). They also showed that endurance-trained women consumed more energy than untrained women ($P = 0.03$) and that their diets were more carbohydrate rich ($P = 0.03$). During the day before fat tolerance tests, endur-
Mean differences between groups for summary measures of postprandial responses is a paucity of evidence on the influence on TAG metabolism of either single exercise sessions or training using these modes.

The 60-h interval between determinations of fat tolerance and athletes’ training sessions probably explains why we did not find lower lipemia in endurance-trained athletes. It is well documented that a single session of endurance exercise reduces fasting (37, 38) and postprandial plasma TAG concentrations (41). TAG concentrations in the fasted state (which are strongly related to postprandial concentrations) begin to rise again 24 h after an exercise session (12) but may not return to the prebout level until 42 h (22). In some earlier studies, athletes were requested not to train for 24 h before fat tolerance testing (28, 36), whereas in others no restriction was placed on training (5, 20). Athletes will invariably train unless specifically requested not to, and so levels of lipemia measured in these circumstances will likely reflect the effects of recent exercise in addition to long-term adaptations to a training regimen. These interactions were specifically examined in a recent study in which blood lipids were measured before and after a 24-wk training period at a succession of time points after the most recent exercise session (7): when blood was collected 60 h after exercise, there were no significant effects of training on fasting plasma TAG concentrations, in line with our findings for the postprandial state.

Table 2. Concentrations of plasma and serum constituents measured in the fasted state and summary measures of postprandial responses

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
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<th>Women</th>
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<tbody>
<tr>
<td></td>
<td>Untrained</td>
<td>Endurance-trained</td>
<td>Sprint/strength-trained</td>
<td>Untrained</td>
</tr>
<tr>
<td>no. of subjects</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Fasting</td>
<td></td>
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</tr>
<tr>
<td>Total cholesterol, mmol/l</td>
<td>4.38 ± 0.12</td>
<td>4.58 ± 0.33</td>
<td>4.34 ± 0.33</td>
<td>4.40 ± 0.22</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/l</td>
<td>1.07 ± 0.08</td>
<td>1.09 ± 0.06</td>
<td>1.06 ± 0.03</td>
<td>1.51 ± 0.09</td>
</tr>
<tr>
<td>Postprandial responses</td>
<td>TAG, mmol/l × h</td>
<td>11.10 ± 1.16</td>
<td>10.17 ± 0.85</td>
<td>9.93 ± 0.85</td>
</tr>
<tr>
<td>Glucose, mmol/l × h</td>
<td>30.52 ± 0.93</td>
<td>27.84 ± 0.89</td>
<td>29.03 ± 0.69</td>
<td>26.65 ± 0.48</td>
</tr>
<tr>
<td>Insulin, μIU/ml × h</td>
<td>127.0 ± 11.1</td>
<td>89.7 ± 8.2</td>
<td>115.5 ± 11.8</td>
<td>123.7 ± 18.1</td>
</tr>
<tr>
<td>NEFA, mmol/l × h</td>
<td>3.11 ± 0.12</td>
<td>2.59 ± 0.12</td>
<td>2.92 ± 0.17</td>
<td>3.04 ± 0.27</td>
</tr>
</tbody>
</table>

Values are means ± SE. Postprandial responses are summary measures (6-h areas under the plasma or serum concentration-vs.-time curves). HDL, high-density lipoprotein; TAG, triacylglycerol; NEFA, nonesterified fatty acids.

DISCUSSION

Our major finding is that, in the absence of the effects of a recent exercise session, postprandial lipemia was not influenced by habitual exercise level in these young adults. Our trained subjects all pursued rigorous training regimens, and fitness levels clearly differed markedly between groups. Although the untrained subjects possessed higher than average values for maximal oxygen uptake (30), these may overestimate the true values because the five subjects who were not willing to perform this test were probably the least fit.

For men, our findings conflict with earlier reports that postprandial lipemia was lower (3, 5, 20, 28) and that the rate of clearance of exogenous fat was faster in endurance-trained men (41, 43) in endurance-trained than in untrained individuals. Few comparable data are available for women: one study found that the clearance rate of exogenous fat was faster in endurance-trained women (32), but two found no significant difference in postprandial lipemia between endurance-trained and untrained women (41, 43). As far as we know, ours are the only available data on postprandial TAG concentrations in sprint/strength-trained athletes. Indeed, there is a paucity of evidence on the influence on TAG metabolism of either single exercise sessions or training using these modes.

Table 3. Mean differences between groups for summary measures of postprandial responses

<table>
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<tr>
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<th>Men</th>
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<th>Women</th>
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<tbody>
<tr>
<td></td>
<td>Endurance-trained</td>
<td>P</td>
<td>Sprint/strength-trained</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>vs. untrained</td>
<td></td>
<td>vs. untrained</td>
<td></td>
</tr>
<tr>
<td>TAG, mmol/l × h</td>
<td>−0.94</td>
<td>0.52</td>
<td>−1.17</td>
<td>0.23</td>
</tr>
<tr>
<td>Glucose, mmol/l × h</td>
<td>−2.68</td>
<td>0.05</td>
<td>−1.49</td>
<td>0.43</td>
</tr>
<tr>
<td>Insulin, μIU/ml × h</td>
<td>−37.4</td>
<td>0.01</td>
<td>−11.5</td>
<td>0.22</td>
</tr>
<tr>
<td>NEFA, mmol/l × h</td>
<td>−0.52</td>
<td>0.01</td>
<td>−0.19</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Values are mean differences (95% confidence interval) in 6-h areas under the plasma or serum concentration-vs.-time curves for 11 untrained men, 11 endurance-trained men, 10 sprint/strength-trained men, 11 untrained women, 9 endurance-trained women. *P values for significance of differences between groups by unpaired, two-tailed t-test.
ever, to our knowledge, there are no data for humans, very low-density lipoprotein secretion (29, 39). How-
lished data showing (in rats) that training decreases lipemia could be reduced hepatic very low-
density lipoprotein-TAG secretion, in line with pub-
duced (5). They do, however, suggest that, if changes to mus-
contractile activity is needed before TAG removal is
enhanced. Compared with untrained individuals, endur-
ance-trained athletes would be expected to have enhan-
ced capillarization of muscle and sprint/
been described as an integrative marker for TAG
metabolic capacity (31).
Another factor that would have influenced our find-
trials on HDL cholesterol would be variation due to the
phase of the menstrual cycle. We did not attempt to
control for this for two reasons. First, our main out-
come measure was not likely to be influenced by men-
strual cycle phase; it has been reported that there is no
significant effect on either fasting (10) or postprandial
(42) plasma concentrations of TAG. Second, as might
be expected (11), endurance-trained women had irreg-
lar or absent menses; two were amenorrheic and five
were oligomenorrheic. Scheduling according to men-
strual cycle phase; it has been reported that there is no
for this factor. An alternative (or additional) mechanism by which an exercise session
decreases lipemia could be reduced hepatic very low-
density lipoprotein-TAG secretion, in line with pub-
lished data showing (in rats) that training decreases
very low-density lipoprotein secretion (29, 39). How-
ever, to our knowledge, there are no data for humans,

table 4. Average daily energy intake of energy and the proportion of energy from major nutrients for trained and untrained subjects

<table>
<thead>
<tr>
<th></th>
<th>Untrained</th>
<th>Endurance-trained</th>
<th>Sprint/strength-trained</th>
<th>Untrained</th>
<th>Endurance-trained</th>
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<tbody>
<tr>
<td>No. of subjects</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Energy, MJ</td>
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<tr>
<td>3-day pre-OFTT</td>
<td>10.70 ± 1.96</td>
<td>12.70 ± 3.17</td>
<td>12.00 ± 3.55</td>
<td>6.87 ± 1.58</td>
<td>9.08 ± 2.52*</td>
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<tr>
<td>Fat, %</td>
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<tr>
<td>3-day pre-OFTT</td>
<td>36.4 ± 6.6</td>
<td>26.6 ± 4.7*</td>
<td>31.4 ± 7.9</td>
<td>30.4 ± 9.4</td>
<td>25.1 ± 9.9</td>
</tr>
<tr>
<td>Carbohydrate, %</td>
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<tr>
<td>3-day pre-OFTT</td>
<td>46.4 ± 7.6</td>
<td>56.5 ± 4.2*</td>
<td>50.0 ± 8.9†</td>
<td>50.6 ± 7.8</td>
<td>60.3 ± 9.5*</td>
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<tr>
<td>Protein, %</td>
<td></td>
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<tr>
<td>3-day pre-OFTT</td>
<td>15.3 ± 3.0</td>
<td>16.0 ± 2.4</td>
<td>17.2 ± 3.4</td>
<td>15.1 ± 3.5</td>
<td>13.8 ± 1.7</td>
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<td>Alcohol, %</td>
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<tr>
<td>3-day pre-OFTT</td>
<td>0.7 ± 2.0</td>
<td>0.8 ± 1.3</td>
<td>1.3 ± 2.7</td>
<td>3.6 ± 8.1</td>
<td>0.5 ± 1.4</td>
</tr>
</tbody>
</table>

Values are means ± SD measured using the weighed food inventory technique over two weekdays and one weekend day, together with intake the day preceding the oral fat tolerance test (pre-OFTT). *Significantly different from untrained men or women by two-tailed t-test, P < 0.05; †significantly different from endurance-trained men by two-tailed t-test, P < 0.03.

The present findings are consistent with the observa-
tion that postprandial lipemia increases rapidly when endurance training is interrupted (19) and sug-
gest that only frequent exercise will maintain a low
level of postprandial lipemia. This proposition ties in
persuasively with recent data describing the time
course of exercise-induced increases in skeletal muscle
LPL. Four hours after exercise (90 min of cycling at
63% of maximal oxygen uptake, i.e., a moderately vig-
orous level), mRNA in biopsy samples of muscle was
more than double the pre-exercise value (38). A sub-
sequent increase in LPL mass suggested that enhanced
TAG uptake capability would develop over a somewhat
longer time scale. There appeared to be no strong
Cumulative effect of repeated exercise bouts, but, be-
cause these were only monitored over 5 days, the rel-
evance of these findings to our athletes who trained
regularly and frequently over years cannot be stated.
Our data are not, therefore, inconsistent with exercise-
induced enhancement of muscle LPL activity being a
mechanism by which postprandial lipemia is reduced
(5). They do, however, suggest that, if changes to mus-
cle LPL are important, then the stimulus of recent
contractile activity is needed before TAG removal is
enhanced. Compared with untrained individuals, endur-
ance-trained athletes would be expected to have enhan-
ced capillarization of muscle and sprint/ strength-trained athletes a greater muscle mass; both
adaptations might increase the number of potential
binding sites for LPL. Our findings appear to hold,
therefore, irrespective of this factor. An alternative (or
additional) mechanism by which an exercise session
decreases lipemia could be reduced hepatic very low-
density lipoprotein-TAG secretion, in line with pub-
lished data showing (in rats) that training decreases
very low-density lipoprotein secretion (29, 39). How-
ever, to our knowledge, there are no data for humans,
either for training or for the effect of an exercise ses-
sion. Trained individuals often exhibit higher plasma con-
centrations of HDL cholesterol than their untrained
peers (14), but no such differences were apparent in the
present study. One reason may be that a training-
induced increase in HDL cholesterol cannot be de-
ected when blood samples are obtained ≥60 h after
recent exercise (7). Bearing in mind the fact that we did
not observe differences in postprandial lipemia, the
lack of a difference between groups in HDL cholesterol
is not unexpected. There are close mechanistic links
between the rate of hydrolysis of TAG-rich lipoproteins
and HDL cholesterol concentration, which has there-
fore been described as an integrative marker for TAG
metabolic capacity (31).

As with all cross-sectional studies, concerns arise
about selection bias and confounding factors. The lat-
ter include differences between groups in body fatness because fasting and postprandial plasma TAG concentrations are positively related to adiposity (34). However, the three groups of men had similar levels of body fat, and the untrained women, who possessed more body fat than endurance-trained women, clearly did not have a higher postprandial TAG response than the lean athletes.

Postprandial lipemia varied appreciably within groups, as in other such studies (20, 43), probably because of genetic factors. We were able to characterize our subjects with respect to only one such factor, namely apolipoprotein E phenotype. This apolipoprotein facilitates hepatic uptake of remnants of TAG-rich particles: different isoforms have distinct affinities, and both the E2 and the E4 alleles probably impair TAG clearance (8). Comparisons of postprandial lipemia were repeated with individuals who had either the E4/4 or the E4/2 phenotype excluded, but this did not alter our findings.

Diet is another potential confounding factor because the athletes, particularly those who were endurance trained, consumed high-energy, high-carbohydrate diets. The substitution of dietary fat for carbohydrate increases fasting and postprandial TAG concentrations (4), and so the athletes’ dietary habits could have enhanced their lipemic response, making it less likely that we would discern differences between groups. Previous comparative studies have found lower postprandial lipemia in athletes, however, despite the fact that similar dietary differences probably existed between trained and untrained groups.

Insulin was measured because it plays an important coordinating role in postprandial metabolism, and insulin sensitivity is enhanced in endurance-trained subjects (9). There were indications of a lower insulin response to the test meal for our endurance-trained athletes compared with untrained subjects. The glycemic response was also lower in endurance-trained than in untrained men, as were fasting and postprandial NEFA concentrations. Adipose tissue lipolysis is suppressed by insulin (17), and this effect is impaired in insulin-resistant states (6). Thus, taken together, the lower postprandial responses of glucose, insulin, and NEFA exhibited by the endurance-trained subjects may indicate better insulin sensitivity. Differences from untrained subjects were not significant for the female endurance athletes, but similar trends were evident. On the other hand, despite having a greater lean body mass than the other male groups, our sprint/ strength-trained men did not show evidence of better insulin sensitivity than untrained men. Thus endurance training appears to have unique metabolic effects in this regard.

Training-induced improvements to insulin sensitivity, like the effects on postprandial TAG metabolism (19), are rather rapidly lost when training is interrupted (26). Our data suggest that the time course of these changes may differ, the alterations to insulin/glucose dynamics persisting for somewhat longer than those to TAG metabolism. This is in agreement with an earlier longitudinal study of the effects of training by brisk walking (1). When evaluated 60 h after the last session of brisk walking, postprandial lipemia was no different from pretraining. By contrast, the insuline-mic response to a high-fat meal similar in composition to that employed in the present study was clearly reduced.

In summary, we found no differences in postprandial lipemia between young adults of contrasting physical training status when the effects of recent exercise were controlled for by asking athletes to refrain from exercise for 2 days. Our findings strongly suggest that the TAG-lowering effects of exercise can be maintained only through frequent sessions, i.e., on most days of the week. The importance of training may be to enhance the transient effects of single exercise sessions by facilitating increases in the intensity and/or the duration of these sessions.

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