

**Effects of Intermittent Games Activity on Postprandial Lipemia in Young Adults**

*<sup>1</sup>LAURA A BARRETT, <sup>1</sup>JOHN G MORRIS, <sup>1</sup>DAVID J STENSEL AND <sup>1</sup>MARY E NEVILL*

<sup>1</sup>Institute of Youth Sport, School of Sport and Exercise Sciences, Sir John Beckwith Centre for Sport, Loughborough University, LE11 3TU, United Kingdom.

**Corresponding Author:** Laura A. Barrett, Institute of Youth Sport, School of Sport and Exercise Sciences, Sir John Beckwith Centre for Sport, Loughborough University, Leicestershire LE11 3TU, United Kingdom.  
Phone: +44(0)1509 226351. Fax +44(0)1509 226301. E-mail: L.A.Barrett@lboro.ac.uk

**Running Title:** Games Activity and Postprandial Lipemia

## ABSTRACT

**Purpose:** To investigate if a single session of intermittent games activity would reduce postprandial lipemia.

**Methods:** Twelve male volunteers completed three, two-day trials: Rest, Continuous exercise and Intermittent games activity. Trials were performed a minimum of 6 d apart in a balanced crossover design. In the Rest trial subjects took no exercise on day 1. On day 1 of the Continuous and Intermittent games trials subjects completed four blocks (approximately 15 min per block) of uphill treadmill walking or intermittent games activity with 3 min rest between each block. On day 2 subjects came to the laboratory for an oral fat tolerance test [blood taken fasted and for 6 h following a high fat test meal (1.25 g fat and 1.07 g carbohydrate per kg body mass)].

**Results:** The Intermittent games protocol elicited a higher exercise intensity than the Continuous trial (lactate:  $4.3 \pm 0.6$  vs  $2.4 \pm 0.3$  mmol·L<sup>-1</sup>; %  $\dot{V}O_2$  max:  $72 \pm 2$  vs  $62 \pm 1$  respectively; mean  $\pm$  SE). The total area under the plasma triacylglycerol (TAG) versus time curve was lower in both the Intermittent games (25%,  $P = 0.001$ ) and the Continuous (19%,  $P = 0.028$ ) trials than in the Rest trial.

**Conclusion:** These findings show for the first time that intermittent games activity can reduce postprandial lipemia and confirm that continuous exercise reduces postprandial lipemia.

**Keywords:** triacylglycerol; lipid metabolism; exercise; cardiovascular disease risk;

## **INTRODUCTION**

### **Paragraph Number 1**

While many of the postprandial changes in lipid metabolism are transient in nature, the customary intake of food in Western societies of three meals spread through the day means that the metabolic disturbances associated with one meal are unlikely to have subsided before another meal is ingested. As a result people can spend up to two thirds of the day in the postprandial state and therefore from a metabolic viewpoint this could be thought of as the “normal” physiological state (7).

### **Paragraph Number 2**

Exaggerated postprandial lipemia indicates poor triacylglycerol (TAG) metabolic capacity (14) and has been implicated in the development of atherosclerosis (30). Therefore long-term interventions to reduce postprandial lipemia could potentially slow atherogenic progression. Several studies have shown that a single session of exercise can reduce postprandial lipemia (1, 11, 20, 24-26, 29). It appears that exercise induced reductions in postprandial lipemia are linked to the energy expenditure of an exercise session. Increasing the energy expenditure of an exercise session by increasing either the duration (2) or exercise intensity (25) has been found to result in a greater reduction in lipemic response. Also similar energy expenditures at different exercise intensities have been found to elicit similar attenuations in postprandial lipemia (24).

### **Paragraph Number 3**

To date only the effects of continuous modes of exercise such as treadmill walking or running have been determined. As the process leading to coronary atherosclerosis begins during childhood and early adulthood (as evident by the presence of fatty streaks and raised lesions) (13) interventions to protect against this condition should occur in all age groups. Therefore it is important to investigate what effect modes of exercise commonly undertaken by young people, such as intermittent games type activity (for example field hockey, rugby or soccer), have on postprandial lipemia. The present study sought to examine the influence of intermittent games activity on postprandial lipemia in a group of young adult males and to test the hypothesis that if the energy expenditure was sufficient a single session of this type of exercise would reduce postprandial lipemia.

## **METHODS**

### **Subjects**

### **Paragraph Number 4**

Twelve, healthy, recreationally active males aged  $21.1 \pm 0.4$  yr (mean  $\pm$  SE) volunteered to take part in this study. Their body mass index, sum of skinfolds (bicep, tricep, subscapular and suprailiac skinfolds) and directly determined and predicted maximal oxygen uptakes ( $\dot{V}O_2$  max) (by treadmill and Multistage Shuttle Run Test respectively) were:  $23.0 \pm 0.5$  kg·m<sup>-2</sup>;  $37.9 \pm 3.6$  mm;  $53.0 \pm 1.5$  and  $52.7 \pm 1.5$  ml·kg<sup>-1</sup>·min<sup>-1</sup>. The study was conducted

with the approval of the Loughborough University Ethical Advisory Committee and subjects gave written informed consent before participation.

## **Experimental Design**

### **Paragraph Number 6**

Prior to the main trials subjects completed a maximal oxygen uptake test, a progressive multistage shuttle run test (MSST) (21) and two familiarisation sessions. Following this each subject took part in three main trials: a Rest trial, a Continuous exercise trial and an Intermittent games activity trial. The trials were separated by a minimum of 6 days, in a balanced cross-over design.

### **Preliminary Tests**

#### **Paragraph Number 6**

Maximum oxygen uptake was measured directly using an incremental, uphill treadmill walking test to exhaustion. The test protocol commenced at a belt speed selected by the subject (range 6.2 to 7 km·h<sup>-1</sup>) and at an initial incline of 5%. The belt speed remained constant throughout the test with the inclination increasing by 4% at the end of every 3 min stage. This test was also used to establish the relationship between oxygen uptake, speed and gradient in order to set the gradient necessary to elicit 60% of each subjects  $\dot{V}O_2$  max at their self-selected speed for the Continuous exercise trial. Oxygen consumption and carbon dioxide production were determined using standard Douglas bag methods. The maximum speed achieved during the MSST was used to calculate the running speeds during the Intermittent games trial. The two familiarization sessions, consisting of 4 blocks of either uphill walking or

simulated games activity, with each block separated by a 3 min rest period. This replicated the amount of exercise performed during the main trials.

#### **Paragraph Number 7**

In both the uphill walking and the simulated games activity the target exercise intensity was 60%  $\dot{V}O_2$  max over each block. During the walk sessions expired air collections were made during the final minute of each block using a Douglas bag attached to an adapted rucksack as this was the method used to make expired air collections during the Intermittent games activity trial. Heart rate was monitored and ratings of perceived exertion (RPE) (3) noted during each expired air collection. Capillary blood samples were taken to determine blood lactate concentration at rest and immediately after the completion of each block. The gradient each subject walked at was adjusted during the familiarisation session until the desired exercise intensity of 60%  $\dot{V}O_2$  max over each block was achieved. The gradient was not adjusted during the main trial.

#### **Paragraph Number 8**

The Loughborough Intermittent Shuttle Test (LIST) was used to simulate games activity and was a modified version of the test reported by Nicholas and colleagues (16). The LIST protocol required subjects to repeat a pattern of exercise, which consisted of a walk, sprint, “cruise” and “jog” over a marked 20 m distance in a sports hall (see Figure 1). During the LIST sessions an expired air collection was made at the end of each block (during the 10th cycle of the repeated exercise pattern) using a Douglas bag attached to a rucksack.

Heart rate was monitored throughout the exercise sessions (Polar Electro S810, Finland) and RPE was noted just before sprint 8 of each block. Capillary blood samples were collected as in the walk sessions. If the desired exercise intensity of 60%  $\dot{V}O_2$  max over each block was not achieved using the running speeds predicted from the Multistage Shuttle Run Test, the “cruise” and “jog” speeds were lowered during the familiarisation session until the intensity achieved was as close as possible to 60% of  $\dot{V}O_2$  max without the speeds becoming so slow subjects had to walk. The speeds were not adjusted during the main trials.

## **Main Trials**

### **Paragraph Number 9**

During the Rest trial subjects refrained from exercise on day 1. During the exercise trials on the afternoon of day 1, subjects performed a 15 min warm-up on a treadmill consisting of: 7 min of walking at a 1% gradient at the speed maintained during the  $\dot{V}O_2$  max test; 5 min of stretching; and 3 min of walking at a speed and gradient selected to elicit 60% of  $\dot{V}O_2$  max. Subjects then completed either four blocks of treadmill walking or four blocks of the LIST, with a 3 min rest between each block. On the morning of day 2 subjects attended the laboratory for an oral fat tolerance test. Exercise was completed at the same time of day (between 1530 and 1700 h) in both exercise trials so that the time interval between the end of the exercise sessions and beginning of the fat tolerance tests was the same in both trials ( $\approx 16$  h).



**Paragraph Number 10**

On day 2 of each trial subjects reported to the laboratory at 0800 h after an overnight fast. A cannula was inserted into an antecubital vein and the subject rested quietly for 10 min before a baseline blood sample was obtained. Subjects then consumed a high fat mixed meal comprising of cereal, fruit, nuts, chocolate and whipping cream, providing 1.25 g fat, 1.07 g carbohydrate and 0.20 g protein per kg body mass. A clock was started when subjects began eating. Further blood samples were collected at 0.5, 0.75, 1, 2, 3, 4, 5 and 6 h. Subjects rested throughout this period. Subjects consumed water *ad libitum* during the first trial and the volume ingested was replicated in the subsequent trials.

**Paragraph Number 11**

Subjects were asked to refrain from physical activity for the 2 days before the commencement of each trial. Subjects also recorded their food and drink intake during the 2 day period before their first oral fat tolerance test, and were asked to replicate this diet during the subsequent trials. Subjects were also asked not to consume alcohol during these periods.

**Analytical Procedures****Paragraph Number 12**

Blood samples were drawn into syringes (Becton-Dickinson, Oxford, U.K.) and immediately dispensed into pre-chilled potassium EDTA tubes (Sarstedt

Ltd., Leicester, U.K.) and placed on ice. Plasma was separated within 15 min of collection, divided into aliquots and stored at – 80 °C.

### **Paragraph Number 13**

Plasma samples were analyzed for total cholesterol, high-density lipoprotein (HDL) cholesterol, TAG, glucose (Randox Laboratories Ltd, U.K.) and non-esterified fatty acids (NEFA) (Wako Chemicals GmbH, Germany) by enzymatic, colorimetric methods with the use of a centrifugal analyser (Cobas Mira Plus, Roche, Basel, Switzerland). Plasma samples were analysed for insulin using a solid-phase <sup>125</sup>Iodine radioimmunoassay available in a commercial kit (ICN Pharmaceuticals, Inc., Costa Mesa CA U.S.A.). Radioactivity was measured using an automated gamma counting system (Cobra II, Packard Instrument, Downers Grove, IL U.S.A.). Whole blood lactate concentration was established using an enzymatic, fluorimetric method described by Maughan (12) using a Locarte Fluorimeter (Model 8-9, Locarte, London, U.K.). Within-batch coefficients of variations were 1.3% for TAG, 2.6% for glucose, 1.9% for total cholesterol, 0.9% for HDL cholesterol, 1.1% for NEFA, 9.7% for insulin and 1.3% for lactate. To eliminate inter-assay variation, samples from each trial for each participant were always analysed in the same batch.

### **Statistical Analysis**

### **Paragraph Number 14**

The 6 h area under the plasma concentration versus time curves for TAG, NEFA, glucose and insulin were calculated using the trapezium rule. The

incremental area under the curve for TAG was calculated using the same method after correcting for baseline concentrations. Fasting concentrations for total cholesterol, HDL cholesterol, TAG, NEFA, glucose and insulin and the area under the curve values for TAG, NEFA, glucose and insulin were compared between trials using one-way ANOVA for correlated means with a Bonferroni adjustment. Two-way ANOVA (trial - time) with Bonferroni adjustment was used to determine differences between trials and over time for postprandial plasma concentrations of TAG, NEFA, glucose and insulin as well as to compare lactate, heart rate, percentage of maximum heart rate (% HR max), %  $\dot{V}O_2$  max, RPE, and block time from the exercise trials. Data whose distributions were significantly different from normal were logarithmically transformed prior to statistical analysis, thus normalizing the data. Normality was checked via the Anderson-Darling test for normality using Minitab software release 14 for Windows (Minitab Ltd, Coventry, England). Data were analyzed using the Statistical Package for Social Science (SPSS) software version 11.0 for Windows (SPSS Inc, Chicago, IL). Statistical significance was accepted at the  $P < 0.05$  level. Data are presented as means  $\pm$  SE.

## **RESULTS**

### **Reponses During Exercise Trials**

#### **Paragraph Number 15**

The averages shown in Table 1 are based on the mean of measurements made over the 4 blocks of exercise. Lactate, heart rate, % HR max, and %  $\dot{V}O_2$

max were all found to be lower during the Continuous than in the Intermittent games trial. Also the time to complete each exercise block was on average 1 min 15 s shorter during the Continuous than the Intermittent games trial. The ratings of perceived exertion were not found to differ between trials. The mean gross energy expenditure for the Continuous trial was  $3.1 \pm 0.2$  MJ or  $40.2 \pm 1.5$  kJ·kg<sup>-1</sup> body mass. The energy expenditure for the Intermittent games trial was not calculated due to the methodological difficulties in calculating energy expenditure in non steady state exercise when the RER is above unity.

### **Plasma Concentrations in the Fasted State**

#### **Paragraph Number 16**

Plasma concentrations in the fasted state are shown in Table 2. There were no differences in fasting plasma concentrations of total cholesterol, HDL cholesterol, NEFA or glucose between trials. Fasting plasma TAG and insulin concentrations were lower in the Intermittent games than the Rest trial.

### **Postprandial Plasma Responses to the Fat Tolerance Tests**

#### **Paragraph Number 17**

The plasma TAG responses to the test meals are shown in Figure 2. Postprandial TAG concentrations were found to be lower during the Continuous and Intermittent games trials than the Rest trial. In addition the

total area under the plasma TAG versus time curve was also lower in both the Continuous (reduced by 19%,  $P = 0.028$ ) and the Intermittent games trials (reduced by 25%,  $P = 0.001$ ) than the Rest trial (see Table 3). Although a main effect of trial was found in the incremental areas under the curves for TAG ( $P = 0.046$ ), the location of the difference/s could not be found using a Bonferroni adjustment, however it is reasonable to assume that there is a difference between the highest and the lowest values, that is between the Rest and the Intermittent games trials.

### **Paragraph Number 18**

The plasma NEFA, glucose and insulin responses to the test meals are shown in Figure 3. The total areas under the concentration versus time curves for these parameters are given in Table 3. No differences were found in postprandial glucose concentrations between trials. However, postprandial NEFA concentrations were found to be higher during the Intermittent games than the Rest trial and postprandial insulin concentrations to be lower in the Intermittent games than the Rest and Continuous trials. No differences were found in the total areas under the concentration versus time curves for glucose between trials. Although a main effect of trial was found for NEFA ( $P = 0.045$ ), the location of the difference/s could not be found using a Bonferroni adjustment, however it is reasonable to assume that there is a difference between the highest and the lowest values, that is between the Rest and the Intermittent games trials. The total areas under the concentration versus time curves for insulin were lower in the Intermittent games than the Rest trial.

## **DISCUSSION**

### **Paragraph Number 19**

The main finding in the present study was that a single session of both continuous exercise and intermittent games activity performed 16 h prior to an oral fat tolerance test reduced postprandial lipemia in a group of young adult males. The total area under the plasma TAG versus time curve was reduced by 19% as a result of the uphill walking and 25% as a result of the games activity. To the knowledge of the authors this is the only study that has examined the effect of games activity on postprandial lipemia thus the key finding of a reduction in postprandial lipemia as a result of games activity is novel.

### **Paragraph Number 20**

Although the mediating factors are not completely understood, it seems likely that exercise reduces postprandial TAG concentration by two complementary mechanisms. One is thought to involve increased lipoprotein lipase (LPL) activity in the skeletal muscle (18), which may enhance TAG clearance from the blood stream. The other is thought to be reduced hepatic very low-density lipoprotein (VLDL) secretion (6, 8, 9, 15, 22). It is not possible to tell conclusively which of these two mechanisms if any predominates in the present study, although insulin concentrations were lower in the Intermittent games trial compared to both the Walk and Rest trials. As insulin inhibits muscle LPL activity in the postprandial state (10) the attenuated insulin response in the Intermittent games trial might have resulted in an upregulation of muscle LPL activity and therefore greater TAG clearance compared with

the Walk and Rest trials. The lower fasting and postprandial insulin concentrations seen during the Intermittent games trial are indicative of improved insulin sensitivity as a result of exercise. It appears from the literature that it is the energy expenditure not the intensity of exercise that is of prime importance in eliciting increased insulin sensitivity, however this is still a matter of debate (5, 28). The mechanisms involved may be associated with exercise induced glycogen depletion and involve effects on insulin stimulated glucose transporters [for review see Borghouts & Keizer, (4)].

### **Paragraph Number 21**

Fasting TAG concentrations were lower in the Intermittent games trial compared with the Rest trial. The lower fasting TAG concentrations seen may be due to the fact that during low and moderate intensity exercise, the muscle derives energy mainly from circulating free fatty acids and from its own TAG store and therefore the TAG muscle store is depleted. This store is restored during recovery by an increase in LPL activity in muscle that enables the tissue to take up circulating TAG more readily than in the nonexercised state. This results in lower fasting TAG concentrations. As endogenous (VLDL) and exogenous (chylomicrons) TAG are cleared by a common saturable pathway (the rate-limiting step of which is hydrolysis of core TAG by LPL), levels of postprandial lipemia are related to the size of the endogenous TAG pool (17). Therefore, the lower fasting TAG levels seen in the Intermittent games trial could have aided increased TAG clearance. The effect of exercise cannot, however be attributed solely to its influence on fasting TAG pool size as the

incremental area (above baseline) under the TAG versus time curve was also reduced.

### **Paragraph Number 22**

Postprandial NEFA concentrations were also found to be higher during the Intermittent games than the Rest trial; as substrate delivery to the liver is the major determinant of VLDL secretion (23) this would not be consistent with decreased hepatic secretion of these lipoproteins after exercise. However NEFA could also have been oxidized in the liver, which would lead to reduced VLDL secretion. As we did not measure hepatic ketone body production (an indicator of hepatic fatty acid oxidation) we cannot make any firm conclusions regarding this mechanism.

### **Paragraph Number 23**

The 6% greater attenuation in postprandial lipemia following the Intermittent games trial in comparison with the Continuous trial may be explained by two factors, working individually or more likely in combination. The durations of the Intermittent games sessions were on average 5 min longer than the Continuous sessions. Also, although every attempt was made to match the exercise intensity elicited by the two different exercise modalities, the intensity was  $71.8 \pm 1.6\%$  of  $\dot{V}O_2$  max in the Intermittent games trials compared with  $61.6 \pm 1.0\%$  in the Continuous trials. The significantly elevated lactate, heart rate, and % HR max values in the Intermittent games trials confirm that the exercise intensity maintained was higher than that in the Continuous trials. The fact that both the exercise duration and intensity were



greater in the Intermittent games trials suggests the energy expenditure was also higher. Energy expenditure has been shown to be an important determinant of the extent to which TAG is lowered following exercise (24, 25) and to increase insulin sensitivity leading to reduced fasting and postprandial insulin concentrations (4).

#### **Paragraph Number 24**

Despite a number of variables indicating a greater physiological strain in the Intermittent games trials no differences in RPE ratings were evident when the two types of exercise were compared. This is of particular interest because it suggests that for the same subjective effort the exercise mode closest to games type activity produces greater reductions in postprandial lipemia than steady rate exercise. It is also important to be aware that the times given to complete both the cruises and jogs in the adapted LIST protocol used in this study were increased greatly from those in the original protocol. This was necessary to reduce the overall intensity of the LIST session. However, there was a limit to how far speeds could be reduced before subjects were walking. Therefore in an actual game/match of field hockey, rugby or soccer the exercise intensity, and as a result the energy expended, would almost certainly be much greater than that seen in the Intermittent games trials in the present study. This could potentially result in an even greater reduction in postprandial lipemia than that seen in this study. Of course it also has to be recognized that the intermittent nature of the LIST protocol (including 40 maximal sprints) may artificially elevate many of the markers, which are used to indicate exercise intensity during steady state exercise and may make them inappropriate indicators

during intermittent exercise involving maximal sprinting. It is also possible that the subjects enjoyed the LIST sessions more than the uphill walking sessions due to the variety of different speeds that subjects were required to walk and run at and the greater level of concentration this required. This may have reduced the RPE.

### **Paragraph Number 25**

In conclusion the findings of this study confirm that continuous exercise can reduce postprandial lipemia and show for the first time that games activity can reduce postprandial lipemia. Therefore both continuous exercise and games activity can be recommended as appropriate modes of exercise with which to meet recommended activity guidelines for health (19, 27).

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**TABLE 1.** Blood Lactate, heart rate, percentage of maximum heart rate (% HR max), percentage of maximal oxygen uptake (%  $\dot{V}O_2$  max), rate of perceived exertion (RPE) and time to complete each exercise block (Block time) during the Continuous exercise and Intermittent games trials.

	Continuous exercise	Intermittent games
Blood lactate (mmol·L <sup>-1</sup> )	2.4 ± 0.3	4.3 ± 0.6 <sup>T</sup>
Heart rate (beats·min <sup>-1</sup> )	146 ± 3	160 ± 3 <sup>T,i</sup>
% HR max	77.0 ± 2.1	85.1 ± 1.8 <sup>T,i</sup>
% $\dot{V}O_2$ max Treadmill	61.6 ± 1.0	71.8 ± 1.6 <sup>T</sup>
RPE median (range)	12 (9 – 15)	12 (8 – 16) <sup>t,i</sup>
Block time (min:s)	15:00 ± 00:00	16:15 ± 00:14 <sup>T</sup>

Values are mean ± SE of measurements made over the 4 blocks of exercise,  $N = 12$ . Data were analyzed using two-way ANOVA (trial - time) with repeated measures. <sup>T</sup> main effect trial (lactate,  $P = 0.002$ ; HR,  $P < 0.001$ ; % HR max,  $P < 0.001$ ; % peak  $\dot{V}O_2$ ,  $P < 0.001$ ; Block time,  $P = 0.001$ ). <sup>t</sup> main effect time (RPE,  $P = 0.001$ ). <sup>i</sup> interaction trial – time (HR,  $P = 0.028$ ; % HR max,  $P = 0.028$ ; RPE,  $P = 0.012$ ).

**TABLE 2.** Fasting plasma concentrations of total cholesterol, high density lipoprotein (HDL) cholesterol, triacylglycerol (TAG), non-esterified fatty acids (NEFA), glucose and insulin in the Rest, Continuous exercise and Intermittent games trials

	Rest	Continuous exercise	Intermittent games
Total Cholesterol ( $\text{mmol}\cdot\text{L}^{-1}$ )	$3.83 \pm 0.13$	$3.74 \pm 0.16$	$3.88 \pm 0.17$
HDL-Cholesterol ( $\text{mmol}\cdot\text{L}^{-1}$ )	$1.27 \pm 0.05$	$1.26 \pm 0.06$	$1.24 \pm 0.06$
TAG ( $\text{mmol}\cdot\text{L}^{-1}$ )	$0.95 \pm 0.06$	$0.80 \pm 0.07$	$0.72 \pm 0.07$ <sup>T</sup>
NEFA ( $\text{mmol}\cdot\text{L}^{-1}$ )	$0.36 \pm 0.05$	$0.51 \pm 0.07$	$0.45 \pm 0.05$
Glucose ( $\text{mmol}\cdot\text{L}^{-1}$ )	$4.90 \pm 0.06$	$5.06 \pm 0.16$	$5.03 \pm 0.15$
Insulin ( $\text{pmol}\cdot\text{L}^{-1}$ )	$111.3 \pm 7.00$	$114.5 \pm 9.0$	$89.8 \pm 7.9$ <sup>T</sup>

Values are mean  $\pm$  SE,  $N = 12$ . Data were analyzed using one-way ANOVA

for correlated means with Bonferroni adjustment. <sup>T</sup> Significantly different from rest trial (TAG,  $P = 0.008$ ; insulin,  $P = 0.032$ ).



**TABLE 3.** Six hour area under the plasma concentration versus time curves for triacylglycerol (TAG), non-esterified fatty acids (NEFA), glucose and insulin in the Rest, Continuous exercise and Intermittent games trials

	Rest	Continuous exercise	Intermittent games
Total TAG ( $\text{mmol}\cdot\text{L}^{-1}\cdot 6\text{ h}$ )	$9.85 \pm 0.77$	$8.02 \pm 0.85^{\text{T}}$	$7.41 \pm 0.61^{\text{T}}$
Incremental TAG ( $\text{mmol}\cdot\text{L}^{-1}\cdot 6\text{ h}$ )	$4.13 \pm 0.50$	$3.27 \pm 0.55$	$3.11 \pm 0.37^{\text{T}}$
NEFA ( $\text{mmol}\cdot\text{L}^{-1}\cdot 6\text{ h}$ )	$2.44 \pm 0.15$	$2.71 \pm 0.17$	$2.74 \pm 0.18^{\text{T}}$
Glucose ( $\text{mmol}\cdot\text{L}^{-1}\cdot 6\text{ h}$ )	$30.46 \pm 0.70$	$31.04 \pm 0.76$	$30.43 \pm 0.47$
Insulin ( $\text{pmol}\cdot\text{L}^{-1}\cdot 6\text{ h}$ )	$1384.1 \pm 102.1$	$1364.0 \pm 120.2$	$1103.6 \pm 65.3^{\text{T}}$

Values are mean  $\pm$  SE,  $N = 12$ . Data were analyzed using one-way ANOVA

for correlated means with Bonferroni adjustment. <sup>T</sup> Significantly different

from Rest (Total TAG Continuous exercise,  $P = 0.028$ ; Total TAG

Intermittent games,  $P = 0.001$ ; Incremental TAG  $P = 0.046$ ; NEFA,  $P = 0.032$ ;

Insulin,  $P = 0.004$ ).

### Legends for figures

**FIGURE 1.** The Loughborough Intermittent Shuttle Test (LIST) protocol. Subjects were allowed 13 s to complete each of the three 20 m walks, the sprint was maximal, and the intensity of the cruise and jog phases of the test was set relative to each subjects  $\dot{V}O_2$  max as estimated on the Multistage Shuttle Run Test. The average intensity of the cruise and jog phases in the study was set at 70/40% of estimated  $\dot{V}O_2$  max. This pattern was repeated 10 times forming one “block” of exercise.

**FIGURE 2.** Fasting and postprandial triacylglycerol concentrations for Rest ( $\circ$ ), Continuous Exercise ( $\blacktriangle$ ) and Intermittent games ( $\square$ ) trials. Mean  $\pm$  SE;  $N = 12$ . Black rectangle indicates consumption of test meals. Data were analyzed using two-way ANOVA (trial - time) with repeated measures with Bonferroni adjustment. Main effect trial,  $P = 0.001$ ; main effect time,  $P < 0.001$ ; interaction time – trial,  $P = 0.420$ .

**FIGURE 3.** Fasting and postprandial insulin, glucose and non-esterified fatty acid (NEFA) concentrations for the Rest ( $\circ$ ), Continuous exercise ( $\blacktriangle$ ) and Intermittent games ( $\square$ ) trials. Mean  $\pm$  SE;  $N = 12$ . Black rectangle indicates consumption of test meal. Data were analyzed using two-way ANOVA (trial - time) with repeated measures with Bonferroni adjustment. <sup>T</sup>significant differences were found in insulin between Rest and Intermittent games (main effect trial,  $P = 0.002$ ) and Intermittent games and Continuous exercise (main effect trial,  $P = 0.031$ ) trials and in NEFA between Rest and Intermittent games (main effect trial,  $P = 0.027$ ) trials.

FIGURE 1.

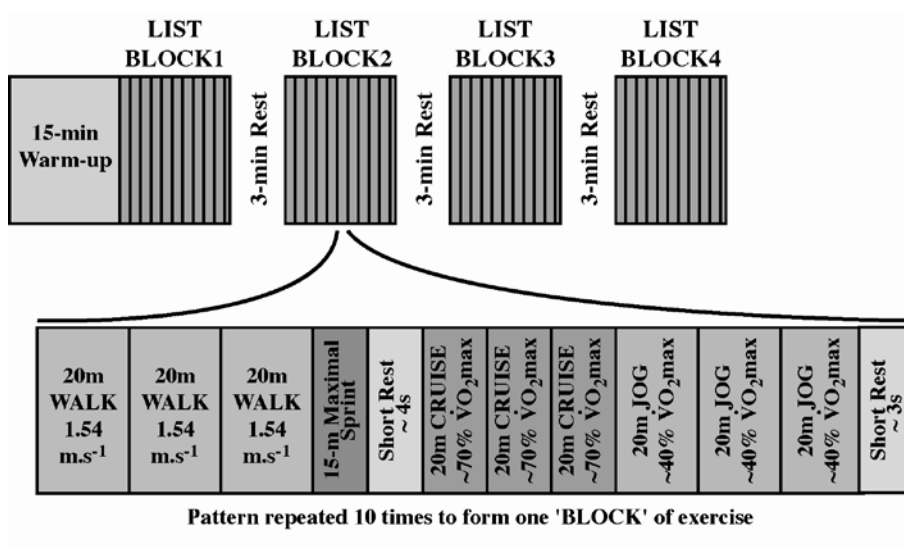


FIGURE 2.

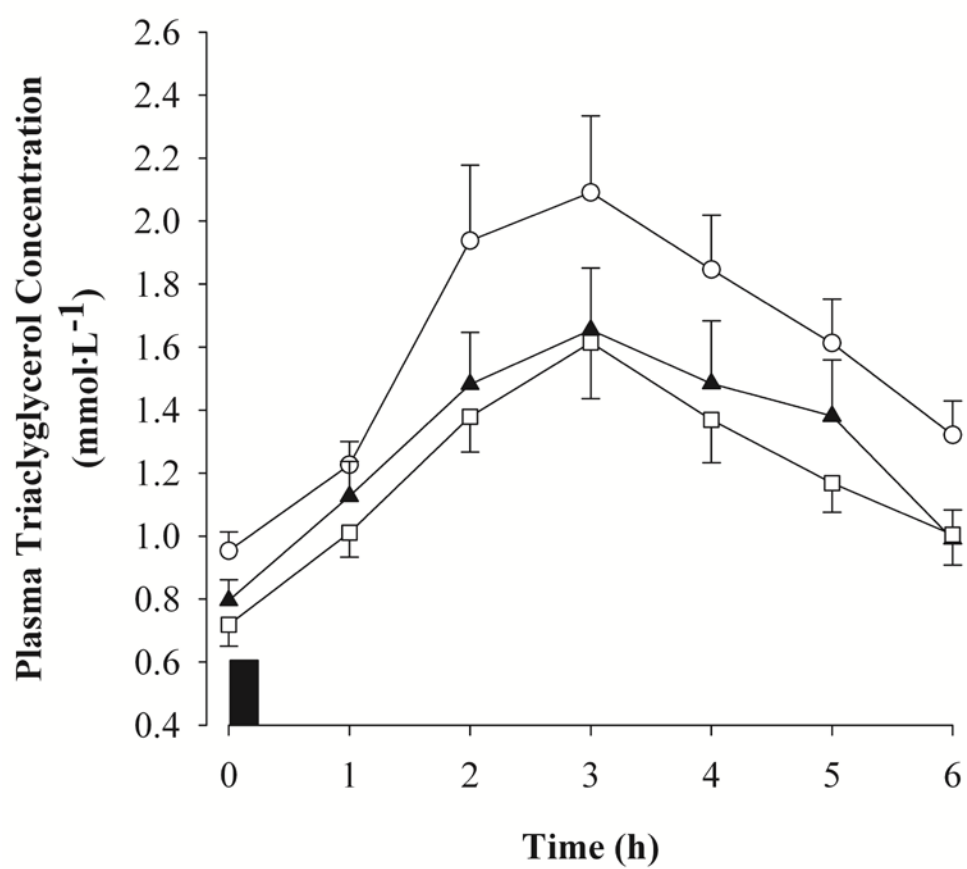


FIGURE 3.

