Accumulating exercise and postprandial lipaemia

Masashi Miyashita*, Stephen F Burns and David J Stensel

1 Tokyo Gakugei University, Department of Health and Sports Sciences, 4-1-1 Nukuikitamachi, Koganei 184-8501, Japan
2 Nanyang Technological University, Physical Education and Sports Science Academic Group, 1 Nanyang Walk 637616 Singapore
3 Loughborough University, School of Sport, Exercise and Health Sciences, New Ashby Road, Loughborough LE11 3TU United Kingdom

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Abstract Cardiovascular disease is a major cause of death in many developed countries. Impaired clearance of postprandial triacylglycerol has been associated with an increase in cardiovascular disease risk. Physical activity can reduce many cardiovascular disease risk factors including postprandial triacylglycerol concentrations. Public health guidelines suggest that physical activity can be accumulated in several short bouts throughout the day, with a minimum duration of 10 minutes per activity bout. Until recently, limited evidence was available to support the effect of accumulating physical activity on postprandial lipaemia. Thus, the authors conducted a series of investigations to examine the influence of accumulated physical activity on postprandial lipaemia. The implications of the research findings are discussed in keeping with practical guidance for those wishing to engage in exercise that will lower postprandial triacylglycerol concentrations.

Keywords: accumulating exercise, exercise patterns, postprandial lipaemia, cardiovascular disease risk

Introduction

In 1979, Zilversmit1 proposed that atherosclerosis is a postprandial phenomenon. Good evidence now supports the notion that the impaired clearance of triacylglycerol (TAG)-rich lipoproteins, namely chylomicrons and very-low-density lipoproteins, is a strong risk factor for cardiovascular disease (For a detailed review of the relationship between postprandial lipaemia and cardiovascular disease, readers can refer to Jackson et al2). Measurement of fasting TAG concentration does not necessarily provide the best index of TAG metabolic capacity, as the major catabolic pathway of TAG-rich lipoproteins occurs during the postprandial state3). Moreover, people spend most of their lifetime, up to three-quarters of each day, in the postprandial state. Thus, repeated daily episodes of increased concentrations of postprandial TAG, often termed postprandial lipaemia, and prolonged residence in the circulation of TAG-rich lipoproteins are considered a risk factor for cardiovascular disease4,5). This notion is supported by the findings of large prospective cohort studies, which reveal that elevated non-fasting TAG concentrations are an independent risk factor for cardiovascular disease in men and women6,7). Thus, it is important to consider lifestyle modifications which may be effective in reducing repeated daily episodes of exaggerated postprandial lipaemia since there is an increased incidence of cardiovascular disease in middle-aged and older populations, particularly postmenopausal women.

Aerobic exercise

Aerobic exercise is one strategy that has been demonstrated to be effective in the reduction of postprandial lipaemia. It is well established that a single bout of aerobic exercise can cause a reduction in postprandial TAG concentrations8,9). The energy expenditure of exercise appears to be the primary determinant of the exercise-induced reduction in postprandial TAG concentrations8). Experimental evidence has shown that walking for 90 minutes at 60% of maximum oxygen uptake or 180 minutes at 30% of maximum oxygen uptake reduced postprandial lipaemia to a similar extent the next morning10). Moreover, a 2-hour walk at 50% of maximum oxygen uptake reduced postprandial TAG concentrations approximately two-fold in comparison with a 1 hour walk at the same intensity11). These data are supported by earlier meta-analysis showing a significant negative relationship between energy expenditure and postprandial lipaemia8). A recent review, however, has questioned this proposal, showing little difference in effect size among studies examining the effect of aerobic exercise bouts eliciting different energy expenditures on postprandial incremental TAG area under the curve8). The authors suggest that while energy expenditure probably plays a role in reducing postprandial lipaemia, it is not the sole determinant of the reduction. Their sugges-
tion is supported by studies of resistance exercise showing no relationship between the energy expenditure of the exercise and reductions in postprandial lipaemia.

The reduction in postprandial TAG concentrations is thought to be mediated via two main mechanisms: 1) an increase in skeletal muscle lipoprotein lipase activity, which enhances the uptake of TAG into previously exercised muscle^{12}, and/or 2) a reduced rate of secretion of hepatic very-low-density lipoprotein TAG^{13}. The reduction is transient, however, since detraining leads to a prompt elevation in postprandial lipaemia^{4}. Thus, exercise needs to be performed frequently for continued benefit.

Although frequent, regular physical activity is undoubtedly important for lowering postprandial lipaemia^{8,10} estimates from many countries suggest that most individuals do not complete a sufficient amount of physical activity to meet the guidelines set out by expert panels^{15,16}. The notion of accumulating physical activity has been proposed as one way individuals can meet daily physical activity targets. Much of this work has examined bouts of exercise with a minimum duration of 10 minutes in length, but the authors have conducted a series of studies to examine how accumulating very short bouts of exercise affects postprandial lipaemia. This is important because if exercise sessions are partitioned throughout the day, it increases opportunities for activity in sedentary/working populations who have low physical fitness levels and/or limited time to commit to longer bouts of activity. Moreover, from a physiological standpoint, if energy expenditure is the prime determinant of postprandial TAG reductions, it follows that individuals should be able to accumulate exercise in almost any pattern and still benefit as long as the total daily energy expenditure of exercise is sufficient.

In one study^{17}, the authors examined the effect of accumulating a large volume (4.18 MJ = 1000 kcal) of exercise in short (6 minute) bouts performed throughout the day on postprandial TAG concentrations in young healthy men. These bouts of running lowered postprandial TAG concentrations, in response to a high-fat breakfast and lunch, by 18% the next day compared with the control resting condition.

In two subsequent studies we examined how accumulating smaller bouts of running, of a total duration in keeping with current guidelines, affected postprandial TAG concentrations. In the first study, accumulating short 5-minute bouts of running, totalling 30 minutes across the day, reduced the postprandial TAG response to breakfast and lunch taken the same day in healthy young men^{18}. The total energy expended during running was 1.76 MJ (420 kcal). The total area under the postprandial TAG concentration versus time curve was 22% and 24% lower on the accumulated and continuous running trials, respectively, compared with the control trial (Fig. 1) whilst the incremental area was reduced by 31% and 32%, respectively.

Collectively these three studies are important as they demonstrate the ability of short bouts of exercise to reduce postprandial lipaemia. However, these studies involved an exercise intensity which is incompatible with the expectations of most sedentary or unfit individuals. We therefore examined how walking, a common form of recreational activity for many, could influence postprandial lipaemia^{20}. We found that accumulating ten, 3-minute bouts of walking (1.1 MJ = 265 kcal) at a self-selected pace, over the course of a day, reduced postprandial plasma TAG concentrations on the next day to a similar extent as that observed after 30 minutes of continuous walking^{20}. These findings are supported by a further study (Miyashita 2008) showing similar reductions in postprandial lipaemia after low-volume (total estimated energy expenditure 0.9 MJ, 200 kcal) cycling performed in either one continuous 30 minute bout or in ten 3-minute bouts^{21}. Importantly, the participants in this study were obese young men exercising at approximately 60% of maximum heart rate (HR max).

The evidence from our studies is consistent, and demonstrates that accumulating exercise in bouts of less than 30 minutes of continuous running versus ten 3-minute bouts of accumulated running were compared in healthy males. The energy expenditure of exercise totalled 2.0 MJ (476 kcal) in both trials and exercise intensity was ~70% of maximum oxygen uptake. The total area under the postprandial plasma TAG concentration versus time curve was 22% and 24% lower on the accumulated and continuous running trials, respectively, compared with the control trial (Fig. 1) whilst the incremental area was reduced by 31% and 32%, respectively.

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**Fig. 1** Plasma total and incremental (adjusted for fasting value) triacylglycerol area under the curve (AUC) values for 7 h after the consumption of test meals in accumulated running, continuous running, and control trials (n = 10). Data are means ± SD. Means were compared using one-factor ANOVA for the main effect of the trial followed by a Bonferroni multiple-comparisons test. There was a significant main effect of trial (*P* = 0.010). * Significantly different from the control trial (*P* ≤ 0.020). (Data from Reference 19).

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10 minutes is sufficient and as effective as continuous exercise for lowering postprandial lipaemia in young healthy and obese men17-21). The authors demonstrate that, for reductions in TAG, the total energy expenditure of physical activity is more important than the pattern of physical activity. Thus, these data could have implications for individuals whose occupational activity is intermittent (e.g. a postman, gardener or cleaner). Moreover, older adults, with limited capacity to perform exercise for long periods because of pre-existing or chronic disease, could potentially benefit from these findings as they may be able to perform bouts of physical activity similar in duration to those described here. However, it is important to recognise that performing multiple bouts of low-moderate intensity exercise to accumulate sufficient energy expenditure may also be challenging for unfit adults to achieve. Thus, there is a need to establish the minimum amount of activity energy expenditure which can lower postprandial lipaemia sufficiently to impact cardiovascular disease risk. Clarity on this threshold could provide practical guidance to the general public that could assist with exercise adherence. In one study, self-report data revealed that overweight women who accumulated short bouts of exercise, with a minimum duration of 10 minutes per session, had better exercise adherence than women who did longer bouts of exercise over 20 weeks of intervention22).

Resistance exercise

In recent years, there has been growing interest in the effects of resistance exercise on cardiovascular health. The authors, therefore, investigated whether resistance exercise could reduce postprandial lipaemia. In an initial study23, 11 healthy young males (age 23 ± 4.6 years, mean ± SD) undertook a high-fat test meal on two mornings at least one week apart in random order: 1) the morning after an 88 minute bout of resistance exercise, or 2) the morning after an inactive rest day. Resistance exercise was performed using free weights and included four sets of 10 repetitions of each of 11 exercises. There was no difference in the 6 hour total (control, 9.8 ± 4.6 mmol·6h/L versus exercise, 9.4 ± 3.7 mmol·6h/L, mean ± SD; \( P = 0.47 \)) or incremental (control, 3.7 ± 2.2 mmol·6h/L versus exercise, 3.8 ± 2.1 mmol·6h/L, mean ± SD; \( P = 0.63 \)) area under the plasma TAG concentration versus time curve between trials. We postulated that low energy expenditure accounted for the failure of resistance exercise to influence postprandial lipaemia, but at least one other study has found a lowering effect of resistance exercise on postprandial lipaemia using a similar energy expenditure to that employed in the authors’ study24.

For these reasons, a follow-up study was conducted25 investigating how performing multiple bouts of light resistance exercise over the course of a day might affect postprandial lipaemia in 24 healthy young adult males (age 23.5 ± 3.4 years, mean ± SD). On day 1 of the exercise trials, participants completed 20 sets of 15 repetitions of 5 different resistance exercises divided into five 45-minute bouts of exercise – 100 sets and 1500 repetitions, in total, for all exercises. Exercises were performed at 30-40% of 1-repetition maximum. For the control trial, participants rested on day 1. On day 2 of each trial, participants consumed a high-fat test meal. Total and incremental areas under the postprandial TAG concentration versus time curve were 12% and 18% lower in the exercise than control trial, respectively (Fig. 2). In terms of the practical applications of findings with resistance exercise, it is suggested that workers whose jobs involve heavy manual labour throughout the day (e.g. builders and construction workers) may gain some benefit in terms of lower postprandial lipaemia.

To date, all the studies examining resistance exercise and postprandial lipaemia have been undertaken in young adults using arduous bouts of exercise29. Moreover, all of these studies have examined the acute response to exercise rather than long-term training effects. Increases in muscle mass often occur with resistance exercise, and recommendations for older adults have proposed that this type of exercise can be used to increase functional capacity in this population26. Given these factors, future studies examining how resistance exercise and resistance training affect postprandial lipaemia in older adults should be undertaken.

Implications for promoting physical activity/exercise

It is not known whether individuals in real-life would ever choose to accumulate leisure-time physical activity in such disparate patterns (i.e. performing lots of short bouts of activity throughout the day) as used in the

![Fig. 2](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAAAoAAAAHgCAYAAAD70tjHAAAABGd7U2QLPUVQsGxIY5gAAAAASUVORK5CYIIQ==)

**Fig. 2** Plasma total and incremental (adjusted for fasting value) triacylglycerol area under the curve (AUC) values for 6 h after the consumption of a test meal in accumulated weight lifting and control trials (n = 24). Data are means ± SD. Means were compared using Student’s t-tests for correlated data. * Significantly different from the control trial (\( P \leq 0.043 \)). (Data from Reference 25).
experiments in these studies. Nevertheless, it has been demonstrated that, for reductions in postprandial TAG, the total energy expenditure of physical activity is more important than the pattern of physical activity. With respect to this aspect, the findings of these studies have potential implications for individuals whose occupational activity is intermittent, and for older adults with limited capacity to perform exercise for long periods because of chronic disease. Future studies need to investigate these implications. Furthermore, estimates in many countries suggest that most individuals do not complete a sufficient amount of physical activity to meet the guidelines set out by expert panels. Thus, the reduction in postprandial lipaemia achieved with accumulating exercise, in line with the minimum dose recommended (intensity \times time) as described in our studies\textsuperscript{20,21}, may encourage more individuals to incorporate a small amount of activity into their lives. In addition, there has been increased interest in identifying the health risks associated with sedentary behaviour and prolonged sitting in particular\textsuperscript{27}. Thus, it would be interesting to examine whether chronic changes in “total standing time”, over several weeks/months under free-living conditions, have beneficial effects on postprandial lipaemia in sedentary individuals.

Summary and conclusions
Postprandial lipaemia is associated with an increased incidence of cardiovascular disease. Physical activity is one strategy for reducing postprandial lipaemia. Accumulating exercise throughout the day has been suggested as one strategy by which many individuals can achieve physical activity recommendations. It was found that accumulating short bouts of exercise - 10 minutes in duration and with a total volume in line with current physical activity recommendations - is as effective in reducing postprandial lipaemia, in response to high-fat meals, as a single longer bout of exercise. In addition, there has been growing interest in the effects of resistance exercise on cardiovascular health. The authors’ data indicate that the effect of resistance exercise on postprandial lipaemia is less consistent than that of aerobic exercise; but when the energy expenditure of resistance exercise was increased, by performing multiple bouts of lifting throughout a day, a reduction in postprandial TAG concentrations, in response to a high-fat meal taken the next morning, was observed in most participants. These data may have relevance for those involved in heavy occupational physical activity. A limitation of this work is that people with exaggerated postprandial lipaemia (i.e. those already at increased risk of cardiovascular disease) were not examined, and this in particular is a gap in the research literature. Thus further studies are required to determine if the lowering of postprandial lipaemia, observed in healthy individuals after accumulated exercise, also occurs in people who have elevated postprandial lipaemia.

References


