A Narrative Review of Various Exercise and Dietary Interventions on Triglyceride Metabolism

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REVIEW

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ABSTRACT

The increased adherence to a high-fat, high-sugar diet places stress on the metabolic system and leads to heart disease. Researchers in the field of lipidology have sought nonpharmaceutical options to attenuate chronic increased levels of free circulating triglycerides (TG). This narrative review concerns common practices and recommendations for researchers and practitioners seeking information relating to recommendations for methodologies and statistical practices. The information provided is of particular importance to persons with hidden postprandial lipemia, a progressive condition which is commonly overlooked in health evaluations. This concise review pays specific attention to Kilocalorie and Macronutrient content variability among commonly used oral fat tolerance tests (OFTT). As not all substrates metabolize in the same way, the composition of previously utilized OFTT should be scrutinized. Further attention is given to the aerobic and anerobic (resistance) training effects on metabolism. Regular adherence to an exercise program improves all measures of a lipid panel, including a reduction in TG, low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) subfractions, and an accompanying increase in circulating high-density lipoproteins (HDL) and metabolic rate (oxygen consumption). This increased prescription of exercise, both aerobic and anaerobic, by a physician or primary care provider. This review also highlights discrepancies among OFTT methodologies and supports the need for a reliable OFTT.

Keywords: Resistance training, lipolysis, cardiovascular disease, metabolism, aerobic training, high-intensity interval exercise.

ABBREVIATIONS

AUC: Area Under the Curve

CHO: Carbohydrates

HDL: High-density Lipoproteins

HIIE: High-Intensity Interval Training

LDL: Low-density Lipoproteins

LPL: Lipoprotein Lipase

OFTT: Oral Fat Tolerance Test

PPT: Post-prandial Triglycerides

TG: Triglycerides

VLDL: Very-low density Lipoproteins

INTRODUCTION

Much of the population adhering to a Western diet spend the day in a postprandial (or fed) state. An effect of perpetually being in the postprandial state is the constant elevation of TG throughout the day. Elevated TG levels have been linked to cardiovascular disease and atherosclerosis, with the former being the leading cause of mortality and morbidity among industrialized countries [1,2]. Cardiovascular disease is the number one cause of mortality worldwide, therefore it is imperative that research focus on behaviors which limit the risk of developing this disease. Regular exercise has consistently shown to reduce the deleterious effects of multiple diseased conditions, including obesity and dyslipidemia. Chronic exercise attenuates TG elevation following feeding, as do some forms of acute exercise [3-6]. The determining factors of TG response to exercise appear to be the volume of kilocalories consumed, the time relative to feeding, and the intensity of the exercise [7]. There is data available which supports a decrease in postprandial triglycerides (PPT) following acute exercise among various exercising populations [8-11]. The results among the literature are dependent on timing of data collection relative to the exercise bout, intensity of the exercise, type of exercises employed, and substrate structure of the test meal or OFTT. There is a need for standardization practices among researchers in the field of lipidemiology, as the substrate concentrations among the various OFTT increase the probability of a type-2 error. For example, a high-calorie/high-fat test meal would require an increase in exercise intensity and/or duration to observe the noticeable effects of metabolism overtime. Conversely, a low-calorie/low-fat test meal may overestimate the effects of exercise on metabolism or be too low in fat to stimulate a noticeable resting effect. Metabolic standardizations should also be given to the time in which the OFTT and independent variable are measured.

Timing of Data Collection

The timing in which PPT metabolism following exercise is measured has been previously debated among the literature. Early investigations sought to determine the acute effects of exercise on lipid metabolism immediately before or after the ingestion of an OFTT. These early investigations commonly found lipids to be unchanged or elevated within these time parameters [12]. This elevation of lipids is due to the increase in lipolysis which occurs immediately following a high fat meal. Current research endeavors concur with a model consisting of an exercise bout, followed by 10-16 hours (commonly an overnight fast), followed by the administration of an OFTT [13]. As lipoprotein lipase (LPL) activation peaks between 4-16 hours, this delayed model identifies the desired metabolic effect [14]. An investigation by Zhang, et al. sought to determine if pre-meal exercise or post-meal exercise had a greater influence on triglyceride metabolism [15]. Following an overnight fast of 12-hours, participants ingested a meal consisting of 121g carbohydrates, 26g protein, and 29g fat, at varying times dependent on each trial. The exercise intervention for all groups consisted of a single bout of treadmill activity, at 60%VO2max, for 1-hour. The post-meal trial consumed the OFTT and performed the exercise protocol one-hour post-feeding, the 1-hour pre-exercise trial completed the exercise trial followed by the OFTT, and the 12-hour pre-exercise trial completed the 1-hour exercise protocol the evening prior to ingestion of the OFTT. The control trial did not participate in exercise and consumed the OFTT following the overnight fast. Blood samples were taken at 0, 2, 4, 6, 8, and 24 hours, with the 0-hour being the onset of the OFTT. These data revealed that PPT were attenuated among both pre-meal exercise trials, however, the magnitude by which TG were attenuated was greater among the 12-hour pre-meal exercise trial than was the 1-hour pre-meal exercise (51% and 38% AUC, respectfully). These findings were consistent with similar investigations determining the optimal time for observing the acute exercise effects on TG is 12-16 hours following the exercise intervention [7,16]. Additionally, the consensus among researchers is the beneficial effects of acute exercise are absent 24-hours following the activity [7,14,15]. This includes the hydrolysis of free-fatty acids (FFA), including TG, through LPL activation following exercise [15].

Effect of Exercise on PPT

Aerobic Exercise Effects on Triglyceride Metabolism

Aerobic Exercise Does Not Attenuate PPT

There remain few research studies which have found that exercise does not attenuate PPT. There are varying possible causes for this lack of attenuation of PPT. In studies of young males with a walking intervention, no attenuation of PPT were observed [1,17]. A commonality of these, and similar investigations yielding nonsignificant results, is the intensity of exercise is too low to elicit a change in circulating TG. One such investigation utilized 30-minutes of moderate walking (50%VO2max) 12-hours prior to a high fat meal, and no differences of TG metabolism were observed [17]. Additionally, the OFTT used in the aforementioned investigation contained one gram of fat per kilogram of body weight with no carbohydrates [17]. This exceedingly high concentration of lipids is too great for the light exercise to effect change within the measured time.

The timing at which TG metabolism is measured is cause for type 2 error, in which researchers do not observe a significant change within the examined time. One such design examined the exercise effect of 30, 60, and 90 minutes of walking on TG metabolism. Sixteen healthy males participated in three walking trials at 50%VO2max [1]. The OFTT of roughly 35g of fat was administered immediately following exercise and blood analysis was recorded over a 6-hour period. No statistical significance was reported among all trials, which is contrary to similar exercise interventions, in which 90-minutes of walking at 50%VO2max attenuated PPT among 20 healthy men by 29% (47.2±9.2 years) [18]. The latter investigation administered the exercise intervention the evening prior to the OFTT, following an overnight fast of 12-hours; whereas the former investigation administered the OFTT immediately following exercise. Between 12-16 fasted-hours following exercise is the optimal time to observe the PPT response [15]. Investigations utilizing a protocol of feeding and blood analysis directly preceding or following exercise are unaware of the changes occurring at 12-hours postprandially. These nonsignificant findings highlight limitations of previous investigations which did not have an appropriate lipid collection timing, OFTT, or exercise intervention within the methodology. Comparing data which has shown no change against the data which indicated a positive change, will guide future researchers in the selection of an exercising model and time of blood analysis. Researchers need to be aware of the current methodological practices in the field with regard to time of feeding, test meal substrate composition, and exercise intensity.

Aerobic Exercise Attenuates PPT

Most investigations have found an attenuation of PPT following acute exercise. When utilizing a lower percentage (50%) of VO2max as a measure of intensity, it is necessary to exercise for a longer duration (1-2 hours) to decrease postprandial triglycerides; the longer the duration, the greater an impact on attenuating PPT [12,19,20]. Exercising at 60-70% of VO2max for duration of 0.5-1 hour has been shown to reduce PPT elevation. When developing a protocol in which higher intensity exercise is established, a shorter duration is required to elicit similar effects, as is shown in the long duration/low intensity groups [15,17]. The amount of exercise required to elicit a response has also been measured in the amount of caloric energy expended. It has been observed that the accumulation of 500-kilocalories during exercise is enough to stimulate a decrease the elevation of PPT, regardless of the intensity [2,7]. An energy deficit created through caloric restriction does not appear to reduce PPT, however, a decrease in caloric intake coupled with light exercise (30% VO2max) stimulates the attenuation of PPT [12,21]. Researchers have also examined the process of accumulating exercise compared to continual exercise. The results of which indicate an accumulation of exercise throughout the day is equally beneficial in attenuating PPT as is a single continuous bout of exercise [22,23].

Chronic adherence to an aerobic exercise regimen enhances the metabolic capacity to process lipids. The stimulation of adipose triglyceride-lipase is the mechanism by which fatty acid mobilization is affected by exercise [24].

In an eight-week endurance training protocol, researchers sought to examine the metabolism of TG within the skeletal muscle. Ten healthy untrained men (30 years of age) underwent a VO2max, muscle biopsy, and blood analysis prior to the start of the trial. The exercise intervention included 40-90 minutes of cycling three times per week in weeks 1 and 8, four times per week in weeks 2 through 6, and five times in week. The results show an increase in adipose triglyceride-lipase activity, indicative of an increase in fatty acid mobilization and utilization when adhering to an 8-week endurance protocol, further supporting chronic adherence to exercise [24].

High-Intensity Interval Exercise Effects on Triglyceride Metabolism

Researchers suggest the intensity of exercise, not the duration, has a greater influence on TG metabolism. One such investigation examined walking and high-intensity intermittent exercise (HIIE) [22]. The protocol required 2 days per trial, for a total of 6 days, with a minimum 7 days between trials. Participants reported back following an overnight fast and consumed a standardized breakfast and lunch over a 7-hour period. The meals were individualized to the participant's body weight and consisted of 56% fat, 33% carbohydrates, and 11% protein, for an average of 917-kilocalories. The findings revealed that the HIIE trial experienced an attenuation of PPT elevation (50.78% CI, $p<0.05$). Furthermore, there was no change in TG metabolism among control and walking groups. Their findings also show the beneficial effects on TG extend across two meals (both breakfast and lunch). Additionally, HIIE were the only group to elicit a protective mechanism against oxidative stress markers, as shown by an increase above baseline in protein carbonyl levels among the control and walking groups ($p<0.05$) [22]. These findings are an indication that volume of exercise (not duration) can bring about advantageous metabolic changes. A follow-up investigation sought to answer the question of the duration and mechanism for the beneficial effects of HIIE examined over a 48-hour period [25]. On day one participants either participated in HIIE cycling or the non-exercise control. Participants reported to the lab (9:00 hours) following an overnight fast and ingested a standardized breakfast of 812±96-kilocalories, consisting of 56% fat, 33% carbohydrates, and 11% protein; this meal was replicated for lunch 3 hours later. Data analysis found that prior HIIE attenuated TG elevation on the following day, but these benefits were not present 48-hours after a bout of HIIE (26.94% CI, $p\leq0.05$). The mechanism by which this attenuation occurs is a result of the reduction in VLDL released from the liver along with an increase in circulating LPL and subsequent reduction in TG. These investigations give credence to the practice of anaerobic work as means to decrease circulating TG [25].

The use of shorter duration cycle sprints on TG metabolism have also been examined utilizing an exercise trial of 8 seconds of maximal cycling followed by 12 seconds of active rest (light cycling) for 20-minutes [26]. Following an overnight fast, participants ingested a high-fat meal of 996.7-kilocalories constituting 98g fat, 24g carbohydrates, and 8.4g protein. The results show that prior HIIE significantly decreases next-day postprandial triglycerides in young women (81% confidence interval, 13% decrease) [26]. This investigation highlights the probability of a volume effect of exercise on TG and offers the possibility of a unique training regimen, such as daily exercise accumulation, to improve one's lipid profile.

In comparing the aforementioned investigations we see there is no effect of sex on HIIE among younger persons [25,26]. Interestingly, the study using short duration cycle sprints of 8 second sprints and 12 seconds of active rest for 20 minutes showed a markedly less PPT attenuation than did the sprint trial employing 4 minutes of active rest [25,26]. This can likely be attributed to the generalization of the OFTT or total volume of exercise and not a difference of sex. The meal used in the 4 minutes active rest study fed participants based on their relative weight in kg (56.8±6.1g fat), while the 12 second rest trial delivered the same oral fat load to all participants (98g fat). It seems likely there exists an OFTT threshold, above which an exercise intervention would fail to meaningfully attenuate the extreme amounts of lipids ingested. The

influence of HIIE and moderate-continuous exercise on PPT metabolism has shown to have beneficial effects 2. One such investigation sought to neutralize the volume discrepancy responsible for the beneficial effects of exercise, consisting of a control, moderate continuous, and intense intermittent exercise. Each exercise trial was concluded upon reaching an energy expenditure of 500 kilocalories. The OFTT was individualized and consisted of 1 gram of fat per kilogram of body weight (69.2±9kg). Both the continuous and vigorous trials showed a reduction in PPT over the control group (24% and 18%, respectively) from the 2nd to the 4th hour over the control. However, the vigorous trial elicited a decrease in very-low density lipoproteins in the 3rd and 4th hour which was not seen among the continuous trial. These results indicate that when volume is controlled, both continuous and vigorous intermittent exercise attenuate PPT. This design has a limitation, in that the continuous group (walking at 85%VO2max) are exercising at a higher intensity than is commonly practiced. This higher intensity likely utilized more intramuscular lipid stores than would a traditional moderate intensity (65%VO2max). Additionally, it has been observed that the optimal time for blood analysis following an OFTT is 12-18 hours post-exercise due to the peak time for LPL activation [11]. It is possible blood analysis 12-18 hours following the meal would reveal differing results. These data show a reduction of PPT through anaerobic pathways, leading to the question of resistance training effects on TG metabolism.

Resistance Exercise Effects on Triglyceride Metabolism

Postprandial lipemia is linked to cardiovascular disease, insulin resistance, glucose intolerance, central adiposity, and hyperlipemia [27]. The interaction of resistance training on postprandial lipemia has been examined among younger persons (24.3±2.9 years) participating in either a resistance training trial, aerobic trial, or a non-exercise control trial. Following exercise, and a 12-hour overnight fast, participants consumed a high fat meal and blood was collected at 0, 1, 2, 3, 4, 5, and 6-hours post-feeding. These data revealed a decline in PPT within the resistance training trial at 0, 1, 2, and 3-hours compared to both the control and aerobic trials [27]. There is a greater effect of acute exercise when utilizing resistance training and isolates resistance training as a more effective long-term lipid clearance modality (22% CI, p≤0.01). The participants were recreationally trained, and performed resistance training, 3 days a week for 6 years. This population, having been chronically trained and experiencing the improvements in muscle quality therein, do not accurately represent the acute changes to lipid metabolism which occur following resistance training among sedentary individuals; however, it can be inferred that these benefits would be extenuating. The resistance training protocol utilized resembles a circuit training protocol, employing aerobic qualities, and does not identify the effect of a traditional strength or hypertrophy training. Furthermore, the utilization of a whole-body protocol lasting 88-minutes is not practical for all populations.

A further investigation sought to determine the effectiveness of volume matched resistance training to that of endurance training. The endurance trial consisted of 90 minutes of treadmill walking at 30%VO2peak. The resistance trial performed 90 minutes of resistance training specific exercises. The resistance protocol consisted of 12 exercises constituting an upper and lower body workout, of three sets of ten repetitions, at 80% peak torque, with 2 minutes rest between sets. Following a 12-hour overnight fast, a catheter was inserted into the forearm and the participants were given a glycerol solution. This was followed by 6-hours of blood collection and analysis to follow the metabolism of VLDL. The results show that the rate of VLDL clearance is increased, leading to a decrease in concentration and circulation among the resistance trained trial (p=0.034, d=0.33) [13]. No significant change was observed among the endurance trial from baseline (p=0.191). It is important to note that this investigation has the following limitations:

1) The sample examined (n=7) is relatively small and not representative of the population.

2) This sample contained only male participants and therefore cannot be used to extrapolate the resistance training effects on females. This becomes problematic due to the naturally occurring differences of circulating testosterone and subsequent differences in protein synthesis with resistance training.

3) The exercise protocol employed in the endurance trial, although matched for time, was not matched for intensity. The endurance trial, at 30%VO2peak, is classified as light exercise, whereas the resistance training trial, at 80% peak torque is a moderate to vigorous intensity.

The effects of circuit training on strength among older adults was examined in a longitudinal, 12-week, study that utilized 35 older adults (aged 68.3±4.9), divided into an exercise group and a non-exercise control [28]. The exercise group trained three times per week for duration of 30-minutes of resistance training each time. The circuit incorporated 12 resistance training exercises, and 12 aerobic dance exercises, to constitute a full body workout; each exercise was 30 seconds in length and involved 10-15 repetitions. The participants performed these exercises at 70% of their maximal heart rate. These data show increases in oxygen consumption, HDL subfractions, lactate threshold, muscular strength (evaluated by an increase in weight lifted over time), and a decrease in body fat. The utilization of a whole-body workout which incorporates aerobic and anaerobic activity is important for the older adult population, as they are likely not independently exercising all components of health-related physical fitness. However, this investigation does not allow for the examination of the individual contribution resistance training has on muscle quality and strength. Additionally, the resistance training employed constitutes muscular endurance training, which has an inherent aerobic contribution. Further investigation into traditional resistance training design influences on lipid attenuation is required.

Strength to Mass Imbalance

Muscle quality is the observed strength of the muscle relative the muscle mass [29]. The adherence to a resistance training program improves muscle quality and lipid metabolism, yet resistance training is often overlooked when prescribing an exercise intervention [13]. Walking is a commonly prescribed form of exercise and has shown to be an effective tool in reducing lipid levels and reducing instances of mortality and morbidity [30]. However, walking does come with inherent limitations, including access to a safe walking area, specificity of muscle activation, and measured intensity of exercise. For example, older adults cite safety as a primary concern for performing outdoor walking [27]. Additionally, the limited budget of some populations does not allow for at-home fitness equipment or gym membership. The principle of specificity states that gains from exercise are limited by the exercise performed. Therefore, if an increase in muscle quality is the anticipated exercise outcome it would require the increased muscle activation brought about through resistance training. Although studies on self-selected intensity of exercise have shown to induce the positive effects of training; the utilization of resistance training is easier to quantify and report to a primary care physician (eg. 3 sets of 10 push-ups). Unfortunately, physicians are not typically trained exercise physiologists, and do not “prescribe” resistance exercise as tool for preventative medicine. In documenting regular resistance training, physicians will be able to track any strength abnormalities. This is especially important among older persons who could attribute the decline in strength to the aging process and overlook a progressive disease condition. Physicians and exercise practitioners should stress the importance of a resistance training program among older adults. Further, resistance training should be used as an effective tool to reduce and maintain lipid levels (specifically TG) thus limiting the need for pharmaceutical intervention and lowering health care cost. Although some health care providers have already adopted the practice of inquiring as to their patient’s frequency of exercise; there exists a need for a more detailed explanation of exercise activities, with an emphasis of resistance training.

Chronic Adaptations to Resistance Training

An acute bout of resistance training has shown to attenuate PPT elevation following an OFTT. The chronic adaptations of resistance training on lipids further outlines the importance of adapting to a lifestyle incorporating resistance training. In a 14-week investigation examining the resistance training effects on triglycerides including three bouts of resistance training (8 exercises, both upper and lower body), 45-50 minutes in duration, and two sets of eight repetitions, and a third set to exhaustion [30]. The resistance was set at 85% of the one-repetition maximum and participants were given 30-60 seconds of recovery between sets. The one-repetition maximum was reevaluated weekly and resistance was adjusted accordingly. These data revealed a decrease in body fat (5%), low-density lipoproteins (14%), total cholesterol (14%), and total cholesterol/high-density lipoprotein ratio (14.3%) [30]. It can therefore be extrapolated that chronic resistance training has beneficial effects on overall lipid panel. Although there was no observed effect among TG it is important to note that an OFTT was not administered in this investigation and active TG metabolism was not a variable.

Table 1: OFTT Variability Among the Literature; carbohydrates (CHO), Triglycerides (TG), Area under the curve (AUC) atherosclerotic process among this population [16,31,32]. As such, it is not ideal to use this population when developing and administering an OFTT. Additionally, there appears to be a lack in heterogeneity of participants, including males and females ages 35-65, and a power analysis of the nondiabetic, male and female, group reveal a small effect size (n=20, f=23.2%, α=0.05). This OFTT has not been accepted by research or clinical communities. Further investigation into the development of a reliable test is required. Numerous investigations have been published since the aforementioned attempt of creating a standardized OFTT. These meals have varied widely in composition and substrate utilization, including solid or liquid meals of varying fat and carbohydrate concentrations. This further supports the necessity for the continued investigation of a reliable standardized OFTT for clinical and research application.

OFTT Variability

There is not currently a universally accepted OFTT for research or clinical application. This has led to the development of a wide variety of high-fat meals reported in the literature. There are obvious detriments to the lack of a standardized OFTT, including the lack of generalizability of an independent variable on lipid metabolism and the increased likelihood for error upon statistical analysis. Common OFTT have included a large dose of heavy whipping cream or a sandwich with high-fat accompaniments, such as mayonnaise, chips, and milk (Table 1) [22,26]. The metabolic discrepancy of solid to liquid meals presents the first problematic methodology. Liquid meals metabolize faster than solid and often have less variety of substrates [16,31]. The most cited rational behind a solid high-fat meal is that is replicates that of a normal meal a person would consume. However, if the goal is to isolate the lipid response to a postprandial challenge, the OFTT should be liquid and contain primarily lipids. There is an accompanying LPL response to insulin stimulation which confounds the desired results when using an OFTT containing a high carbohydrate dose 16. Additionally, there is a discrepancy among metabolism rates of varying carbohydrates, such as simple (white bread) or complex (whole grain), which is not reported among investigations employing a solid OFTT. There has been an attempt at OFTT standardization, using 200-ml of a liquid consisting of 50g of fat and 50g of simple carbohydrates, administered to diabetic and nondiabetic subjects [32]. The aforementioned investigation developed an easily reproducible meal, as well as validated the use of capillary blood sampling against venous values; however, the 1:1 fat to carbohydrate ratio is not ideal when evaluating the specific action of lipid clearance. Diabetic and obese persons elicit a delayed clearance of TG, which further progresses the

Clinical Applications of an OFTT

Recent literature has determined the use of fasting TG values as a diagnostic tool is not appropriate for those

who potentially have cardiovascular health risks. It is common for persons with coronary heart disease to display normal fasting TG values yet have an undesirable PPT response [39]. This increased elevation of TG, coupled with a decreased clearance time, facilitates a prolonged elevation of circulating plasma TG and can lead to vascular damage and disfunction. Further, participants with fasting TG values between 89mg/dL and 180mg/dL appear to have an increased likelihood of displaying hidden postprandial lipemia ($p<0.001$) [39]. A similar investigation found that fasting and PPT were increased in persons with coronary artery disease over that of normal healthy persons ($p=0.001$). Additionally, it appears that persons with coronary artery disease are more sensitive to a postprandial challenge, rather than fasting values alone [40]. These findings support the clinical application of a standardized OFTT among persons with fasting TG values of 89-180mg/dL to uncover hidden postprandial lipemia, a precursor of the disease condition dyslipidemia. This practice would lead to the early detection of cholesterol related coronary artery disease.

STATISTICAL ANALYSES

There is some debate as to which statistical analysis is appropriate among research employing an OFTT. Commonly seen analysis includes repeated measures ANOVA with simple main effects, and area under the curve (AUC). Firstly, it is imperative that the statistical analysis answer the proposed question. A repeated measure ANOVA detects differences between the related independent and dependent variables across all conditions. In an investigation monitoring PPT following an OFTT from Hashimoto, et al. data were analyzed through repeated measures ANOVA, isolating the time-course changes from baseline values 41. Using AUC is suitable when examining time and duration of exposure, in this case, PPT. Although AUC provides data that is concise, easily comparable with other reported AUC, and compatible with other analysis (such as correlation), it should serve as a supplementary analysis of the outcome variable. AUC analysis can beget misleading results, as well as misclassification of distributions [42]. The AUC is dependent on empirical score distributions and relies on uniform distribution of specificity. Although AUC is an objective measure and is easily comparable, as all data points have been transformed, caution should be taken when collapsing data from multiple investigations due to the decreased likelihood of uniform distribution [42]. Therefore, we conclude that the statistical analysis of TG following an OFTT must include a repeated measures ANOVA (or similar analysis) to uncover any differences between the associated means. An AUC analysis should be considered as a supplementary outcome variable, as it will aide in data interpretation and will more easily facilitate cross-reference comparisons.

LIMITATIONS

Any review of the literature is not without limitations, to include potential bias, gaps in the literature, or a misinterpretation of the original source. These limitations have been mitigated. Any inferences to physiological function have been referenced and cited to avoid any potential bias. Studies employing an OFTT in the Methodology were sought out for this review. Current and past researches were examined, with greater attention to the former, as the practice of utilizing an OFTT is relatively current. This review presents both significant findings and non-significant findings. This dichotomy is important as the substrate concentrations within the OFTT could result in a type-2 error. The details within this review regarding statistical values, OFTT substrates, and methodologies have been included to avoid misinterpretation of the original source.

CONCLUSION

Acute and chronic exercise of sufficient energy expenditure attenuates PPT. The apparent discrepancies in OFTT design among the literature highlights the importance of a universally accepted, reliable, OFTT. As lipid metabolism is a complex process, the process of OFTT design is likely one which will require multiple investigations. Special attention needs to be given to the

concentration ratio of fat to carbohydrates, as well as specific fat type. An OFTT high in carbohydrates, especially simple carbohydrates, should be avoided to limit the metabolic contribution of insulin. A proactive approach to cardiovascular disease using a fasted OFTT would identify those at risk for hidden postprandial lipemia. Early intervention and healthcare planning would limit the need for pharmaceuticals and lower overall health care cost.

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PEER REVIEW

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TABLES

Table 1: OFTT Variability Among the Literature; carbohydrates (CHO), Triglycerides (TG), Area under the curve (AUC) atherosclerotic process among this population [16,32].

Reference	Subjects	Meal composition	Fat load content	Time before fat load	Postprandial response
Cohen, 1989[5]	M, n=30, 25y	Cream, chocolate flavor	40g fat & 140g fat	n/a	n/a
Hashimoto, 2011[17]	F, n=8, 21y	Cream	0.35g/kg (~17.92g)	12h	No Δ
Harrison, 2009[33]	M, n=8, 27y	Croissants, butter, ice cream, chocolate, chips	97g fat, 124g CHO	10h	↓TG
Herd, 2001[34]	M/F, n=53, 22-26y	Whipping cream, fruit, cereal, nuts, and chocolate	1.2g/kg fat (~80.4g), 1.1g/kg CHO (~73.7g)	12h	No Δ
Ferreira, 2011[1]	M, n=20, 21y	Nuts, eggs, milk powder, olive oil	1g/kg fat (~69.2g), 0.62g/kg CHO (42.9g)	30min	↓TG AUC
Freese, 2011[35]	M/F, n=12, 20-22y	Croissant, omelet, cheese, sausage, hash brown potatoes	1.2g/kg fat (~85.36g), 0.9g/kg CHO (~64.02g)	13h	↓TG AUC
Gabriel, 2012[22]	M, n=9, 24y	Bread, mayo, butter, whole milk, cheese, chips	0.7g/kg fat (~56.7g), 1g/kg CHO (~81g)	*"overnight"*	↓TG
Gill, 2006[18]	M, n=20, 47y	Whipping cream, fruit, cereal, nuts, chocolate	80g fat, 70g CHO	12h	↓VLDL
Gill, 2002[36]	F, n=11, 24y	Whipping cream, fruit, cereal, nuts, chocolate	1.3g/kg fat (~78g), 1.2g/kg CHO (~72g)	12h	↓TG
Gill, 2000[12]	F, n=12, 60y	whipping cream, oats, nuts, coconut, chocolate, fruit	1.7g/kg fat, 1.65g/kg CHO	12h	↓TG
Maraki, 2008[21]	F, n=8, 27y	Vanilla ice cream, whipped cream, syrup	1.2g/kg fat (~75.48g), 1.1g/kg CHO (~69.19g)	12h	↓TG AUC
Miyashita, 2010[37]	M, n=10, 46y	Bread, cheese, butter, mayo, cocoa powder, yogurt	0.34g/kg fat (~31.45), 1.11g/kg CHO (~102.68)	10h	↓TG AUC