TRIGLYCERIDE METABOLISM FOLLOWING ORAL FAT TOLERANCE TESTS OF VARYING FAT CONTENT IN ADULTS

By

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A dissertation submitted in partial fulfillment
of the requirement for the

Doctor of Philosophy - Interdisciplinary Health Sciences

Department of Kinesiology and Nutrition Sciences
College of Allied Health Sciences
The Graduate College

University of Nevada, Las Vegas
May 2019

Dissertation Approval

The Graduate College
The University of Nevada, Las Vegas

April 09, 2019

This dissertation prepared by

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entitled

Triglyceride Metabolism Following Oral Fat Tolerance Tests of Varying Fat Content in Adults

is approved in partial fulfillment of the requirements for the degree of

Doctor of Philosophy - Interdisciplinary Health Sciences
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Abstract

Introduction: Investigations of lipid metabolism commonly utilize an oral fat tolerance test (OFTT) to elicit a dramatic increase in serum triglycerides (TG). Although this is common practice there does not currently exist an agreed upon formula for an OFTT. Nor has there been in investigation as to the reliability among commonly used OFTT. Furthermore, the effects of sex and activity level are mixed among the literature. The purpose of this investigation is to discover an ideal OFTT for research and clinical purposes, evaluate the effects of activity and sex on TG metabolism, and to test each OFTT concentration for reliability.

Methods: A sample of 30 healthy college-aged adults consumed three different OFTT, with a seven-day washout. The population consisted of 8 active males, 9 active females, 7 sedentary males, and 6 sedentary females. The OFTT consisted of fat concentrations approximating 50g, 100g, and 150g. An additional OFTT of one of the aforementioned concentrations was administered to determine reliability.

Results: Plasma TG was lower among the 50g load compared (1h = 134±20, 2h = 140±15, 3h = 130±15, 4h = 125±20 mg/dL) compared to the 100g (1h = 170±20, 2h = 180±25, 3h = 170±25, 4h = 160±20 mg/dL) and 150g loads (1h = 175±20, 2h = 200±25, 3h = 180±30, 4h = 175±20 mg/dL) ($F=1.508$, $p=0.033$). Females showed greater attenuation of TG among than did males within the 100g load from the 2-3-hour time point Females 3h = 152±71, Males 3h = 186±106)($F=3.115$, $p=0.049$). The 100g load has the greatest reliability outcome, with an ICC of 0.924 ($p<0.001$).

Conclusion: The proposed 100g OFTT load is ideal for lipid testing and has shown to be valid and reliable. Persons maintaining an active lifestyle metabolize TG more efficiently than their sedentary counterparts. No difference of TG metabolism is present between sex.

Acknowledgements

This project would not have been possible without the unyielding support of my advisor, Dr. James Navalta. Thank you for always believing in me and supporting my research endeavors. It has been a great pleasure to have had the opportunity to work with such an honorable human being.

Thank you to the members of my dissertation committee: Dr. James Navalta, Dr. Jennifer Kawi, and Dr. Timothy Bungum. Though your schedules are perpetually full you always made time for me and I am sincerely grateful.

I would like to thank the faculty and staff within the College of Allied Health Sciences. Thank you for facilitating a pleasant environment in which to learn and grow as a professional.

I would like to thank my peers for their support and encouragement throughout my time here at UNLV: Jeffery Montes, Charli Aguilar, Elizabeth Tanner, Dustin Dunnick, Kristy Wigand, Takahiro Iwatsuki, Andrew Craig-Jones, Lidio Albuquerque, Daniel Lidstone, Cordero Roche, and Jessica Deberardinis.

I would like to thank all those who participated in the data collection for investigation. Further, I would like to thank my research assistants who aided me in this endeavor: Stacie Gomez, Mara Quinonez, Pidim Mukherjee, Alexander Mirzoyan, Chloe Lee, and Duy Le. Thank you for your time and efforts. I wish you all the best on your future endeavors.

Last, but certainly not least, I would like to thank my undergraduate advisor, Dr. Bryan Haddock, and my master's advisor, Dr. Treavor Gillum. Thank you for inspiring me to see my potential.

Dedication

Firstly, this culmination of my collegiate career is dedicated to my son, Byron. You are my light in the darkness, my heart, my soul, my everything. May you continue to explore this world and beyond with undying curiosity.

Thank you to my best-friend and partner, Annie. I absolutely would not be here if it was not for your loving support.

Thank you to my amazing family: Brad Bodell, Rene Adams, Linda Bodell, Kenny Adams, Matthew Bodell, Katie Bodell, and my wonderful nieces Abigail, Hannah, and Beth. I love you all more than you know.

Lastly, thank you to my beautiful friends Floyd and Deedee. You have always been a shining beacon of support and love.

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List of Acronyms

TG – Triglycerides

OFTT – Oral fat tolerance test

PPT – Postprandial triglycerides

LPL – Lipoprotein lipase

ACSM – American College of Sports Medicine

NSCA – National Strength and Conditioning Association

50g – OFTT containing macronutrients: 49.5g fat, 19.13g CHO, 14.5g Protein

100g – OFTT containing macronutrients: 99g fat, 38.25g CHO, 29g Protein

150g – OFTT containing macronutrients: 148.5g fat, 57.38g CHO, 43.5g Protein

POLY – Polyunsaturated fat

MONO – Monounsaturated fat

CHO – Carbohydrate

ICC – Interclass correlation coefficient

CVD – Cardiovascular disease

1.0 Introduction

Cardiovascular disease is the leading cause of premature death in the United States[1]. Primary contributors to this effect are vascular diseases, such as atherosclerosis. Prolonged elevation of circulating blood lipids can lead to vascular damage[1]. Chronic elevation of blood lipids is compounded by frequent high dietary fat intake, commonly observed in the Western diet. A primary mover of lipids are small fatty acid particles called triglycerides (TG). These fatty-acid movers allow for the transport of fatty acid substrates throughout the body. In a disordered condition the circulating triglycerides can accumulate within the blood stream and damage the endothelial lining. This damage leads to a hardening of the vessels causing narrowing and stiffness, increasing the risk of developing coronary artery disease[2].

Traditionally, fasting TG have been the primary focus when evaluating a patient's blood lipid panel. However, it has become evident in recent years that active metabolism of TG is more indicative of the development of a chronic disease condition[3,4]. Fasting TG values may not correctly identify those at risk for disordered postprandial lipid metabolism as their baseline value may still be below the established 150mg/dL marker for intervention[3,4]. This disorder is defined as having normal fasted values with an exaggerated elevation following a high-fat meal. Persons with fasting TG values between 89-180mg/dL are at an increased risk for disordered postprandial lipid metabolism[4]. Therefore, it would be beneficial for clinicians to administer a standardized oral fat tolerance test (OFTT) for persons with fasting TG values between 89-180mg/dL to reveal the onset of a diseased process. This would identify those who may be at an increased risk for developing chronic dyslipidemia requiring pharmaceutical treatments.

Acute and chronic exercise attenuate elevated TG and improve an overall blood lipid profile[5,6,7]. TG respond acutely to a bout of exercise, whereas low and high-density lipoproteins require chronic exercise to elicit a positive change[6]. In this context, a positive change equates to a decrease in low-density lipoprotein (LDL) and an increase in high-density lipoprotein (HDL) subfractions. There have been many investigations into the appropriate type and intensity of acute exercise. This is commonly achieved by administering an exercise session, followed by 12-16 hours of fasting (usually an overnight fast), and the ingestion of a high-fat meal[8]. Blood lipids are then analyzed, and the effects of exercise are observed. It is common for the no-exercise control and exercise groups to consist of the same participants, in a cross-over design, with 40-hours between trials to ensure no lasting effects of the high-fat trial[7].

The problem lies in the lack of a universally-recognized standardized OFTT. Although attempts have been made to create a repeatable OFTT, these attempts rarely test for reliability and lack clarity in the development and administration of the high-fat load[9,10,11]. These considerations make it difficult to replicate an OFTT. Additionally, these OFTT often contain a wide variety of substrates which metabolize differently, such as fat sources of varied saturations (saturated, monounsaturated, and polyunsaturated) and meals high in carbohydrates[12]. As insulin activation from glucose also stimulates the activation of lipoprotein lipase (LPL), a primary motivator of lipid metabolism, it would appear imperative that carbohydrate substrates be limited in an OFTT[2]. Additionally, it is known that not all fats metabolize the same and that this variation exists across saturated, monounsaturated, and polyunsaturated fats[13,14]. One attempt at standardizing an OFTT developed 200ml of a liquid containing equal parts fat and carbohydrates at 50g[9]. This OFTT was administered to diabetic and nondiabetic individuals age 35-65. This use of an equal ratio of fats and carbohydrates is not ideal due to the competing effects on metabolism. In addition the stimulating effects of insulin on LPL would aid in the metabolism of fat[1]. The use of an OFTT on diabetic persons is not recommended due to the commonality of impaired lipid values typically seen among this population[2,9,15].

The OFTT-fat load variations among the literature ranges from 16.32g of fat to as much as 140g of fat, with multiple values therein[9,16,17,18,19,20,21]. This clearly indicates the necessity for a standardized OFTT. The present investigation seeks to determine a reliable OFTT with a fat concentration eliciting an ideal metabolic curve over four-hours. An ideal OFTT displays a peak elevation of TG between followed by a return to baseline at hours two and three. It has been determined that four hours is a valid time to observe an effect on TG among healthy individuals[22]. One such investigation analyzed data from an 8-hour observation period and found that 89-96% of variance is accounted for within 4-hours[22]. Further investigation into fatty acid metabolism looked at varying fatty acid composition (saturated, monounsaturated, and polyunsaturated) and their respective rate of absorption. The findings revealed that the metabolic effect of fat type is absent within a four-hour time period. There is a time effect present at 8 hours, with polyunsaturated fat displaying an increased clearance over saturated (SMD -2.28, 95% CI)[13]. Therefore, a four-hour observation period is ideal when examining postprandial effects of an OFTT, as it limits the variability which may be brought about via fat substrate metabolism.

Investigation into the effects of an active lifestyle on lipid metabolism has returned mixed results. In a study of 15 active males and 15 sedentary males, both groups were given two OFTT. These OFTT were administered on separate occasions and consisted of fat concentrations of 40g and 140g. The active group demonstrated lesser PPT elevation over the sedentary group[16]. Greater magnitude was seen following the 140g fat challenge, with an increase of 14% and 18% over the corresponding 40g condition[16]. In both trials the active group displayed a more efficient clearance of circulating TG. Contrary results were observed in a study of 42 active and sedentary males and females given a high fat meal of 68g-92g (dependent on body mass)[23]. This investigation found no difference (F=0.937, p=0.425) in lipid metabolism following a high fat meal among active and sedentary persons. Common limitations include the wide variety of OFTT composition along with the lack of clarity as to the training habits of active individuals (high-intensity, moderate long-duration, aerobic, or anaerobic). Additional limitations among the literature include the metabolic discrepancy between sexes; to include activity, dietary habits, menstruation, and age.

Similar studies administering an exercise intervention among young males (23.4±0.8 years), and another among young females (27.1±1.3 years), both found that the exercise intervention minimized the elevation of TG when compared to the no-exercise control[20,24]. Separate investigations have also reported an exercise derived attenuation of TG following a high-fat meal among middle aged males (47.2±9.2 years) and females (42.1±3.8 years)[21,25]. There does appear to be an age threshold at which TG metabolism is delayed. The exact parameters of this threshold have yet to be determined, however is appears to present itself in persons greater than 60 years of age[2,26]. This age related decline in TG metabolism may be attributed to the loss of muscle mass seen with age (sarcopenia), along with the decreased activity of LPL, both being a primary metabolizer of TG[1,27]. Additionally, it has been observed that postmenopausal women have decreased fatty acid oxidation originating from the lack of circulating sex hormones, primarily estrogen[2]. Hence, this investigation will seek to gain clarity as to the effects of sex among college aged student receiving a standardized OFTT.

Given the equivocal findings currently in the literature, and the lack of consistency in which an OFTT is developed and administered in research studies, highlighting a clear need for further investigation into the development of a standardized and reliable lipid challenge test. Furthermore, the effects of lipid metabolism and the interaction of sex and fitness should be examined utilizing an unambiguous OFTT. Such a test can help avoid errors arising from inappropriate generalization of previous findings. Therefore, the purpose of this investigation is threefold: 1) to examine the effect and reliability of three OFTT loads (50, 100, 150g) on TG metabolism, 2) determine how the response to a high fat challenge differs between sedentary and active individuals, and 3) to determine whether sex differences exist with respect to the OFTT in our college-aged cohort. It is expected all three concentrations of an OFTT will be reliable (r>0.70), with one eliciting a greater level of reliability. We hypothesize one OFTT will present itself as being ideal for research and clinical usage within a 4-hour observation, displaying the greatest magnitude of change at the 3rd and 4th hour. We hypothesize a greater elevation of TG, accompanied by a delayed clearance, among the sedentary group when compared to the fit group. Lastly, we hypothesized that no difference of sex on TG metabolism will be present among college-aged males and females.

2.0 Review of Current Literature

Most of the population who adhere to a Western diet spend much of 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 for mortality and morbidity among industrialized countries[19,28]. Cardiovascular disease is the number one cause of mortality worldwide, therefore it is imperative that researchers focus on behaviors which limit the risk of developing this disease. Chronic exercise limits TG elevation following feeding, as do some forms of acute exercise[5,6,16,29]. The determining factor of TG response to exercise appears to be the volume of kilocalories consumed, the time relative to feeding, and the intensity of the exercise[1]. There is data available which supports a decrease in postprandial triglycerides (PPT) following acute exercise among various exercising populations[25,30,31,32]. These effects are dependent on timing of data collection relative to the exercise bout, intensity, type of exercise, substrate structure of the test meal, and clinical applications of an OFTT.

2.1 Timing of Data Collection

The timing in which PPT metabolism following exercise is measured has been debated among the literature. Early investigations sought to determine the acute effects of exercise on lipid metabolism immediately before or after an OFTT. These early investigations commonly found lipids to be unchanged or elevated[33]. This is likely due to the increased lipolysis occurring immediately following a high fat meal. Current research endeavors subscribe to the model of an exercise bout, followed by 10-16 hours, and the administration of an OFTT[8]. As LPL activation peaks between 4-16 hours, this delayed model identifies the desired metabolic effect[7]. An investigation by Zhang, et al. sought to determine if pre-meal exercise or post-meal exercise had a greater influence on triglyceride metabolism[34]. The 21 recreationally trained participants took part in four trials, including: a control trial with no exercise intervention, a post-meal exercise trial, a pre-meal exercise trial, and a 12-hour pre-meal exercise trial. The order of trial participation was randomized, and participants had 1-2 weeks to recover following each trial. 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%VO_2max, for 1-hour. The control trial did not participate in exercise and consumed the OFTT following the overnight fast. The post-meal trial consumed the OFTT and performed the exercise protocol one-hour post-feeding. Conversely, the 1-hour pre-exercise trial completed the exercise trial, followed by the OFTT. The 12-hour pre-exercise trial completed the 1-hour exercise protocol the evening prior to ingestion of the OFTT. 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 are consistent with similar investigations which have determined that the optimal time for observing the acute exercise effects on TG is 12-16 hours following the exercise intervention[1,2]. Additionally, there is a consensus among researchers that the beneficial effects of acute exercise are absent 24-hours following the activity[1,7, 34].

2.2 Effect of Exercise on PPT

2.2.1 Aerobic Exercise Effects on Triglyceride Metabolism

2.2.2 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 the lack of attenuation of PPT. In studies of young males with a walking intervention no attenuation of PPT were observed[18,28]. A commonality of these findings is that the intensity of exercise may be too low to elicit a change in circulating TG. One such investigation utilized 30-minutes of moderate walking (50%VO_2max) 12-hours prior to a high fat meal, and no difference of TG metabolism were observed[18]. Additionally, the OFTT used in the aforementioned investigation contained one gram of fat per kilogram of body weight with no carbohydrates[18]. This exceedingly high concentration of lipids may have been too great for the light exercise to effect change within the measured time.

The timing at which TG metabolism is measured may also be a cause for type 2 error, in which researchers may not have observed a significant change within the examined time. One such design examined the exercise effect of 30, 60, and 90 minutes of walking on TG. Sixteen healthy males participated in three walking trials at 50%VO_2max[28]. 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%VO_2max attenuated PPT among 20 healthy men by 29% (47.2±9.2 years)[21]. 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.

As previously reported, 12-16 fasted-hours following exercise is the optimal time to observe the PPT response[34]. Investigations utilizing a protocol of feeding and blood analysis directly preceding or following exercise are not conscious of the changes occurring at 12-hours postprandially. These nonsignificant findings highlight limitations of previous investigations which may not have had an appropriate sample size or lipid collection timing 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.

2.2.3 Aerobic Exercise Attenuates PPT

Most investigations have found an attenuation of PPT following acute exercise. When utilizing a lower percentage (50%) of VO_2max it may be 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[11,33,35]. Exercising at 60-70% of VO_2max 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 may be required to elicit similar effects, as is shown in the long duration/low intensity groups.[34,36].

The amount of exercise required to elicit a response has also been measured in the amount of caloric energy expended. It has been shown that the accumulation of 500-kilocalories during exercise is enough to stimulate a decrease the elevation of PPT, regardless of the intensity[1,19]. An energy deficit created through caloric restriction does not appear to reduce PPT, however, a decrease in caloric intake coupled with light exercise (30% VO_2max) stimulates the attenuation of PPT[20,33]. 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[10,24].

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. 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) were recruited and underwent a VO_2max, 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[37].

2.3 High-Intensity Interval Exercise Effects on Triglyceride Metabolism

Some researchers suppose that intensity of exercise, not duration, has greater influence on TG metabolism. Nine healthy male participants (age 24±3) took part in the control, walking, and high-intensity intermittent exercise (HIIE) trials to compare the effects of moderate and HIIE on PPT[10]. The protocol required 2 days per trial, for a total of 6 days, with a minimum 7 days between trials. The walking trail consisted of 30 minutes of brisk walking (a pace eliciting breathlessness), and the control trial took part in seated rest of 30 minutes. The HIIE trial was conducted on a cycle ergometer and consisted of four 30-second maximal sprints, against 7.5% of their weight in kilograms, with 4 minutes of unloaded cycling between sprints. 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 ($p<0.05$)[10]. 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[38]. This investigation required eight male volunteers (25±4 years) to complete two (control and exercise), 3-day trials. On day one (14:00 hours) the control trial underwent 30-minutes of seated rest; while the exercise group participated in HIIE, consisting of a 4-minute warm up on a cycle ergometer, followed by four maximal sprints against 7.5% of the participants' weight in kg, with 4-minutes of active rest between sprints. During the active rest participants cycled at 70 rpm with no resistance. On day two and three the 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. Blood samples were collected on the hour for 7 hours following breakfast. Participant water intake was recorded and replicated on their second trial, as was the dinner of their choosing. 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, $p \leq 0.05$). The mechanism by which this attenuation occurs may be a result of the reduction in very-low density lipoproteins (VLDL) released from the liver along with the stimulation of an increase in circulating LPL. These investigations give credence to the practice of anaerobic work as means to decrease circulating TG[38].

The use of shorter duration cycle sprints on TG metabolism have also been examined[17]. Twelve sedentary females (21.3±2.1 years) participated in both control and exercise trials. The exercise trial consisted of 8 seconds of maximal cycling followed by 12 seconds of active rest (light cycling) at a resistance matching 65% of their VO_2max; this pattern was repeated for 20-minutes. The control trial did not participate in exercise. Following an overnight fast, participants ingested a high-fat meal of 996.7-kilocalories constituting 98g fat, 24g carbohydrates, and 8.4g protein. Circulating TG were drawn on the hour for 4-hours. The results show that prior HIIE significantly decreases next-day postprandial triglycerides in young women (81% confidence interval, 13% decrease)[17]. This investigation highlights the probability of a volume effect of exercise on TG and offers the possibility of a unique training regimen to improve ones lipid profile.

In comparing the aforementioned investigations we see there is no effect of sex on HIIE among younger persons[17,38]. 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[17,38]. 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 been shown to have beneficial effects[19]. One such investigation sought to neutralize the volume discrepancy that may be responsible for the beneficial effects of exercise. Twenty healthy male volunteers (21.5±3.5 years) underwent three trials consisting of a control, moderate continuous, and intense intermittent exercise. The control trial omitted exercise while the moderate trial took part in jogging at 85%VO_2max. The intense exercise trial underwent 3 minutes of maximal exercise (115% anaerobic threshold) followed by 1.5 minutes of recovery. Each exercise trial was concluded upon reaching an energy expenditure of 500 kilocalories. All three trials were given an OFTT 27-30 minutes following the cool-down. The OFTT was individualized and consisted of 1 gram of fat per kilogram of body weight (69.2±9kg). Blood was taken pre-meal and for 4-hours following the OFTT. 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 may have a limitation, in that the continuous group (walking at 85%VO_2max) may have been 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%VO_2max). 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[32]. It is possible blood analysis 12-18 hours following the meal would reveal differing results. These data are indicative of a reduction of PPT through anaerobic pathways, leading to the question of resistance training effects on TG metabolism.

2.4 Circuit Training Effects on Triglyceride Metabolism

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) and divided them into an exercise group and a non-exercise control[39]. The exercise group trained three times per week for a 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 showed increases in oxygen consumption, lactate threshold, muscular strength (evaluated by an increase in weight lifted over time), HDL subfractions, 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.

2.5 Resistance Exercise Effects on Triglyceride Metabolism

Postprandial lipemia is linked to cardiovascular disease, insulin resistance, glucose intolerance, central adiposity, and hyperlipemia[40]. The interaction of resistance training on postprandial lipemia has been examined among younger persons (24.3±2.9 years). Ten men and four women participated in three trials, including: a resistance training trial, aerobic trial, and a non-exercise control trial. The resistance training trial consisted of three sets of ten repetitions for ten exercises constituting a whole-body workout. The total time of the resistance training session was 88±3-minutes. The aerobic trial consisted of walking for a similar duration at a pace which would elicit a similar energy expenditure as the resistance training 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.

The 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[40]. These data reveal a greater effect of acute exercise when utilizing resistance training and may isolate resistance training as a more effective long-term lipid clearance modality (22% CI, $p \leq 0.01$). 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, may not accurately represent the acute changes to lipid metabolism which occur following resistance training. Furthermore, the utilization of a whole-body protocol lasting 88-minutes may not be practical for all populations. 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.

A further investigation sought to determine the effectiveness of volume matched resistance training to that of endurance training. Seven healthy males (25 years) were recruited to participate in three trials: control, endurance, and resistance training. The endurance trial consisted of 90 minutes of treadmill walking at 30%VO_2peak. The control trial participated in 90 minutes of rest. 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)[8]. 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 may not be 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%VO_2peak, is classified as light exercise, whereas the resistance training trial, at 80% peak torque is a moderate to vigorous intensity.

2.5.1 Strength to Mass Imbalance

Muscle quality is the observed strength of the muscle relative the muscle mass[41]. The adherence to a resistance training program improves muscle quality and lipid metabolism, yet resistance training is often overlooked when prescribing an exercise intervention[8]. 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[42]. 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[40]. Additionally, the limited budget of older adults may 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 may be easier to quantify and report to a primary care physician. In documenting regular resistance training physicians will be able to track any strength abnormalities. This is especially important among older persons who may attribute the decline in strength to the aging process and overlook a progressive disease condition.

Theoretically, it may be possible to use the determination of muscle quality as a predictor for cardiovascular disease. This information may give credence to physicians and exercise practitioners to stress the importance of a resistance training program among older adults. Further, it could identify resistance training 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 may exist a need for a more detailed explanation of exercise activities, with an emphasis of resistance training.

2.5.2 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. Twenty-four healthy, active, women (27 years) participated in a 14-week investigation examining the resistance training effects on triglycerides[42]. Participant skinfold measurements, estimated one-repetition maximum, and lipid panel were collected prior to the start of the trial. The training protocol consisted of three bouts of resistance training per week, 45-50 minutes in duration. The protocol included two sets of eight repetitions, and a third set to exhaustion. Eight exercises were selected, incorporating both upper and lower body activity. The resistance was set at 85% of their 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%)[42]. 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 to examine active TG metabolism.

2.6 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. 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)[10,17]. 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[2,13]. The most cited rational behind a solid high-fat meal is that is replicates that of a normal meal in which a person may 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 may confound the desired results when using an OFTT containing a high carbohydrate dose[2]. 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[9]. 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 atherosclerotic process, and is commonly seen among this population[2,9]. 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, with a combined BMI of 53.8±5.9. A power analysis of the nondiabetic, male and female, group revealed a small effect size (n=20, f=23.2%, α=0.05). This OFTT has not been accepted by research or clinical communities and requires further investigation into the development of a reliable test. 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.

Table 1: Examples of OFTT Variability Among the Literature

Reference	Subjects	Meal composition	Fat load content	Time before fat load	Postprandial response
Cohen, 1989[16]	M, n=30, 25y	Cream, chocolate flavor	40g fat & 140g fat	n/a	n/a
Hashimoto, 2011[18]	F, n=8, 21y	Cream	0.35g/kg (~17.92g)	12h	No Δ
Harrison, 2009[43]	M, n=8, 27y	Croissants, butter, ice cream, chocolate, chips	97g fat, 124g CHO	10h	↓TG
Herd, 2001[23]	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[19]	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[44]	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[10]	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[21]	M, n=20, 47y	Whipping cream, fruit, cereal, nuts, chocolate	80g fat, 70g CHO	12h	↓VLDL
Gill, 2002[45]	F, n=11, 24y	Whipping cream, fruit, cereal, nuts, chocolate	1.3g/kg fat (~78g), 1.2g/kg CHO (~72g)	12h	↓TG
Gill, 2000[33]	F, n=12, 60y	whipping cream, oats, nuts, coconut, chocolate, fruit	1.7g/kg fat, 1.65g/kg CHO	12h	↓TG
Maraki, 2008[20]	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[46]	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

Table 1: Examples of OFTT Variability Among the Literature cont.

Reference	Subjects	Meal composition	Fat load content	Time before fat load	Postprandial response
Miyashita, 2009[36]	M, n=10, 21-32y	Bread, cheese, butter, mayo, potato crisps, whole milk, milkshake powder	0.69g/kg fat (~49.13g), 0.95g/kg CHO (~67.64g)	n/a	No Δ
Miyashita, 2006[5]	M, n=10, 21-32y	Bread, cheese, butter, mayo, chips, milk, milkshake powder	0.69g/kg fat (~55.2g), 0.95g/kg CHO (~76g)	17h	↓TG AUC
Mohanlal, 2004[9]	M/F, n=50,	Maltodextrin, long-chain triglycerides	50g fat, 50g CHO	10h	↓TG AUC
Murphy, 2000[11]	M/F, n=10, 34-66y	Cream, yogurt, bread, eggs, milk	30±9g fat, 58±17g CHO	3h	↓TG AUC
Petitt, 2003[40]	M/F, n=14, 24y	sausage, egg, and cheese, and hash brown potatoes	89±17.2g fat, 74±13.8g CHO	12h	↓TG AUC
Pfeiffer, 2005[28]	M, n=16, 25y	Cereal, yogurt, cream, chocolate drink	0.5g/kg fat (~35g), 1.6g/kg CHO (~112g)	3h	No Δ
Tan, 2014[17]	F, n=12, 21y	Cereal, ice cream, sweetener	98g fat, 24g CHO	12h	↓TG
Tsetsonis, 1997[25]	F, n=22, 40-43y	Whipping cream, cereal, fruits, chocolate, coconut, sultanas, nuts	1.7g/kg fat (~103.28g), 1.65g/kg CHO (~100.24g)	12h	↓TG AUC
Zhang, 1998[34]	M, n=21, 27y	Cream, Ice cream, walnuts	100g fat, 17g CHO	12h	↓TG AUC

2.7 Clinical Applications of an OFTT

Recent literature has determined the use of fasting TG values may not be appropriate for those who potentially have cardiovascular health risks. In an investigation of 1,115 persons with coronary heart disease, 49% displayed normal fasting TG values yet had an undesirable PPT response[4]. This increased elevation of TG, coupled with a decreased clearance time, facilitates a prolonged elevation of circulating plasma TG and can lead to vascular disfunction. Further, participants with fasting TG values between 89mg/dL and 180mg/dL appear to have an increased likelihood of displaying hidden postprandial lipemia ($p<0.001$)[4]. 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[3]. These findings support the clinical application of an OFTT among persons with fasting TG values of 89-180mg/dL to uncover hidden postprandial lipemia. This may lead to the early detection of cholesterol related coronary artery disease.

2.8 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 measures ANOVA detects differences between the related independent and dependent variables across all conditions[47]. In an investigation monitoring PPT following an OFTT from Hashimoto, et al. data were analyzed through a repeated measures ANOVA, isolating the time-course changes from baseline values[48]. 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[49]. 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[49]. 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.

2.9 Conclusion

The apparent discrepancies in OFTT design among the literature highlight the importance of a universally accepted test. 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 could identify those at risk, and with early intervention would limit the need for pharmaceutical intervention and lower overall health care cost.

3.0 Methodology

3.1 Participants

A purposeful sample of college aged males and females were recruited from the University of Nevada, Las Vegas and surrounding communities. A total of 15 males and 15 females were recruited to participate in this investigation (Table 4). The active and sedentary groups were defined using the American College of Sports Medicine (ACSM) parameters of participating in exercise of 30-minutes a day, three days per week, for the past three months[41]. A similar investigation by Cohen et al. was utilized to determine statistical power *a priori*[16]. A power analysis of the aforementioned investigation determined that a sample n=6 would be sufficient to observe an effect, if an effect is present (80%, $\alpha=0.05$); with an effect size of f=0.59 (G*Power v.3.1.9.2, Bayern, Germany)[16]. The present investigation observed a power of 70% (f=0.501, $\alpha=0.05$, n=30) between the three OFTT concentrations.

3.2 Demographics

Participants completed a health history questionnaire and were classified as low-risk as outlined by the ACSM algorithm[50]. All participants were free of any known cardiovascular disease, metabolic disorder, implantable device, liver or gallbladder complications (such as surgery, cirrhosis, or fatty liver), and were normolipidemic (fasting TG>150 mg/dL). All participants were non-smokers or had ceased smoking for longer than six-months. Prior to initiation of the protocol, an informed consent form was completed notifying participants as to any potential risks, benefits, and confidentiality concerns. It was explicitly written that participation was voluntary and that participants could drop out for any reason at their discretion. This protocol was approved by the Internal Review Board for Human Subjects Research at the University of Nevada, Las Vegas (#1157372-8). Following completion of the health history questionnaire and informed consent, height was recorded using a stadiometer and weight and body composition was estimated through the SECA bioelectrical impedance (BIA) device (Hamburg, Germany).

The SECA BIA has been shown to be a valid and reliable method of evaluating fat and lean mass in an investigation employing magnetic resonance imaging (MRI) as the criterion measure[51]. Participants were advised to keep a food journal documenting all food and beverage consumption on the day prior to data collection. This journal would serve as a reference for individual meal replication prior to the ensuing trials. Participants were required to adhere to an overnight fast of 12-16 hours prior to data collection. Additionally, exercise was prohibited on the day prior to data collection (defined as any repetitive activity elevating the heart rate over resting for greater than 20 minutes). Participants were advised to abstain from caffeine intake on the day of OFTT administration.

3.3 Blood Sampling

Capillary blood plasma TG analysis was undertaken prior to the consumption of an OFTT. The time of completion of the OFTT was recorded and subsequent blood analysis was collected at 1, 2, 3, and 4-hours post-consumption. Circulating blood plasma TG was analyzed using the CardioChek® point of care *in vitro* diagnostic system (Polymer Technology Systems, Inc., Indianapolis, IN, USA). This point of care system has been deemed to be a valid and reliable tool for clinical application[52]. The four-hour observation time has been proven to be a reliable time constraint for lipid analysis among healthy participants[1,22].

3.4 OFTT

Following fasting blood analysis, one of three OFTT of varying fat concentrations were administered in randomized-crossover design. Participants were given 20 minutes to consume the OFTT. Water was given ad libitum on the first trial and was measured to replicate fluid consumption during subsequent trials. The three fat concentrations used were 49.5g, 99g, and 148.5g and represented a small, medium, and high fat load. For clarity, these concentrations were rounded to 50g, 100g and 150g loads, and referenced in this paper as such.

Carbohydrates among the 50g, 100g, and 150g loads were 19.13g, 38.25g, and 57.38g respectively (Table 2). These fat concentrations were selected to replicate similar OFTT concentrations seen among the literature[10,17,20,28]. Previous investigations used concentrations ranging from 16g to 140g of fat[16,18]. The consumption of an OFTT places the participant at or above the recommended daily allotment of fats (20-30% of dietary intake). Although the risk of an adverse effect was low, we recommended that participants limit high-fat intake for the duration of the testing day. The OFTT was composed of commercially available products and is easily replicated. Ensure® Plus (Abbott©, Abbott Park, IL) was used as a flavor base (chocolate) for the OFTT. The majority of fat originates from the heavy dose of Benicalorie® (Nestle©, Vevey, Switzerland) high-fat food additive. The components of the OFTT were poured into a mixing pitcher and mixed thoroughly with a silicone spatula. The individual portions were measured using a graduated measuring cup and poured into individual disposable cups. Caution was taken to ensure all remaining remnants of the OFTT were removed from the measuring cup following pouring. As the Benicalorie® consists of primarily sunflower oil it has a tendency to harden. Therefore, the sealed Benicalorie® cup was placed on a heating pad for approximately two minutes prior to mixing to allow it to liquefy. Additionally, the Benicalorie® and Ensure® Plus should be shaken prior to mixing.

The OFTTs were volume matched, with the small dose receiving 300ml of water, the medium dose receiving 150ml of water, and the large dose receiving no additional water. Water measurement was accomplished via graduated measuring cup and poured into the respective disposable cups. All participants ingested three OFTT in a counter balanced order corresponding to three different fat concentrations, separated by seven days. The reliability trial consisted of consuming an additional one-of-three possible OFTT. A subset (n=20) returned to complete reliability testing. This consisted of ingesting one of the three OFTT in a test-retest manner.

The OFTT was received well by the majority of subjects. No adverse effects of digestion were observed (e.g. vomiting, diarrhea, gastrointestinal discomfort). A common complaint was that the large (150g) dose was too great. Few participants had a difficult time ingesting it within the allotted 20min time frame. Nausea and the feeling of fullness were cited as inhibitory factors. Conversely, the meal was enjoyed by some who verbally reported that they “looked forward to it,” and “would eat it again.”

Table 2: OFTT substrate breakdown, 11:3 ratio (Benicalorie® to Ensure®)

	50g	100g	150g
Milliliters	149	299	448
Fat (g)	50	99	149
Saturated fat (g)	5	9	14
Carbohydrates (g)	19	38	57
Sugar (g)	17	33	50
Protein (g)	15	29	44
Calories	585kcal	1,170kcal	1,755kcal

3.5 Statistical Analysis

Inter-test reliability was analyzed using a single measures consistency intraclass correlation coefficients, ICC (3,1) with significance accepted at $r>0.75$[53]. Additional reliability variables include the highest observed 95% confidence interval, as well as the coefficient of variation (CV). To determine the effect of fitness on OFTT concentrations over time, data were analyzed through a two (group: active, sedentary), by three (condition: 50, 100, 150), by five (time: pre, 1h, 2h, 3h, 4h) repeated measures ANOVA, with an alpha level of $p \leq 0.05$. To determine the effect of sex on OFTT concentrations over time, data were analyzed through a two (group:

male, female), by three (group: 50, 100, 150), by five (time: pre, 1h, 2h, 3h, 4h) repeated measures ANOVA, with an alpha level of $p \leq 0.05$. The assumption of sphericity was examined using Mauchly's test of sphericity. If sphericity was violated ($p \geq 0.05$), the more conservative F-test of Huynh-Feldt was adopted when determining the significance level. If a significant interaction was present pairwise comparisons were examined using independent T-tests at each time point between each concentration. These statistical analysis were modeled from similar investigations examining the effects of an OFTT and TG response[5,6,8,11,29,31,39,54-56].

4.0 Results

4.1 Demographics

A total of 32 participants were recruited for this investigation. Of these, two participants failed to complete all required trials and their corresponding data was removed. One participant withdrew from the investigation due to unrelated personal circumstances. Yet another dropped citing unrelated health concerns. Of the 30 participants who completed all three OFTT concentration trials, 20 completed four trials in a test-retest reliability model. The participants were all able to consume their respective OFTT concentrations with minimal discomfort. Some minor discomfort was reported among the high-fat load (150g OFTT) and manifested in the form of satiety or over-fullness. Males were significantly taller (p=0.024) with greater mass (p=0.001) compared to females. There was no difference with respect to age (p=0.25) (Table 3).

Table 3: Participant Demographics, (*) significant difference between height and weight (*p*=0.024 and *p*=0.001, respectively).

	Demographics			
	Males		Females	
	Mean	SD	Mean	SD
Height	173	12	163	5
Weight	85	18	61	11
Age	28	5	26	5
n	15		15	
Active	8		9	
Sedentary	7		5	

4.2 Reliability

When considering the test-retest reliability of the OFTT loads, the 150g, 100g, and 50g were significant (*p*<0.001) with ICC at 0.745, 0.923, and 0.715, respectfully (Table 4).

Table 4: Single Measures Intraclass Correlation for Each OFTT Concentration (CV: Coefficient of Variation)

	Single Measures Intraclass Correlation						
	N	CV (%)	ICC	Lower Bound	Upper Bound	F-Value	Sig.
150g	14	24.3	0.745	0.551	0.863	6.837	p<0.001
100g	14	16.7	0.924	0.855	0.961	25.332	p<0.001
50g	12	14.6	0.715	0.483	0.854	6.029	p<0.001

4.3 OFTT Metabolism

The 50g, 100g, and 150g OFTT load TG revealed a significant interaction with time (F=1.508, *p*=0.033). Significantly lower plasma TG concentrations were observed in the 50g load compared to both the 100g and 150g loads at time points 1h, 2h, 3h, and 4h postprandially (p=0.001, *p*=0.003; *p*=0.01, *p*<0.001; *p*=0.004, *p*=0.002; *p*=0.003, *p*=0.001, respectfully), with an effect size of 0.80 (figure 1). No differences with respect to TG were observed between the 100g and 150g loads (*p*>0.05). Each test found significantly increased plasma TG above baseline at the 1h, 2h, 3h, and 4h timepoints (*p*<0.001).

4.4 Sex Interactions

No interaction between sex, time, and plasma TG was present (F=0.83, *p*=0.55). Additionally, no interaction between OFTT and sex was present (F=0.057, *p*=0.935). There was an interaction of OFTT and time (F=2.325, *p*=0.034). There was an interaction between time and sex as determined by one-tailed independent T-test (F=3.115, *p*=0.049) (figure 2). There was a main effect for time (F=31.196, p<0.001) and among OFTT (F=10.466, p<0.001).

Figure 1: Mean TG metabolism (mg/dL) among the 50g, 100g, and 150g OFTT loads, (*) Significantly different than 100g and 150g time points.

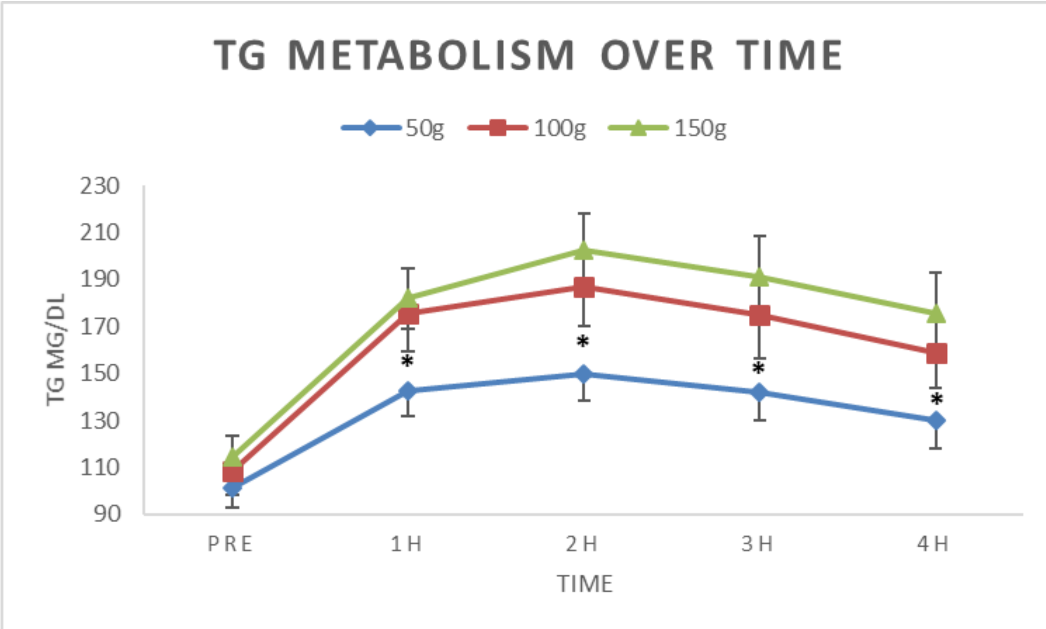
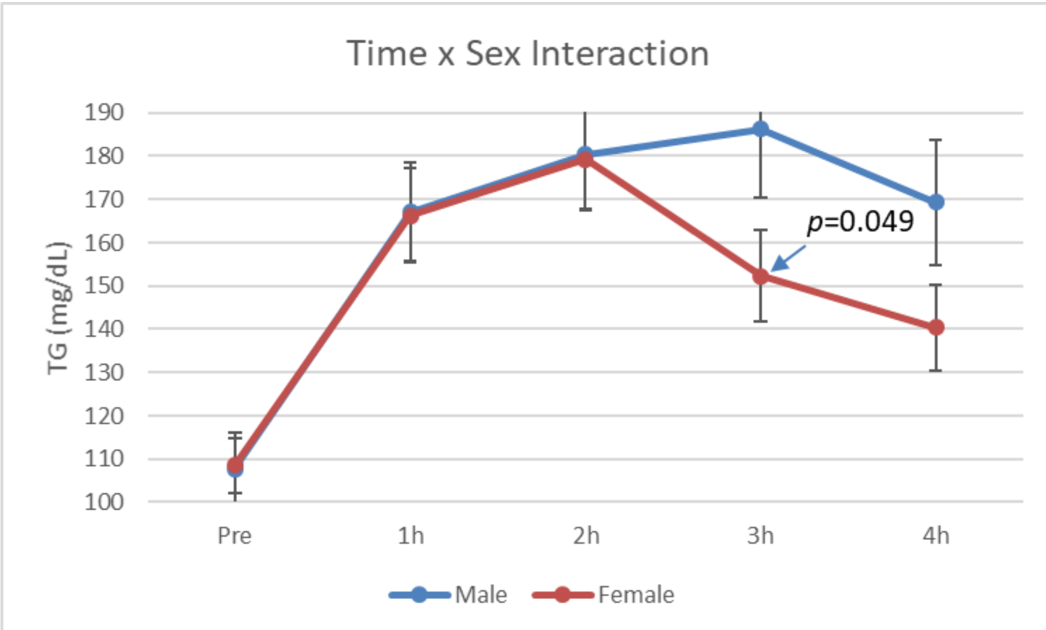


Figure 2: Time by sex interactions of TG metabolism (mg/dL) following the 100g OFTT concentration, between males and females over time.



4.4.1 Active Lifestyle Interactions

There was no 3-way interaction between time, fitness, and OFTT concentrations ($F=0.514$, $p=0.805$). There was a significant interaction between OFTT and time ($F=2.482$, $p=0.026$), and a main effect for OFTT ($F=11.874$, $p<0.001$). There was a significant main effect of time from baseline at the 1h, 2h, 3h, and 4h timepoints ($F=30.405$, $p<0.001$).

5.0 Discussion

5.1 Reliability of OFTT

Reliability is the agreement of consistent results between different observations[57]. Results from the current study provide evidence that the 100g OFTT concentration load is highly reliable, with an ICC of 0.923 (table 4). From this we can assume 8% of variability to random variation. The 100g coefficient of variation at 16.7% would be considered good. In an evaluation of CV threshold among clinical testing, Reed et al. determined that a CV above 20% should not be considered reliable[58]. Validity is defined as the extent to which the testing procedures are applicable to the desired measurement of the outcome[57]. The present investigation satisfies the parameters of construct validity as outlined via the homogeneity parameters, in which all persons were tested exclusively for TG. As such we can confidently report that the 100g OFTT is both reliable and valid for research purposes. These finding are unique, since we know no previous investigations that employed an OFTT for lipid metabolism analysis purposes have determined reliability.

The aim of the current investigation was to construct an OFTT that was both valid and reliable. To our knowledge, there is a dearth of literature focusing on the test-retest reliability of plasma TG metabolism following the administration of differing OFTT loads. This lack of reliability analysis among the literature is prevalent, despite the use of multiple OFTT configurations. Previously established guidelines of single measures consistency intraclass correlation coefficients, ICC (3,1) ICC categorize values as: less than 0.5 being poor, between 0.5 and 0.75 as having moderate reliability, between 0.75 and 0.90 as having good reliability, and values greater than 0.9 as reflective of excellent reliability[53]. Moderate reliability was observed in the 150g OFTT load measurements when considering both the ICC and the 95% confidence intervals. The 150g ICC was 0.745 with a 95% confidence interval from 0.551 to 0.863 (F=6.837, *p*<0.001). An excellent degree of reliability was found between 100g OFTT measurements when taking into account both the ICC and the 95% confidence intervals. The average measure ICC was 0.923 with a 95% confidence interval from 0.845 to 0.963 (F=25.059, *p*<0.001). While a moderate reliability was seen in between the 50g OFTT measurements, with an of ICC (0.715), and having a 95% confidence interval indicative of poor reliability (0.483 to 0.854, F=6.029, *p*<0.001). These data identify the 100g OFTT load as having the most desirable reliability effects of all of all high-fat loads that were tested in the present investigation. This 100g concentration is similar to other volumes seen among the literature, including an expert panel conclusion of 75-80g being an ideal concentration[59]. Further testing needs to be done on a larger sample size to more fully determine precision measures.

Table 5: ICC Demographics

	50g		100g		150g	
	Mean	SD	Mean	SD	Mean	SD
Age	27	6	26	4	28	3
Hight (cm)	165	17	170	8	171	7
Mass (kg)	80	26	66	10	78	20
Male	3		4		3	
Female	3		3		4	

5.2 OFTT Concentration Comparison

This investigation sought to determine an ideal fat concentration of an OFTT for clinical and research purposes, among three different concentration approximations (50g, 100g, and 150g). These data unequivocally identify the 100g OFTT as being the ideal concentration (F=1.508, *p*=0.033). As predicted, the 50g OFTT appears to be too low of a lipid challenge. This was displayed in participant's that had consistently favorable TG levels at all concentrations. Amongst these participants TG levels remained below a 3-digit mg/dL value.

Conversely, it is likely the 150g OFTT was too great a challenge to observe the metabolism of TG within the established 4-hour observation period (Figure 4). Amongst those participants with consistently unfavorable lipid values (having 3-digit values at baseline), this extremely high lipid challenge was too great to observe the desired trend toward baseline at the 3 to 4-hour time point[59].

When considering the entire sample, there was no significant difference (p=0.676) in TG metabolism between the 100g and 150g OFTT load concentrations. At 1h there was a 14% difference between 100g and 150g OFTT; 14% at 2h, 13% at 3h, and 16% at 4h. Thus, we recommend that the 100g load would better serve participants and clients, as it would not subject them to an unnecessarily high fat load or potential discomfort.

Increasing evidence points toward the administration of a postprandial OFTT to identify potential metabolic and cardiovascular abnormalities[3,59,60]. To our knowledge, this practice is not yet reflected among health care institutions. Such a practice would involve at risk individuals, having elevated fasting TG values, being assessed following ingestion of an OFTT[3]. The cut-off for healthy fasting TG is <150mg/dL. Researchers have more recently observed that a fasted blood draw is not sufficient to identify metabolic TG abnormalities. The National Cholesterol Education Program (NCEP), and American Heart Association (AHA) are in agreement with the health guidelines for elevated TG (Table 5)[59,61].

Figure 3: TG values of participant #8 over time following a 50g load (male, 73.92kg, 170.18com, 29 years)

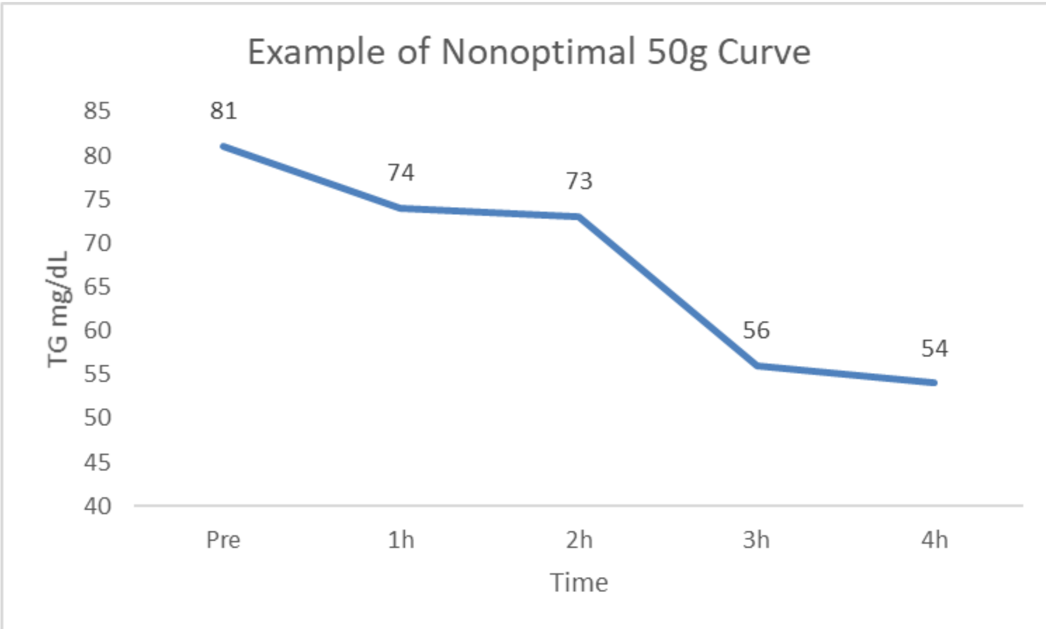
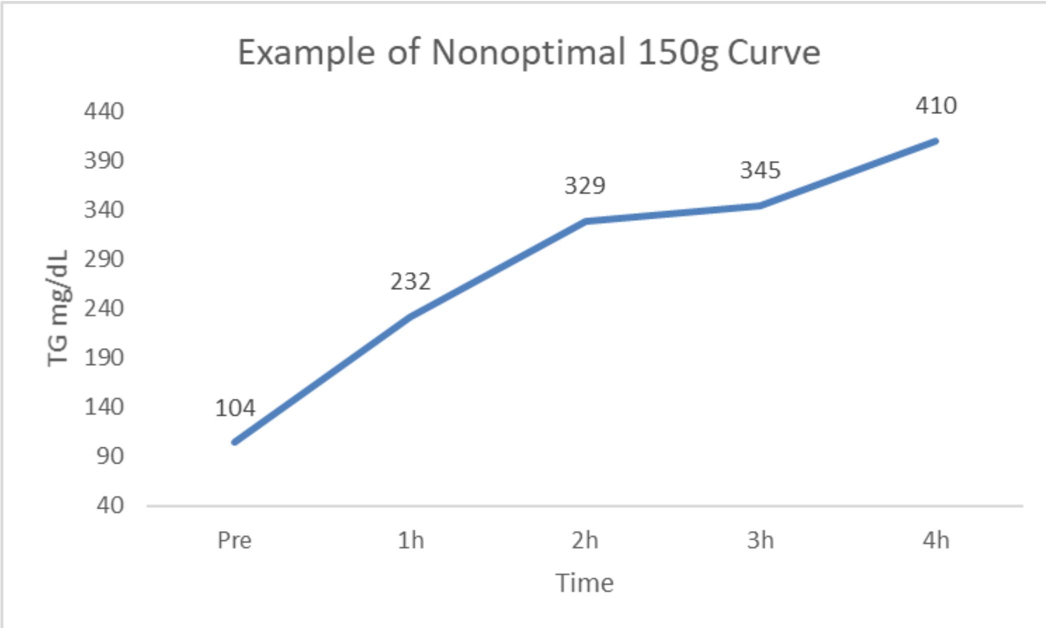


Figure 4: TG values of participant #2 over time following a 150g load (male, 69.5kg, 180.34cm, 31 years)



Common practice when evaluating lipid values is to draw and analyze fasted blood. More recent evidence points toward the administration of an OFTT in effort to evaluate active TG metabolism[3,59]. These tests would aide in diagnosing those with disordered lipid metabolism, and hidden postprandial lipemia[3,59]. Postprandial TG values less than 220mg/dL over a four-hour observation period is ideal[59]. Persons with fasting TG values between 89-180mg/dL may potentially have hidden postprandial lipemia[3,59]. These persons are at a greater risk for developing early atherosclerosis[59]. As such, it would be beneficial for those patients with elevated fasting values to undergo an OFTT to evaluate active TG metabolism. The tested 100g concentration is a reliable and valid OFTT which can be used in for the aforementioned application. Early intervention of disordered TG metabolism should be prescribed a combination of: exercise, dietary restrictions, statins, fibrates, and nicotinic acid[59].

Table 6: TG Classifications, as outlined by the National Cholesterol Education Program

Classification	Fasting serum TG
Normal	<150 mg/dL
Borderline High	150-199 mg/dL
High	200-499 mg/dL
Very High	≥500 mg/dL

A common ingredient in the development and implementation of an OFTT consists, in large majority, of heavy whipping cream[18,21,23,25,34,45]. The use of commercially available heavy whipping cream in research and clinical endeavors is not without limitations. The first and primary limitation would be the macronutrient concentration of heavy whipping cream (Table 6). It has long been accepted that long-term heavy doses of saturated fat are linked to an increased risk for CVD[2]. Another focus of the present investigation was to create an OFTT which minimizes the volume of saturated fats, supplanting it with healthier fats, such as polyunsaturated fat (PUFA) and monounsaturated fat (MUFA). There exist time discrepancies regarding the metabolism of these three fat substrates. PUFA and MUFA breakdown more rapidly than do saturated fats, however this difference in breakdown efficiency does not present itself until eight-hours postprandially. Therefore, the process by which the different fat substrates are broken down should not confound data collection under an eight-hour observation window[13]. The tested OFTT, having approximately 4% saturated fat, and containing roughly 43% of PUFA and MUFA would be a healthier option for patients or participants (Table 3). There also exist potential for confounding results based on the distribution of fatty acid isoforms. There exist evidence to support that the ingestion of PUFA and MUFA, concurrent with saturated fat, attenuates the elevation in TG[14].

Table 7: Comparison of macronutrients between proposed 100g OFTT and heavy whipping cream equivalent

	100g OFTT	Low-fat HWC	High-fat HWC
Volume (ml)	299	325	244
Fat (g)	99	99	99
Saturated Fat (g)	9	66	58
Carbohydrates (g)	38	22	17
Protein (g)	29	0	0
Calories	1170kcal	990kcal	990kcal

The present investigation isolated the 100g concentration as being ideal for research and clinical purposes. The 100g concentration is similar to that proposed by Kolovou et al. in a meta-analysis expert panel review[59]. The panel proposed having 70-80g (68%) fat, 25g of CHO (22%), and 10g of protein (9%). The 100g concentration utilized within this present investigation contains 99g of fat (60%), 19.13g of CHO (23%) and 14.5g of protein (17%) (Table 3). The percent fat and CHO subfractions are similar between these OFTT. However, the protein concentration in the proposed OFTT is nearly double that of the macronutrient recommendation set forth by Kolovou et al.[59]. Additionally, the proposed OFTT contains a similar percentage of

CHO, with a lower overall percentage of fat. It is the opinion of the author that the proposed OFTT contains a more favorable macronutrient distribution for participant health among research and clinical purposes.

It is advisable to limit carbohydrates (CHO) when developing and OFTT since a 1:1 ratio or greater of CHO creates a competition for enzymatic activity and can convolute lipid metabolism[57]. The tested OFTT contains approximately 23% of CHO and 60% total fat (Table 3). This fat to CHO ratio is much less than comparative investigations in which an OFTT was employed (Table 1). This low ratio should further isolate the lipid metabolism effects following consumption of an OFTT. Protein does not appear to interfere with lipid metabolism[62]. As such, a greater ratio of protein (over that of CHO and saturated fats) is encouraged when developing an OFTT. The proposed 100g OFTT consists of roughly 17% protein, which is favorable to the heavy whipping cream base which contains a negligible volume of protein. This concentration of protein is superior to that commonly observed within commercially available heavy whipping cream, which ranges from 0-1g of protein per tablespoon. Consequently, the implementation of the proposed OFTT retains further health benefits over varieties holding to a base of heavy whipping cream.

5.3 Male and Female Triglyceride Metabolism

The interaction of OFTT and time is to be expected as all values increase above baseline values postprandially. There exists an interaction of time and sex ($F=3.115$, $p=0.049$), indicative of a more efficient TG metabolism among females. This sample was composed of young, apparently healthy, individuals (age: mean 27 years, SD=4.6). As age was thought to be a protective mechanism of TG metabolism, these findings were unexpected. There does not appear to exist any metabolic advantage of sex among healthy young adults among the liturature[63]. This is consistent with our findings; however, caution should be used prior to generalizing this relationship. TG metabolism slows as we age, therefore age could serve as a protective factor when challenged with a high-fat load[1]. The sex disparity among lipid metabolism is more noticeable with advancing age[1,2]. Persons with pre-existing conditions, such as hypertriglyceridemia, CVD, or diabetes, can skew these findings regardless of age[2]. As such, it is recommended that participants be screened for any health or lifestyle disparity prior to participation. Similar caution should be upheld when examining older adults (>50 years). With age, and in direct association with menopause, females lose their protective mechanism of circulating estrogen[2]. As such, it is common to observe a decreased ability to efficiently metabolize TG among older females[1,2].

5.3.1 Active and Sedentary Triglyceride Metabolism

There exists no significant interaction of TG metabolism among active and sedentary conditions (F=0.514, p=0.805). The lack of significant effects (p=0.805, d=0.209) of an active lifestyle are contrary to our hypothesis, as well as other research findings. In a study by Cohen et al. active and non-active persons were given a high-fat challenge. This was undertaken absent of an exercise intervention. The authors found that the active population displayed an attenuation of TG over that of the sedentary population sample[1,16]. However, in a more recent investigation examining postprandial lipemia in young men and women of contrasting activity, there was determined no benefits of an active lifestyle when controlled for recent exercise[23]. Thus, it appears more active persons elicit a more favorable TG response following exercise than does their sedentary counterparts.

Investigations which have previously examined TG metabolism among active and sedentary individuals have found greater attenuation among the active population. One such investigation analyzed data from 671 individuals belonging to the Phenotype Intervention Heart Study[64]. Activity was continuously measured over the course of seven days. Those persons with usual physical activity expressed a decrease in postprandial triglyceride (PPT) elevation[64]. The protective effects of an active lifestyle likely originate from the protective relationship of HDL on TG subfractions[65]. These data further conflict with our results which reflect an active lifestyle does not attenuate PPT following a high-fat meal. There is substantial evidence to support disordered lipid metabolism as a precursor to greater health defects such as hyperlipidemia[66]. Maintaining an active lifestyle as a resource for sustaining an improvement in lipid metabolism should be adopted among all populations.

Potential limitations of the present investigation include the lack of pre-test meal standardization. To minimize this potential effect, participants kept individual food journals. Although participants gave verbal confirmation of meal replication, some variation may exist. Additionally, participants were advised to abstain from alcohol and vigorous exercise the day prior to data collection. These lifestyle interventions could not be tracked and validated by any member of the research team. It is unknown how this valid and reliable 100g OFTT will respond to populations outside of our healthy, college-aged, sample. The effect size of the three-way sex interaction was low (0.325), thus caution should be used when seeking this interaction as these present findings are underpowered. Lastly, AUC comparisons have yet to be determined.

6.0 Conclusion

In conclusion, the 100g OFTT load has proved to be a reliable and valid measure for observing TG elevation over time. The composition of a specific ratio of Benicalorie® and Ensure® Plus, totaling 99g of fat, 38.25g of CHO, and 29g of protein, is more appropriate than the 50g and 150g loads. Further, the 100g load would be a reliable for research and clinical purposes. We observed females have a more favorable TG panel following an OFTT than do males. Thirdly, there is no apparent difference in TG metabolism between active and sedentary persons, absent an exercise intervention. Benicalorie® and Ensure® Plus are commonly administered in clinics and hospitals and consist of standardized ingredients. The use of these commercially available products is encouraged as it is easily repeatable, converse to other OFTT consisting of an unspecified combination of ingredients. These practices will limit error potential and lend a more accurate representation of lipid metabolism over time. Future investigations should consider more rigorous diet and exercise constraints, such as standardized meals on the day preceding the administration of an OFTT. Additionally, as this is the only investigation (to our knowledge) examining reliability and validity, it would be of benefit to the scholarly body of knowledge to re-visit previous investigations utilizing a previously established and reliable OFTT.

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65. Thompson PD, Cullinane EM, Sady SP, Flynn MM, Chenevert CB, Herbert PN. High density lipoprotein metabolism in endurance athletes and sedentary men. *Circulation*. 1991;84(1):140-152. https://www.ncbi.nlm.nih.gov/pubmed/2060090. doi: 10.1161/01.CIR.84.1.140.

66. Sanda S, Mamilla R. A comparative study of lipid profile in sedentary and active adult females. *Journal of Evidence Based Medicine and Healthcare*. 2017;4(91):5499-5501. https://www.openaire.eu/search/publication?articleId=doajarticles::ea648d9b20bd8086d07376d4c9fcc2c3. doi: 10.18410/jebmh/2017/1099.

Curriculum Vitae

Nathaniel G. Bodell

University of Nevada, Las Vegas

Email: nbodell@gmail.com

Education

Ph.D., Interdisciplinary Health Sciences, Exercise Physiology

University of Nevada, Las Vegas, Las Vegas, NV 2019

Dissertation: *"Triglyceride Metabolism Following Oral Fat Tolerance Tests of Varying Fat Content Among Young Healthy Sedentary and Active, Males and Females"*

Advisor: James Navalta, Ph.D.

M.S., Exercise Science

California Baptist University, Riverside, CA 2015

Thesis: "*90 Minutes of Moderate-Intensity Exercise does not attenuate Postprandial Triglycerides in Older Adults"*

Advisor: Treavor Gillum, Ph.D.

B.S., Exercise Science

California State University of San Bernardino, San Bernardino, CA
2013

Advisor: Bryan Haddock, Ph.D.

Academic Appointments

University of Nevada, Las Vegas (UNLV)

Teaching Assistant, Dept. of Kinesiology and Nutrition Sciences 2016-Present

Doctoral Graduate Research Assistant, Dept. Kinesiology and Nutrition 2016-Present

California State University of San Bernardino (CSUSB)

Adjunct Teaching Professor, Dept. of Kinesiology 2015-2017

Teaching Experience

Universities

University of Nevada, Las Vegas Dept. of Kinesiology and Nutrition Sciences

KIN 491-02: Exercise Physiology Lab

Topics related to the function and testing of exercise physiology, health, and fitness, to include: Sub-maximal cardiovascular testing, Maximal cardiovascular testing, muscular strength, muscular endurance, flexibility, body composition testing, balance, heart rate and blood pressure, field v lab tests of fitness, and consenting process.

California State University San Bernardino, Dept. of Kinesiology

KIN486 Exercise Science Instrumentation

Prepares students to calibrate and operate basic physiological equipment used in fitness assessment. Content is consistent with skills necessary to prepare students as a health and fitness specialist by the American College of Sports Medicine

KIN360 Activity and Aging

Examination of the neurological and physiological changes associated with the aging process from post-adolescence through the senior years. Includes information concerning special planning, implementing and evaluation of adult oriented physical activity programs

KIN270 Introduction to fitness testing

Provide an understanding of the scientific basis for assessing physical condition, fitness, and strength development. Acquisition of the skills and techniques necessary for designing and evaluating fitness programs for specific applications. Understanding the scientific basis for assessing physical conditional, fitness, and strength development. Acquisition of the skills and techniques necessary for designing and evaluating fitness programs for specific applications.

KIN240 Exercise Science Software

Provide the student with the tools for examination and analysis of computer software utilized in exercise science, physical education and athletics; including: Microsoft PowerPoint, Word, Excel, and SPSS

KIN210 Introduction to Kinesiology

A survey of the discipline of Kinesiology, including knowledge derived from performing physical activity, studying about physical activity, and professional practice centered in physical activity. It includes an analysis of the importance of physical activity in daily life, the relationship between physical activity and the discipline of Kinesiology, and the general effects of physical activity experiences.

Primary and Secondary Education

Snowline Joint Unified School District

Substitute Teacher – Serrano High School 2014-2015

Diligently and effectively carry out the lead teacher's daily plans. Efficiently manage classroom etiquette and behavior.

Interim Physical Education Teacher – Vista Verde Elementary, Phelan Elementary, Baldy Mesa Elementary 2013-2014

Lesson plan, organize, and administer a comprehensive physical education program for grades K-5, with class sizes ranging from 40-140 students.

Physical Education Assistant – Vista Verde Elementary, Phelan Elementary, Baldy Mesa Elementary 2013

Administer a physical education program to elementary aged students, grades K-5, as directed by the primary instructor.

San Bernardino County Superintendent of Schools 2005-2008

Special Educational Assistant

Assist teachers in the instruction and education of special education students, grades preschool-12, and deliver lesson plans as designed by the instructor.

Academic Publications

Peer-Reviewed Publications

Bodell NG, Gillum, T. 30 Minutes of Acute Moderate-Intensity Exercise Prior to a High Fat Meal Does not Attenuate Postprandial Triglycerides in Postmenopausal Women, *International Journal of Physical Education, Fitness and Sports*, 8(1):72-78, 2019. DOI: 10.26524/ijpefs1919

Navalta, JW, Tanner EA, **Bodell NB**. Effect of Acute Normobaric Hypoxia Exposure on Excess Postexercise Oxygen Consumption, *Aerospace Medicine and Human Performance*, 2018 -In Press

Navalta, JW, Montes J, **Bodell NB,** Aguilar CD,…DeBeliso M. Wearable Device Validity in Determining Step Count During Hiking and Trail Running, *Journal for the Measurement of Physical Behavior*, 1(2):86-93, 2018.

DOI: https://doi.org/10.1123/jmpb.2018-0010

Navalta, JW, Radzak, KN, Montes J, Tanner EA, **Bodell NG**, Manning JW. Prediction of 5 km trail race performance from a shorter distance trail run, *Biology of Exercise*, 14(1): 23-30, 2018.

Impact factor: 0.987. D.O.I: https://doi.org/10.4127/jbe. 2018. 0127

Navalta, JW, Montes, J, **Bodell, NG**, Tanner, EA, Young, JC. Sex and Age Differences in Trail Half Marathon Running, *International Journal of Exercise Science*, 11(6): 281-289, 2018.

Bodell NG, Gillum T. 90 Minutes of Moderate-Intensity Exercise does not attenuate Postprandial Triglycerides in Older Adults. *Int J Exerc Sci*. 9(5):677-684, 2016.

In Press

Navalta JW, Radzak K, Montes J, **Bodell NB**, Aguilar CD, Manning JW, BeBeliso M. Reliability of the Stryd Power Meter in Hiking and Trail Running, Measurement in Physical Eduation and Exercise Science, September 2018.

Articles in Preparation

Bodell NG. (In preparation) Review: The Resistance Training Effects on Lipolysis

Bodell NG, Craig-Jones A. (In preparation) Does False Feedback Alter Performance in an Anaerobic Maximal Test Among Healthy Young Adults?

Presentations and Invited Talks

Conference Presentations

Bodell NG, Craig-Jones A, Navalta JW. Does False Feedback Alter Performance in an Anaerobic Maximal Test Among Healthy Young Adults? Annual Meeting of the American College of Sports Medicine, Minneapolis, MN. Medicine and Science in Sports and Exercise, 50(5): S85-86, 2018.

Navalta JW, **Bodell NG**, Tanner EA, Aguilar CD. Effect of Exercise in a Desert Environment (“Brown Exercise”) on Emotional and Physiological Measures. Annual Meeting of the American College of Sports Medicine, Minneapolis, MN. Medicine and Science in Sports and Exercise, 50(5): S66, 2018.

Aguilar CD, **Bodell NG**, Montes J, Tanner EA, Woita A, Knurick J, Navalta JW. Comparison between Six Hours of Continuous Walking to Six Hours of Intermittent Walking. Annual Meeting of the American College of Sports Medicine, Minneapolis, MN. Medicine and Science in Sports and Exercise, 50(5): S739-740, 2018.

Navalta JW, Tanner EA, Tacad DK, **Bodell NG**. Effect of Acute Simulated Altitude Exposure on Excess Postexercise Oxygen Consumption. Annual Meeting of the American College of Sports Medicine, Denver, CO. Medicine and Science in Sports and Exercise, 49(5): S183, 2017.

Bodell NG, Craig-Jones A, Navalta JW. Does False Feedback Alter Performance in an Anaerobic Maximal Test Among Healthy Young Adults? Annual Meeting of the Southwest American College of Sports Medicine, Long Beach, CA, Oct 2017.

Taylor JE, Manning JW, Thomas C, Tanner E, **Bodell NG**, Montes J, Navalta JW. Rock Climbing Speed Impacts Energy Expenditure. National Strength and Conditioning Association Annual Conference, Las Vegas, NV, 2017.

Bodell NG, Tanner E, Montes J, MacDonald GA, Thomas C, Manning JW, Taylor JE, Navalta JW. Excess Post-Exercise Oxygen Consumption Following Bouts of Moderate and Vigorous Climbing. American College of Sports Medicine 64th Annual Meeting & 8th World Congress on Exercise is Medicine, Denver, CO, May 2017.

Bodell NG, Tanner E, Montes J, MacDonald GA, Thomas C, Manning JW, Taylor JE, Navalta JW. Excess Post-Exercise Oxygen Consumption Following Bouts of Moderate and Vigorous Climbing. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA, Oct 2016.

Aguilar CD, Woita AC, Montes J, **Bodell NG,** Tanner EA, MacDonald GA, Thomas C, Manning JW, Taylor J, Navalta JW. Prediction of Mechanical Efficiency from Body Fat Percentage and Years of Experience in Male and Female Rock Climbers. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA, Oct 2016.

MacDonald GA, Montes J, Tanner EA, **Bodell NG,** Manning JW, Navalta JW. A Mile Trail Run can Predict Performance for a 5K Trail Race. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, Oct CA, 2016.

Navalta JW. Montes J, Tanner EA, **Bodell NG,** Young JC. Sex and Age Differences in Trail Half Marathon Running. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA, Oct 2016.

Tallent RC, Woita AC, Aguilar CD, Young J, Navalta JW, **Bodell NG,** Montes J, Tanner EA, MacDonald GA, Thomas C, Manning JW, Taylor J. Comparison of Mechanical Efficiencies from Steady State and Rapid Speed Rock Climbs. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA, Oct 2016.

Woita AC, Young J, Navalta JW, **Bodell NG,** Montes J, Tanner EA, MacDonald GA, Thomas C, Manning JW, Taylor J. Mechanical Efficiency during Repeated Attempts of Indoor Rock Climbing. Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA, Oct 2016.

Bodell NG, Gillum T. 90 Minutes of Moderate-Intensity Exercise does not attenuate Postprandial Triglycerides in Older Adults. Poster Presentation. SWACSM Conference, Costa Mesa, California, Oct 2015.

Bodell NG, Gillum T. 30 Minutes of Acute Moderate Exercise Prior to a High Fat Meal Does not Attenuate Postprandial Triglycerides in Postmenopausal Women. Poster Presentation. SWACSM Conference, Costa Mesa, California, Oct 2014.

University Conferences

Excess Post-Exercise Oxygen Consumption Following Bouts of Moderate and Vigorous Climbing. 20th Annual Graduate & Professional Student Research Forum, University of Nevada, Las Vegas, Feb 2018.

Journal Involvement and Activity

Student Managing Editor, International Journal of Exercise Science, 2018-Present

Reviews

Papalia Z, Wilson O, Bopp M, Duffey M. Technology-Based Physical Activity Self-Monitoring Among College Students. *Int J Exerc Sci*. (*in press*) 2018.

Pereira UR, Ribeiro GS, Lopes AL. Can Heart Rate Variability Predict the Second Metabolic Threshold in Young Soccer Players? *Int J Exerc Sci.* (in press) 2018.

Knechtle B, Knechtle C, Rosemann T, Pantelis NT. Pacing of an Untrained 17-Year-Old Teenager in a Marathon Attempt Marathon pacing of an untrained teenager. *Int J Exerc Sci*. 11(6): 856-866, 2018.

Monteiro ER, Novaes JS, Fiuza AG, Portugal E, Triani FS, Bigio L, Santos R, Palma A, Correa Neto VG. Behavior of Heart Rate Variability After 10 Repetitions Maximum Load Test for Lower Limbs. *Int J Exerc Sci*. 11(6): 834-843, 2018.

Orr RM, Caust EL, Hinton B, Pope, R. Selecting the Best of the Best: Associations between Anthropometric and Fitness Assessment Results and Success in Police Specialist Selection. *Int J Exerc Sci*. 11(4): 785-796, 2018.

Simpson GW, Pritchett R, O'Neal E, Hoskins G, Pritchett K. Carbohydrate Mouth Rinse Improves Relative Mean Power During Multiple Sprint Performance. *Int J Exerc Sci.* 11(6): 754-763, 2018.

Rist B, Young JA, Pearce AJ. Attitudes towards sports concussion in Australian exercise science students. Does the type and level of participation in sport matter? *Int J Exerc Sci.* 11(5): 739-753, 2018.

Brousseau H, Kuchta K, Potter S, Newhouse I. The Effect of Active Ankle T1™ Ankle Braces on the Timing of Muscular Activation in the Leg in Female Varsity Volleyball Players: A Pilot Study. *Int J Exerc Sci*. (*in press*) 2018.

Peterson JA, Darling TV. Childhood Cancer and Treatment Effects on Motor Performance. *Int J Exerc Sci.* 11(3): 657-668, 2018.

Moreno MR, Lockie RG, Kornhauser CL, Holmes RJ, Dawes JJ. A Preliminary Analysis of the Relationship between the Multistage Fitness Test and 300-m Run in Law Enforcement Officers: Implications for Fitness Assessment. *Int J Exerc Sci.* 11(4): 730-738, 2018.

Johnson B, Vanbelkum A, Kraft J. A Description of Physical Activity Outcomes during Beginning Curling. *Int J Exerc Sci.* 11(6): 633-639, 2018.

Stavres JR, Zeigler MP, Bayles, MP. Six Weeks of Moderate Functional Resistance Training Increases Basal Metabolic Rate in Sedentary Adult Women. *Int J Exerc Sci.* 11(2): 32-41, 2018.

Pearson, RC, Crandall, JK, Dispennette, K, Maples, JM.Students' Perceptions of an Applied Research Experience in an Undergraduate Exercise Science Course. *Int J Exerc Sci*. 10(7): 926-941, 2017

Beyer, KS, Fukuda, DH, Miramonti, AM, Hoffman, MW, Wang, R, LaMonica, MB, Riffe, JJ, Tanigawa, S, Stout, JR, Hoffman, JR. Spatial Awareness is Related to Moderate Intensity Running during a Collegiate Rugby Match. *Int J Exerc Sci*. 9(5): 599-606, 2016.

Grants and Funding

Funded Grants

Southwest Airlines Travel Award, 2018, ($600, *under consideration*)

UNLV Summer Doctoral Research Fellowship, 2018 ($7000)

UNLV Graduate & Professional Student Association

Travel grant for American College of Sports Medicine National Meeting, Minneapolis, MN, 2018 ($650)

UNLV Dept. of Kinesiology and Nutrition Sciences

Travel Grant for American College of Sports Medicine National Meeting, Minneapolis, MN, 2018 ($500)

UNLV Graduate & Professional Student Association

Graduate Research Grant, 2018 ($500)

UNLV Graduate & Professional Student Association

Travel grant for American College of Sports Medicine National Meeting, Denver, CO, 2017 ($700)

UNLV Dept. of Kinesiology and Nutrition Sciences

Travel Grant for American College of Sports Medicine National Meeting, Denver, CO, 2017 ($319.67)

Non-funded Grants

Bodell, NB. The Standardization and Reliability of an Oral Fat Tolerance Test for Clinical and Research Applications. American College of Sports Medicine: ACSM Foundation Doctoral Student Research Grant ($5000)

Navalta JW, Angosta A, Montes J, **Bodell, NB**, Aguilar C. Evaluation of Intermittent Hypoxic Resistance Training on Biometric Parameters. UNLV Center for Biobehavioral Interdisciplinary Science ($10,000)

Volunteer and Internship Work

Graduate Professional Student Association, *UNLV 2017*

Fit, Fresh, Fun ‘n Young Committee, *City of Riverside 2014*

Disability Sports Festival Volunteer, *CSUSB 2012*

Claremont Club Wellness Intern, *Claremont Club 2012*

Honors, Awards, and Scholarships

National Association for Sport and Physical Education (NASPE) Outstanding Major of the Year Award, *2013*

Annual Dean’s List, *CSUSB 2012*

Presidents List, *VVC 2010*

Membership in Professional Organizations

American College of Sports Medicine (ACSM), 2012

National Association for Sport and Physical Education (NASPE), 2012

National Strength and Conditioning Association (NSCA), 2012

Equipment Competencies

- Metabolic testing: *VIAYSYS/CareFusion, Parvo Medics TrueOne 2400, Medgraphics, MOXIS II, Cosmed k4*
- Electromyography: *BIOPAC systems MP150*
    - *Developed lab protocol for equipment, CSUSB*
- Lactate Testing: *NOVA biomedical lactate plus, Accutrend Lactate, Accusport*
- Wingate Anaerobic Test: *Monark cycle ergometer, Wattbike Pro*
- Electrocardiogram (ECG) Collection and Interpretation: *Quinton Q710, Atria 6100*

- Isokinetic Testing: *Biodex System 3*
- Cholesterol Testing: *Alere Cholestech LDX*, *CardioChek PA*
- Anthropometrics: *Hydrostatic Weighing: Exertech, Bod Pod: COSMED, Bioelectrical Impedance: Omron, Tanita BF-350, ImpediMed Imp SFB7, Bodystat 1500*
- Balance Testing: *Biodex Balance System SD*
- Field Testing: *YMCA Step Test, Queens College Step Test, One Mile Walk Test, YMCA Sit and Reach, Upper and Lower Body Goniometer Testing*

Certifications

2016 American Heart Association First Aid/BLS/CPR/AED Certified

2012 California Basic Educational Skills Test, Substitute Teaching Prerequisite

2012 American College of Sports Medicine (ACSM) Certified Personnel Trainer