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A 16-week run sprint interval training does not have an effect on cardiovascular risk measured by Framingham risk score on prediabetic women

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A 16-Week Run Sprint Interval Training Does Not Have an Effect on Cardiovascular Risk
Measured by Framingham Risk Score on Prediabetic Women

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Dedication

I would like to dedicate this thesis to my amazing husband, Adam.

Returning to school, this research, and so much of the past four years would have never

come to fruition had it not been for your unwavering encouragement, love, and support.

Thank you for helping me pursue my dreams. Thank you for always listening and telling me

how it is. Thank you for all the pep talks. Thank you for everything.

Love Always,

Joan

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Abstract

The Framingham Risk Score (FRS) was developed to determine the likelihood of developing cardiovascular disease (CVD) in the next 10 years using an individual's age, gender, total cholesterol (TC), High Density Lipoprotein Cholesterol (HDL-C), smoking habits, and systolic blood pressure (SBP). Run-Sprint Interval Training (R-SIT) has shown improvements in various health and blood markers while reducing total exercise time. To date there has not been a study that examines the effects of R-SIT and Moderate Intensity Training (MIT) on Framingham Risk. The purpose of this study was to determine if a reduction of the 10-year risk of CVD (determined by Framingham CVD risk calculator), is greater in an R-SIT experimental group compared to a moderate intensity group (MIT) of sedentary prediabetic women, after a 16-week intervention. Participants were randomized into R-SIT (n=6) or MIT (n=9) groups and required to attend 3 weekly training sessions and 1 weekly Diabetes Prevention Program session for 16-weeks. During the first 4 weeks, R-SIT performed 4x30s maximal sprints on a treadmill at a self-selected speed and incline, followed by a 4-min active recovery between intervals. Intervals increased by 2 every 4 weeks. MIT walked continuously at 45-55% Heart Rate Reserve for 30-mins during the first 4 weeks, and increased by 10-mins every 4 weeks. FRS markers were measured at baseline, mid, and post intervention.

After 16-weeks of exercise training, there was a significant time by group interaction in weight, Body Mass Index (BMI), and Body Fat Percent (BF%). *T*-tests indicate MIT significantly decreased in weight (-2.60±1.32 kg), BF% (-1.58±1.54), and BMI (-2.42±1.32 kg). R-SIT significantly changed in BF% from baseline to mid (-2.33±0.72) and mid to post (+1.53±0.46), but not from baseline to post (-2.16±2.53). Additionally, there was a trend toward significant improvements in BMI (p=0.078) and lean body mass

(p=0.059) (-0.85±0.06 kg/m^2, +1.05±0.46 kg, respectively). Lastly, R-SIT participants also significantly decreased changes in TGs from midline to post (-23.33±17.92 mg/dL). Though FRS and Vascular Age (VA) were significantly different between groups at all three time points, there were no significant within group changes observed

The major findings of this study were that after 16-weeks of exercise training, MIT had significant within group decreases for weight, BMI, and BF%, while R-SIT significantly decreased in BF% and VO_{2max} ($mLkg^{-1}min^{-1}$). In conclusion, though previous R-SIT and HIIT studies have suggested improved body composition and cardiovascular risk factors when compared to MIT, the present study only observed significant changes in body composition and minimal changes to CVD risk factors. Additional research is needed to further understand the effects of R-SIT on blood lipid profiles and its relationship with CVD, especially in the clinical population.

<u>Keywords</u>

Framingham Heart Study; Cardiovascular Disease (CVD); High Intensity Interval Training (HIIT); exercise intensity; interval training; diabetes

Chapter I

<u>Introduction</u>

According to the Centers for Disease Control and Prevention (CDC), more than one third of the American adult population are obese (1). Often there is a correlation between obesity and sedentary behavior (2, 3). Consequently, obesity and inactivity are known to be linked to health related problems such as cardiovascular disease (CVD), stroke, insulin resistance, type 2 diabetes, certain types of cancer, reproductive abnormalities, and osteoarthritis (2-8). According to Reaven et al., both obesity and sedentary behaviors are "strongly and independently" associated with diabetes and its comorbidities (3). As a result of this link between inactivity and certain diseases, emerging research exploring the role of exercise is being closely investigated. Exercise is a direct, cost-effective way of improving overall health (5-7, 9, 10). Improved fitness has proven benefits to cardiovascular health and the prevention of metabolic diseases such as CVD and type 2 diabetes (2, 3, 11-15). Furthermore, it can also "reverse" some of the adverse effects associated with metabolic syndrome (16). According to Bird et al., there is "no single intervention with greater efficacy than physical exercise to reduce the risk of virtually all chronic diseases simultaneously" (17). Benefits of exercise training include reduced blood pressure (BP), increased high-density lipoprotein cholesterol (HDL-C), improved body composition, and improved VO_{2max}.

The American College of Sports Medicine (ACSM) recommends that most adults should accumulate at least 150 minutes a week of moderate intensity, 75 minutes per week of vigorous intensity, or a daily combination of moderate and vigorous aerobic exercise per week (18). Individuals participating in these recommendations have shown improvements in fasting blood glucose and type 2 diabetes risk (19). For diabetics there may be additional benefits gained from intensities >60% of VO_{2max} (19). According to a meta-analysis

conducted by Boule et al., when compared to moderate intensity exercise, higher intensities produced better results in glucose control and VO_{2max} in type 2 diabetics (20).

Despite exercise being a cost-efficient and effective response to many of the acute and chronic diseases that Americans face, only about 15% of American adults participate in vigorous regular exercise (three times a week for at least 20 minutes) and only 22% participate in regular exercise at any intensity (five times a week for at least 30 minutes) (21). The most-cited reason for poor participation in exercise programs, regardless of age, sex, ethnic background, or health status (17), is a lack of time (7, 9, 13, 22-24). For many, time is limited and ACSM's recommendations seem unrealistic and unattainable (17). As a result, more research has focused on reducing the time factor involved in physical activity, while maintaining and/or improving aerobic and metabolic benefits seen with traditional exercise programs (7, 9, 13, 22-24).

High intensity interval training (HIIT) is an exercise protocol that has recently been the subject of many research studies (2, 5, 7-10, 16, 22, 25-37). HIIT is defined as intense periods of intermittent exercise above anaerobic threshold (80-100% maximal heart rate or $\%HR_{max}$), separated by periods of rest or low intensity exercise that do not allow for full recovery (10, 38, 39). Repeated bouts at a high intensity have shown improved lipid oxidation, insulin sensitivity, and vascular endothelial function as well as increased maximal oxygen uptake and decreased subcutaneous fat (2, 17). The observed benefits are thought to be the result of continuous stress that increases participants' metabolic demand, more so than traditional endurance exercise (2). Not only has HIIT proven to produce rapid aerobic improvements similar to what is seen in traditional endurance protocols, but it accomplishes this in less active time (7, 13, 17, 23).

HIIT encompasses several different exercise interventions that manipulate levels of intensity, interval duration, recovery times, and total work volume (10, 38). Additionally, it encompasses various modalities, including running and cycle ergometers. Generally, HIIT protocols are completed at near maximal intensities (between 80-100%) for longer periods of time (three-four minutes) (39). Sprint Interval Training (SIT), a type of HIIT, incorporates all-out supramaximal (>100% %HR_{max}) all-out sprint intervals (~30 seconds) with relatively long periods of active recovery between the intervals (39). The major difference between HIIT and SIT is in the 'all-out' effort expected of the participants. The higher intensity results in shorter intervals and total duration (10, 37, 38). Generally, HIIT protocols are completed at high (but not maximal) intensities for longer periods of time (two-four minutes) (38). Both HIIT and SIT have shown rapid, beneficial adaptations that may help with cardiovascular health and type 2 diabetes prevention in both pre-clinical and clinical populations (17). For the purposes of this paper we will review Running-SIT (R-SIT) protocols that resemble the methods studied here, but because of limited available research, HIIT and cycling SIT studies will be referenced for additional comparison.

<u>Cardiovascular Disease and Framingham Scores</u>

CVD is the leading cause of death in the United States, accounting for approximately 1.2 million deaths from 2010-2011 (40). CVD is defined by the American Heart Association as problems related to atherosclerosis or plaque buildup that restrict blood flow in the arteries (41). The major risk factors for CVD are dyslipidemia, hypertension, physical inactivity, obesity, type 2 diabetes, insulin resistance, and smoking (42). An individual's risk can be controlled or reduced with regular exercise, weight control, diet, and smoking cessation (42).

In 1948, the National Heart, Lung, and Blood Institute (NHLBI) partnered with Boston University to learn more about the causes of CVD, resulting in what is now an on-going study known as the Framingham Heart Study (43). The original cohort had 5,209 participants and followed individuals over the course of several years to identify what common characteristics resulted in CVD. Participants returned every two years for a detailed physical examination. In 1971, a second cohort of 5,124 individuals was enrolled. These new participants were children of the original participants, allowing for long-term hereditary effects to be studied. Since the inception of the two original cohorts there have been four more added and studied: the Omni Cohort (1994), Third Generation Cohort (2002), New Offspring Spouse Cohort (2003), and Second Generation Omni Cohort (2003). As a result of the valuable information gathered from this on-going study, the Framingham Risk Scores were developed in 1998. These algorithms rate the risk of different outcomes, such as atrial fibrillation, CVD, congestive heart failure, coronary heart disease, diabetes, hypertension, intermittent claudication, and stroke (44).

For the purposes of this study we will assess baseline, midline, and post scores of participants' CVD risk in the next 10 years. The CVD risk calculator uses age, gender, total cholesterol, HDL-C, smoking habits, and systolic BP to estimate the risk of non-diabetics (fasting blood glucose at or below 125 mg/dL) between the ages of 30-74 who have no previous heart disease diagnosis. Potential CVD outcomes predicted by the score are coronary death, myocardial infarction, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, transient ischemic attack, peripheral artery disease, and heart failure.

To our knowledge there are no HIIT or SIT studies that have documented pre and post-Framingham scores.

Blood Lipid Profile

Poor lipid values are highly correlated with instances of atherosclerosis. High triglycerides (TG) and low HDL-C are risk factors for CVD (3, 25, 45, 46). High HDL-C is known to have an atheroprotective role because of its ability to carry cholesterol from the vascular system and arterial walls to the liver for excretion (25). The chance of a cardiac event is five times greater in someone who has a total blood cholesterol over 259 mg/dL as opposed to someone whose total blood cholesterol is under 200 mg/dL (47).

Exercise is known to have a positive impact on cholesterol and as a result is often prescribed to patients at risk for CVD (12, 27). It increases HDL-C concentration and, as is suggested by some of the literature, it also may lower total cholesterol and low-density lipoproteins cholesterol (LDL-C). Additionally, exercise has an atheroprotective effect by increasing the mean size of HDL-C and LDL-C particles. Small particles are known to be related to complications of the disease process (12). Lastly, exercise reduces plasma TG concentrations, especially exercise in a postprandial state. Reduced plasma TG concentrations are likely the underlying mechanism for the effect exercise has on the size of HDL-C and LDL-C, and HDL-C concentration (12). A decrease in TG concentrations may be a result of TG clearance in the skeletal muscle and a decreased hepatic production of very-low-density lipoproteins (VLDL-C) (11). Though changes in TG concentrations are acute and likely associated to the energy expenditure, repeated bouts of exercise often lead to a more favorable blood lipid profile (12).

Results of current SIT and HIIT studies are mixed in regards to changes in blood lipid profiles, and the exact impact of interval training has yet to be defined. This could be a result of differing methodology, though the main reasons are likely short intervention time (24) and/or healthy participants with normal blood lipid profiles at baseline (8, 22, 25).

Additionally, timing of meals and diet may exacerbate these discrepancies (26). Regardless, studies that incorporate blood lipid profiles are limited.

Of the studies reviewed with blood lipid comparisons, there are three that involved running interval interventions, all with differing results. Sandvei et al. reported that eight weeks of R-SIT improved total cholesterol in healthy young participants when compared to the control group. The study observed a 9% improvement in LDL-C but no changes in HDL-C (8). Alternately, a six-week R-SIT study conducted on a group of 15 recreationally active females reported no change in LDL-C, TG, or total cholesterol and a small decrease in HDL-C (22). Lastly, Musa et al. observed an 18% improvement in HDL-C and no significant changes in total cholesterol after eight weeks of R-HIIT at 90% HR_{max} on untrained young men (25). The study concluded that significant improvement of HDL-C was likely the result of unfavorable baseline concentrations. It should be noted that this R-HIIT study was conducted on an outdoor track instead of a treadmill, as is typically seen in the literature. The little-to-no changes observed in other blood lipid markers of all of these R-SIT studies were likely due to the healthy sample pool and otherwise normal baseline levels (8, 22, 25).

To our knowledge there are no R-SIT or R-HIIT studies with clinical participants that consider blood lipid profiles. Of the studies there are three cycling interventions on clinical and obese/overweight participants (13, 24, 30). The results of these studies are also mixed. Keating et al. reported that 12 weeks of HIIT on overweight adults had significant improvements in total cholesterol and LDL-C when compared to a continuous exercise group. However, the study found no significant interaction between TGs and HDL-C (13). Alternatively, Heydari et al. found no significant change in blood lipids after 12 weeks of HIIT on inactive overweight males, however the study indicated that participants' baseline

levels were within the normal range (30). Similarly, Whyte et al. also reported no change in total cholesterol or HDL-C after two weeks of SIT on sedentary overweight/obese men (24). It should be noted, though, that this study lasted only two weeks and according to the researchers a longer intervention may be needed to see the chronic adaptations of exercise.

Kraus and colleagues took a different approach in analyzing lipid changes and its relationship to intensity. Their research compared the effects of six months of high-amount-high-intensity (the caloric equivalent of jogging 20 miles per week at 65-80% VO_{2peak}), low-amount-high-intensity (the equivalent of jogging 12 miles per week at 40-55% VO_{2peak}), low-amount-moderate-intensity exercise (the equivalent of walking 12 miles per week at 40-55% VO_{2peak}), to a control group of overweight men and women and found that changes in lipoproteins were independent of exercise intensity (15). They reported that all exercise groups had improvements in TG concentration, concentration of VLDL-C, concentration of large VLDL-C particles, and size of VLDL-C particles. Additionally the high-amount-high-intensity group had significantly-reduced concentrations of LDL-C and small LDL-C particles, and increases in HDL-C concentration. Both high and low-intensity groups also observed increases in the average size of LDL-C particles. It is important to note that though this research was not a typical R-HIIT protocol, the lipid profiling methods used may prove more valuable than a standard lipid panel in clearing up contradicting HIIT evidence. Of the results reported, only HDL-C and TG would have been detected in a standard lipid panel and according to the researchers "the concentrations of LDL-C particles, small LDL-C particles, large HDL-C particles, and large VLDL-C particles are better indicators of CVD risk than are the elements of the traditional lipid profile" (15).

Blood Pressure

As with the previous variable, hypertension is an important risk factor for CVD. Since a change in BP is a function of cardiac output times total peripheral resistance (Δ pressure = cardiac output x total peripheral resistance), an increase in BP is the result of changes in cardiac output or total peripheral resistance. Elevated BP progressively causes cellular damage and hardening of the arteries, which results in a reduction of stroke volume and maximal oxygen consumption. This reduction in stroke volume causes an overall decrease in cardiac output, leading to an increase in peripheral resistance (42).

However, hypertension can be controlled with medication, diet, weight control and exercise, and all are common prescriptions for cardiac rehabilitation. Notably, the inclusion of exercise can mitigate the use of medications and often results in improved body composition (42). Exercise training has been proven to decrease both systolic and diastolic BP with more pronounced results in hypertensive patients (14, 32, 42). Improvements in BP as a result of training are related to the changes in the sympathetic nervous system (and potentially the renin-angiotensin system) that cause a decrease in total peripheral resistance (14). According to Foss, the traditional expected decrease as a result of training is about ~10mmHg and ~8 mmHg in systolic and diastolic, respectively (47). As little as a 5mmHg decrease in BP can translate to a 14% reduction in stroke mortality and a 9% reduction in CVD mortality (14).

Information on HIIT and BP is limited, though studies with clinical populations and higher baselines often resulted in improved BP (16, 32, 35). Though different variables of BP are considered, studies reviewed for these purposes indicated a reduction in both systolic and diastolic BP (16): a decrease in resting diastolic BP, exercise diastolic BP, recovery systolic BP, and recovery diastolic BP in normotensive women (with a family history hypertension)

(32); and a reduction in systolic ambulatory BP and diastolic ambulatory BP in hypertensive patients (35).

<u>Body Composition</u>

Obesity, particularly excess abdominal fat and visceral adipose tissue, is known to be linked to health-related problems including CVD, type 2 diabetes, and increased mortality (2, 13, 16). Obesity is associated with insulin resistance, poor lipid profiles, impaired cardiac function during exercise, decreased GLUT 4 transporters, impaired immune function, depression, chronic pain, and impaired mobility (2, 42). A modest weight loss of 5-10% of an individual's starting body weight can decrease body fats as well as improve glucose control (42). Furthermore, regular exercise can improve overall body composition (including visceral fat) independent of weight loss (13). Metabolically, exercise induces increases in epinephrine, norepinephrine, and growth hormone resulting in hormone-stimulated lipolysis. This leads to an increase in fatty acid availability and thus an increase in fatty acid uptake and oxidation for energy (13, 16). Acute bouts of HIIT appear to significantly increase these hormones, and since visceral fat is particularly sensitive to these hormones, it has been suggested that HIIT may be an effective method in improving body composition and reducing visceral fat (13). However, research regarding the effects of HIIT on body composition is limited and mixed, especially on clinical populations. Furthermore, because the total amount of fatty acid oxidation during and after exercise is not only a result of availability and uptake but a function of the activity's duration, more research is needed to definitively compare the efficacy of HIIT to prolonged traditional exercise (13). Observations of HIIT and SIT studies with overweight/obese participants include decreases in BMI (2, 16), waist circumference (16, 30), waist to hip ratio (2), body fat percent (BF%) (2), trunk fat (30), android fat (30), weight (16, 30), fat mass (30), visceral fat (30), increases

in fat free mass (30), and changes in body mass (2, 48). To our knowledge this is the first R-SIT study to look at body composition in prediabetics.

The most relevant running protocol with clinical participants found that after 16 weeks of running-HIIT (R-HIIT), weight was reduced by three and four percent by the R-HIIT and moderate intensity groups, respectively (16). Likewise, BMI and waist circumference were significantly reduced in both groups with no significant differences between the groups. It should be noted, however, that the purpose of this study was to compare the modes independent of the time, thus training volumes were equalized to similar amounts of kilocalories per session so that R-HIIT exercised for 40 minutes while the moderate intensity group exercised for 47 minutes.

Similarly, after 12 weeks of R-HIIT, Tan et al. found that body mass, BMI, BF%, and Waist-to-Hip Ratio (WHR) were significantly reduced in both R-HIIT and moderate intensity group in overweight college age women (2). Most notably, there was a 9.9% body fat loss in the R-HIIT group, which was significantly more when compared to a 5.2% loss in the moderate intensity group. The researchers concluded that R-HIIT "can be of great help to these obese people by decreasing the accumulation of fat tissue in different parts of the body while the low intensity exercise training has failed to produce any notable change" (2). It is important to mention that during the 12 weeks participants of this study exercised five times per week on an outdoor track as opposed to the typical three times on a treadmill seen in most R-HIIT and R-SIT studies, which could account for some of the results observed.

Alternatively, Keating et al. found that there were no significant changes between continuous exercise and HIIT groups in waist and hip circumferences, body mass, total lean mass, and gynoid fat. Additionally, they observed significant differences between groups in trunk fat, android fat, and total body fat. Both trunk and android fat increased in HIIT and

decreased in the continuous exercise group, while total body fat stayed the same in HIIT and decreased in the continuous exercise group. The researchers of this study concluded that continuous exercise, not HIIT, improves fat distribution in overweight adults (13).

<u>Insulin Resistance</u>

As abdominal adiposity increases there is usually an increase in insulin resistance (3, 12). It is this relationship between obesity and insulin resistance that plays a major role in CVD and diabetes (3, 12, 49, 50). Diabetes accelerates the atherosclerotic process and patients diagnosed with type 2 diabetes are two-to-five times more likely to have a cardiac event when compared to their non-diabetic counterparts (12, 19, 49). As a result, CVD is the leading cause of death in type 2 diabetics (49). Furthermore, HOMA-IR, a measure of insulin resistance, is considered a strong and independent predictor of CVD (49-51).

Cardiovascular disease risk can be reduced with exercise as a result of its positive effects on insulin resistance. After a single bout of exercise there is an increase in insulin sensitivity, an effect that has been observed for up to two days following the initial activity. The magnitude and impact of this effect is increased by periods of continuous exercise (12). The mechanical movement of exercise causes a release of calcium, which begins a cascade of signals ultimately leading to the translocation of GLUT 4 to the cell membrane (12, 19). The key in this process is that the mechanical translocation happens independent of insulin and as a result there is an acute increase of glucose uptake in the skeletal muscle, regardless of a person's insulin sensitivity status (12, 19). The control of blood glucose through regular exercise and weight loss can help lower the risk of type 2 diabetes by up to 58% in high-risk populations (19).

Evidence that HIIT and SIT provide additional benefits to insulin resistance when compared to traditional exercise is varied. A systematic review conducted by Sloth et al.

reported that SIT may have beneficial results to insulin sensitivity and glycemic control, but noted that HIIT and SIT studies conducted on clinical populations are limited (10). Furthermore, it has been suggested that subjects with metabolic abnormalities may show greater improvement because of a lower baseline than their healthier counterparts (32).

Tjonna et al. and Ciolac et al. both reported improvements in insulin sensitivity in interval groups with metabolic abnormalities (16, 32). These studies suggested that the improvement in insulin sensitivity from interval training may be attributed to an increase in β-cell function resulting from an enhanced insulin response and signaling. Furthermore, interval training improved activation and phosphorylation of the insulin receptor in both muscle and fat. Though the mechanism in muscle is not fully understood, it's generally accepted that there is a decrease in intracellular accumulation of triglycerides and increase in fatty acid oxidation, resulting in an increase of insulin's action (16, 32). Additionally there is an increase in mitochondrial biogenesis with interval training (13, 16).

VO_{2max}

VO_{2max} is known to be the best measure of a person's cardiovascular fitness and mortality. Reports from epidemiological studies indicate that low fitness and low VO_{2max} levels are often related to higher CVD rates and are strong predictors of future cardiac events (5, 35). Additionally it is also a measure of a person's oxidative phosphorylation capabilities, meaning that VO_{2max} reflects the highest rate of energy that an individual receives from aerobic metabolism. Improvements in VO_{2max} are a result of improved cardiac output as well as increased muscle oxidative potential (10). Improved cardiac output increases the oxygen that is available to the body, while the ability to extract the oxygen is a result of enzymatic and mitochondrial muscle adaptations. Intense interval training elicits rapid changes by challenging the aerobic energy system (10).

Typically, results from HIIT and SIT studies have shown improvements in VO_{2max}, with some studies showing a significantly higher improvement when compared to a moderate exercise group (5, 6, 8, 10, 16, 22, 24, 30-35). According to a review published by the Scandinavian Journal of Medicine & Science in Sports, there is enough evidence to support that 2 to 8 weeks of SIT will improve VO_{2max} in populations that have been studied, including sedentary, untrained, overweight/obese, as well as recreationally active individuals. Typical increases of about 4 to 13.5% were seen in most SIT studies (10).

A second meta-analysis conducted by Gist et al. reported an average 8% increase in VO_{2max} in the SIT intervention group when compared to the no-exercise control (5). The study went on to indicate that the improvements seen in oxidative capacity and exercise performance are similar to those seen in traditional endurance groups of moderate-to-vigorous intensity, however the training volume of the SIT group was only 10% of the endurance training group (5). Gist et al. also noted that though training volume was significantly less, warm up, active recovery, and cool down time will obviously increase the person's activity time, reducing the time-efficient appeal of HIIT and SIT (5).

R-SIT and R-HIIT studies conducted on clinical populations have shown similar improvements in VO_{2max}, with some studies reporting better results than the endurance or control group (2, 16, 35). Tjonna et al. suggested that intensity plays an important role in improving aerobic capacity, resulting in a higher reduction of risk factors, with 46% of the interval participants no longer having the metabolic syndrome diagnosis, compared to 37% of the moderate intensity group (16).

Diabetes Prevention Program

The Diabetes Prevention Program (DPP) began as a randomized control trial with 3,234 participants at 27 different centers, and has continued as an ongoing lifestyle

intervention program geared towards diabetes prevention in individuals with prediabetes or at risk for developing type 2 diabetes. The initial goals of the study were to determine if lifestyle changes or drug therapy (metformin) would have a greater effect on participants (52). Primary results from the program are in line with other organizations such as the American Diabetes Association and ACSM and indicate that people at risk for type 2 diabetes can avoid or delay the onset with the addition of physical activity, weight loss, and diet changes that include a reduction in fat and calories. Initial DPP findings revealed that lifestyle intervention reduced type 2 diabetes by 58% when compared to 31% observed with the metformin intervention (52). Adults 60 or older that participated were particularly successful, reducing their risk by 71% (53).

Participants of both groups (R-SIT and MIT) of this study received DPP education with lifestyle coaches. The program was broken down into 16 sessions that covered nutrition education, lifestyle changes, stress management, and motivation (54). The first eight weeks of the program were geared towards teaching participants fundamental information about caloric intake and exercise. During the second eight weeks the focus shifted towards psychological, social, and motivational components (52). These are important to help ensure long-term lifestyle modifications in maintaining healthy habits.

<u>Summary</u>

As the obesity epidemic in the US continues to grow, exercise training is a common prescription because of its known benefits and central and peripheral adaptations (5-7, 9, 10). The most commonly-cited reason for poor physical fitness is a lack of time (7, 9, 13, 22-24). As a result, protocols such as SIT and HIIT are being studied as time-efficient solutions with similar benefits to those seen in traditional exercise programs. Improvements in VO_{2max} have been reported by most studies(5, 6, 8, 10, 16, 22, 24, 30-35), but results of other

cardiovascular markers such as BP, body composition, glycemic control, and blood lipid profiles are inconclusive. The mixed results could be due to differences in the protocols, methods (interval times, rest times, study duration) and participants. Additional research to understand the cardiovascular benefits of SIT and HIIT is needed, especially on clinical populations.

An epidemiological study that looked at the participants of the Framingham Study concluded that the risk factors associated with CVD are increased 30 years before the individual is diagnosed with type 2 diabetes (45). This suggests that control of the risk factors, particularly glycemic control, hypertension, dyslipidemia and smoking cessation, should start early in life, and improvements on these factors could potentially decrease instances of CVD and type 2 diabetes.

<u>Limitations of Current Research</u>

The majority of HIIT and SIT studies have been done on healthy, physically active, and/or athletic individuals (7, 9, 13). Minimal work has been done on clinical populations, specifically prediabetic, type 2 diabetic, overweight, or obese participants. Additional research in this area may prove valuable since benefits and adaptations observed in studies on clinical populations may differ as a result of poor baseline measures. Furthermore, research within this population will have added benefits since generally this is the group that needs to improve baseline measures.

Another limitation of current studies is that the majority use cycle ergometer protocols instead of running protocols (2, 6, 8, 16, 22, 32, 35). Running is considered to be an easily accessible, affordable, and a popular mode of exercise for many. Consequently, there is little data on the adaptations resulting from R-SIT and R-HIIT. Additionally, the data that is seen in cycle protocols may not translate to the same results in running (8, 22).

Lastly, there is limited, and often mixed, information on variables such as body composition, insulin resistance, blood lipids, and BP. Differences observed in the literature could be a result of the timing of the intervals and active recovery periods, sample sizes, study duration, sample demographics, differences at baseline, and intervention mode.

Purpose

The purpose of this study was to determine if the reduction of the 10-year risk of CVD (determined by Framingham CVD risk calculator), is greater in an R-SIT experimental group compared to a moderate intensity group (MIT) of sedentary prediabetic women, after a 16-week intervention.

Hypothesis

It was hypothesized that 16 weeks of run spring interval training would show greater improvements in 10-year CVD Framingham Risk Score, body composition, VO_{2max}, blood pressure, and blood lipid values compared to moderate intensity training and control groups.

Assumptions

Assumptions for this study include: participants would be able to perform all-out maximal efforts on a treadmill; participants would not engage in other regular exercise programs outside of the intervention; participants were healthy with no previous CVD, pulmonary, or metabolic diagnosis.

Limitations

Seasonal changes were a limitation to this study. As the weather got colder, participants may have been less likely to spend time outside, which could have resulted in an average reduction of unstructured activity (55). Furthermore, holidays that occurred during the 16-week span (Thanksgiving to New Year's) may have negatively impacted participants' body weight, BF%, and BP (56).

Delimitations

A delimitation for this study is that the prediabetic sample were only recruited from the Harrisonburg, VA area.

Definitions

Cardiovascular Disease (CVD): As defined by The American Heart Association, problems related to atherosclerosis or plaque buildup that restrict blood flow in the arteries. CVD is also known as heart disease and includes heart attack, ischemic stroke, hemorrhagic stroke, heart failure, arrhythmia, mitral valve prolapse and heart valve disease.

Diabetes Prevention Program (DPP): A research study led by The National Institute of Health (NIH) with assistance from The Center for Disease Control and Prevention (CDC) that resulted in a lifestyle intervention program geared towards diabetes prevention in prediabetes or at those at high risk for developing type 2 diabetes.

Framingham Risk Score: As defined by The National Heart, Lung, and Blood Institute and Boston University, a score that predicts the chances (in percent) that an individual (non-diabetic and no prior history of heart disease) will have CVD (coronary death, myocardial infarction, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, transient ischemic attack, peripheral artery disease, heart failure) in the next 10 years. The score is based on age, gender, total cholesterol, HDL-C, smoker, and systolic BP (treated and untreated). For purposes of this study, the risk score will be calculated using a downloaded excel calculator from https://www.framinghamheartstudy.org (Appendix A).

Prediabetes: As defined by The American Heart Association,

- Hemoglobin A1C test: glycated hemoglobin indicative of blood glucose levels over a period of time, result within a range of 5.7-6.4

- Fasting Blood Glucose Test (FBG): 8 hour fasting blood sugar within a range of 100-125 mg/dl

- Oral Glucose Tolerance Test (OGTT): results within a range of 140-199 mg/dl

Sedentary: As defined by the ACSM, an individual who does not participate in at least 30 minutes of physical activity at 40-50% VO_2R at least 3 times per week.

Chapter II

Research Design

This study was a 16-week randomized controlled trial. Participants were randomly divided into two groups: Running-Sprint Interval Training (R-SIT) or Moderate Intensity Training (MIT). Additionally, all participants attended 16 weeks of Diabetes Prevention Program (DPP) education with trained lifestyle coaches. Data was collected at baseline, midline, and post intervention and included: Framingham Risk Score, vascular age, Blood Pressure (BP), Total Cholesterol (TC), High Density Lipoprotein Cholesterol (HDL-C), Low Density Lipoprotein Cholesterol (LDL-C), Very Low Density Lipoprotein Cholesterol (VLDL-C), Triglycerides (TG) body weight, height, body composition, and cardiovascular fitness level (VO_{2max}). This study was approved by The Institutional Review Board at James Madison University.

Statistical Analysis

All statistical data were analyzed using IBM SPSS 21.0 statistical software package (Armonk, NY). Data was analyzed via repeated-measures ANOVA. Paired sample and independent sample t-test were used to compare the relationship of the variables. Significance level was set *a priori* at $p < 0.05$.

As part of a larger study, participant randomization was based on gender, age, and Body Mass Index (BMI), limiting the ability of the present study to randomize for age and baseline risk of CVD.

Participants and Recruitment

Sedentary prediabetic men and women were recruited and screened throughout Harrisonburg, VA. Recruitment included ads in the local Harrisonburg paper, a bulk email dispersed to the James Madison University community (faculty, staff, and students), a public

service announcement that aired on a local channel, fliers posted around the community, and a Facebook page. As defined by ACSM, sedentary individuals are those who do not participate in at least 30 minutes of physical activity at 40-50% VO_2R at least three times per week. Participants were screened to ensure that they met the requirements to participate in the study. They were classified as "low" or "moderate" risk according to ACSM risk categories and had to be able to perform all-out efforts on a treadmill. Additionally, they had to be in overall good health with no previous CVD, pulmonary, or metabolic syndrome diagnosis. Participants were excluded if they could not perform the activities, were not physician-diagnosed prediabetic, were not of mental capacity to consent, or were pregnant and/or breastfeeding.

Thirty-one sedentary, prediabetic men and women were recruited and randomly allocated to either MIT (n=13) or R-SIT (n= 18) groups (see Figure 1). Twenty-four participants completed midline testing (MIT=10, R-SIT=13) and 16 participants completed the 16-week intervention (MIT=10, RSIT=6). From baseline to post-testing four dropped due to an unrelated injuries, two due to medial tibial stress syndrome, two reported ankle and knee pain, five due time constraints, and two for an unknown reasons. Five male participants completed the screening and recruiting process. Of the five only one completed the 16-week intervention, as a result, the data presented in this study only includes female participants.

<u>Testing Meetings</u>

-Familiarization Meeting (baseline): In the initial meeting participants met with researchers in the Kinesiology Human Performance Lab (Godwin, room 217) to discuss procedures, risks, and questions. Participants completed the Informed Consent form (Appendix B), the Physical Activity Readiness Questionnaire form (PAR-Q) (Appendix C), the Health Status

Questionnaire form (Appendix D), the International Physical Activity Questionnaire (IPAQ)

(Appendix E), and received Three Day Food Intake Records (to be completed at home

during two weekdays and one weekend day) (Appendix F). The researchers provided

participants with detailed verbal and written instructions (Appendix F) on how to accurately

collect Three Day Food Intake Records. A follow-up meeting with the participants was

scheduled for a later date to review recorded food intake data. Lastly, participants were

required to get a Physician Approval Form (Appendix G) and either provide it at the

Familiarization Meeting or return with the completed form. Physician approval was required

prior to any exercise, and if presented at this time, participants could begin fitness and

anthropometric testing at this meeting (described below). If not, a follow-up fitness and

anthropometric testing meeting was scheduled.

-Fitness and Anthropometric Testing (baseline, midline, and post): Testing was performed in the

Kinesiology Human Performance Lab (Godwin, room 217). Participant's resting BP, weight,

height, and body composition were recorded. BP was measured using a Prosphyg Standard

Aneroid cuff (Adcuff [TM], Hauppauge, NY) and an Adscope-lite stethoscope (Hauppauge,

NY). Body composition was collected using a GE Lunar iDEXA (Madison, WI). Height was

measured with Charder Height Measurement Model HM 200P (Issaquah, WA). The scale

used to measure weight was a SECA (Chino, CA). Additionally, participants completed a

VO_{2max} test on a Cosmos Treadmill (Nussdorf-Traunstein, Germany) using ParvoMedics

TrueOne Metabolic System (Sandy, UT). Protocol used for testing was the Modified Balke

(57). The test consisted of a three minute warm-up followed by 2.5% grade increase every

three minutes at a self-selected speed that the participant could maintain for the duration of

the test. The test proceeded until maximal effort was accomplished or until volitional fatigue.

Maximal effort was considered accomplished when participants reached one or all of the

following: 19-20 on the RPE scale, Respiratory Exchange Rate (RER) on the metabolic cart reached 1.1 and/or the participant was within 10 beats of age-predicted max heart rate. This protocol was selected because it is recommended by ACSM for older or deconditioned participants with chronic diseases (57). During the test HR was monitored using Polar Watch and Polar Electro and recorded every minute after the third minute. Additionally, BP and Rate of Perceived Exertion (RPE) were recorded every third minute. RPE was based on Borg's scale in which the participant rates the exercise on a scale of 6-20, ranging from extremely light exertion to maximal exertion (42).

-Clinical Testing (baseline, midline, and post): On a separate day (from fitness and anthropometric testing) participants were instructed to visit one of four SRMH location for a blood draw administered by a certified phlebotomists. Participants were required to fast for 8-10 hours and refrain from exercise for 24-hours prior to their appointment. Blood draws were analyzed at SRMH and results were faxed on a secure line to researchers. Framingham Risk Score was calculated using a calculator (Appendix A) downloaded from www.framinghamheartstudy.org (43) and the results from the blood draws.

-Three Day Food Intake Records (baseline, midline, and post): The researchers provided participants with detailed verbal and written instructions for Three Day Food Intake Records at the familiarization meeting. Completed food records were then collected at baseline, midline, and post intervention and reviewed by the researchers and participant in a separate meeting. The purpose of this meeting was to ensure that all items were recorded as accurate as possible. Food intake records were analyzed at a later date using University of Minnesota Nutrition Data System for Research 2012 (Minneapolis, MN).

Figure 1: Timeline of 16-Weeks for R-SIT and MIT Sedentary Prediabetic Participants
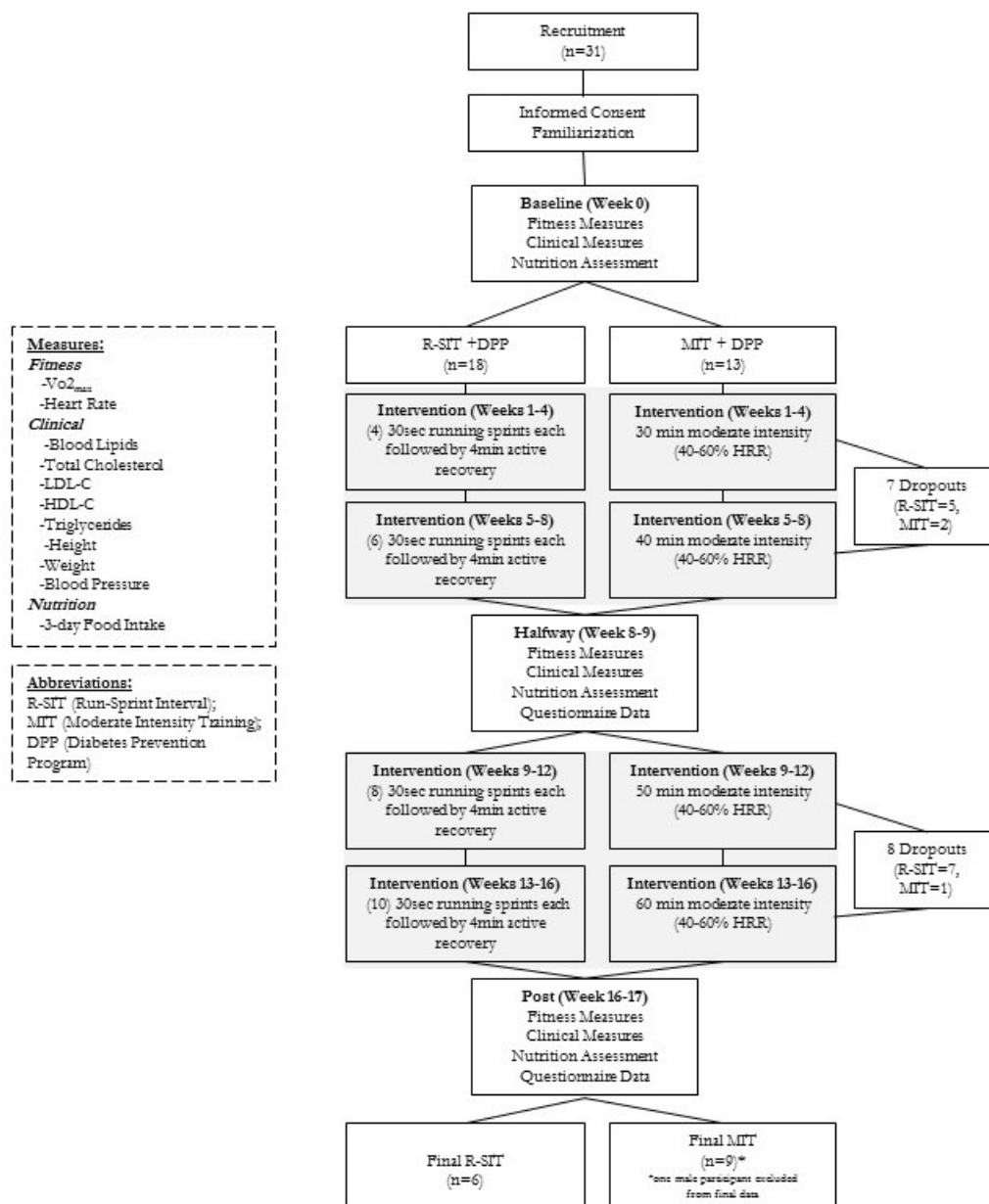
Intervention Protocols

DPP and training interventions lasted 16 weeks. Participants had the option of attending one of two weekly DPP meetings available at SRMH or Godwin Hall. DPP meetings typically lasted one hour and all participants were expected to be compliant with the program.

Additionally, participants met three times per week for 34-84 minutes for supervised

trainings in Godwin, room 116 A/B. Both training protocols were broken up into four

progressing blocks consisting of four weeks per block (see Table 1).

*R-SIT Group***:** Prior to all exercise resting BP and resting HR were recorded in the seated

position. Participants began each training with a warm-up that consisted of five minutes of

dynamic stretching plus five minutes of walking on the treadmill at a self-selected speed with

no incline (0% grade). Total warm-up time was 10 minutes. Immediately following warm-up,

participants began interval training. One interval was defined as 30-seconds of all-out sprint

at a self-selected speed and grade, followed by four minutes of active recovery at self-

selected speed and 0% grade. Participants received encouragement from the researchers to

sprint as fast as possible to ensure that maximal effort and heart rate was achieved. HR was

recorded at the end of each active recovery and at the end of each sprint. RPE was recorded

at the end of each sprint. Once all session intervals were completed, participants ended each

session with a five minute treadmill cool down at a self-selected speed and 0% grade.

Immediately following every treadmill cool down, final HR and RPE for the entire session

were recorded. Participants then completed five minutes of dynamic stretching. Total cool

down time was 10 minutes. Resting BP was measured after cool down and a brief period of

seated rest. Every four weeks the training progressed with the addition of two intervals. The

progression was as follows: weeks 1-4, four intervals; weeks 5-8, six intervals; weeks 9-12,

eight intervals; and weeks 13-16, 10 intervals.

MIT Group: Prior to all exercise resting BP and resting HR were recorded in the seated

position. Participants began each training with a warm-up that consisted of five minutes of

dynamic stretching plus five minutes of walking on the treadmill at a self-selected speed with

no incline (0% grade). Total warm-up time was 10 minutes. Immediately following warm-

up, participants began moderate intensity training at 45-55% Heart Rate Reserve. This was calculated by subtracting resting HR and maximal heart rate. The result was then multiplied by 45-55% and added to resting HR to ensure target HR (47). HR was recorded every five minutes. Once participants reached the time goal for the session, they began a five minute treadmill cool down at a self-selected speed and 0% grade. Immediately following every treadmill cool down, final HR and RPE for the entire session were recorded. Participants then completed five minutes of dynamic stretching. Total cool down time was 10 minutes. Resting BP was measured after cool down and a brief period of seated rest. Every four weeks the training progressed with the addition of 10 minutes. The progression was as follows: weeks 1-4, 30 minutes; weeks 5-8, 40 minutes; weeks 9-12, 50 minutes; and weeks 13-16, 60 minutes.

Table 1: Breakdown of Training Sessions

R-SIT	MIT
Warm-Up 5 minutes dynamic stretching 5 minutes treadmill walking	
Weeks 1-4: 4 intervals **Weeks 5-8:** 6 intervals **Weeks 9-12:** 8 intervals **Weeks 13-16:** 10 intervals	**Weeks 1-4:** 30 minutes **Weeks 5-8:** 40 minutes **Weeks 9-12:** 50 minutes **Weeks 13-16:** 60 minutes
Cool Down 5 minutes treadmill walking 5 minutes dynamic stretching	
Active Time (Total Sprint Minutes + Total Recovery Minutes) **Weeks 1-4:** 14 minutes (2+12) **Weeks 5-8:** 23 minutes (3+20) **Weeks 9-12:** 32 minutes (4+28) **Weeks 13-16:** 41 minutes (5+36)	**Active Time** **Weeks 1-4:** 30 minutes **Weeks 5-8:** 40 minutes **Weeks 9-12:** 50 minutes **Weeks 13-16:** 60 minutes
Total Time **Weeks 1-4:** 34 minutes **Weeks 5-8:** 43 minutes **Weeks 9-12:** 52 minutes **Weeks 13-16:** 61 minutes	**Total Time** **Weeks 1-4**: 50 minutes **Weeks 5-8**: 60 minutes **Weeks 9-12**: 70 minutes **Weeks 13-16**: 80 minutes

Chapter III

<u>Title</u>

A 16-Week Run Sprint Interval Training Does Not Have an Effect on Cardiovascular Risk
Measured by Framingham Risk Score on Prediabetic Women

<u>Abstract</u>

The Framingham Risk Score (FRS) was developed to determine the likelihood of developing cardiovascular disease (CVD) in the next 10 years using an individual's age, gender, total cholesterol (TC), High Density Lipoprotein Cholesterol (HDL-C), smoking habits, and systolic blood pressure (SBP). Run-Sprint Interval Training (R-SIT) has shown improvements in various health and blood markers while reducing total exercise time. To date there has not been a study that examines the effects of R-SIT and Moderate Intensity Training (MIT) on Framingham Risk. The purpose of this study was to determine if a reduction of the 10-year risk of CVD (determined by Framingham CVD risk calculator), is greater in an R-SIT experimental group compared to a moderate intensity group (MIT) of sedentary prediabetic women, after a 16-week intervention. Participants were randomized into R-SIT (n=6) or MIT (n=9) groups and required to attend 3 weekly training sessions and 1 weekly Diabetes Prevention Program session for 16-weeks. During the first 4 weeks, R-SIT performed 4x30s maximal sprints on a treadmill at a self-selected speed and incline, followed by a 4-min active recovery between intervals. Intervals increased by 2 every 4 weeks. MIT walked continuously at 45-55% Heart Rate Reserve for 30-mins during the first 4 weeks, and increased by 10-mins every 4 weeks. FRS markers were measured at baseline, mid, and post intervention.

After 16-weeks of exercise training, there was a significant time by group interaction in weight, Body Mass Index (BMI), and Body Fat Percent (BF%). *T*-tests indicate MIT significantly decreased in weight (-2.60$\pm$1.32 kg), BF% (-1.58$\pm$1.54), and BMI (-2.42$\pm$1.32 kg). R-SIT significantly changed in BF% from baseline to mid (-2.33$\pm$0.72) and mid to post (+1.53$\pm$0.46), but not from baseline to post (-2.16$\pm$2.53). Additionally, there was a trend toward significant improvements in BMI (p=0.078) and lean body mass (p=0.059) (-0.85$\pm$0.06 kg/m^2, +1.05$\pm$0.46 kg, respectively). Lastly, R-SIT participants also significantly decreased changes in TGs from midline to post (-23.33$\pm$17.92 mg/dL). Though FRS and Vascular Age (VA) were significantly different between groups at all three time points, there were no significant within-group changes observed

The major findings of this study were that after 16-weeks of exercise training, MIT had significant within-group decreases for weight, BMI, and BF%, while R-SIT significantly decreased BF% and increased VO$_{2max}$ (mLkg^{-1}min^{-1}). In conclusion, though previous R-SIT and HIIT studies have suggested improved body composition and cardiovascular risk factors when compared to MIT, the present study only observed significant changes in body composition and minimal changes to CVD risk factors. Additional research is needed to further understand the effects of R-SIT on blood lipid profiles and its relationship with CVD, especially in the clinical population.

Introduction

  According to the Centers for Disease Control and Prevention (CDC), more than one third of the American adult population are obese (1). Often there is a correlation between obesity and sedentary behavior (2, 3). Consequently, obesity and inactivity are independently known to be associated with health related problems such as cardiovascular disease (CVD), stroke, insulin resistance, and type 2 diabetes, as well as, certain types of cancer, reproductive abnormalities, and osteoarthritis (2-8). Furthermore, according to a study published by the American Diabetes Association, risk factors associated with CVD are increased 30 years before the individual is diagnosed with type 2 diabetes (45). This suggests that control of the risk factors, particularly glycemic control, hypertension, dyslipidemia and smoking cessation, should start early in life, and improvements on these factors could potentially decrease instances of both CVD and type 2 diabetes.

  In 1948, the National Heart, Lung, and Blood Institute (NHLBI) partnered with Boston University in what ultimately became the Framingham Heart Study (43). The original cohort had 5,209 participants and followed individuals over the course of several years to identify what common characteristics resulted in CVD. Over the course of the study, risk factors such as dyslipidemia, hypertension, physical inactivity, obesity, type 2 diabetes, insulin resistance were identified. This valuable information lead to the development the Framingham Risk Calculators and Scores (FRS). The algorithms rate the risk of different outcomes, such as atrial fibrillation, CVD, congestive heart failure, coronary heart disease, diabetes, hypertension, intermittent claudication, and stroke and determines an individual's risk of developing the conditions in the next 10 or 30 years (44).

  Improved fitness has proven benefits to cardiovascular health and the prevention of metabolic diseases such as CVD and type 2 diabetes (2, 3, 11-15). Furthermore, exercise is

considered a direct, cost-effective way of improving overall health (5-7, 9, 10) and can

reverse or impede some of the adverse effects associated with metabolic syndrome (16).

Benefits of exercise training include reduced blood pressure (BP), increased high-density

lipoprotein cholesterol (HDL-C), improved body composition, and improved maximal

oxygen uptake (12, 14, 17, 19-21, 52, 58). Despite exercise being a cost-efficient and effective

intervention for many chronic diseases that Americans face, approximately 22% participate

in regular exercise at any intensity (21). The most- cited reason for poor participation in

exercise programs, regardless of age, sex, ethnic background, or health status (17), is a lack of

time (7, 9, 13, 22-24). As a result, more research has focused on reducing the time involved

in physical activity, while maintaining and/or improving aerobic and metabolic benefits seen

with traditional exercise programs (7, 9, 13, 22-24).

High intensity interval training (HIIT) is an exercise protocol that has recently been

the subject of many research studies (2, 5, 7-10, 16, 22, 25-37). HIIT is defined as intense

periods of intermittent exercise above anaerobic threshold, separated by periods of rest or

low intensity exercise that does not allow for full recovery (10, 38). Repeated bouts at a high

intensity have been shown to improve lipid oxidation, insulin sensitivity, and vascular

endothelial function as well as increased maximal oxygen uptake, and decreased

subcutaneous fat (2, 17).

HIIT encompasses several different exercise protocols that manipulate levels of

intensity, interval duration, recovery times, and total work volume (10, 38). Additionally, it

encompasses various modalities, including running and cycle ergometers. Generally, HIIT

protocols are completed at near maximal intensities (between 80-100%) for longer periods of

time (three-four minutes) (39). Sprint Interval Training (SIT), a type of HIIT, incorporates

all-out supramaximal (>100% %HR_{max}) sprint intervals (~30 seconds) with relatively long

periods of active recovery between the intervals (39). The major difference between HIIT and SIT is in the 'all-out' effort expected of the participants. The higher intensity results in shorter intervals and total duration (10, 37, 38). Both HIIT and SIT have shown rapid, beneficial adaptations that may improve cardiovascular health and facilitate type 2 diabetes prevention in both pre-clinical and clinical populations (17). However, to our knowledge, no studies have evaluated how these changes might affect an individual's risk of developing CVD in the next ten years. The purpose of this study was to determine if 16 weeks of R-SIT and Diabetes Prevention Program (DPP) reduces the 10-year risk of CVD (determined by Framingham CVD risk calculator), in a sedentary prediabetic women as compared to a moderate intensity continuous training protocol combined with DPP.

Methods

This study was a 16-week randomized controlled trial. Sedentary prediabetic women were recruited from a suburban college city in Virginia and randomly divided into two groups: Running-Sprint Interval Training (R-SIT) or Moderate Intensity Training (MIT). Sedentary was defined as those who do not participate in at least 30 minutes of physical activity at 40-50% VO_2R at least three times per week. Recruitment included ads in the local newspaper, bulk emails dispersed to the university, a local TV public service announcement, fliers posted around the community and physician's offices, and a Facebook page. Additionally, all participants attended 16 weeks of Diabetes Prevention Program (DPP) education with trained lifestyle coaches. Data was collected at baseline, midline, and post intervention and included: Framingham Risk Score (FRS), Vascular Age (VA), Blood Pressure (BP), Total Cholesterol (TC), High Density Lipoprotein Cholesterol (HDL-C), Low Density Lipoprotein Cholesterol (LDL-C), Very Low Density Lipoprotein Cholesterol (VLDL-C), Triglycerides (TG), body weight, height, and cardiovascular fitness level (VO_{2max}).

Participants were all classified as "low" or "moderate" risk according to American College of Sports Medicine (ACSM) (57). Additionally, they had to be in overall good health with no previous CVD, pulmonary, or metabolic syndrome diagnosis. Participants were excluded if they could not perform the activities, were not physician-diagnosed prediabetic, were not of mental capacity to consent, or were pregnant and/or breastfeeding. This study was approved by James Madison University's Institutional Review Board.

Preliminary Meetings

Participants attended two or three preliminary meetings prior to randomization (see Figure 1). Participants that had physician approval during the familiarization meeting were able to condense the familiarization and fitness/anthropometric testing meetings into one. During the familiarization meeting, researchers explained testing and study procedures, and risks. Participants completed an Informed Consent form and received three day Food Intake Records (to be completed at home during two weekdays and one weekend day). The researchers provided participants with detailed verbal and written instructions on how to accurately collect three day Food Intake Records. A follow-up meeting with the participants was scheduled for a later date to review recorded food intake data. Records were analyzed using University of Minnesota Nutrition Data System for Research 2012 (Minneapolis, MN). Records were reviewed by a different researcher after the initial analyses to ensure accuracy.

Fitness Testing

A physician approval form was required prior to any exercise or fitness testing. During the fitness and anthropometric meeting, participant's resting blood pressure (BP), weight, height, and body composition were recorded. All BP measurements were made via auscultation. Body composition was collected using a GE Lunar iDEXA (Madison, WI). Additionally, participants completed a Modified Balke VO_{2max} test on a Cosmos Treadmill

(Nussdorf-Traunstein, Germany) using ParvoMedics TrueOne Metabolic System (Sandy, UT) (57). The Modified Balke protocol was selected based on recommendations by ACSM for older or deconditioned participants with chronic diseases (57). Heart Rate (HR) was monitored using Polar Heart Rate Monitor (Oulu, Finland) and recorded every minute after the third minute. Additionally, BP and Rate of Perceived Exertion (RPE) based on Borg's scale were recorded every third minute. Maximal effort was defined as participants having reached one or all of the following: 19-20 on the RPE scale, Respiratory Exchange Rate (RER) reached 1.1 and/or the participant was within 10 beats of age-predicted max heart rate. All testing was repeated at midline and post intervention.

Figure 1: Timeline of 16-Weeks for R-SIT and MIT Sedentary Prediabetic Participants
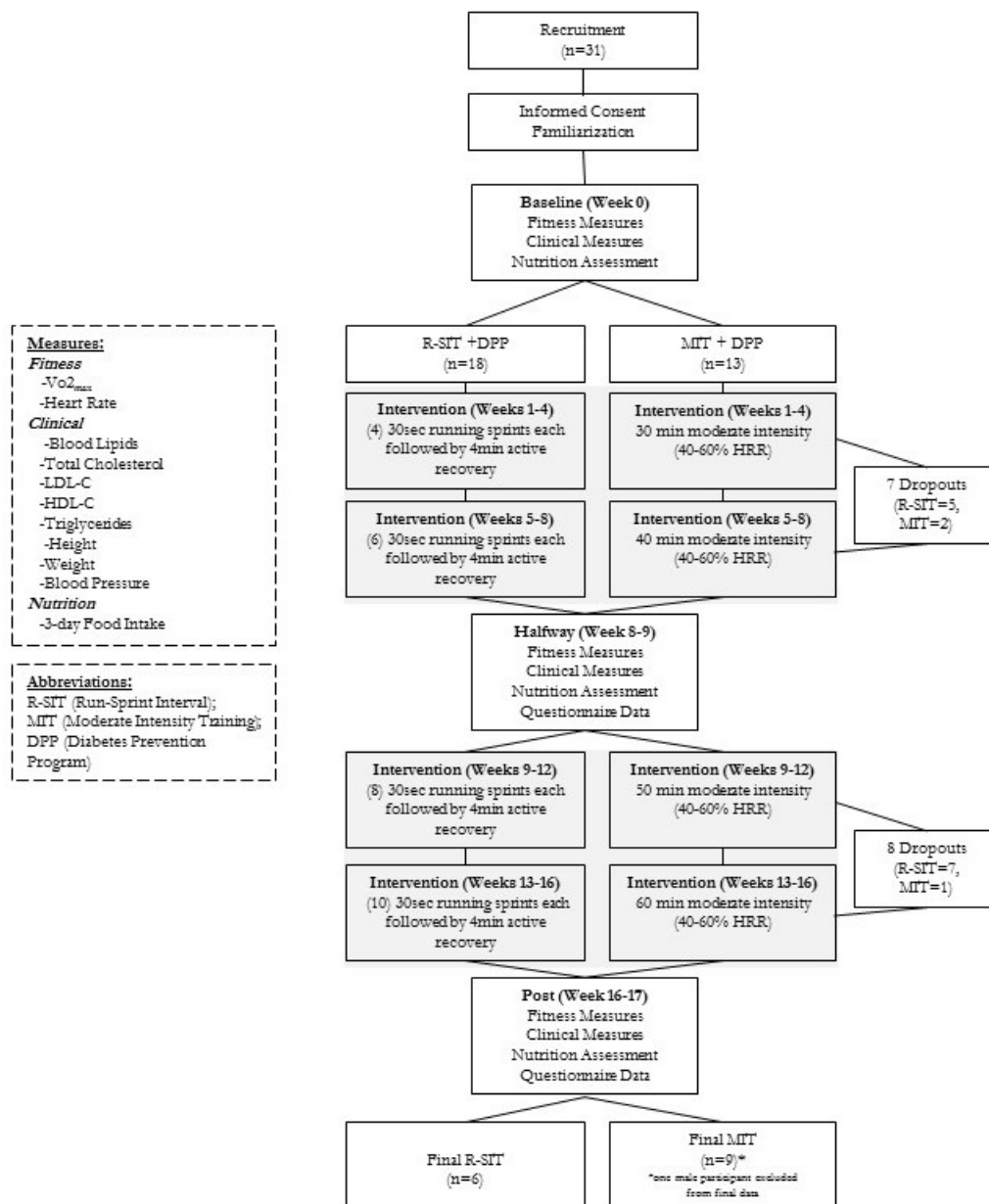
Blood Samples

Participants were instructed to fast for 8-10 hours and report to a clinical lab at one of three Sentara RMH Medical Centers (Harrisonburg, VA) for a blood draw administered by certified phlebotomists.

Framingham Risk Score

FRS was calculated using a calculator downloaded from www.framinghamheartstudy.org (43). The CVD calculator uses age, gender, total cholesterol, HDL-C, smoking habits, and systolic BP to estimate the risk of developing CVD in the next 10 years of non-diabetics between the ages of 30-74 who have no previous heart disease diagnosis.

Experimental Intervention

DPP and training interventions lasted 16 weeks. DPP meetings lasted one hour and all participants were expected to be compliant with the program. Additionally, participants met three times per week for 34-84 minutes of supervised training per session. Both training protocols were broken up into four progressing blocks consisting of four weeks per block (see Table 1). Prior to all exercise resting BP and resting HR were recorded in the seated position. Participants began each training with a warm-up that consisted of five minutes of dynamic stretching plus five minutes of walking on the treadmill at a self-selected speed with no incline (0% grade). Total warm-up time was 10 minutes. Participants ended each session with a five minute treadmill cool down at a self-selected speed and 0% grade. Immediately following treadmill cool down, final HR and RPE were recorded. Participants then completed five minutes of dynamic stretching. Total cool down time was 10 minutes. After cool down and a brief period of rest, resting BP was measured and recorded. Every four weeks, training progressed for both groups. In both groups participants were allowed to exercise at a self-selected incline to reduce orthopedic stress (59).

R-SIT Group: Immediately following warm-up, participants began interval training. An interval was defined as 30-seconds of all-out sprint at a self-selected speed and grade,

followed by four minutes of active recovery (walking) at self-selected speed and 0% grade.

Participants received encouragement from the researchers to sprint as fast as possible to

ensure that maximal effort and heart rate was achieved. HR was recorded at the end of each

active recovery and at the end of each sprint. RPE was recorded at the end of each sprint.

Every four weeks the training progressed as follows: weeks 1-4, four intervals; weeks 5-8, six

intervals; weeks 9-12, eight intervals; and weeks 13-16, 10 intervals (Table 1).

MIT Group: Immediately following warm-up, participants began moderate intensity

training at 45-55% Heart Rate Reserve. HR was recorded every five minutes. Every four

weeks the training progressed as follows: weeks 1-4, 30 minutes; weeks 5-8, 40 minutes;

weeks 9-12, 50 minutes; and weeks 13-16, 60 minutes.

Statistical Analysis

All statistical data was analyzed using IBM SPSS 21.0 statistical software package

(Armonk, NY). Data were analyzed via repeated-measures ANOVA. For variables where

Mauchly's Test of Sphericity had been violated, the Huynh-Feldt correction was applied.

Paired sample and independent sample t-test were then used to compare the relationship of

the variables. Significance level was set *a priori* at $p < 0.05$.

Table 1: Comparison of Training Sessions for R-SIT and MIT Sedentary Prediabetic Women

R-SIT*	MIT*
Warm-Up 5 minutes dynamic stretching 5 minutes treadmill walking	
Weeks 1-4: 4 intervals **Weeks 5-8:** 6 intervals **Weeks 9-12:** 8 intervals **Weeks 13-16:** 10 intervals	**Weeks 1-4:** 30 minutes **Weeks 5-8:** 40 minutes **Weeks 9-12:** 50 minutes **Weeks 13-16:** 60 minutes
Cool Down 5 minutes treadmill walking 5 minutes dynamic stretching	
Active Time (Total Sprint Minutes + Total Recovery Minutes) **Weeks 1-4:** 14 minutes (2+12) **Weeks 5-8:** 23 minutes (3+20) **Weeks 9-12:** 32 minutes (4+28) **Weeks 13-16:** 41 minutes (5+36)	**Active Time** **Weeks 1-4:** 30 minutes **Weeks 5-8:** 40 minutes **Weeks 9-12:** 50 minutes **Weeks 13-16:** 60 minutes
Total Session Time **Weeks 1-4:** 34 minutes **Weeks 5-8:** 43 minutes **Weeks 9-12:** 52 minutes **Weeks 13-16:** 61 minutes	**Total Session Time** **Weeks 1-4**: 50 minutes **Weeks 5-8**: 60 minutes **Weeks 9-12**: 70 minutes **Weeks 13-16**: 80 minutes
*Abbreviations: R-SIT (Running Sprint Interval Training); MIT (Moderate Intensity Training)	

Results

Thirty-one sedentary, prediabetic men and women were recruited and randomly assigned to either MIT (n=13) or R-SIT (n= 18) groups. Twenty-four participants completed midline testing (MIT=10, R-SIT=13) and 16 participants completed the 16-week intervention (MIT=10, RSIT=6). From baseline to post-testing four dropped due to

unrelated injuries, two due to medial tibial stress syndrome, two reported ankle and knee pain, five due time constraints, and two for an unknown reasons. Five male participants completed the screening and recruiting process. Of the five, only one completed the 16-week intervention. As a result, the data presented in this study only includes female participants. All remaining participants were required to attend at least 40 of the 48 training sessions to meet the adherence requirement. There were no significant differences in adherence between the groups (R-SIT: 43.00±3.16, MIT: 43.00±4.09 total sessions).

Baseline Measurements

At baseline, there were no significant differences between groups in age, weight, BMI, TC, HDL-C, VLDL-C, LDL-C, TG, VO$_{2max}$, and BP (p<0.05; Table 2). Significant differences were observed in FRS (R-SIT: 3.45±2.39, MIT: 6.41±2.26%) and Vascular Age (VA) (R-SIT: 43.33±14.58, MIT: 59.33±9.19 years). There were no significant baseline differences between groups in any dietary markers. Additionally, there were no dietary differences between groups at any time point (see Table 3).

Framingham Risk Scores, Vascular Age, Clinical, and Blood Lab Values

There were no significant differences for FRS, VA, clinical, and blood lipid markers. Nevertheless, there was a trend towards significance for several variables (see tables 4 and 5).

There were observed between-group differences (R-SIT, MIT respectively) at midline in TC (168.83±19.47, 216.56±58.85 mg/dL), FRS (2.90±2.10, 6.41±2.34%), and VA (39.83±14.03, 59.00±10.26 years). There were between group differences at 16-weeks in TC (167.17±19.89, 218.89±55.13 mg/dL), VLDL (18.67±4.97, 30.55±8.5 mg/dL), TG (101.33±25.44, 152.56±42.90 mg/dL), FRS (2.73±1.59, 6.74±2.90%), and VA (39.50±11.18, 60.56±11.38 yo). Lastly, R-SIT significantly changed from midline to post in TG (-23.33 ± 17.92 mg/dL) and DBP (6.33 ± 5.85 mm/Hg).

Anthropometric and Fitness

There was a significant time by group interaction in weight, BMI, and BF%. Additionally, there was a statistically significant effect of time on weight, BMI, and body fat percent (BF%).

A significant decrease in BMI from baseline to mid (-0.63±0.60 kg/m^2) and a trend towards a significant decrease (p=0.078) from baseline to post (-0.85±0.94 kg/m^2) in the R-SIT group were observed. There were also significant decreases in BF% from baseline to mid (-2.33±0.72%), however, there was a significant increase from mid to post (+1.53±0.46%) in this group. Lastly, the increase in lean body mass from mid to post (+1.05±0.46 kg) in R-SIT was trending towards significance (p=0.059). Though there was not a main effect of time within R-SIT for VO$_{2max}$, a significant increase from baseline to post (+1.86±1.011 mL kg^{-1}min^{-1}) occurred.

Alternatively, t-test results for MIT indicated a significant decreased in both weight and BMI from baseline to mid (-3.76±1.63 kg, -1.36±0.85 kg/m^2, respectively), mid to post (-1.95±2.36 kg, -1.07±0.95 kg/m^2), and from baseline to post (-5.71±3.61 kg, -2.42±1.40 kg/m^2). BF% decreased from baseline to mid (-0.90±1.21%) with trending significance (p=0.074) and significantly decreased from baseline to post (-1.58±1.54%). Lastly, there was a trend to significance (p=.083) in lean body mass of MIT from baseline to post (-1.14±1.72 kg).

Table 2: Baseline Characteristics for R-SIT$^{\epsilon}$ and MIT$^{\epsilon}$ Sedentary Prediabetic Women

	All Participants (n=15)	R-SIT (n=6)	MIT (n=9)
Age (years)	47.80±15.67	39.17±20.52	53.56±8.56
Weight (kg)	107.83±31.11	112.01±28.93	105.04±33.89
BMI (kg/m²)	40.51±10.78	40.65±9.15	40.41±12.29
Body Fat (%)	57.36±5.32	49.74±4.13	50.71±6.10
Lean Body Mass (lbs)	109.16±22.53	104.37±25.96	107.17±23.52
Total Cholesterol (mg/dL)	199.73±45.91	179.83±10.50	213.00±55.89
HDL-C (mg/dL)	59.47±20.30	52.50±18.12	64.11±21.34
VLDL-C (mg/dL)	25.93±10.76	20.67±12.61	29.44±8.28
LDL-C (mg/dL)	113.73±33.06	106.67±14.83	118.44±41.39
Triglycerides (mg/dL)	148.33±50.03	124.17±59.64	164.44±37.79
Framingham (%)	5.23±2.69*	3.45±2.39	6.41±2.26
Vascular Age (years)	52.93±13.79*	43.33±14.58	59.33±9.19
VO$_{2max}$ (mL kg^{-1}min^{-1})	21.45±3.97	22.40±3.03	20.81±4.54
RHR (bpm)	75.87±9.75	77.33±12.24	74.89±8.36
SBP (mm Hg)	131.07±14.96	127.33±11.29	133.56±17.17
DBP (mm Hg)	82.53±12.06	83.33±13.84	82.00±11.58

Data are presented as mean±SD, *Significant difference between groups at baseline (p<0.05)

$^{\epsilon}$*R-SIT: Running Sprint Interval Training; MIT: Moderate Intensity Training*

Table 3: Dietary Markers at Baseline, Midline, and Post 16-Week Intervention for R-SIT[€] and MIT[€] Sedentary Prediabetic Women

	All Participants (n=15)	R-SIT (n=6)	MIT (n=9)
Calories (kcals)			
baseline	2246.87±828.72	2697.33±740.05	1946.56±778.41
midline	1797.40±408.34¥	1819.17±123.49¥	1782.89±530.73
post	1774.67±533.42¥	1806.67±451.60¥	1753.33±607.62
Carbohydrates (%)			
baseline	43.58±9.90	45.00±7.54	42.64±11.55
midline	47.49±12.86	50.86±3.09	45.23±16.41
post	47.91±13.91	51.99±8.12	45.18±16.63
Fat (%)			
baseline	40.28±7.66	37.73±4.56	41.99±9.02
midline	34.74±12.29¥	30.45±4.23¥	37.60±15.17
post	33.09±8.40¥	31.37±5.87	34.24±9.91¥
Protein (%)			
baseline	14.43±2.63	15.22±2.43	13.91±2.76
midline	16.76±3.17¥	17.50±2.55¥	16.26±3.60
post	20.35±9.14¥	16.80±3.43	22.71±11.10¥
Saturated Fat (g)			
baseline	36.32±12.02	38.51±10.16	34.85±13.51
midline	24.72±11.03¥	20.69±3.63¥	27.40±13.58
post	22.86±11.72¥	21.73±6.62¥	23.61±14.53¥

Data are presented as mean±SD, *Significant difference between groups at given time point ($p<0.05$), ¥Significant difference within group from baseline ($p<0.05$), αSignificant difference within group from midline ($p<0.05$)

[€]*R-SIT: Running Sprint Interval Training; MIT: Moderate Intensity Training*

Table 4: Framingham Risk Scores, Vascular Age, and Input Variables that Effect Framingham Risk Score at Baseline, Midline, and Post 16-Week Intervention for R-SIT[€] and MIT[€] Sedentary Prediabetic Women

	All Participants (n=15)	R-SIT (n=6)	MIT (n=9)
Age (years)			
baseline	47.80±15.67	39.17±20.52	53.56±8.56
Framingham Risk Score (%)			
baseline	5.23±2.69	3.45±2.39*	6.41±2.26*
midline	5.01±2.82	2.90±2.14*	6.41±2.34*
post	5.14±3.14	2.73±1.60*	6.74±2.90*
Vascular Age (years)			
baseline	52.93±13.79	43.33±14.58*	59.33±9.19*
midline	51.33±15.00	39.83±14.03*	59.00±10.26*
post	52.13±15.25	39.50±11.18*	60.56±11.38*
Cholesterol (mg/dL)			
baseline	199.73±45.91[+]	179.83±10.50	213.00±55.89
midline	197.47±51.96[+]	168.83±19.47*	216.56±58.85*
post	198.20±50.65[+]	167.17±19.89*	218.89±55.13*
HDL-C (mg/dL)			
baseline	59.47±20.30[ω]	52.50±18.12	64.11±21.34
midline	56.53±17.15[ω]	48.33±13.25	62.00±17.92
post	55.13±19.95[¥ω]	49.33±16.28	59.00±22.11
SBP (mm/Hg)			
baseline	131.07±14.96	127.33±11.29	133.56±17.17
midline	126.00±14.56	120.67±15.88	129.56±13.33
post	126.93±12.58	122.67±13.72	129.78±11.68

Data are presented as mean±SD, *Significant difference between groups at given time point ($p<0.05$), [¥]Significant difference within group from baseline ($p<0.05$), [α]Significant difference within group from midline ($p<0.05$). [ω]Trending towards significant effect of time ($p<0.08$). [+]Trending towards significant time x group interaction ($p<0.08$). [€]*R-SIT: Running Sprint Interval Training; MIT: Moderate Intensity Training*

Table 5: Blood Lipid Variables Related Cardiovascular Disease at Baseline, Midline, and Post 16-Week Intervention for R-SIT$^{\epsilon}$ and MIT$^{\epsilon}$ Sedentary Prediabetic Women

	All Participants (n=15)	R-SIT (n=6)	MIT (n=9)
VLDL-C (mg/dL)			
baseline	25.93$\pm$10.76	20.67$\pm$12.61	29.44$\pm$8.28
midline	27.49$\pm$8.23	23.00$\pm$7.38	30.49$\pm$7.70
post	25.80$\pm$9.31	18.67$\pm$4.97*	30.56$\pm$8.52*
LDL-C (mg/dL)			
baseline	113.73$\pm$33.06[+]	106.67$\pm$14.83	118.44$\pm$41.39
midline	113.04$\pm$39.27[+]	96.50$\pm$18.61	124.07$\pm$46.27
post	117.07$\pm$38.27[+]	97.83$\pm$23.61	129.89$\pm$41.86
TG (mg/dL)			
baseline	148.33$\pm$50.03	124.17$\pm$59.64	164.44$\pm$37.79
midline	140.93$\pm$37.92	124.67$\pm$32.81	151.78$\pm$38.90
post	132.07$\pm$44.25	101.33$\pm$25.44* $^{\alpha}$	152.56$\pm$42.90*

Data are presented as mean$\pm$SD, *Significant difference between groups at given time point (p<0.05), ¥Significant difference within group from baseline (p<0.05), $^{\alpha}$Significant difference within group from midline (p<0.05). ꙍTrending towards significant effect of time (p<0.08). [+]Trending towards significant time x group interaction (p<0.08).$^{\epsilon}$*R-SIT: Running Sprint Interval Training; MIT: Moderate Intensity Training*

Table 6: Anthropometric and Fitness Measures at Baseline, Midline, and Post 16-Week Intervention for R-SIT$^\epsilon$ and MIT$^\epsilon$ Sedentary Prediabetic Women

	All Participants (n=15)	R-SIT (n=6)	MIT (n=9)
Weight (kg)			
baseline	107.83±31.11	112.02±28.93	105.04±33.89
midline	105.16±31.04$^¥$	110.98±29.74	101.28±33.03$^¥$
post	103.73±30.04 $^{\alpha\ ¥}$	110.33±30.05	99.33±30.99 $^{\alpha\ ¥}$
BMI (kg/m²)			
baseline	40.51±10.78	40.65±9.15	40.41±12.29
midline	39.44±10.72$^¥$	40.02±9.17$^¥$	39.06±12.17$^¥$
post	38.71±10.22 $^{\alpha\ ¥}$	39.80±9.21	37.99±11.32 $^{\alpha\ ¥}$
Body Fat (%)			
baseline	50.36±5.32	49.74±4.13	50.71±6.10
midline	48.69±6.47$^¥$	46.03±3.95*$^¥$	49.69±7.16*
post	48.45±6.10$^¥$	47.43±5.13$^\alpha$	49.13±6.88$^¥$
Lean Body Mass (kg)			
baseline	49.62±10.24	51.24±10.34	48.71±10.69
midline	48.69±10.30	47.44±11.80	49.19±12.69
post	50.66±10.92	55.29±11.47	47.58±9.97
VO$_{2max}$ (mLkg^{-1}min^{-1})			
baseline	21.45±3.97	22.40±3.03	20.81±4.54
midline	22.44±4.58	23.50±1.95	21.83±5.64
post	22.32±6.37	24.54±2.81$^¥$	22.84±5.82

Data are presented as mean±SD, *Significant difference between groups at given time point ($p<0.05$), $^¥$Significant difference within group from baseline ($p<0.05$), $^\alpha$Significant difference within group from midline ($p<0.05$). $^\epsilon$*R-SIT: Running Sprint Interval Training; MIT: Moderate Intensity Training*

Discussion

For the purposes of this study, baseline, midline, and post scores of participants' risk of developing CVD in the next 10 years were determined and analyzed. The CVD risk calculator uses age, gender, total cholesterol, HDL-C, smoking habits, and systolic BP to estimate the risk of non-diabetics between the ages of 30-74 who have no previous heart disease diagnosis. Since there were no significant within-group changes in any of the input variables used to calculate FRS and VA, there were no significant changes in these scores (see table 4). The differences observed between groups is likely the result of increases by

MIT from midline to post. Additionally, global high risk is considered >20% FRS, and both groups mean baseline were both below high risk and considered low risk (R-SIT: 3.45±2.39, MIT: 6.41±2.26%). As a result, more research is needed to determine if an individual with a high starting FRS may benefit from an R-SIT or MIT protocol.

The secondary findings of this study were that after 16-weeks of exercise training, MIT had significant within group decreases for weight, BMI, and BF%, while R-SIT significantly decreased in BF% and significantly increased VO_{2max} ($mLkg^{-1}min^{-1}$). There was also a trend towards significance for BMI within R-SIT (p=.078) (see Figure 2). Additionally, R-SIT participants had significant changes in TGs from midline to post. Though FRS and VA were significantly different between groups at all three time points, there were no significant within-group changes observed. Participants attended weekly DPP classes and were expected to improve dietary intake during the 16 weeks. Since there were no between group differences in dietary markers, it can be expected that both groups experienced the same changes, suggesting that diet did not have a different impact on the results of either group.

Changes observed for weight and BMI are typical, so the findings here are consistent with the present literature (2, 16). A prior study using a running training protocol in clinical participants revealed that after 16 weeks of running-HIIT (R-HIIT), weight was reduced by three and four percent by the R-HIIT and moderate intensity groups, respectively (16). Likewise, BMI was significantly reduced in both groups with no significant differences between the groups. It should be noted, however, that the purpose of that study was to compare the modes independent of the time; thus training volumes were equalized to similar amounts of kilocalories per session so that R-HIIT exercised for 40 minutes while the moderate intensity group exercised for 47 minutes.

Similarly, after 12 weeks of R-HIIT, Tan et al. found that BMI, was significantly reduced in both R-HIIT and moderate intensity group, with no significant differences between groups, in overweight college age women (2). Most notably, there was a 9.9% body fat loss in the R-HIIT group, which was significantly more when compared to a 5.2% loss in the moderate intensity group. The researchers concluded that R-HIIT would be more beneficial than moderate intensity exercise in an overweight population, as a result of the decrease in fat tissue accumulation (2). It is important to mention that during the 12 weeks participants of this study exercised five times per week on an outdoor track as opposed to the typical three times on a treadmill seen in most R-HIIT and R-SIT studies, which could account for some of the findings. Results of the present study also noted changes in BF% in line with the findings of Tan et al. Both R-SIT and MIT significantly decreased BF% (R-SIT: -2.16 ± 2.53%, MIT: -1.57 ± 1.54%). The changes from baseline to post were significant for MIT, however, there was only significance from baseline to midline $(-2.33\pm0.72$%) and midline to post $(+1.53\pm0.46$%) for R-SIT. Though there was an overall decrease in BF% in R-SIT from baseline to post, it was likely not significant because of the increase from midline to post. The groups were only significantly different from each other at midline.

Metabolically, exercise induces increases in epinephrine, norepinephrine, and growth hormone resulting in hormone-stimulated lipolysis. This leads to an increase in fatty acid availability and thus an increase in fatty acid uptake and oxidation for energy (13, 16). Acute bouts of HIIT appear to significantly increase these hormones, and since visceral fat is particularly sensitive to these hormones, it has been suggested that HIIT may be an effective method in improving body composition and reducing visceral fat (13). The impact of lipid

oxidation on clinical populations and its relationship to intensity still needs further investigation (2).

Results of current SIT and HIIT studies are mixed in regards to changes in blood lipid profiles, and the exact impact of interval training has yet to be defined. This could be a result of differing methodology, though the main reasons are likely short intervention time (24) and/or healthy participants with normal blood lipid profiles at baseline (8, 22, 25). Additionally, timing of meals and diet may exacerbate these discrepancies (26). Regardless, interval studies that incorporate blood lipid profiles are limited.

The present study observed significant decreases in TG from midline to post testing in R-SIT participants. There were no significant changes in other blood lipid markers for either R-SIT or MIT. However, there was a significant change in HDL-C for the group as a whole from baseline to post. Typically a decrease in saturated fat consumption will positively impact lipid values, yet, participants of the present study decreased HDL-C. There is evidence to suggest that the decrease in HDL-C may be due to a decrease in saturated fat coupled with a corresponding increase in carbohydrate (60, 61). Lastly, there were between group differences at post testing for total cholesterol and VLDL. This between group differences are likely the result of increases in both cholesterol and VLDL for MIT from baseline to post testing.

A proposed mechanism for a decrease in TG concentrations may be a result of TG clearance in the skeletal muscle and a decreased hepatic production of very-low-density lipoproteins (VLDL-C) (11). Though changes in TG concentrations are acute and likely associated to the energy expenditure, repeated bouts of exercise often lead to a more favorable blood lipid profile (12).

To our knowledge our present study is the first to closely investigate the effects of two exercise protocol on the 10-year risk of developing CVD in prediabetic women. Specifically, we are the first study to investigate FRS and VA as it relates to interval training in a clinical population. There are limitations of the present research that should be taken into consideration. The first major limitation is while participants were diagnosed prediabetic and as a result at higher risk for CVD (19, 45), the average baseline FRS scores were within a normal range, suggesting that any improvement would have been minimal and not significant. To fully understand the effects that interval training might have on FRS, more research should be done in individuals with higher baseline scores. Another major limitation was related to individuals with prescribed hypertension medication (prior to beginning the study). While the Framingham calculator accounts for hypertension control, it is not sensitive to incremental changes to the medication dosage. As the training progressed, there were some participants that reduced their dose without completely discontinuing the medication. The change in medication might suggest that the exercise was helping control BP, however, the FRS calculator cannot account for this reduction in dose and still classified the participants as higher than normal risk. Additionally, changes to these medications may have had an initial and potentially adverse effect on BP while the body adjusted to the change.

The present study had challenges with high drop-out rates, specifically within the R-SIT intervention group. Of the 12 R-SIT drop-outs, four had injuries that may have been related to the exercise intervention (3 females, 1 male). The physical strain of this exercise was often verbalized to researchers by the remaining R-SIT participants. Alternatively, there were no injury related drop-outs in MIT. This suggests that R-SIT may be too strenuous for an overweight/obese population. Additionally, the average age of the R-SIT participants

with an injury related drop-out was 52 ± 10.90 years old. The average age R-SIT participants that completed was 39.17 ± 20.52. If the injury-drop out ages are included, the average age increases to 44.40 ± 17.86 years. This may also suggest that this type of strenuous exercise may not be appropriate for an older population. Research with a more appropriate mode that reduces orthopedic stress, such as elliptical or cycle ergometer should be considered, especially for an older population. Additionally, an introductory period for participants to get accustomed to the equipment and exercise may also reduce injury related drop-outs.

Other limitations included food record discrepancies. It is well documented that individuals often underreport intake (26). Discrepancies between reported and actual diet may have provided further evidence to some of the changes. Additionally, the small sample size may have also limited the results observed in this study. Lastly, holidays and seasonal changes were a limitation to this study. As the weather got colder, participants may have been less likely to spend time outside, which could have resulted in an average reduction of unstructured activity (55). Also, seasonal holidays that occurred during the 16-week span (Thanksgiving to New Year's) may have negatively impacted participants' body weight, body fat percent, BP, and dietary intake (56).

In conclusion, though previous R-SIT and HIIT studies have suggested improved body composition and cardiovascular risk factors when compared to MIT, the present study only observed significant changes in body composition and minimal changes to CVD risk factors. Additional research is needed to further understand the effects of run sprint interval training on blood lipid profiles and its relationship with CVD, especially in the clinical population.
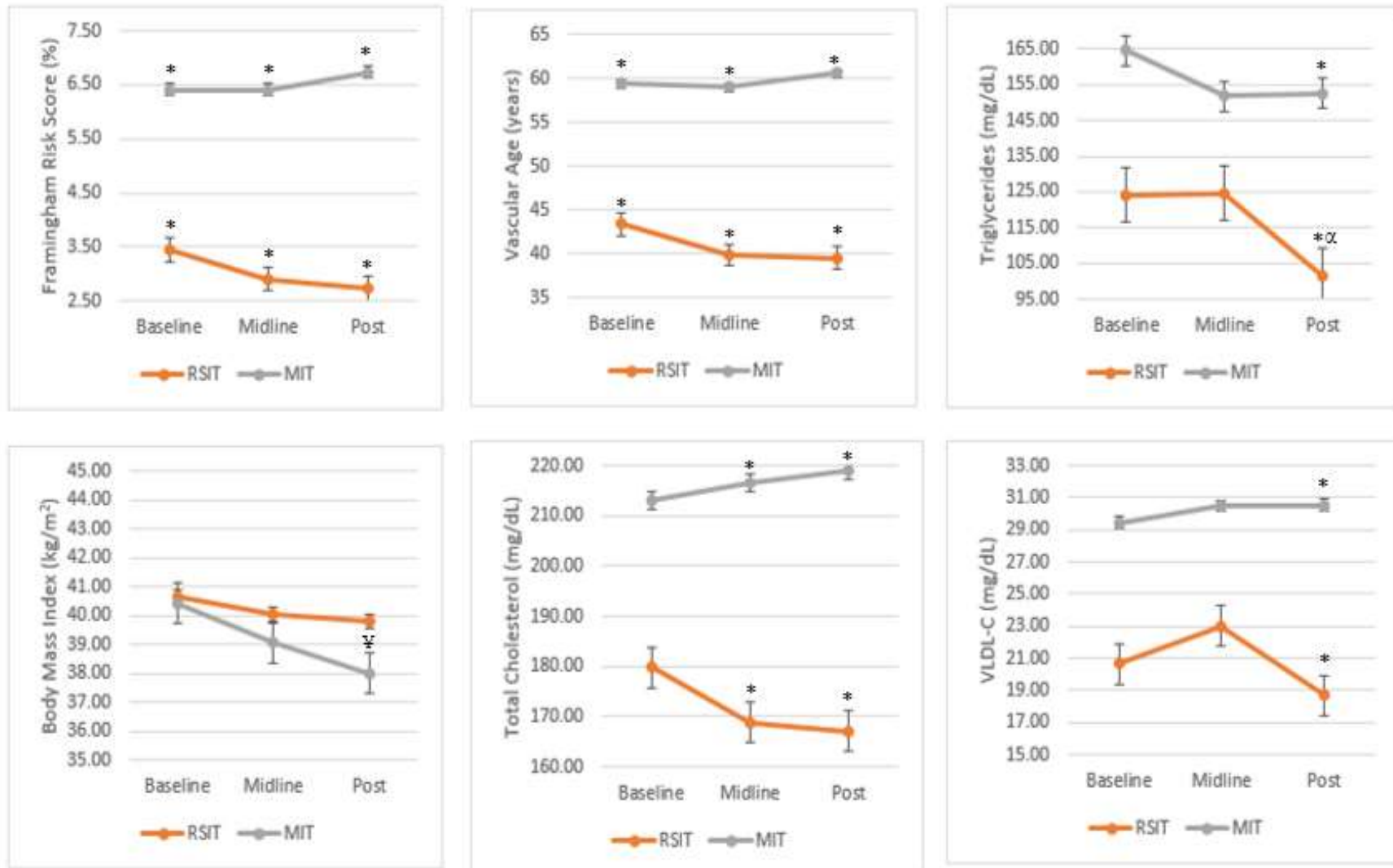
Figure 2: Average Framingham Risk Score (%), Vascular Age (years), Body Mass Index (kg/m²), Total Cholesterol (mg/dL), Triglycerides (mg/dL), VLDL-C (mg/dL) of all participants, R-SIT, and MIT groups at baseline, midline and post intervention during the 16-week study. *Significant difference between groups at given time point (p<0.05), ¥Significant difference within group from baseline (p<0.05), ᵅSignificant difference within group from midline (p<0.05)

Appendices

Appendix A: General CVD Risk Prediction Calculator

From The Framingham Heart Study		Enter Values Here	
General CVD Risk Prediction			
Risk Factor	**Units**	**(Type Over Placeholder Values in Each Cell)**	**Notes**
Sex	male (m) or female (f)	f	
Age	years	24	Enter a Value Between 30-74
Systolic Blood Pressure	mmHg	125.0	
Treatment for Hypertension	yes (y) or no (n)	n	
Smoking	yes (y) or no (n)	n	
Diabetes	yes (y) or no (n)	n	
HDL	mg/dL	45	
Total Cholesterol	mg/dL	180	
Your 10-Year Risk (The risk score shown is derived on the basis of an equation. Other print products, use a point-based system to calculate a risk score that approximates the equation-based one.)		0.8%	If value is < the minimum for the field, enter the minimum value. If value is > the maximum for the field, enter the maximum value.
Your Heart/Vascular Age		24	

Calculator prepared by R.B. D'Agostino and M.J. Pencina based on a publication by D'Agostino et al. in Circulation

(Downloaded from https://www.framinghamheartstudy.org/risk-functions/cardiovascular-disease/10-year-risk.php# on June 23, 2014)

Appendix B: Informed Consent

James Madison University
Departments of Kinesiology and Health Sciences
Consent for Investigative Procedure
(Informed Consent)

You are being asked to participate in a research study conducted by Drs. Elizabeth Edwards, Jeremy Akers, Trent Hargens, David Wenos, and graduate students Katie Hilovsky, Jo Mandelson, and Nicole Gilbertson from the Departments of Kinesiology and Health Sciences at James Madison University. The purpose of this study is to determine the effect of low volume, high intensity training on physical fitness, physical activity enjoyment, and physical activity adherence, along with factors known to increase risk for chronic disease (blood lipids, etc.) by conducting an experimental study in a cohort of prediabetic men and women.

Research Procedures. The study will consist of a 16-week supervised exercise program. The research study will consist of three groups. Each participant will be randomized to a control, low volume, high intensity training, or moderate intensity training group. Prior to beginning the study, at the mid-point of the study (8 weeks), upon completion of the study (16 weeks), and at three-month and six-month follow-up, you will complete various supervised tests and questionnaires to measure the physical fitness, health status, lifestyle behaviors, body composition, blood lipids, insulin, and blood glucose levels.

Note: In the event you discover that any of the following information is not clear, please ask one of the researchers to explain immediately.

Blood Pressure. Blood pressure measurements will be taken using a sphygmomanometer and stethoscope. A blood pressure cuff will be placed over the upper portion of your right arm, slightly above the elbow. The cuff will be inflated to approximately 200mmHg and then slowly released, while a researcher uses a stethoscope to listen to sounds of blood flow through the vein on this inside of your elbow.

Blood Draws.   A fasted (8-10 hour) blood sample will be obtained by a butterfly needle in a vein in your mid arm. All blood draws will be taken from Sentara Rockingham Memorial Hospital (SRMH). In order to minimize the transfer of blood-borne pathogens, the trained person taking your blood will wear latex gloves at all times during blood sampling and testing. All values will be sent to researchers in a sealed envelope. Per SRMH protocol you will be required to provide a medical provider's information at each blood draw session. If blood values are outside normal/optimal ranges the blood values will be sent to your primary medical provider. For each blood draw, we will be measuring several different substances in the blood related to health and disease risk.

Preparation for Blood Draw. You will be asked to fast for 8-10 hours before the session. This includes coffee, tea, alcohol, or tobacco products.

Body Composition and Bone Mineral Density. Your height and weight will be measured and used to calculate body mass index BMI (kg/m^2). Additionally, the size of your waist and hips will be measured with a cloth tape measure. Your waist measurement is important in determining your risk for cardiovascular disease and diabetes. Dual-energy x-ray absorptiometry (DXA) will be used to estimate body composition data and bone mineral density through the whole body scan. For the DXA scan, you'll be asked to lie on your back and remain still for the whole scan; the scan will last approximately 6-10 minutes.

Maximal Exercise Test. The purpose of the maximal graded exercise test, also known as the VO₂max test, is to measure cardiorespiratory fitness. Cardiorespiratory fitness is the ability to engage in dynamic moderate- to high-intensity exercise for a prolonged period of time. Cardiorespiratory fitness is an important consideration when health risks and overall exercise capability are assessed. High levels of cardiorespiratory fitness are correlated with reduced risk coronary artery disease.

Preparation for Exercise Testing. Prior to exercise testing, we will ask you to not <u>eat</u> or <u>drink</u> anything, except water for three hours prior to the test. Please note that this includes caffeinated beverages – such as coffee or tea! Use of tobacco products should be avoided at least three hours prior to testing as well. Please avoid heavy exercise on the testing day. Try to get to get at least six hours of sleep the night before, to ensure that you are well rested. Wear clothing that is comfortable and allows you to move freely, such as shorts, a t-shirt, and comfortable running shoes. Be aware that the test is fatiguing, so you may wish to be fully hydrated before the test.

Procedure for Exercise Testing. Resting heart rate and blood pressure will be taken prior to testing. The treadmill test follows a predetermined protocol to obtain a maximal oxygen uptake. You will run on a treadmill, with the speed and/or grade increasing as the test progresses, until you're working as hard as you can. You will be fitted with a heart rate monitor chest strap and a pulmonary facemask. Nonverbal cues will be used to communicate during the test. Hand signals include "yes," "no," and/or "stop the test." It is important to realize that you may stop the test when you wish because of feelings of fatigue or any other discomfort. Additionally, we may stop the test at any time due to signs of fatigue or abnormal physiological responses. These may include failure for heart rate increase with increased workload, dizziness, chest pains, or muscular fatigue. Please note that both protocols and procedures are in adherence with the guidelines set forth by the American College of Sports Medicine for exercise testing.

You will be permitted to leave once post exercise heart rate drops below 100 beats per minute or resting heart rate levels. Avoid a hot shower and a heavy meal for at least an hour after the exercise test.

At-Home Sleep Assessment: The at-home sleep assessment will be utilized to screen for possible obstructive sleep apnea (OSA), a frequent co-morbid condition with diabetes, and a condition that may confound data analysis without accounting for. Research staff will instruct the you on the proper setup and use of the ApneaLink™ at-home screening device. The ApneaLink device is composed of a pulse oximeter, which is worn on the end of an index finger, and a nasal cannula, which is worn over the face, and into the nose to measure airflow. The ApneaLink device is harmless and painless to wear. You will be wearing this device one night while you sleep only at the beginning of the study.

Heart rate variability (HRV): HRV will be utilized to assess autonomic function, which is another proposed mechanism linking **obstructive sleep apnea and cardio vascular disease**. You will be asked to complete a resting HRV and heart rate measurement using a monitor that is strapped on your chest. You will be asked to lie flat on your back in a darkened room, while heart rate and HRV are measured over a 15 minute time period. You will be asked to breathe in rhythm with an instrument that is set at 12 beats per minute, thus representing 12 breaths per minute which is considered to be the average respiration rate for a healthy adult.

Health Status. Your health status will be determined via questionnaires and ACSM's Risk Stratification for Cardiovascular Disease Risk (ACSM, 2010). Assessment of your risk for cardiovascular disease will be made using the ACSM's Coronary Artery Disease Risk Factor

Thresholds along with the ACSM Risk Stratification. Risk stratification is based upon age, family history, smoking habits, blood lipid levels, and fasted blood glucose values, resting blood pressure, body mass index and physical activity habits. We will also be asking about current and previous conditions, surgeries, and medications, so that we may ensure that you are healthy enough to participate in this study.

Lifestyle Behaviors
You will be asked to complete the following questionnaires:
a. *Exercise Behavior* – The International Physical Activity Questionnaire (IPAQ) estimates how much activity you have participated in over the previous seven days. It will ask about your physical activity as part of your daily life, including work, as well as leisure time activity.

b. *Perceived Enjoyment*– The Physical Activity Enjoyment Scale *(PACES)* asks you about your perceptions and feelings about physical activity.

c. *Dietary Behavior* –A 3-day dietary record, where you will record what you consumed for 3 nonconsecutive days.

d. *Sleepiness-* The Epworth Sleepiness Scale is a measure of a person's general level of daytime sleepiness, or their average sleep propensity in daily life.

f. *Health Related Quality of Life-* The Health Related Quality of Life Scale is a measure of a person's physical and mental health and function.

Time Required. If you are randomized to the training group then you will be asked to commit to up to three hours per week, for sixteen weeks for the training segment of this project. Additionally, you will be asked to commit to ten testing and informational sessions that will each last up to two hours. Testing and training will take place as follows:

- **Familiarization Session (Pre)**: This is the familiarization session. During this session, all tests and procedures will be explained, after which we'll ask you to complete the appropriate health and medical status questionnaires and an Informed Consent Form. Additionally, participants will be asked to complete the questionnaires pertaining physical activity levels, health behavior, sleepiness, and perceived enjoyment. This session is estimated to last approximately 1 ½ -2 hours. You will also be given dietary record forms to be completed and returned to the researchers at the next meeting. After this session, future questionnaires will be completed during the clinical testing sessions.

- **Clinical Testing (Pre, Mid, Post, 3M FU, 6M FU):** In this session we measure your blood pressure and heart rate and complete a dual x-ray absorptiometry (DXA) scan for the assessment of body composition and bone mineral (hip) density. Diet records will also be collected. This session is estimated to last approximately 1 ½ -2 hours: 1 ½ hours for testing, 20 minutes for dietary records. All clinical testing will take place in the Kinesiology Human Performance Lab. For the mid-point, post-training, follow-up sessions, you will also be asked to complete the study questionnaires at this session. This is expected to add approximately 15 minutes to the session.

- **Fitness Testing (Pre, Mid, Post, 3M FU, 6M FU):** You will be asked to come to complete a maximal exercise test (VO_{2max} test) the same day as your clinical testing. Maximal testing will be completed in the Kinesiology Human Performance Lab.

- **Blood Values (Pre, Mid, Post, 3M FU, 6M FU):** In this session you will be asked to visit the Sentara RMH Outpatient Center located with the Sentara RMH Occupational Health Center at

1790-64B to have blood taken. Researchers will provide all documentation for you to take to each session. You will be required to fast for 8-10 hours. Please note that per SRMH protocol you will be required to provide a medical provider's information at each blood draw session. If blood values are outside normal/optimal ranges the blood values will be sent to your primary medical provider. This session should last 15 minutes.

- **Training Protocol:** As the main portion of the study, you will participate in a training session 3 days per week that will progress from 30 minutes per session, to 60 minutes per session for the next 16 weeks. Your group assignment will determine exactly what these exercise sessions will consist of. In brief, you will either be participating in moderate-intensity training, which consists of a continuous bout of exercise performed at a moderate intensity (moderate intensity is described as a 5 or 6 on a scale of 1 to 10); short high-intensity interval training, which consists of short bouts (30 seconds) of maximal effort exercise followed by longer recovery periods (4 minutes); or a combination of the two, which consists of one day of the continuous moderate intensity training session and two days of the high intensity interval training. You will be asked to come into the Marilyn Crawford Fitness Center (Godwin Hall) to complete all training sessions. Training groups are expected to see improvements in fitness.

Risks. There is minimal risk associated with submaximal exercise testing in individuals who are "low" or "moderate" risk according to guidelines established by the American College of Sports Medicine. There is a minimal level of discomfort that may be experienced during the exercise testing, which includes muscle soreness and fatigue. Muscle soreness may be felt 24-48 hours following the testing.

The risks of venipuncture blood sampling include possible mild bruising and the risk of transfer of blood-borne pathogens. This risk is considered to be minimal and all safety precautions for handing blood samples will be followed according to OSHA protocols and SRMH.

According to the manufacture's specifications (i.e., GE Healthcare), whole body DXA analysis exposes participants to 1.5 mrem of radiation. The exposure to radiation during a single chest x-ray (i.e., 5 mrem) is more than 3 times greater than radiation from DXA. Also, background radiation from DXA is about equal to the amount of radiation one experiences during a flight from New York to London. Please note that the effects of the DXA scan are cumulative depending on your prior exposure to radiation. If you have questions regarding your risk from the scan please consult with the researchers.

Benefits. Potential benefits from participation in this study include free testing of cardiorespiratory fitness, body composition, lipid profile, and bone mineral density. You will receive the results from your individual tests, including a rating of how you compare to individuals within your age category. Along with these results, you'll receive information regarding the importance and meaning of measure, as well as what steps you could take to improve these measures if you would like to. You will also have the opportunity to learn about habitual dietary intake and your percentages of energy nutrients and total caloric intake. Participation in this study will also help researchers understand metabolic responses and adherence to long-term exercise. Finally, if you complete the study, you'll receive a free dietary consultation.

If you are randomized to the two training groups you will also receive free monitored workout sessions and motivation from the researchers. The researchers expect to see positive metabolic changes for participants in all training protocols that may result in improved health and general well-being.

Confidentiality. All data and results will be kept confidential. You will be assigned an identification code. All of your questionnaires and other results will be filed only according to your identification code, with your full name not located in that file. For the duration of the study, your first name will be stored with this data, so that research staff may address you, but this will be removed at the completion of the study. These results will be stored in a locked cabinet in a locked office. Electronic copies of the data will be password protected and kept only on secure servers. Only research personnel, who may include students, will have access to this data in either hard or electronic format. Any forms that link your name with your identification number, including this form, will be kept in a different file, which will be located in the office of one of the head researchers on this study. Additionally, any electronic formats of this information will be kept by one of the head researchers and will be password protected with a different password than the data. None of your test results or data will be located in this file. Access to these files will be limited to the head researchers on this staff and will only be used for the purposes of matching up your data to previous results and to contact you for the follow-up measures. After the second follow-up measure, any form that links your name to your identification number will be destroyed. The data collected will be analyzed and used to complete three graduate student research theses, a national presentation, and submission for publication in a professional journal.

Participation and Withdrawal. Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind. If at any time you choose to withdraw from the study, any identifying information that links your name to your data will be destroyed at that time.

Reporting Procedures. You will be provided health and fitness tests data at the completion of each test and will receive the results of your blood tests after they have been processed. The findings of the study will be presented at regional and national organizations conferences and submitted for publication in professional journals.

Questions about the Study. If you have questions or concerns during the time of your participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

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Chair, Institutional Review Board
Sentara RMH Medical Center
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SGPOLLO3@sentara.com

Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

_____
Name of Participant (Printed)

_____   _____
Name of Participant (Signed)   Date

_____
Name of Researcher (Printed)

_____   _____
Name of Researcher (Signed)   Date

Demographic Information

Full Name: _____   Nickname: _____
_____

ID# _____ (Research personnel use)

Address: _____

Preferred phone: _____Is this your: ☐ Work   ☐ Home   ☐ Cell   ☐ Other:
_____

Email address: _____   Date of Birth: _____
(Month/ Day/ Year)

Optional Additional Consent

I understand that new risk factors are constantly emerging and that further analysis of my blood samples, beyond those tests outlined in this consent form may provide valuable information. I consent to having my blood samples stored indefinitely, so that they may be used in future analyses. If my blood is used in these tests and yields information that would be pertinent to my health, the research team will attempt to contact me to give me these results.

_____
Name of Participant (Printed)

_____   _____
Name of Participant (Signed)   Date

_____
Name of Researcher (Printed)

_____   _____
Name of Researcher (Signed)   Date

Appendix C: Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

→ **DELAY BECOMING MUCH MORE ACTIVE:**
- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____   DATE_____

SIGNATURE OF PARENT _____   WITNESS_____
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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<u>Appendix D: Health Status Questionnaire</u>

Health Status Questionnaire

Part I Medical History

1. Has anyone in your family had a heart attack, heart surgery, or sudden death due to cardiovascular disease prior to the age of 65? (Circle one)   Yes   No

      If yes, who? _____
      How old were they? (Circle one)   54 or younger   55-59   60-64

2. Date of last medical exam: _____   Last physical fitness test: _____

3. Please list any operations that you have had:
_____
_____
_____
_____
_____

4. Please list any condition for which you have been diagnosed or are being treated for by a physician or health professional:
_____
_____
_____
_____

5. Please list all medications taken in the last six months:
_____
_____
_____
_____
_____

6. The occurrence of any of these health symptoms frequently is the basis for medical attention. Please check how often you have each of the following:

Symptom	1 Rarely	2 Infrequently	3 Sometimes	4 Fairly Often	5 Very Often
Cough up blood					
Abdominal pain					
Low back pain					
Leg pain					
Arm or shoulder pain					

Chest pain					
Swollen joints					
Feel faint					
Dizziness					
Breathless on slight exertion					

7. Do you smoke? (Circle one)   Yes   No

If yes, how many per day: Cigarettes: 40 or more   20-39   10-19
          1-9

                        Cigars or pipes only: 5 or more or any inhaled   less than 5, none inhaled

Adapted from: Howley and Franks. (1992). *Health Fitness Instructor's Handbook*. Health Status Questionnaire. Champaign :Human Kinetics.

Appendix E: International Physical Activity Questionnaire (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

LONG FORM: LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an **International Physical Activity Prevalence Study** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the <u>**last 7 days**</u>. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the <u>**last 7 days**</u>. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1.   Do you currently have a job or do any unpaid work outside your home?

           Yes

           No   ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2.   During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

    _____ days per week

    No vigorous job-related physical activity   ***Skip to question 4***

3.   How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

    _____ hours per day
    _____ minutes per day

4.   Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

    _____ days per week

    No moderate job-related physical activity   ***Skip to question 6***

5.   How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.
_____ **days per week**

No job-related walking   *Skip to PART 2: TRANSPORTATION*

7. How much time did you usually spend on one of those days **walking** as part of your work?
_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.
8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?
_____ **days per week**

No traveling in a motor vehicle   *Skip to question 10*

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?
_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?
_____ **days per week**

No bicycling from place to place   *Skip to question 12*

11. How much time did you usually spend on one of those days to **bicycle** from place to place?
_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?
_____ **days per week**

No walking from place to place   *Skip to PART 3:*
                                                            HOUSEWORK, HOUSE

13. How much time did you usually spend on one of those days **walking** from place to place?

    _____ **hours per day**

    _____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

    _____ **days per week**

    No vigorous activity in garden or yard   ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

    _____ **hours per day**

    _____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

    _____ **days per week**

    No moderate activity in garden or yard   ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

    _____ **hours per day**

    _____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

    _____ **days per week**

    No moderate activity inside home   ***Skip to PART 4:
    RECREATION, SPORT
    AND LEISURE-TIME
    PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

    _____ **hours per day**

    _____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY
This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?
   _____ **days per week**

   No walking in leisure time   *Skip to question 22*

21. How much time did you usually spend on one of those days **walking** in your leisure time?
   _____ **hours per day**
   _____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?
   _____ **days per week**

   No vigorous activity in leisure time   *Skip to question 24*

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?
   _____ **hours per day**
   _____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?
   _____ **days per week**

   No moderate activity in leisure time   *Skip to PART 5: TIME SPENT SITTING*

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
   _____ **hours per day**
   _____ **minutes per day**

PART 5: TIME SPENT SITTING
The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?
   _____ **hours per day**

_____   **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?
    _____   **hours per day**
    _____   **minutes per day**

This is the end of the questionnaire, thank you for participating.

<u>Appendix F: Three Day Food Intake Records</u>

Food Intake Record Directions and Tips:

- In the first two columns, note the time and location the food or beverage was consumed.
- In the third column, record the food or beverage.

  - Be as detailed as possible in describing the food item. For example not just chicken, but how it was cooked (fried, grilled, baked, etc), and include any sauces or dressings put on any food item. If you eat a salad, try and write down everything that was in the salad with appropriate portion sizes. See descriptive words page for words that you can use.
  - Include brand names or restaurant names with item names whenever possible. Examples: Kraft, General Mills, Campbell's, McDonalds 6 piece McNuggets, etc.
  - Include toppings such as mustard, ketchup, mayonnaise, cream, sugar, steak sauce, salsa, dressing, gravy, pickles, honey, butter etc.
  - If you are at a restaurant, it is more than OK to ask the staff or waiter/waitress how something was cooked, or about the ingredients in a particular item (ie whether a dressing is low-fat vs. regular). Additionally, if you want, you can include the description off the menu.
  - If you have a recipe or a label of a common food you consume, feel free to bring it in. The more details you can provide us with, the better!

- Determine serving size for food or beverage (columns 4-7):
  - *Portion Size: How many?*: How many of this item did you consume?
  - *Portion Size: Food Model:* Estimate the size of your food. Options:
    - Use the Food Amounts Booklet as a visual guideline.
    - OR if you're cooking at home and you know the measured amount, include the measurements. You can use household measures such as measuring cups and spoons to further help you estimate how much you ate.
    - OR if a weight from the package is available, include the weight.
  - *Thickness/Ice in drink*: If you are using the Food Amounts Booklet, estimate the thickness of your food. Additionally, this is where you can document drinks with ice.
  - *Reviewers Notes*: Leave this column blank.

- Please pick two weekdays and one weekend day. The three days should be consecutive days.
- Be as honest as possible! This really helps with the accuracy of the data that is collected. We are simply trying to document what you consumed over a three day span.
- Keep your Food Intake Record and Food Amounts Booklet handy.
- You do not need to record while you are eating. We want you to enjoy your meal and avoid altering what you're eating. You can wait until the meal is over to start recording. It is better, however, to record soon after the meal and avoid recording at the end of the day if possible. This makes it easier to remember what you ate and will likely provide the research team with a more accurate record.
- No need to carry a food scale with you. That's what the Food Amounts Booklet is for!
- Remember to include beverages (even water) and snacks as well.

Descriptive words you can include:

1% fat	2 % fat	Air Popped	Au Gratin	Au jus	Au Lait
Baked	Broiled	Basted	Braised	Breaded	Battered
Buttery	Bisque	Creamy	Candy Coated	Chocolate Covered	Charbroiled
Candied	Canapé	Canned	Deep pan	Drenched	Dressed with
Deep fried	Fire roasted	Flamed broiled	Fresh	Fudgy	Farci
Fat free	Fire grilled	Frozen	Fried	Garden fresh	Gooey
Golden	Grilled	Ground	Glazed	Hand battered	Homemade
Honeyed	Lean	Low sodium	Layered	Lemony	Light
Loaded	Low fat	Marinated	Meaty	Melted	Non Fat
Poached	Pan-seared	Reduced Fat	Roasted	Slow Cooked	Smokey
Seared	Seasoned	Sautéed	Skinny	Stuffed	Sugar Coated
Sugared	Stuffed	Sweet	Toasted	Topped With	Tossed With

Some information adopted from Nutrition Therapy & Pathophysiology, 2nd edition, 2011

Subject ID Number _____   Date _____
Page ___ of ___
Day (circle):   1   2   3

Food Intake Record

Time	Place	**Food Description** (Please specify, if known: brand names, cooking method, type of product, and include labels when possible)	**Portion Size : How many?**	**Portion Size : Food Model**	Comments

Physician Approval Form

Patient Name: _____

1. Are there specific concerns or conditions we should be aware of before this individual engages in the physical fitness assessment for this study??

_____
_____

_____
_____

2. If this individual has completed a graded exercise test (stress test) please provide the following:

      a. Date of Test:

_____

      b. A copy of the final exercise report and interpretation.

3. Please provide the following information so that we may contact you if we have any further questions:

_____ I AGREE to the participation of this individual in the herein described study.

_____ I DO NOT AGREE that this individual is a candidate for this study.

Physician's Signature

      _____

Physician's name (printed)

      _____

Address

      _____

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