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The Efficacy of HIIT and HIRT in Older Adults

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ABSTRACT

Moderate intensity continuous exercise (MICE) improves aerobic and functional fitness and prevents chronic disease and premature morbidity. Aerobic and functional fitness are validated clinical indicators of chronic disease risk. High intensity interval training (HIIT) is a time efficient and safe alternative to MICE that has positive effects on some chronic diseases and risk in younger healthy populations. Limited research has investigated HIIT in older, at-risk populations; and the health benefits of including *resistance training* into HIIT approaches (HIRT) is even more limited in older, at-risk adults. The purpose of this research was to determine the aerobic and functional fitness efficacy of HIIT and HIRT exercise interventions compared to MICE in older adults at-risk for chronic disease.

Forty-eight adults (≥65 years) were recruited and randomized into three 8-week exercise intervention groups: MICE (active control), HIIT, and HIRT. Aerobic (VO_2max) and functional fitness (functional movement screen, FMS; timed-up-and-go, TUG; floor transfer time, FTT) were measured at baseline and after 8-weeks. VO_2max improved similarly in all groups (HIIT 2.2±0.3; HIRT=3.5±0.7. MICE 2.1±0.5 ml/kg/min, $P<0.01$). Both high-intensity groups improved in FTT (HIRT=17%, $P<0.01$; HIIT=12%, $P<0.05$) and FMS (HIRT=17%, HIIT =10%, $P<0.01$). Only HIRT improved in TUG (10.6%) and balance (9%). No injuries or adverse events occurred in any group. HIRT and HITT are as safe and efficacious as MICE in older adults for improving aerobic and functional fitness. HIRT appears to elicit additional functional fitness benefits, but both high-intensity approaches are safe and effective alternatives for older adults' with or at-risk for developing chronic disease.

AGING:

Aging is an inevitable process of life. With life span increasing and an aging baby boomer population, the United States' older adult population ($\geq$ 65 years of age) is expected to double in the next 25 years, reaching nearly 72 million (*National Center for Chronic Disease and Prevention and Health* 2013). By 2030, approximately 20% of the U.S. population will be comprised of older adults (*National Center for Chronic Disease and Prevention and Health* 2013). Along with aging comes a multitude of changes in the body, both physiological and anatomical. Four of the most prominent changes associated with aging include strength, bone mineral density (BMD), cognition, and aerobic fitness. These four components are directly related to changes in a person's ability to perform activities of daily living (ADL's).

Sarcopenia

Sarcopenia refers to the progressive loss of skeletal muscle mass and strength. It is one of the most recognizable changes associated with aging (Cruz-Jentoft et al. 2010). Approximately 1-2% of muscle mass is lost per year after the age of 50 (Muscaritoli et al. 2012). This drastic change is accompanied by "intramuscular fat accumulation, muscle atrophy, decreased satellite cell proliferation and differentiation capacity, and reduction in motor unit number" which plays a key role in the loss of muscle force and power characteristics in advanced age (Muscaritoli et al. 2012). A decrease in muscle endurance, muscle mass, and muscle strength inhibits a person's ability to carry out everyday tasks that are vital to their overall wellbeing, causing a reduction in their quality of life (QOL). Even more concerning is the increased fall risk associated with weakened muscles, as older adults get fatigued more quickly and have decreased balance, resulting in potentially dangerous falls in and around the home.

Bone Mineral Density

While falls alone can be detrimental to one's health, if a person's bone mineral density (BMD) is below what is considered healthy for his or her age, gender, and ethnicity, these falls can result in fractures, which are commonly seen in the pelvis, spine, and hips. A longitudinal study by Berger et. al. (2008) measured BMD in nearly 10,000 participants in three separate locations: lumbar spine, total hip, and femoral neck. The female subjects began to show a decrease in BMD in all three sites at age 40-44 with the greatest loss occurring in the total hip at age 50-54 as they transitioned from premenopause to postmenopause. Female subjects saw another large decrease of BMD at age 70. The male subjects in the study saw an earlier decline in BMD which began at age 25-39; however, their decline in BMD was much steadier and not affected by changes in hormones. They also measured a more drastic decline with age, beginning at age 65. The deterioration seen in the composition, structure, and function of bone puts older adults at a risk for osteoporosis, that is, "deterioration in bone mass and micro-architecture with increasing risk to fragility and fractures" (Demontiero et. al. 2012).

A slight decrease in BMD is inevitable, however, one of the main causes of BMD loss is a lack of physical activity, specifically mechanical loading. The reduction of mechanical loading reduces the effects of osteoblasts – the cells in charge of secreting the matrix for bone formation – and instead stimulate osteoclast formation and activity – the bone cells that absorbs bone tissue during growth and healing (Demontiero, et al. 2012). Certain exercises such as high impact movements and resistance training have been shown to prevent and/or reverse approximately 1% of bone loss per year in both premenopausal and postmenopausal women (Wolff et al. 1999).

Cognition

Intellectual decline does not invariably accompany aging, but older people are at a much greater risk (Keefover, 1998). Approximately 5% of older adults suffer from dementia, demonstrated by significant impairments in memory, disturbances in one or more additional cognitive domains, and limitations associated with ADL's. The prevalence rate of cognitive decline doubles to 10% when including older adults without full dementia, and exponentially increases to two-thirds when considering "normal" older adults who demonstrate subtle cognitive declines in neuropsychologic testing.

A growing body of evidence supports the effectiveness of physical activity improving cognitive health (Gomez-Pinilla & Hillman 2013). Exercise that targets aerobic fitness has been proven to enhance functional aspects involved in cognition as well as spare age-related loss of brain tissue that is associated with aging. Individuals who are regularly active are able to process information more quickly and are less likely to develop neurological disorders.

Aerobic Fitness

Peak-oxygen consumption (VO_2) can be defined as the "maximum capacity to transport and utilize oxygen" and is currently the most widely used measure of maximal functional aerobic capacity (Kim et. al. 2016; Fleg 2012). On average, healthy men and women see an 8-10% decline per age decade after their third decade of life with a drastic decline of 20-25% per decade in healthy adults over the age of 70 (Fleg 2012). A combination of aging factors contributes to the noticeable decline: decreased maximal heart rate and stroke volume, reduction in blood volume, stiffening of both heart muscle fibers and arterial walls, reduced peripheral oxygen extraction, and a greater maximal A-VO_2 difference (Kim et al. 2016).

There is a noticeable correlation between aging the decline in aerobic capacity, but physical inactivity is the greatest contributor to a reduction in a person's VO_2 max. Numerous longitudinal studies have published similar results over the years agreeing that a decline in VO_2max is inevitable but being physically active can slow the decline (Betik & Hepple 2008). A longitudinal study by Kasch et al. (1999) reported a VO_2max decline of approximately 5% per decade in highly active individuals as opposed to the 10% decline per decade seen in less active adults.

Activities of Daily Living

Many older adults experience a drastic reduction in their QOL and independence due to disabilities associated with sarcopenia, BMD, cognition, aerobic fitness, and the potential development of chronic disease(s). The above factors greatly inhibit a person's ability to perform important and essential tasks both in and out of their home. A decrease in functional ability – either mental or physical – affects activities of daily living (ADLs) which can range anywhere from personal hygiene and feeding themselves to getting dressed and toileting (*National Center for Chronic Disease and Prevention and Health Promotion* 2013). Additional declines can be seen in a person's instrumental activities of daily living (IADLs) which include their ability to manage money, shop, prepare meals, and take their prescribed medications on their own (*National Center for Chronic Disease and Prevention and Health Promotion* 2013).

Mobility is an important building block for both ADLs and IADLs, as it refers to a person's ability to move his or her body through space, allowing one to walk, stand up, reach, turn over in bed, and climb stairs both functionally and independently (Lowry, Vallejo, & Studenski 2011). Walking is considered the most fundamental mobility task for human life. A study performed by Studenski et al. (2003) looked at walking speed as an objective measure of walking ability in older adults. The study concluded that older adults with the ability to walk at speeds greater than or equal to 1.0 m/s (~2.24 mph) were associated with greater independence in their ADLs. Additionally, there was significantly less likelihood of being hospitalized or experiencing other adverse events. However, older adults who averaged a walking speed of 0.6 m/s (~1.34 mph) or slower had greater dependence on other to perform ADLs and a higher likelihood of being hospitalized.

Currently, 50% of Americans over the age of 85 require assistance with ADLs either from family members or close friends, within a nursing home, or through a home health nurse (*National Center for Chronic Disease and Prevention and Health Promotion* 2013). The decrease in the ability to perform these necessary tasks results in a loss of independence and QOL, leading to emotional and psychological stress for the older adult in addition to emotional and financial stress on his or her family members and the health care system.

AGING AND CHRONIC DISEASE:

Conditions and/or diseases that people develop as they age can be broken down into two categories: acute or chronic. Acute illnesses come on suddenly but have a short(er) duration, usually days or weeks; while chronic illnesses generally develop slowly over the course of months or even years. The causes of acute and chronic illnesses vastly differ. Acute conditions are generally a result of an infection, virus, or a fall while chronic conditions are often the consequence of poor nutrition, lack of physical activity, excessive alcohol consumption, smoking, or other factors including social, emotional, environmental, and/or genetics (*National Council on Aging)*. For the older U.S. population, the most prevalent chronic diseases are heart disease, cancer, stroke, chronic lower respiratory disease, diabetes, and Alzheimer's (*National*

Center for Chronic Disease and Prevention and Health Promotion 2013). Chronic diseases comprise the majority of global disease burden and are the most common causes of mortality (Kennedy et. al. 2014). Currently, 80% of older adults have at least one chronic disease and 77% have at least two chronic diseases (*National Council on Aging*). Heart disease, cancer, stroke, and diabetes are the four most common types of chronic diseases among older adults in the U.S., accounting for nearly two-thirds of all deaths in the U.S. each year (*National Council on Aging*).

The United States expenditures for health care are currently the highest among all developed countries and are expected to rise 25% due to the influx of the older adult population (*National Center for Chronic Disease and Prevention and Health Promotion* 2013). Ninety-five percent of all health care costs for older adults are for chronic diseases, totaling $555 billion in 2011 alone (*National Center for Chronic Disease and Prevention and Health Promotion* 2013).

PHYSICAL ACTIVITY AND PHYSICAL INACTIVITY

The American College of Sports Medicine (ACSM) currently recommends that adults get 150 minutes/week of moderate-intensity aerobic training which can include aerobic modes such as walking, jogging, cycling, hiking, and/or swimming (Chodzko-Zajko et al. 2009). These aerobic modes have been proven to improve aerobic fitness, overall cardiovascular health, and reduce disease risk. In addition to the 150 min/week of aerobic training, the ACSM recommends incorporating 2 days/week of resistance exercises, flexibility, and balance training.

While there are some risks associated with exercise, especially for those living with one or more chronic diseases, the benefits greatly out-weigh the risks. Regular physical activity has been shown to contribute to primary and secondary prevention of several chronic diseases including diabetes mellitus, cancer (colon and breast), obesity, hypertension, bone and joint diseases including osteoporosis and osteoarthritis, and depression (Warburton, Nicol, & Bredin 2006). Regular physical activity has been shown to lessen a person's risk of premature death. A linear relationship between the amount of physical activity and health status has also been shown among participants in numerous studies. People who participate in regular physical activity are more likely to have better QOL (Warburton, Nicol, & Bredin 2006).

According to the Centers for Disease Control and Prevention (CDC), only 21% of adults meet the current physical activity guidelines (CDC 2018). Adults living in the South are even less likely to meet the guidelines when compared to adults living in the West, Northeast, or Midwest parts of the United States. It can be assumed that the nation's rising rates of chronic disease are due to the high percentage of adults not getting the recommended amount of physical exercise.

A 1990 study by Sallis & Hovell looked at the most common barriers to physical activity. Lack of confidence, self-motivation, gym equipment, and fear of injury were among the most common responses. However, the most common barrier recorded among American adults was a lack of time.

HIGH-INTENSITY INTERVAL TRAINING & HIGH-INTENSITY RESISTANCE TRAINING

High-Intensity Interval Training

High-intensity exercises have increased in popularity over the last few years as they follow a different work-to-rest ratio and require less time overall per week. High-intensity interval training (HIIT) refers to repeated sessions of quick, intermittent exercise typically performed at max effort (≥90% of VO_2max) (Gibala & McGee 2008). The actual format for a

HIIT session can vary from workout to workout but the single effort of high-intensity generally lasts from a few seconds to a few minutes and is followed by a few minutes of rest.

A study by Gibala & McGee (2008) took young, healthy college students of "average fitness" and had them perform the Wingate test, which consists of 30-second sprint intervals on a specialized ergometer with a high braking force. The subjects would repeat the sprint intervals four to six times in a single session with a four-minute recovery periods between exercise bouts. This totaled just two to three minutes of extremely intense exercise per training sessions with three training sessions per week for two to six weeks. The conclusion of the study showed a "dramatic improvement in exercise performance" as the subjects were able to double the length of time that exercise could be maintained at a fixed submaximal workload. Additional improvements were shown in muscle oxidative capacity, which was assessed using the needle biopsy technique.

Little et al. (2011) studied the effects of HIIT on a more specific group, looking at the benefits of HIIT in those with Type II Diabetes (T2D). All subjects were diagnosed with T2D at least three months prior to the start of the study. Similarly, the subjects performed bouts of high intensity intervals on a cycle ergometer where they had six supervised sessions (Monday, Wednesday, and Friday) over a two-week period. Their sessions consisted of 10 intervals lasting 60 seconds each with 60 seconds of recovery between intervals. Subjects were required to stay within a constant workload with a pedal cadence of 80-100 revolutions/minute and specific workloads were set so that each subject was reaching a heart rate of 90% HR_{max} during each interval. The results of the study showed a rapid decrease in hyperglycemia, demonstrated by a decrease in the 24-hour average blood glucose concentration and reduced post meal blood glucose excursions, as well as increased markers of skeletal muscle mitochondrial capacity in just two weeks (Little et al. 2011). On average, the subjects were engaging in 75 mins/week, half of the recommended 150 mins/week, providing a time-efficient, effective alternative for those living with T2D.

A meta-analysis of 10 studies and 273 patients living with chronic diseases such as coronary artery disease, heart failure, hypertension, metabolic syndrome, and obesity looked at the effect HIIT had on the subject's cardiorespiratory fitness (CRF) (Weston, Wisløff, & Coombes 2014). This particular meta-analysis is significant as the patients in these studies had lifestyle-induced cardiometabolic diseases due to poor diet and lack of exercise. Seven of the ten studies used a treadmill as the primary exercise modality, changing the incline and speed to elicit changes in heart rate. The other three studies conducted their research study using a cycle ergometer. While there were slight variances in testing protocols between each study, the intensities were set based on baseline maximal/peak testing data. Six studies used a percentage of maximal heart rate, two studies used a percentage of peak power, and the final two used the VO_2 peak. Results of the HIIT groups were compared to a control group consisting of subjects doing moderate-intensity continuous training (MICT).

The meta-analysis reported a multitude of adaptations unique to or greater in magnitude in HIIT compared to MICT including an increase in: VO_2peak, high density lipoproteins, adiponectin, insulin sensitivity and β-cell function, maximal rate of Ca^{2+} reuptake, availability of nitric oxide, cardiac function, enjoyment of exercise, and QOL. Further reductions in systolic and diastolic blood pressure, triglycerides and fasting glucose, oxidative stress and inflammation, fatty acid transport protein 1 and fatty acid synthase were also noted among the 10 studies. The meta-analysis concluded that HIIT had more physiological benefits when compared to MICT in patients with lifestyle-induced cardiometabolic disease. Overall CRF significantly improved in

HIIT when compared to MICT (19.4% vs. 10.3%) showing that HIIT is a feasible way for patients with cardiometabolic disease to improve their health.

High Intensity Resistance Training

High-intensity resistance training (HIRT) is similar to HIIT in that it incorporates short bursts of high-intensity exercises with maximum effort and heart rate. However, HIRT incorporates compound, multi-joint muscle group exercises as opposed to strictly endurance focused exercises such as walking, jogging, sprinting, or cycling. This exercise regime targets both aerobic and anaerobic modes of training, increasing cardiorespiratory fitness as well as muscular strength, muscular endurance, and power.

Paioli et al. (2012) studied the acute effects of HIRT versus traditional training (TT) on a person's resting energy expenditure (REE) and respiratory ratio (RR). Seventeen resistance-trained males (28 ± 4.5 years) participated in the study which had subjects complete both the HIRT and the TT sections. In the HIRT section of the study, each subject completed three series of 6 repetition maximal effort tests followed by 20 seconds of rest. The subjects would then lift the same weight until reaching the point of failure (~2 repetitions) followed by another 20 second rest period before performing another 2-3 repetitions. This total sequence equaled one set. Following the first set, the subjects rested for 150 seconds before completing sets two and three. Including the warmup, the entire session lasted 32 minutes.

In the TT session, subjects performed four sets of eight different weight-lifting exercises including bench press, dorsal machine, military press, bicep curls, tricep extensions, leg press, and leg curls. The weight used for each exercise was 70-75% of their previously determined 1 repetition max effort. Subjects were instructed to complete each exercise to the point of failure, which generally fell between 8 and 12 repetitions. Exercises that were considered single-joint exercises allowed for a one-minute rest period between sets and exercises that were considered multiple-joint exercises allowed for a two-minute rest period between sets.

There were no significant differences found between TT and HIRT in terms of REE and RR, however, there was a significant elevation in the subject's VO_2 noticeable even 22 hours post exercise upon the completion of the HIRT protocol. Paioli et al. (2012) also discovered a significantly greater mean level of maximal post-exercise blood lactate after HIIT compared to after TT, which they explained is due to the fact that lactate plays a role in the total increase of post-exercise energy expenditure. The increased levels demonstrated after the HIRT protocol reflects a "major metabolic stress derived from high intensity resistance training and may reflect the utilization of lactate as fuel in the aerobic pathway" (Paioli et al. 2012).

Hagerman et al. (2000) studied strength, cardiovascular, and metabolic responses in untrained older men (60-75 years) using a HIRT protocol. This approach was contrary to the common low-intensity, short-term programs commonly prescribed to older adults. Twenty-two male subjects were randomly assigned to either the control, untrained (UT) group, or to the resistance-trained (RT) group where the average age of the RT group was 63.7 ± 5.0 and that of the UT group was 66.2 ± 6.5 years. Similar to the above study, subjects based their lifting weights on a percentage of their 1 repetition max for exercises including double leg extension, double leg press, and half squat. Those in the RT group had two sessions per week for 16 weeks where they warmed up for five minutes and then completed one set of 10 repetitions of 50% of their 1RM. This was followed by three sets to failure (~6-8 repetitions) at 85-90% of their 1 repetition max with two minutes of rest between sets. Resistance was increased for each exercise as long as subjects could still reach 6-8 repetitions each time.

The RT group saw a significant decrease in percent body fat over the 16 weeks of resistance training while the UT showed slight but non-significant changes. Significant increases in 1 repetition max were observed in all three exercises for the RT group as well as a significant increase for absolute and relative values of VO_2peak. The conclusion of this study stated that high-intensity resistance training is safe and effective for "reasonably healthy aging men" (Hagerman et al. 2000).

Little research-based evidence exists regarding the effectiveness and safety of both HIIT and HIRT for older adult populations, specifically those living with chronic disease. The purpose of this study was to test the efficacy and safety of HITT and HIRT compared to moderate-intensity continuous exercise (MICE) in an older adult population.

METHODOLOGY

Recruitment and Pre-testing

A total of 48 volunteers between the ages of 60 and 95 were recruited for this study. Of the 48, 18 were male and 30 were female. Sixty percent of the participants had multiple chronic conditions, and a breakdown of each condition can be seen in Table 1. Flyers were distributed to various locations throughout Laramie, WY in addition to being sent via email to local physicians and the University of Wyoming faculty and staff. Once the interested participants contacted the lead researcher, they were scheduled to come into the University of Wyoming Human Integrative Physiology Lab in Corbett Building to complete the University of Wyoming Health History Screening Questionnaire (UWHHSQ). This was the primary tool used to determine inclusion and exclusion criteria.

Table 1: Preexisting conditions and disease prevalence in participants prior to baseline testing.

Preexisting Conditions/Disease	**N (%)**
Asthma	6 (13)
Blood Disorders	2 (4)
Cancer	5 (11)
COPD	2 (4)
Dyslipidemia	21 (47)
Hypertension	17 (36)
Immunological	2 (4)
Neurological	2 (4)
Osteoporosis	3 (6)
Pre/Diabetes Type II	9 (19)
Psychological	6 (13)
Pulmonary Hypertension	1 (2)
Sleep Apnea	3 (4)
Stoke/TIA	3 (4)
Syncopal Disorders	2 (4)

The UWHHSQ is an in-depth questionnaire regarding the subject's personal information, cardiovascular health history, cardiovascular risk factors, alcohol intake, current medications, surgical history, and further diagnostic history. Exclusion criteria was as follows:

1. Female participants who are pregnant or trying to become pregnant
2. Acute or uncontrolled disease such as cardiovascular, pulmonary, neurological, endocrine, musculoskeletal, or immunological

3. Individuals unable to walk or who are 100% reliant on a walking-aid (walker, wheelchair)
4. Uncontrolled or current problems with loss of consciousness/fainting and/or positional hypotension
5. Stroke or aneurysm within the past 3 years
6. Exercise/physical activity restrictions recommended/prescribed by a health provider
7. Visual impairment
8. Cognitive impairment that prevented understanding the risks associated with the research study
9. Medical director exclusion due to an underlying disease/risk not previously known

In addition to the UWHHSQ, the participants completed an informed consent packet, explaining the potential risks and benefits of the study, the research liability waiver, and the participant's ability to stop participating in the study at any time. Participants were also required to sign a medical release/authorization form and complete three additional surveys: the Satisfaction with Physical Function, the Physical Activity Enjoyment Scale (PACES), and the Mobility Assessment Tool Short Form. The Satisfaction with Physical Function form required the participants to assess their satisfaction with their current overall physical fitness, muscle strength in legs, level of stamina, muscle tone, overall energy level, physical ability to do what they wanted to do, weight, shape, and overall physical appearance. Each component was ranked from "very dissatisfied" to "satisfied." The PACES questionnaire assesses the participant's enjoyment with their physical activity exercise(s). The Mobility Assessment Tool Short Form All took the participants through video-animated activities where the person on the screen walked on a flat surface, walked upstairs, walked on uneven ground, and walked carrying an arm full of groceries. After each animation was complete, the participants were prompted to rank their ability to do the animated task on a scale from 1-4 where 1 was "unable to perform." All three tools were used as a baseline measure and were assessed again upon the completion of the exercise intervention.

Once the participants were deemed eligible to participate, each individual was scheduled to come in again for a series of baseline testing measures. Much like the three surveys, all baseline measures were repeated upon the completion of the research study. Each participant's height (cm), weight (kg), and waist circumference (cm) were assessed. Additionally, the subject's resting blood pressure and resting heart rate were measured using an automated blood pressure cuff and heart rate machine. Participants were seated in a chair for a total of five minutes before heart rate and blood pressure measurements were taken.

In order to test each participant's aerobic fitness, they were taken through a maximal (or symptom-limited) Graded Exercise Stress Test (GXT), also known as a VO_2 max test. All GXT's were completed under the supervision of the head researcher and the medical supervisor. To begin, the participant was connected to an electrocardiogram (ECG) to monitor his or her heart. Resting ECG's were obtained at both supine and standing positions in order to determine any underlying diseases/abnormalities before the beginning of the GXT. If the medical supervisor did not clear the participant, he or she was sent to his or her physician for further testing. Those that were cleared began their GXT that also included being connected to an oxygen consumption face mask to measure aerobic fitness (VO_2max).

The format of our GXT required the participants to walk at a comfortable pace based on their current levels of physical activity and their overall functional fitness (e.g., 3.0 mph). Once the desired pace was reached, the incline of the treadmill progressively increased. Participants were instructed to walk for as long as they could – reaching volitional fatigue – or until the max criteria was achieved (age-predicted maximum heart rate or a plateau in oxygen consumption). The GXT generally lasted anywhere from 8-12 minutes during which the participants were asked for their rate of perceived exertion (RPE) and if they were experiencing any signs/symptoms (chest pain, shortness of breath, or leg pain) every minute. Heart rate was assessed through the ECG and exercise blood pressure was taken before exercise, every two minutes during the GXT, and immediately upon the completion of the GXT.

It is important to note that participant randomization and intervention group notification occurred at this point in the pre-testing phase, as any alarming results found in the GXT disqualified participants from doing high-intensity exercise. Randomization occurred using a computer-generated randomizer application that placed participants into their respective groups (MICE, HIIT, or HIRT).

Body composition and BMD were assessed using a Dual Energy X-ray Absorptiometry (DEXA) machine. All female participants were required to take a pregnancy test prior to the DEXA scan. The DEXA scan required the participants to lie supine on the DEXA table for 6-15 minutes (which varied from person to person based on size) until the completion of the total body scan. The DEXA test provides results regarding each participant's body composition which included their percent body lean muscle mass and percent body fat. Further detailed charts broke down the exact percentage of fat in each body region (i.e. legs, trunk, chest, arms, etc.). Bone mineral density was presented on a chart indicating what the subject's BMD was compared to what was a healthy level for people of comparable gender, race, and age. Anyone who fell under the "healthy" BMD line were referred to their health care provider for further testing.

The Functional Movement Screening (FMS) was used to assess asymmetries and dysfunctions in the body while trying to replicate the functional movement patterns a person would complete in their everyday lives. This tool is a validated screening tool commonly used by health professionals, specifically physical therapists assessing a young athlete's ability to return to sports. The FMS consists of seven different movement patterns: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. Each individual test was scored on a scale of 0-3, with two scores given when the movement pattern could be done bilaterally (i.e. in-line lunge with left leg, and in-line lunge with right leg). If any pain occurred during the execution of the movement, the subject received a score of 0. A score of 1 was given when the subject was not able to perform the movement, 2 when the movement was completed but the subject compensated in some way, and a 3 when the movement was completed correctly. Each subject received a total score out of a possible 21 points, with no minimum score required to continue the exercise intervention.

The final group of baseline tests included five functional fitness tests: chair sit-and-reach, back scratch, hand-grip dynamometry, floor transfer time, and timed-up-and-go. These are commonly used fitness tests designed specifically for an older adult population.

Chair sit-and-reach was used as lower leg and lower back flexibility measurement. The subjects were instructed to sit on the edge of the chair with one leg straightened in front of them (scoring leg) and the opposite leg planted comfortably on the floor at a 90-degree angle. Both hands were placed on top of one another while they reached as far forward as possible while keeping their hands together and their scoring leg straight. A total of three trials were completed using the same leg every time for consistency purposes. All measurements were taken in centimeters (cm). Fingers touching the big toe measured 0 cm, fingers over the big toe received a positive score (e.g., +6 cm), and fingers that did not reach the toe received a negative score (e.g., -6 cm)

Similar to the chair sit-and-reach, the back scratch was a flexibility measuring tool focusing on the participant's upper body flexibility. The test was performed in a standing position and required each person to extend their preferred arm and hand overhead while reaching the other hand and arm down and around the bottom of the back, trying to get their fingers to touch along their spine. A total of three trials were used with the same arm reaching overhead each time. Measurements were taken in centimeters, with fingers not touching receiving a negative score and an overlap of fingers receiving a positive score.

A dynamometer was used to measure each subject's hand grip strength. Grip strength is a valid predictor of mortality, disability, and health complications as there is correlation between hand grip strength and overall body strength (Bohannon 2008). The participants were asked to hold the dynamometer in their dominant hand while their elbow was held tightly to their hip, forming a 90-degree angle. When ready, the subject squeezed the dynamometer with maximum force and then relaxed. A total of three trials were complete with the maximum number recorded in kilograms.

Floor transfer time was used as a screening tool to assess each person's fall risk. Subjects were required to go from a standing position, down to a seated position on the floor, and then back to a standing position as quickly as possible. All trials were completed on a padded mat for safety precautions and a stable chair was kept nearby if additional support and assistance was needed. A total of three trials were completed and the best time was recorded. Timing began as soon as the subject initiated movement and stopped once they were completely standing again.

The timed-up-and-go (TUG) was the final functional fitness test completed by each participant. TUG is an important tool used to measure mobility, balance, agility and coordination. Each subject started seated in a chair with his or her back against the back of the chair. When ready, the subjects were instructed to get up from the chair and walk as quickly as possible around the cone placed in front of them before sitting in the chair again. The cone was placed exactly 10 feet in front of the chair. A total of three trials were completed with the fastest trial recorded. Timing began as soon as the subject initiated the movement to get up and out of the chair and ended as soon as they were fully seated in the chair.

EXERCISE INTERVENTION

Acclimation Phase

Once all 48 participants had completed each pre-test, the exercise intervention began with an acclimation phase. The acclimation phase had three main purposes:

1. To get the participants familiar with an increase in both physical activity quantity and intensity
2. To get them accustomed to the exercises, equipment, and overall exercise intervention format including their work to rest ratio, recording their heart rates and recording their RPEs
3. To ensure the safety of all participants

The acclimation phase was imperative to the success of the overall exercise intervention as many of the participants were transitioning from an entirely sedentary lifestyle to a high-intensity exercise program. The participants met three times a week – Monday, Wednesday, and

Friday – for the duration of the two-week acclimation phase before transitioning into the six-week exercise intervention.

To begin each session, each participant secured a Polar HR monitor around their chest corresponding with a watch on their wrist so that their HR's could be assessed and recorded throughout the exercise session. The research members took blood glucose readings from all participants with diabetes prior to starting any exercise. Blood pressure readings were also taken on all participants with hypertension. Readings were taken again after the completion of the session to ensure safe levels prior to leaving.

All three groups went through the same warm-up lasting approximately 5-10 minutes. The warm-up consisted of low-intensity movements including arm circles, neck rolls, marching in place, and modified jumping jacks. The purpose of the warm-up was to get the necessary joints and muscles warm as well as increasing heart rate and overall blood flow. Once all of the necessary warm-up exercises were completed, the participants branched off into their respective groups. Each group had a set of research team members in charge of leading the workout to ensure that things ran smoothly and to record the necessary data throughout the session.

The MICE group was representative of the ACSM's current physical activity recommendations, which included 150 minutes of moderate intensity exercise per week. Each participant in the MICE group chose between cycling, walking on the track, or walking on a treadmill continuously for 50 minutes. For the first week of acclimation, their target was 30-40% of their heart rate reserve (HRR) before increasing to 40-50% HRR the second week. All values were calculated by the research team prior to the session and a specific HR range was given to each participant. Every five minutes, a research member would record each participant's HR based on the reading from their HR monitor and watch. Additionally, they would record their rate of perceived of exertion (RPE) which is a scale ranging from 6-20 where 6 represents "no exertion at all" and 20 represents "maximal exertion." RPE is widely used in exercise settings as "a high correlation exists between a person's perceived exertion rating times 10 and the actual heart rate during physical activity; so a person's exertion rating may provide a fairly good estimate of the actual heart rate during activity" (Borg, 1998).

The HIIT group used an Airdyne bike for the duration of their exercise intervention. An Airdyne bike is a stationary bike that involves both cycling and arm ergometry matching the cycling of the legs, creating more of a total-body workout. Each participant completed 8 rounds of 20 seconds of cycling followed by 120 seconds of rest between exercise bouts. Much like the MICE group, the first week's intensity was 30-40% HRR while the second week was 40-50% HRR.

The HIRT group performed a circuit resistance training program consisting of nine exercises, targeting total body muscle groups and cardiorespiratory exercise. Exercises were performed for 30 seconds followed by a 45-second rest. Once all nine exercises were complete, the participants had a two-minute break before performing the circuit all the way through for a second time. Similar to the other groups, 30-40% HRR was the target HRR for the first week before increasing to 40-50% HRR for the second week. At the end of each respective session, each group performed the same 5-10-minute cool down consisting of static stretches such as a seated hamstring stretch, calf stretch, and head tilts.

Exercise Intervention

The six-week exercise intervention was set up almost identical to the acclimation phase with the exception of intensity levels. Participants exercised every Monday, Wednesday, and

Friday, put on their HR monitors and watches, and completed the 5-10-minute warm-up before splitting off into their respective groups.

Just like in the acclimation phase, the MICE group had the choice to either walk on the treadmill, walk on the track, or bike on a stationary bike for 50 minutes. For the duration of the six-week exercise intervention, their goal increased to 50-60% of their HRR or 64-76% HRmax, as this correlates with moderate intensity levels. HR and RPE were taken by the research team members every five minutes to ensure the participants were staying within their target ranges.

The HIIT group remained on the Airdyne bike for the duration of the six-week exercise intervention as well. However, their intensity increased from 40-50% HRR to voluntary-maximum effort (90-100% HRmax). Participants were instructed to go as hard as possible for the 20-second sprint, aiming for either ≥ 90% HRR or ≥ 96% HRmax. Participants recorded their own HR and RPE after each 20-second interval and were supervised by the research team.

Similarly, the HIRT group greatly increased their overall intensity to either ≥ 90% HRR or ≥ 96% HRmax during their 30-second bouts of total body resistance exercises. They followed the same 30 seconds on and 45 seconds off work-to-rest ratio for a total of nine exercises. After the nine exercises were complete, the participants rested for two-minutes before completing the circuit again. Each session the research members chose from a variety of resistance exercises including: 2-foot jumps, medicine ball slams, lunges, plank, deadlift, push-ups, overhead pull-down with a resistance band, bird-dogs, sumo squat high pulls with a kettlebell, mountain climbers, kettlebell swings, and bridges. Choosing only nine exercises from the above options allowed for a variation in the workout, keeping the participants more engaged. After the 30-second bout of exercise, each participant recorded their HR and RPE.

Upon the completion of the six-week exercise intervention, the participants completed all of the pre-tests again to determine if any changes had been made over the duration of the research study and to make comparisons between groups.

RESULTS

Thirty-one percent of participants were classified as high risk and 48% moderate risk for coronary artery disease according to the American College of Sports Medicine Guidelines for Exercise Testing and Prescription (2014). Of the participants who completed the intervention, session adherence was 98% (847 of 864 sessions).

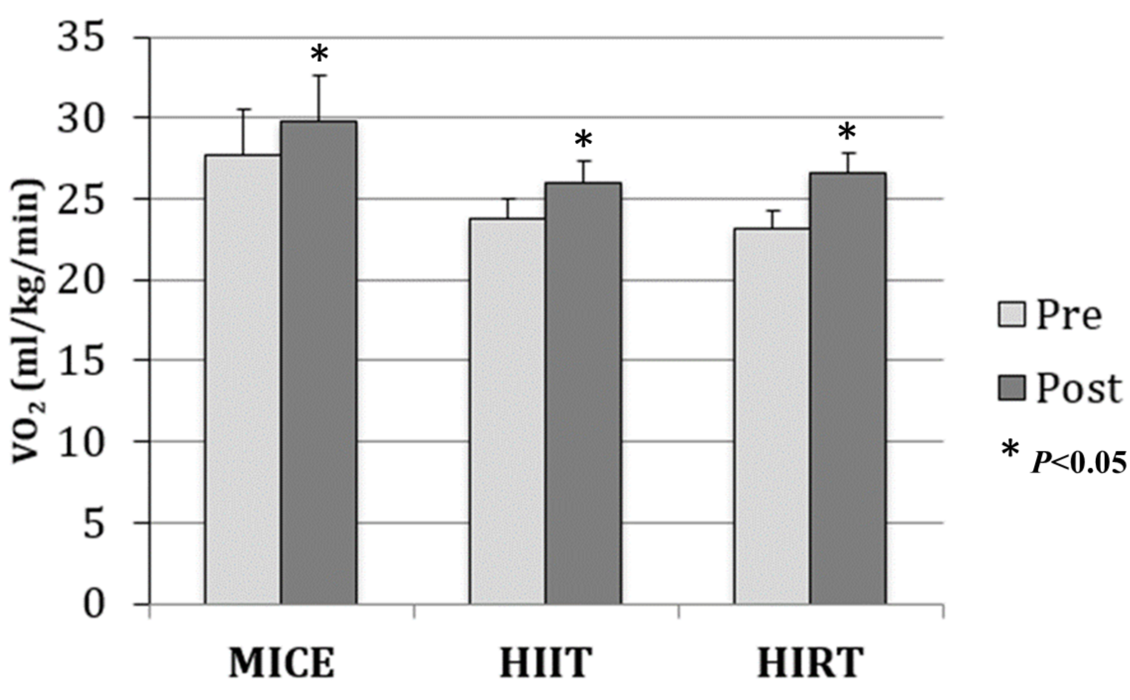
Table 2 displays the baseline descriptive measures for the three groups. At baseline, there were no significant differences between groups in any of the measures. Following 6 weeks of exercise training, there were small but significant effects of time in both body fat percentage (38.6% vs 38.0%, $P<0.05$) and lean muscle mass (47.3kg vs. 48.1kg, $P<0.01$) across the sample but no differences between groups. There was no significant change in handgrip strength or hamstring/low-back flexibility (sit and reach).

Table 2: Baseline descriptive measures between three exercise groups.

	MICE (N=11)	**HIIT (N=17)**	**HIRT (N=20)**	**Total (N=48)**
Male/Female	3/8	7/10	8/12	18/30
Age (years)	66.8±3.4	71.7±6.3	68.1±5.5	69.1±5.6
Weight (kg)	79.9±17.2	80.5 ± 11.3	77.9±14.9	80.7±15.5
BMI (kg/m^2)	28.3±5.8	28.9 ± 3.7	27.3±4.7	28.0±5.5
Body Fat (%)	38.2±9.3	38.1±9.7	37.8±9.5	38.47±9.4
Lean Mass (Kg)	47.2±2.4	48.6±2.6	46.1±2.3	47.2±9.7

All exercise groups had similar maximal aerobic fitness (VO_2max) at baseline and significantly increased at post-test (MICE: 2.1±0.5; HIIT = 2.2±0.3; and HIRT = 3.5±0.7ml/kg/min) as seen in Figure 1.

Figure 1: VO_2max at baseline and post-intervention



Improvements in several functional fitness assessments were observed and are displayed in Table 3. Both high-intensity groups saw improvements in floor transfer time (HIIT = -0.6 ±0.18; HIRT = -1.01±0.23 seconds). Participants in the HIRT group improved in TUG (-0.57±0.26 seconds) and in both balance measures: sway velocity ($P<0.05$) and sway area ($P<0.01$) whereas the MICE and HIIT groups had no change. There were no improvements in functional measures in the MICE group. Post-intervention results of the seven individual FMS assessments and total score are displayed in Figure 2. MICE improved on only one parameter (Hurdle Step); HIIT improved in two parameters (Inline Lunge and Shoulder Mobility), and HIRT improved in 4 parameters (Deep Squat, Shoulder Mobility, Active Straight Leg Raise, and Rotary Stability). Both the HIIT and HIRT groups experienced improvements in total FMS score ($P<0.01$ for both).

Table 3: Functional fitness assessment at baseline and post-intervention (n=48).

Functional Test	**Group**	**Baseline**	**Post**	***P***
Floor Transfer Time (sec)	MICE	4.5±0.4	4.0±0.3	0.1
	HIIT	5.2±0.5	4.6±0.4	<0.01
	HIRT	5.7±0.5	4.8±0.4	<0.01
Timed Up-and-Go (sec)	MICE	6.0±0.4	5.7±0.4	0.32
	HIIT	5.6±0.2	5.3±0.2	0.16
	HIRT	6.2±0.3	5.6±0.2	<0.01
Back Scratch (cm)	MICE	-10.3±3.9	-9.8±3.5	0.37
	HIIT	-7.62±2.2	-7.1±2.6	0.36
	HIRT	-8.9±2.6	-7.0±2.5	0.03
Balance				
Sway Velocity (cm/sec)	MICE	7.3±0.9	7.4±1.6	0.400
	HIIT	5.8±0.5	5.2±0.6	0.22
	HIRT	7.7±0.7	6.4±0.5	0.02
Sway Area (cm^2)	MICE	10.0±1.6	11.1±2.6	0.29
	HIIT	9.9±1.8	8.1±1.0	0.20
	HIRT	13.0±1.6	9.6±1.2	0.03

Figure 2: Baseline and post intervention scores for 7 item and total FMS

The participants' subjective measure of satisfaction with physical function improved significantly in all three groups (MICE = 167%; HIIT=266%; HIRT=389%; all P<0.01) with the subjective mobility assessment improving only in the HIRT group (2%, P=0.02). Post-intervention assessment of physical activity enjoyment showed reports of overall high-level of enjoyment in all three groups (MICE=6.3/7, HIIT=5.8/7, HIRT=5.8/7), with no statistical differences between the three exercise interventions.

DISCUSSION

The main finding of this research study is the fact that both HIIT and HIRT are safe exercise modalities for older adults living with chronic disease. Throughout the duration of the study no adverse health effects occurred in any of the subjects. Many participants showed significant unmeasured but subject-reported health benefits including better sleep quality, increased mood, and decreased dependency on prescription medications such as insulin, cholesterol medication, and hypertension medication. Since these aspects were not measured in this study, further research needs to be done regarding how HIIT and HIRT affect one's sleep quality, mood – specifically in terms of depression and anxiety – and other physiological changes (blood pressure, cholesterol, and insulin production) that result in a decrease in medication changes.

Improvements shown in the participant's VO_2 max, floor transfer time, and FMS exercises indicate that both HITT and HIRT are great ways to increase aerobic and functional fitness. As previously discussed, this leads to a significant improvement in one's QOL and ability to perform their ADL's, securing their independence and decreasing the chance emotional and/or psychological stress.

Time, which is the most commonly self-reported exercise barrier, can be considered more of an excuse rather than an actual barrier. The results of this study prove that everyone has time to meet the ACSM exercise recommendations as long as they take the initiative to make exercise and their health a priority. While the recommended 150 mins/week may not be attainable for everyone, we have found that shorter, high-intensity exercise regimes not only take half of the time as moderate-intensity exercise programs, but also produce better results. The average HIIT and HIRT sessions took anywhere between 20 and 25 minutes (excluding warm-up and cool-down) in comparison to the 50-minute exercise sessions done by the MICE group. By proving that these exercise interventions are both timely and effective, adults of all ages can implement these short-duration, high-intensity workouts into their schedules, no matter how busy they may be.

Since almost all chronic diseases are preventable through diet and exercise, the amounts of chronic diseases seen in the United States would drastically decrease through the implementation of HITT and HIRT exercise interventions. However, implementing these programs is easier said than done. Since many participants reported a decrease in their dependency of prescribed medications, it is our hope that our findings, along with other similar studies, can be the beginning of doctor's prescribing exercise instead of medication. The decreased dependency of medications would drastically cut overall spending on health care for older adults since Qato et al. (2008) reported that 81% of people (age 57-85) use at least one prescription medication and that 29% of people used at least five prescription medications with the largest population being between the ages of 75 and 85. Even a slight decrease in medication usage would drastically decrease the overall health care expenditures for older adults. The increased QOL and ability to perform ADL's previously mentioned would cut health care costs as well. Less reliance on both family members and health care professionals cuts costs for home-health care or nursing home expenses.

CONCLUSION

- Both HITT and HIRT are safe for older adults living with chronic disease, as no adverse side effects occurred throughout the eight weeks of exercise.
- Both the HIIT and HIRT groups experienced improvements in total FMS score (P<0.01 for both), showing that they are beneficial for improving overall functional fitness, which in turn improves a person's ability to get through ADL's and their overall QOL.

- Group settings for exercise interventions result in a large adherence rate (98%) as the social aspect of the intervention played a key role in overall adherence and positive outlook among participants.
- HIIT and HIRT are time-effective, as each session took ~20-25 minutes opposed to 50 minutes for the MICE group. The timeliness aspect of the study can break the commonly reported time barrier.

PERSONAL APPLICATION

As a National Academy of Sports Medicine Certified Group Fitness Instructor, I am motivated to help other improve their physical conditions through exercise. The results of this research study show that it is never too late to improve physical health. I teach both HIIT and HIRT style classes at Half Acre Gymnasium on the University of Wyoming campus and have been able to apply this knowledge as an instructor since I get a wide array of students in my classroom. While the safety of my college-aged students has never been an issue, periodically I get older faculty or staff members in my classes. To know nothing about their health history or current exercise regimen has been of concern to me as I was unsure if HITT and HIRT would be safe for them. With this evidence-based research, I know that it is not only safe for them to do, but also incredibly beneficial.

It is my future goal to pursue a Masters in Exercise Physiology with an emphasis in cardiac rehabilitation. Ideally, this would allow me to work with older adults and formulate a proper exercise prescription for them. The knowledge that I have gained from this study gives me experience of incorporating HIIT or HIRT into exercise programs. Exercise regimes can improve lifestyle, overall health, and QOL and an exponentially decreased risk of a second heart attack.

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