Optimal training frequency in bodyweight and resistance high-intensity interval training for healthy adults

by

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Thesis of 30 ECTS credits submitted to the School of Science and Engineering at Reykjavík University in partial fulfillment of the requirements for the degree of

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Ágrip

Ákjósanleg æfingatíðni há-ákefðarþjálfunar fyrir heilbrigða fullorðna einstaklinga

Inngangur: Það er vísindalega sannað að hreyfing er áhrifarík leið til að bæta líkamlega og andlega heilsu. Hins vegar er sífellt á reiki hver sé ákjósanlegasta tegund, magn og ákefð hreyfingar til að hljóta sem mestan heilsufarsávinning. Þessi rannsókn mat bætingu á líkamssamsetningu (líkamsþyngd, fituprósentu og ummáli), líkamlegu atgervi (þoli, styrk, vöðvaúthaldi og liðleika) og andlegri heilsu (þunglyndi, kvíða og streitu) hjá heilbrigðum fullorðnum einstaklingum í kjölfar 12 vikna há-ákefðarþjálfunar með eigin líkamsþyngd og lóðum (HIIT) og bar saman hópa sem æfðu þrisvar, fjórum eða fimm sinnum í viku.

Aðferð: Þátttakendum var raðað af handahófi í einn af þremur hópum sem stunduðu há-ákefðarþjálfun, annaðhvort þrisvar (n = 17), fjórum (n = 22) eða fimm (n = 15) sinnum í viku í 12 vikur. Þátttakendur voru mældir í upphafi og í lok rannsóknar. Líkamssamsetning var mæld með þyngd, fituprósentu og ummáli mittis, mjaðma og læra. Líkamlegt atgervi var mælt með 500 m róðri, 5RM hnébeygju, hámarksfjölda armbeygja, upphífa og uppseta á einni mínútu og hámarkstíma í hringjastöðu. Liðleiki var mældur með „active lying straight-leg raise“ prófi og loks var andleg heilsa metin með DASS spurningalista til að meta þunglyndi, kvíða og streitu.

Niðurstöður: Eftir 12 vikna há-ákefðarþjálfun kom fram marktæk lækkun á fituprósentu og ummáli mittis og mjaðma ($p<0,05$) í öllum hópum. Einnig var marktækur munur á þoli, styrk, vöðvaúthaldi og liðleika ($p<0,05$), en hópurinn sem æfði fjórum sinnum í viku sýndi einnig lækkun á líkamsþyngd. Ekki var marktækur munur á andlegri heilsu í neinum hóp. Niðurstöðurnar sýndu engan marktækan mun á milli hópa og benda niðurstöður til þess að þegar kemur að há-ákefðarþjálfun með eigin líkamsþyngd og lóð (HIIT) veita fjórar eða fimm æfingar á viku ekki marktækt meiri bætingu og framfarir en þrjár æfingar á viku.

Ályktun: Niðurstöður sýna að há-ákefðarþjálfunin sem var metin í rannsókninni bætir árangur í öllum þáttum líkamlegs atgervis og líkamssamsetningu nema ummáls læra og líkamsþyngd óháð fjölda æfinga á viku, þrisvar, fjórum eða fimm sinnum.

Leitarorð: Há-ákefðarþjálfun, þjálfunartíðni, líkamssamsetning, líkamlegt atgervi, andleg heilsa.

Abstract

Optimal training frequency in bodyweight and resistance high-intensity interval training for healthy adults

Introduction: It is scientifically proven that exercise is an effective way to improve physical and mental health. However, the precise type, volume and intensity needed to accrue these health benefits is a controversial topic. The purposes of the current study were (i) to know and analyse the effects of a high-intensity interval training program on body composition, physical fitness and mental health in healthy adults and (ii) to know and analyse the effects of the number of sessions in a high intensity interval training program on, body composition, physical fitness and mental health in healthy adults.

Method: Subjects were randomly assigned to one of three groups that engaged in bodyweight and resistance HIIT, either three (n=17), four (n=22) or five (n=15) times a week for 12 weeks. Subjects were measured at baseline and after 12 weeks. Their body composition was measured by bodyweight, body fat and waist, hip and thigh circumference measurements. Physical fitness was measured with a 500m row, 5RM squat, maximum push ups, pull ups and sit ups in 60 seconds and maximum time in ring hold. Flexibility was measured with an active lying straight-leg raise test and finally mental health was evaluated with the DASS (depression, anxiety and stress scale) questionnaire.

Results: Following HIIT, body fat, waist and hip circumference decreased ($p<0.05$) and anaerobic endurance, muscle strength, muscle endurance and flexibility was improved ($p<0.05$) in all groups, whereas the 4x/week group also showed decrease in bodyweight ($p<0.05$). No significant changes were observed for mental health in any of the groups. The results did not show any difference between groups. Results indicate that when it comes to bodyweight and resistance HIIT, four or five sessions a week do not provide additional benefits when compared with three times a week.

Conclusion: Results demonstrated that bodyweight and resistance HIIT improves performance in all aspects of physical fitness and body composition except the reduction of thigh circumference and weight loss regardless of how often practiced, three, four or five sessions a week.

Keywords: Bodyweight and resistance high-intensity interval training, high-intensity interval training, training frequency, body composition, physical fitness.

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Table of Contents

List of Tables

List of tables in the Review of the literature

List of Tables in Manuscript

List of Figures in Manuscript

List of abbrevations

ACSM	American College of Sports Medicine
ANOVA	Analysis of variance
AT	Aerobic training
BMI	Body mass index
CME	Continuous moderate exercise
DASS	Depression, Anxiety and Stress Scales
LT	Lactate threshold
MET	Metabolic equivalent of tasks
HDL-C	High-density lipoprotein cholesterol
HIIE	High intensity intermittent exercise
HIIT	High intensity interval training
HR	Heart rate
HRR	Heart rate reserve
KEA	Knee extension angle test
PCr	Phosphatecreatine
RM	Repetition maximum
ROM	Range of motion
SA	Sacral angle test
SD	Standard deviation
SLR	Straight leg raise test
SR	Sit and reach test
ST	Strength training
TG	Triglycerides
$\mathbf{V0_2}$	Oxygen consumption
$\mathbf{V0_2\ R}$	Oxygen uptake reserve
$\mathbf{VO_{2max}}$	Maximal oxygen uptake

VO_{2peak}	Peak maximal oxygen uptake
W	Mean power
Wpeak	Peak power
WHO	World Health Organization
%BF	Percentage of body fat

1 Review of the literature

1.1 Physical activity and exercise

Physical activity and exercise are often used interchangeably, but these terms are not synonymous. *Physical activity* is any body movement produced by the skeletal muscles that results in a substantial increase over the resting energy expenditure (Bouchard & Shepard, 1993). Physical activity includes both “unplanned” activities such as gardening, playing with your children or climbing stairs, and “planned” activities such as participation in a fitness program or going for a run. Physical activity is most often estimated based on self-report and quantified in minutes per day or as energy expenditure in kilocalories per day or per week (Seiler, 2000). *Exercise* is a type of physical activity consisting of planned, structured and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness (Caspersen, Powell, & Christenson, 1985). *Health-related fitness* refers to the state of physical and physiological characteristics that define the risk levels for the premature development of diseases or morbid conditions presenting a relationship with a sedentary mode of life (Bouchard & Shepard, 1993).

Exercise is a clinically proven, cost-effective, primary intervention that delays and in many cases prevents the health burdens associated with many chronic diseases. However, the precise type and quantity of exercise needed to accrue health benefits is a contentious issue with no clear consensus recommendations for the prevention of inactivity-related disorders and chronic diseases (Gibala, Little, MacDonald, & Hawley, 2012).

1.1.1 Public health recommendations

Current public health recommendations for physical activity for adults aged 18–64 are 30 minutes of moderate-intensity activity each day or at least 150 minutes per week or 75 minutes a week of vigorous-intensity aerobic physical activity (Embætti Landlæknis, 2008; World Health Organization, 2011). An equivalent combination of moderate- and vigorous-intensity aerobic activity can be performed which provides substantial benefits across a broad range of health outcomes for sedentary adults (U.S. Department of Health and Human Services, 2008). Also advisable is a minimum of two to three times per week doing activities that strengthen the musculoskeletal system (World Health Organization, 2011). Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week (U.S. Department of Health and Human Services, 2008). This quantity of exercise may not be enough to prevent unhealthful weight gain for some individuals. These individuals may need additional exercise or restriction of calories to minimize the risk of further weight gain. Those who get 30 min of moderate-intensity exercise per day are likely to achieve additional health benefits if they exercise more (Blair, LaMonte, & Nichaman, 2004). For additional health benefits the World Health Organization (WHO) suggests that adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity (World Health Organization, 2011).

In addition to aerobic exercise, WHO recommends that people should engage in strength training (ST) and flexibility exercises at least twice a week, which will promote the maintenance of lean body mass, improvements in muscular strength and endurance, and preservation of function, all of which enable long-term participation in regular physical activity and promote quality of life (Blair, Kohl, Gordon, & Paffenbarger, 1992). Optimal strength training frequency, the number of workouts per week, depends on several factors such as intensity, volume, type of exercise, level of conditioning, ability to recover and the number of muscle groups trained each workout session. Studies have used frequencies of two to three alternating days per week in previously untrained individuals. American College of Sports Medicine (ACSM) recommendations for ST frequency is two to three days a week for novice training, 3 to 4 days a week for intermediate training, and 4 to 5 days a week for advanced training (American College of Sports Medicine, 2009). One Meta-analysis study demonstrates that strength gains in untrained individuals were highest with a frequency of 3 days a week (Rhea, Alvar, Burkett, & Ball, 2003).

Elements such as speed and agility, balance, coordination, jumping ability, flexibility, and other measures of motor performance may be enhanced by ST. A fitness program which includes ST improves cardiovascular function, prevents osteoporosis, promotes weight loss and maintenance, improves dynamic stability and preserves functional capacity and fosters psychological well-being. Progression in power training entails two general loading strategies: (i) strength training and (ii) use of light loads performed at a fast contraction velocity with 3-5 min of rest between sets for multiple sets per exercise. It is also recommended that emphasis be placed on multiple-joint exercises, especially those involving the total body. For local muscular endurance training, it is recommended that light to moderate loads, 40-60% of one repetition maximum (RM), be performed for high repetitions (>15) using short rest periods (<90 s) (American College of Sports Medicine, 2009). Because the human body adapts quickly to a ST program, systematically increasing the demands placed upon the body is necessary in order for continual progression to occur. Variation may take place in many forms and manifests by manipulation of any one or a combination of the acute program variables. It may be accomplished through increasing exercise intensity or the total repetitions performed at the current intensity. Also repetition speed/tempo with submaximal loads may be altered according to goals and rest periods may be shortened for endurance improvements or lengthened for strength and power training and finally the training volume may be gradually increased. The two most commonly studied variables have been volume and intensity (American College of Sports Medicine, 2009).

1.1.2 New approaches

As most adults do not meet current recommendations of physical activity there is a critical need for innovative approaches to increase physical activity among the public (Thompson, 2009). Researchers discuss that elite endurance athletes have long appreciated the role of high-intensity intermittent exercise (HIIE) and high-intensity interval training (HIIT) as part of a comprehensive training program and that recent evidence suggests that, in young healthy persons of average fitness, intense interval exercise is a time-efficient strategy to stimulate a number of skeletal muscle adaptations that are comparable to traditional endurance training. Gibala and McGee (2008) discuss that "fundamental questions remain regarding the minimum volume of exercise necessary to improve physiological well-being in various populations, the effectiveness of alternative, less extreme, interval-training strategies, and the precise nature and magnitude of adaptations that can be elicited and maintained over the long-term. A comprehensive evaluation of the physiological adaptations induced by different interval-training strategies in a wide range of populations will permit evidence-based recommendations that may provide an alternative to current exercise prescriptions for time-pressed individuals" (p.62).

1.2 High intensity interval training

1.2.1 Definition

There seems to be no universal definition of *high intensity interval training (HIIT/HIT)* also called *high intensity intermittent exercise (HIIE)* but it is generally referred to as repeated sessions of relatively brief intermittent exercise, often performed with an "all-out" effort or at an intensity close to that which elicits VO_{2peak} (i.e., ≥90% of VO_{2peak}). Depending on the training intensity, a single effort may last from a few seconds to up to several minutes, with multiple efforts separated by up to a few minutes of rest or low-intensity exercise (Gibala & McGee, 2008). Also HIIT is defined as vigorous exercise performed at a high intensity for a brief period of time interposed with recovery intervals at low-to-moderate intensity or complete rest (Kessler, Sisson, & Short, 2012). In contrast to strength training (ST) in which brief intense efforts are usually performed against a heavy resistance to increase skeletal muscle mass, HIIT is normally associated with activities such as cycling or running and does not induce marked fiber hypertrophy (Gibala & McGee, 2008). Athletes and coaches have historically used HIIT to improve exercise performance, but the effectiveness of HIIT to improve health-related outcomes in non-athletes has recently generated new interest (Kessler et al., 2012). A growing body of evidence demonstrates that HIIT can serve as an effective alternative to traditional endurance-based training, inducing similar or even superior physiological adaptations in healthy individuals and diseased populations, at least when compared on a matched-work basis (Gibala et al., 2012).

In recent years new types of HIIT programs, characterized by high-volume aggressive training workouts that use a variety of high-intensity exercises and often timed maximal number of repetitions with short rest periods between sets have emerged (Bergeron et al., 2011; Hak, Hodzovic, & Hickey, 2013; Smith, Sommer, Starkoff, & Devor, 2013). The popularity of these programs is steadily increasing and they continue to generate growing interest and enthusiastic support among military and many civilian communities. However, some physicians and other primary care and rehabilitation providers are concerned about the risk of overuse injury related to these types of HIIT (Bergeron et al., 2011). Muscle strains, torn ligaments, stress fractures are reportedly occurring at increasing rates as the popularity of these HIIT programs (Bellovary, 2014; Bergeron et al., 2011). Disproportionate musculoskeletal injury risk, particularly for novice participants is also associated with these types of HIIT but the risk may be minimal, if a participant understands their body's limitations in regard to the intensity of HIIT (Bellovary, 2014). A group of researchers (Hak et al., 2013) report that injury rates with this type of HIIT training are similar to that reported for sports such as Olympic weight-lifting, power-lifting and gymnastics and that the rates are even lower than competitive contact sports such as rugby union and rugby league.

Despite the warnings by some health and fitness professionals of potentially increased injury rates using HIIT, this form of exercise has become popular in gyms all over the world and was number one in the worldwide survey of fitness trends for 2014 and in second place for 2015 (Thompson, 2014). Modern fitness programming has adopted the term HIIT as a way to describe this approach to fitness and performance and two categories have emerged.

One category is referred to as *aerobic HIIT* and the other is *bodyweight HIIT* or *resistance HIIT*. Both involve periods of intense effort followed by recovery segments, with the primary difference being the modality of the exercise. Aerobic HIIT training is interval training that uses traditional aerobic exercise modalities, mostly running or cycling, to deliver the desired intensities, for example spinning classes and track based running workouts. In contrast resistance or body weight HIIT training is interval training that uses bodily movements, weighted objects, bars or devices for high-repetition resistance activities. This kind of training makes use of calisthenics, plyometrics and loaded lifts in training programs like Tabata, CrossFit, boot camp training or other similar programs (Kilpatrick, Jung, & Little, 2014). Both types of HIIT programs are used widely and a study indicated the effectiveness of body weight type HIIT programming (McRae, Payne, Zelt, Scribans, et al., 2012). However, most research has focused on HIIT that primarily is aerobic because cycling and treadmill running enable more accurate assessment of work to describe the training stimulus. Modern interval training has linkage to military preparedness and athletic competition, but the recent resurgence of interest in interval training can be attributed to potential health related benefits of HIIT (Kilpatrick et al., 2014).

1.2.2 Intensity

In addition to defining physical activity, exercise and physical fitness as done above, it is important to clearly define the wide range of intensities associated with physical activity. Intensity refers to the amount of work required to achieve the activity (Pescatello, 2014). Table 1 shows the intensity ranges from very light to maximal.

Table 1 - Classification of physical activity intensity

	Relative intensity		Absolute intensity ranges (METs) across fitness levels		
Intensity	$V0_2R$(%)	Maximal HR%	12 METs VO_{2max}	10 METs VO_{2max}	8 METs VO_{2max}
Very light	<20	<50	<3.2	<2.8	<2.4
Light	20≤40	50≤64	3.2≤5.4	2.8≤4.6	2.4≤3.8
Moderate	40≤60	64≤77	5.4≤7.6	4.6≤6.4	3.8≤5.2
Vigorous*	60<85	77≤94	7.6≤10.3	6.4≤8.7	5.2≤7.0
Vigorous**	85≤100	94≤100	10.3<12	8.7≤10	7.0≤8
Maximal	100	100	12	10	8

* Hard; ** very hard; HR, heart rate;

Methods for quantifying the relative intensity of physical activity include specifying a percentage of oxygen uptake reserve (VO_2 R), heart rate reserve (HRR), oxygen consumption (VO_2), heart rate (HR), or metabolic equivalents (MET) (1 MET = 3.5 mL $\cdot$ kg^{-1} $\cdot$ min^{-1}). Each of these methods for describing the intensity of physical activity has strengths and limitations (Pescatello, 2014). Physical fitness is most often measured in terms of maximal aerobic capacity (VO_{2max} in ml/min/kg) or the maximum volume of oxygen consumed per minute (VO_2 L/min) (Seiler, 2000). The VO_{2max} is one of the primary determinants of aerobic endurance performance. HIIT can encompass a considerable range of exercise intensities, for example in a meta-analysis of ten studies HIIT was typically performed at 85–95% maximal heart rate (%HR max) (Weston, Wisløff, & Coombes, 2014). Recently HIIT was defined as "either repeated short (<45 seconds) to long (2–4 minutes) bouts of rather high but not maximal-intensity exercise or short (<10 seconds, repeated-sprint sequences) or long (<20–30 seconds, sprint interval session) all-out sprints, interspersed with recovery periods" (Buchheit & Laursen, 2013). As such, maximal, all-out sprint training is classified as a form of HIIT at the highest end of the intensity spectrum (Gibala et al., 2012; Sloth, Sloth, Overgaard, & Dalgas, 2013). This shows that HIIT training is usually performed at vigorous to maximal intensity.

According to Ekkekakis and Petruzzello (2012), "increased intensity appears to be associated with reduced positivity of affect during and immediately following an exercise bout. Intensity effects appear to be attenuated during recovery. Fitness and training status appear to become significant mediators of the exercise-affect relationship only at high intensities. With intensity being kept constant, different exercise bout durations have not been shown to have a differential impact on pre- to post-exercise affective changes" (p.338). In a study of the impact of rest duration on work intensity during interval training, researchers found out that under self-paced conditions, varying rest duration in a range of 1 to 4 minutes had limited impact on performance during repeated 4 minute HIIT bouts. Approximately 120 seconds of active recovery may provide an appropriate balance between intracellular restitution and maintenance of high VO_2 on kinetics (Seiler & Hetlelid, 2005).

1.2.3 Volume

Training volume refers to the number of exercises, sets and repetitions and number of muscles worked during a single session. Frequency refers to how many training sessions are performed per week. The literature on physical activity and exercise shows us that any amount of exercise is better than none. Exercise, like medicine, is known to reduce risks for many diseases and premature death but unlike medicine exercise does not come with dosing instructions. As previously mentioned the current broad guidelines from governmental and health organizations recommend 150 minutes of moderate exercise per week to build and maintain health and fitness (World Health Organization, 2011). However it is not certain whether that amount of exercise is ideal or represents the least amount that someone should do. The same goes for an upper limit. The studies disagree on whether there is a safe upper limit on exercise, beyond which its effects become potentially dangerous and whether some intensities of exercise are more effective than others at prolonging lives (Arem et al., 2015).

In a recent study (Arem et al., 2015) at Harvard University information was gathered about the exercise habits of more than 661,000 adults, most of them middle-aged, and the results were compared with 14 years worth of death records for the group. The results show that the people who did not exercise at all were at the highest risk of early death, but those who exercised a little but did not meet the recommendations lowered their risk of premature death by 20%. Those who met the public health recommendations precisely enjoyed greater longevity benefits and 31% less risk of dying during the 14 year period compared with those who never exercised. The most promising alternative for exercise benefits came among those who tripled the recommended level of exercise, working out moderately for 450 minutes per week or a little more than an hour each day. Those people were 39% less likely to die prematurely than people who never exercised. Researchers found that people who exercised even more did not gain significantly more health as the benefits plateaued at that point (Arem et al., 2015). In a recent Australian study (Gebel et al.,2015), researchers closely examined health survey data for 204,542 adults aged 45 through 75 years, determining how much time each person spent exercising and how much of that exercise qualified as vigorous, such as running instead of walking, and compared it with death statistics. The study revealed an inverse dose-response relationship between proportion of vigorous activity and mortality and demonstrated that meeting the exercise guidelines substantially reduced the risk of early death but those who engaged in even occasional vigorous exercise gained a small but not unimportant additional reduction in mortality. People who spent up to 30% of their weekly exercise time in vigorous activities were 9% less likely to die prematurely than those who exercised moderately for the same amount of time. People who spent more than 30% of their exercise time in strenuous activities gained an extra 13% reduction in early mortality, compared with people who did not exercise. The researchers did not note any increase in mortality, even among those few people completing the largest amounts of intense exercise. A potential explanation for the positive effect of engaging in some vigorous activity on longevity might be that high-intensity activities lead to more physiologic adaptations, which improve function and capacity. Their findings suggest that vigorous activities should be endorsed in clinical and public health activity guidelines to maximize the population benefits of physical activity (Gebel et al., 2015). A minimum volume of HIIT may be necessary to increase VO_{2peak} and stimulate other adaptations such as an increased capacity for fat oxidation (Talanian, Galloway, Heigenhauser, Bonen, & Spriet, 2007). Interval training pushes the body hard, so it is important to be fully recovered between sessions and the literatures commonly says three HIIT sessions per week may produce the best results while limiting injury (Daussin et al., 2008; Helgerud et al., 2007; Musa, Adeniran, Dikko, & Sayers, 2009; Perry, Heigenhauser, Bonen, & Spriet, 2008).

1.3 Measurements and studies about high intensity interval training

1.3.1 Body composition

1.3.1.1 Weight

Measurement

Body weight is measured on a scale. It is important to use the same scale throughout a study and weigh the subjects at the same time of day every time for the best results. The key to an accurate measurement is consistency, so subjects are encouraged to wear the same type of clothes and shoes whenever they are weighed in.

Studies about HIIT

The measurement of body weight does not differ in studies on HIIT. Being overweight is known to be bad for your health, yet the prevalence of obesity is increasing worldwide. Forecasts suggest that high rates of obesity will affect future population health and economics (Gortmaker et al., 2011). In addition to the general recommendations, limited evidence indicates that a much higher dose of activity, or 45 to 90 min of moderate exercise each day on 5 days a week, may be needed to prevent overweightness and obesity, to promote weight loss and to avoid weight regain in previously overweight and obese individuals (Thompson, 2009). Most exercise protocols designed to induce fat loss have focused on regular steady state exercise such as walking and jogging at a moderate intensity. Disappointingly, these kinds of protocols have led to negligible weight loss. One of the characteristics of HIIT is that it involves markedly lower training volumes making it a time-efficient strategy to accrue adaptations and possible health benefits compared to traditional aerobic exercise programs (Boutcher, 2011). Commonly, HIIT is of short duration and performed above the lactate threshold (LT), close to VO_{2max} with intermittent periods of rest, thus allowing sedentary overweight individuals sufficient time to recover and perform additional high-intensity bouts.

Nevertheless there is little conclusive evidence for more favourable effects on weight loss with HIIT than with continuous moderate-intensity exercise (De Feo, 2013). In the literature only aerobic exercise has solid evidence supporting its efficacy whereas conflicting data regarding the effects of resistance exercise have been produced (Willis et al., 2012). Studies that carried out relatively brief interventions of two to six weeks only resulted in negligible weight loss, however the subjects in these Wingate test studies were mainly young adults with normal body mass index (BMI) and body mass (Boutcher, 2011). In an eight week protocol, exercising three days a week and comparing the effects of aerobic endurance training at different intensities and with different methods matched for total work and frequency there were no significant group differences on weight loss (Helgerud et al., 2007). Longer studies with individuals possessing moderate elevations in fat mass have resulted in greater weight and fat reduction (Trapp, Chisholm, Freund, & Boutcher, 2008). Research has shown that it is feasible that HIIT will have a greater fat reduction effect on the overweight or obese since the greatest HIIT-induced fat loss was found in studies that used overweight type 2 diabetic adults (BMI>29 kg/m^2) as subjects (Boutcher, 2011).

1.3.1.2 Body fat percentage

Measurement

Measurements to assess body composition continue to be developed and according to a group of scientists (Lee & Gallagher, 2008) the most commonly used direct methods are bioelectrical impedance analysis, dilution techniques, air displacement plethysmography, dual energy X-ray absorptiometry, and MRI or magnetic resonance spectroscopy. Recent developments even include three-dimensional photonic scanning and quantitative magnetic resonance. Together, these techniques allow for the measurement of fat, fat-free mass, bone mineral content, total body water, extracellular water, total adipose tissue and its subdepots (visceral, subcutaneous, and intermuscular), skeletal muscle, select organs, and ectopic fat depots. Another very common indirect measurement is the skin fold measurement (Jackson & Pollock, 1978; Jackson, Pollock, & Ward, 1979).

According to Howley and Thompson (2012), "none of the methods currently used actually measure body fat percentage (%BF). The only way to truly measure the volume of fat in the body would be to dissect and chemically analyse tissues in the body. The techniques routinely used to estimate %BF are based on the relationship between %BF and other factors that can be accurately measured, such as skinfold thicknesses or underwater weight. Because of the predictable relationship between the measured value and body composition, %BF can be estimated through these indirect methods” (p.167). For fitness professionals, simplicity of measurement, comparable accuracy and cost are the most important considerations when choosing a technique to measure body fat. In other situations, for research or clinical applications, the accuracy of the measurement may outweigh other considerations. In fact, “measuring skinfold thickness is one of the most frequently performed tests to estimate %BF. This quick, noninvasive, inexpensive method can provide a good assessment of %BF. Skinfold measurement is based on the assumption that, as a person gains adipose tissue, the increase in skinfold thickness is proportional to the additional fat weight. Skinfold thickness is measured with a skinfold caliper” (Howley & Thompson, 2012, p.168).

In the 1970s, researchers published what have been termed ‘generalized body composition equations’(Jackson & Pollock, 1978; Jackson et al, 1979). The generalized equations used large, variable samples of men and women and modelled the data to account for age and the non-linear relationship between body density and skinfold fat (Jackson, Ellis, McFarlin, Sailors, & Bray, 2009). These equations are commonly used to estimate laboratory-measured %BF. The equations were developed on predominantly white individuals using Siri’s two-component percentage fat equation (%BF-GEN). The Jackson – Pollock (JP) generalized equation validation research has been cited over 1300 times in the scientific literature and the men’s study was reproduced in 2004 as a British Journal of Nutrition citation classic (Trayhurn, 2004). The validity of using skinfold equations to predict body composition is restricted to populations from whom these equations were derived (Lukaski, 1987), white males and females. Because sex influences the areas where fat is stored, separate skinfold equations for men and women have been developed (Howley & Thompson, 2012).

Jackson and Pollock equation for estimating body density from skinfold thickness (Jackson & Pollock, 1978; Jackson et al., 1979):

$$\text{Men: } D_b = 1.10938 - 0.0008267\,(X1) + 0.0000016\,(X1)^2 - 0.0002574\,(X2).$$

X1= sum of chest, abdomen and thigh skinfolds (mm),X2= age (year).

$$\text{Women: } Db = 1.0994921 - 0.0009929\,(X1) + 0.0000023\,(X1)2 - 0.0001392\,(X2)$$

X1= sum of triceps, suprailiac and thigh skinfolds (mm),X2= age (year).

Once the body density is calculated, it must be converted into %BF. To make this conversion, a two-compartment model is used. In a two-compartment model, all body tissues are classified as either fat or fat free. One of the most commonly used equations for this procedure is the Siri equation: %BF = (495 / Db) − 450.

Siri's equations for estimating body density from skinfold thickness (Siri, 1956):

$$Men: BF\% = 495/(1.10938-(0.0008267*s)+(0.0000016*s*s)-(0.0002574*a))-450$$

$$Women: BF\% = 495/(1.089733-(0.0009245*s)+(0.0000025*s*s)-(0.0000979*a))-450$$

s = sum of 3 skinfold mm, a = age

Studies about HIIT

Many HIIT studies have measured the BF% and the most used methods seem to be dual energy X-ray absorptiometry (DEXA) (Heydari, Freund, & Boutcher, 2012; Trapp et al., 2008; Willis et al., 2012) and MRI (Boutcher, 2011) and BF% as measured by skinfolds (Tremblay, Simoneau, & Bouchard, 1994; Vincent et al., 2004). The results of a study cross-validating generalized body composition equations with diverse young men and women showed that the JP generalized equations were highly correlated with dual-energy X-ray absorptiometry (DXA) as the BF% referent criterion (BF%-DXA), but lacked accuracy, with the generalized equations systematically underestimating BF%-DXA. The calibration equations provide a valid and accurate statistical model to estimate the BF%-DXA of white, Hispanic and African–American men and women, aged 17–35 years. Further calibration research is needed with older men and women (Jackson et al., 2009). Studies show that HIIT is indeed a very time-efficient strategy to induce adaptations normally associated with endurance training and also HIIT has shown to increase the capacity for fat oxidation during exercise in women in a short amount of time (Talanian et al., 2007). A 12 week HIIT intervention on overweight young males showed a significant reduction in total, abdominal, trunk, and visceral fat and significant increases in fat free mass, with exercising three times a week using eight seconds cycling sprints and 12 second recovery continuously for 20 minutes. The HIIT workload was set at 80–90% of each subject's heart rate (HR) (Heydari et al., 2012). HIIE three times per week for 15 weeks compared to the same frequency of steady-state exercise was associated with significant reductions in total body fat, subcutaneous leg and trunk fat, and insulin resistance in young women (Trapp et al., 2008).

1.3.1.3 Circumference

Measurement

Body and limb circumferences (girth measurements) are used to either estimate body composition or describe body proportions. Girth measurements provide quick and reliable information and are sometimes used in equations to predict body composition. Circumference may also be used to track changes in body shape and size during weight loss. The utmost disadvantage is that it provides little information about the fat and fat-free components of the body (Howley & Thompson, 2012). Waist circumference can be measured by placing a cloth tape measure around the smallest part of the waist while standing relaxed. It should be at or below 102 cm for men and 89 cm for women. The measurement of waist circumference provides an insight to increased risk of obesity-related illness due to the location of excess fat. Android obesity, classified as excess weight located in the trunk area, places an individual at greater risk for high blood pressure, metabolic syndrome, type 2 diabetes, HDL-C, coronary artery disease and premature death (Pescatello, 2014).

Studies about HIIT

Circumference is regularly used in HIIT studies to evaluate body composition as can be seen in review articles on HIIT (Boutcher, 2011; Kessler et al., 2012; Whyte, Gill, & Cathcart, 2010). One study reports that 34% of adults currently meet the criteria for the metabolic syndrome defined by elevated waist circumference, plasma triglycerides (TG), fasting glucose and/or blood pressure, and decreased high-density lipoprotein cholesterol (HDL-C) (Kessler et al., 2012). While these cardiometabolic risk factors can be treated with medication, lifestyle modification is strongly recommended as a first-line approach (Kessler et al., 2012). A research found that two weeks of very high intensity sprint interval training with six sessions of four to six repeats of 30 seconds Wingate test with four to five minutes improved insulin sensitivity, increased resting fat oxidation, and reduced waist circumference and systolic blood pressure in overweight sedentary men (Whyte et al., 2010). Also a 12 week HIIT intervention demonstrated that the major reduction in visceral fat brought about by HIIT appears to have occurred within the first six weeks as reduction in waist circumference was significantly correlated with reduction in visceral fat at week six after which waist circumference did not further decrease (Heydari et al., 2012).

1.3.2 Physical fitness

1.3.2.1 Anaerobic endurance

Measurement

Efforts at moderate to high power and lasting less than several minutes are anaerobic and efforts at low power and lasting in excess of several minutes are aerobic (Janot, 2004). Cardiorespiratory endurance has long been recognized as one of the fundamental components of physical fitness. Because the anaerobic threshold or lactate threshold (LT) reflects an onset of anaerobic metabolism and the coinciding metabolic alterations, this in turn determines the fraction of maximal aerobic power that can be sustained for an extended period (Helgerud et al., 2007). According to the IDEA Health and Fitness Association, the most important measure of aerobic fitness is maximal oxygen consumption (VO_{2max}). VO_{2max} is a measure of how much blood is pumped per minute and the amount of oxygen that is extracted by the working muscles during that minute (Janot, 2004). The LT changes in response to training with the alteration of VO_{2max} and sometimes also as the percentage of VO_{2max}. Accumulation of lactic acid is associated with skeletal muscle fatigue and anaerobic metabolism cannot contribute at a quantitatively significant level to the energy expended (Helgerud et al., 2007). Properly structured, anaerobic activity can be used to develop a very high level of aerobic fitness without the muscle wasting consistent with high volumes of aerobic exercise (Smith et al., 2013).

The most common test where an “all out” effort is performed to measure VO_{2max} is the Wingate test. In a Wingate test subjects are asked to cycle on a mechanically braked cycle ergometer for 30 seconds as fast as possible against a previously determined maximal load. The velocity is recorded throughout the test. Peak power (Wpeak), mean power (W) and fatigue index are subsequently determined using an online data-acquisition system. The external power produced can be calculated at any time with the highest value chosen as the Wpeak. The average of all the calculated power values during the test corresponds to the W. (Burgomaster, Heigenhauser, & Gibala, 2006; Vincent et al., 2004). A typical HIIT or HIIE protocol consists of four to six Wingate tests separated by four minutes of rest approximately, for a total of two to three minutes of maximal exercise spread over 15 to 30 minutes. The Wingate protocol is extremely strenuous and uncomfortable, which is why HIIT is suited to active and motivated individuals (Burgomaster et al., 2006; Gibala et al., 2006)

The effect of HIIT on VO_{2max} has mostly been researched in clinical settings on cycle ergometers or treadmills (Bacon, Carter, Ogle, & Joyner, 2013; Burgomaster et al., 2006; Helgerud et al., 2007; Tabata et al., 1996). But since clinical tests are often expensive, invasive and time-consuming other means of measuring VO_{2max} are often conducted by athletic coaches and fitness professionals in a non-clinical setting. Although the results of clinical test are more exact than in field tests they have other advantages. Field tests for endurance can be performed on groups of athletes or individuals simultaneously and require minimal equipment (Janot, 2004). Examples of field tests include the Balke 15-minute run and the Cooper 12-minute run (Cooper, 1968) which only require a 400m track and a stopwatch. Rowing ergometers are an alternative tool for physiological monitoring and scientific research. The Concept II air-braked rowing ergometer has been popular among researchers and competitive rowers as a sport-specific testing device and indoor trainer. Results from progressive incremental tests performed on Concept II ergometers are commonly used to interpret physiological adaptations to rowing training and to provide specific training-intensity recommendations (Vogler, Rice, & Withers, 2007).

Studies about HIIT

The benefits of vigorous exercise for improving cardiorespiratory fitness is well known and therefore it is not surprising that aerobic HIIT leads to improvements in VO_{2max} and various indicators of the oxidative capacity of the skeletal muscle (Kilpatrick et al., 2014). Regular HIIT has been shown to significantly increase both aerobic and anaerobic endurance. Previous studies indicate that some minimum volume or duration of training may be a key feature in the benefits related to HIIT. Studies in clinical populations have shown that higher volume HIIT programs using longer intervals lead to greater improvements in VO_{2max} when compared with CME of equal volume and time commitment (Guiraud et al., 2012). Studies have also shown potent effects of HIIT for improving VO_{2max} after as little as 2 weeks of training. A growing body of evidence suggests that HIIT, using the Wingate test, can be used by overweight/obese sedentary individuals (Coppoolse et al., 1999; Vincent et al., 2004; Zouhal, Jacob, Delamarche, & Gratas-Delamarche, 2008). This approach to HIIT was primarily developed to demonstrate the potency of interval training in producing rapid cardio-metabolic adaptions and is not generally the style of training suitable for a long-term program (Kilpatrick et al., 2014). The Wingate test is considered a low-volume protocol. Other higher volume protocols used for assessing endurance include the Scandinavian model and the Practical model. The Scandinavian model was developed for cardiac patients and consists of several four minute intervals separated by an easy recovery of similar duration, as such it is considered high-volume interval training since the total time spent performing heavy exercise typically exceeds 15 minutes and therefore similar to traditional endurance training approaches. These intervals are not "all-out" exercise as they are performed somewhat below the maximum heart rate. The Practical model is a more recent variation of HIIT and was developed as an alternative to the all-out intensities linked to the Wingate test that maintains time efficiency. It involves performing 10 intervals on a cycle ergometer at intensities near peak work capacity for 60 seconds alternated with easy recovery intervals of the same duration. This model is considered a medium-volume interval training program since it represents a midpoint of sorts between the Wingate and Scandinavian models with respect to intensity, recovery and total volume (Kilpatrick et al., 2014; Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010) and is appropriate for the general population including type 2 diabetes mellitus patients.

A number of studies have demonstrated that HIIT lasting from 2 to 16 weeks results in significant increases in anaerobic capacity from between 7% to 35% (Kessler et al., 2012). For example, one study used a 20 second work/10 second rest protocol and found that in previously untrained males, anaerobic capacity, measured by maximal accumulated O_2 deficit, was increased by 28% (Tabata et al., 1997). Whyte et al. carried out a two week HIIT intervention and found that previously untrained males increased their anaerobic capacity by 8% (Whyte et al., 2010). Other two week studies with 8-10 subjects have supported these results with a VO_{2max} increase of 9 to 13% (Perry et al., 2008; Talanian et al., 2007).

1.3.2.2 Muscular Strength

Measurement

Maximal strength, 1RM, is the maximal weight that can be lifted through a full range of motion (Cronin & Hansen, 2005). Measurements of maximal strength used in HIIT studies include leg press, squat, knee extension (Campos et al., 2002), bench press, military press and double leg extension exercises (Kraemer et al., 1995). When the squat is used in research as a measure of maximum strength, either 1RM, 3RM or 5RM, it is important to start with a general warm-up followed by static stretching. The subject then performs a few submaximal sets of 3-5 repetitions, gradually building toward an estimated RM load. After that the subject attempts the required repetitions (one, three or five) at the estimated load. Following each successful RM attempt, the load is increased in small increments, for example 2.5 kg until the maximum lift is achieved. The position of the bar should be the same in all squat testing. Squat depth should be visually assessed by the same investigator for all testing, with the subject being required to descend to a depth where a line between the lateral epicondyle of the femur and the greater trochanter is approximately parallel to the floor and is given an oral signal once they reach the appropriate depth (Cronin & Hansen, 2005).

Studies about HIIT

The indication that bodyweight and resistance HIIT training may improve motor unit recruitment patterns is supported by a group of investigators (Glassman, 2002; Kraemer et al., 1995) who reported that heavy ST further enhances the function of the nervous system, thereby activating greater movement force by the recruited muscle groups. The creators of a vast HIIT strength and conditioning program suggest that their exercise programs elicit a strong neuroendocrine response (Glassman, 2002). The neuroendocrine response may be associated with the short rest intervals between sets, high exercise heart rates, and high-intensity training, for example training with heavy weights. These combined physiological elements initiate a release of human-like growth hormones and insulin, which contribute to enhanced skeletal muscle tissue growth and are associated with increased muscular strength levels (Kraemer et al., 1995). A study on muscular adaptations in response to three different ST regimens demonstrated those individuals training with heavier loads improved the most in maximal strength, whereas those who trained with the lighter loads improved the most using 60% of 1RM. Their data showed that low and intermediate RM training appears to induce similar muscular adaptations, at least after short-term training in previously untrained subjects and both groups had a similar hypertrophic response (Campos et al., 2002). Previous literature had often accepted that gains in strength and power result from high intensity/low volume training, whereas low intensity/high volume training maximizes muscle hypertrophy (Hiseada, Miyagawa, Kuno, Fukunaga, & Muraoka, 1996). In a study (Kraemer et al, 1995) examining compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations results indicate that the combination of strength and endurance training results in an attenuation of the performance improvements and physiological adaptations typical of single-mode training. Thirty-five healthy men were matched and randomly assigned to one of four training groups that performed high-intensity strength and endurance training, upper body only high-intensity strength and endurance training, high-intensity endurance training or high-intensity strength training. The training was carried out four days a week for 12 weeks. The high-intensity total body resistance training and combined high-intensity resistance and endurance training groups significantly increased one-repetition maximum for all exercises, namely single knee extensions, single leg curls, calf raises, squats, double knee extensions, and leg press. The high-intensity strength training group showed significant increases in power output and significant transitions in skeletal muscle fiber types, IIb (nonoxidative) to IIa (oxidative) were prominent in all training groups. However, the maximum transition from skeletal muscle fiber IIb to IIa occurred in the groups who strength trained the thigh musculature. Based on the results, the investigators concluded that combining high-intensity resistance and aerobic training (AT) further enhances skeletal muscle size and cortisol levels in comparison to resistance training alone (Kraemer et al., 1995). The literature suggest that resistance HIIT suits all age groups. A classical study concluded that high-resistance weight training leads to significant gains in muscle strength, size, and functional mobility among frail residents of nursing homes up to 96 years of age (Fiatarone et al., 1990).

1.3.2.3 *Muscular endurance*

Measurement

While strength is the most amount of weight that you can lift once, muscular endurance measures how many times you can lift lighter weights or perform an exercise using your body weight as resistance. In a study on airmen muscular endurance of the upper body and abdominal muscles was assessed by having airmen perform push ups and sit ups for one minute (O'Hara et al., 2012). In a previous study on young women, with extremely low volume whole-body aerobic resistance training, researchers measured muscle endurance with leg extensions, chest presses, sit ups, push ups and back extensions (McRae, Payne, Zelt, Scribbans, et al., 2012). Muscle endurance tests are also used in HIIT research to establish subjects training status (Kraemer et al., 1995).

Studies about HIIT

A recent HIIT study demonstrated that although improvements in cardiovascular fitness are induced by both endurance and extremely low volume interval-style training, whole-body aerobic–resistance training imparted additional benefits in the form of improved skeletal muscle endurance. Twenty-two recreationally active females were assigned to one of three groups, interval (HIIT), endurance and control group. The interval group performed a HIIT resistance protocol that consisted of whole-body exercises (burpees, jumping jacks, mountain climbers, or squat thrusts) involving one set of 8 × 20 seconds of a single exercise separated by 10 seconds of rest per session done four times a week (McRae, Payne, Zelt, Scribbans, et al., 2012). This type of protocol is often named Tabata (I. Tabata et al., 1997). The increases observed for leg extensions, chest presses, push ups, sit ups, and back extensions in the HIIT group were significantly greater than the changes in both the control and endurance groups (McRae et al., 2012). Another study demonstrates the potential of HIIT as a method of improving and maintaining physical function in untrained middle-aged individuals. Training was performed twice a week, consisting of 10×6 second cycle sprints with a one minute recovery between each sprint. Physical function (Get up and go test, Sit to stand test and a loaded 50 m walk) was determined before and after training and following eight weeks of HIIT all functional tests were significantly improved but stayed unchanged in the control group (Adamson, Lorimer, Cobley, Lloyd, & Babraj, 2014). There is a strong relationship between muscle power and physical function in men and women across the lifespan. Since muscle strength, muscle endurance and functional mobility decline with age HIIT can be used as a training intervention to improve skeletal muscle performance as we age (Samson et al., 2000).

1.3.2.4 Flexibility

Measurement

Muscular flexibility is important for normal human function and maintaining normal muscle length requires regular stretching to prevent muscle stiffness (Muyor, López-Miñarro, & Casimiro, 2012). Research suggests that females have greater flexibility than males throughout life and that a general decline in flexibility of joints occurs with age, with the maximum range of motion (ROM) occurring in the mid-to-late twenties for men and women (Bell & Hoshizaki, 1981). In the literature muscle tightness and/or weakness of the hamstring muscle is reported as one of the risk factors for injury (Croisier, 2012) and studies demonstrate that hamstring strains remain one of the most prevalent injuries in some sports (Watsford et al., 2010). Tests used to measure hamstring flexibility are for example the knee extension angle test (KEA), sacral angle test (SA), straight leg raising test (SLR) and sit and reach test (SR) (Davis, Quinn, Whiteman, Williams, & Young, 2008). The SLR test is of great value in assessing normality of the roots of the sciatic nerve and tightness of the hamstring muscles. The value of the SLR test can be determined with a goniometer, a gravity-type goniometer, or a tape measure (Hsieh, Walker, & Gillis, 1983). It is commonly used and easily implemented. With the subject lying on his back with his hands down his side, lifting his leg slowly as high as possible and keeping it straight the angle (in degrees) of the hip is measured by a researcher (Muyor et al., 2012). A recent study used the SLR and the toe-touch test to evaluate effects of a 12 week stretching program on women. Fifty-eight adult women were divided into two groups. The experimental group performed three exercises of hamstring stretching of 20 seconds per exercise, three sessions a week for a period of 12 weeks but the control group did not participate in any stretching program. The tests were performed both before and after the stretching program and the conclusions were that hamstring stretching exercises are effective for increasing hamstring muscle extensibility. This increase generates a more aligned thoracic curve and more anterior pelvic inclination when maximal trunk flexion is performed (Muyor et al., 2012). A study examining the concurrent validity of 4 clinical tests, KEA, SR, SL and SLR, used to measure hamstring muscle length, revealed that despite the common clinical use of these measures to assess hamstring length, these tests do not have sufficient concurrent validity to be used interchangeably or to assume that they each measure the same construct (hamstring length). Based on their findings the researchers recommend that researchers, clinicians, and strength and conditioning specialists adopt the KEA test as the gold standard measure for hamstring muscle length (Davis et al., 2008).

Studies about HIIT

In a systematic literature review on the effects of hamstring stretching on range of motion all 28 studies reviewed reported improvements in ROM after stretching. Because of a lack of quality in many of the studies it was difficult to confidently identify one most effective hamstring stretching method (Decoster, Cleland, Altieri, & Russell, 2005). In a 12 week HIIT study that measured lower back and hamstring flexibility with the SR test, there were no improvements. It was speculated that more frequent stretching than three times a week was needed to improve flexibility in these areas (Broadbent et al., 2013). An eight week program, exercising four days a week, of combined group-based HIIT and conventional training, improved various physical fitness parameters including flexibility (Giannnaki, Aphamis, Sakkis, & Hadjicharalambous, 2015).

1.3.3 Mental health. Depression, anxiety and stress

Measurement

Depression and anxiety are the most common psychiatric conditions. The treatments for depression and anxiety are multiple and have varying degrees of effectiveness. Regular physical activity and exercise have been shown to increase psychological well-being and studies have found that it can have positive effects on people who have been diagnosed with mental disorders (Perraton, Kumar, & Machotka, 2010). Stress is a process that occurs when people perceive an imbalance between physical and psychological demands on them and their ability to respond. When subjected to stress, the human immune system will decrease in function and may therefore cause a variety of illnesses and lower quality of life (Cohen, Kessler, & Gordon, 1995). Quality of life has been defined as how one perceives one's state of physical and mental health over time (Carral & Perez, 2007). There are many questionnaires available to assess emotional state and mental health. The Depression, Anxiety and Stress Scale (DASS) is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety and stress. According to the DASS home page (2014), "the DASS was constructed not merely as another set of scales to measure conventionally defined emotional states, but to further the process of defining, understanding, and measuring the ubiquitous and clinically significant emotional states usually described as depression, anxiety and stress. Each of the three DASS scales contains 14 items, divided into subscales of two to five items with similar content". Furthermore, "the Depression scale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest/involvement, anhedonia, and inertia. The Anxiety Scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect. The Stress scale is sensitive to levels of chronic non-specific arousal. It assesses difficulty relaxing, nervous arousal, and being easily upset/agitated, irritable/over-reactive and impatient. Subjects are asked to use 4-point severity/frequency scales to rate the extent to which they have experienced each state over the past week. Scores for Depression, Anxiety and Stress are calculated by summing the scores for the relevant items. As the scales of the DASS have been shown to have high internal consistency and to yield meaningful discriminations in a variety of settings, the scales should meet the needs of both researchers and clinicians who wish to measure current state or change in state over time (e.g., in the course of treatment) on the three dimensions of depression, anxiety and stress". ("Overview of the DASS and its uses," 2014).

Studies about HIIT

Previous research has shown that individuals who suffer from mental disorders are unlikely to meet recommended guidelines (Harris & Barraclough, 1998). Therefore time efficient training like HIIT should be suitable for people suffering from depression and anxiety. Perceived enjoyment of and intentions to engage in, very low volume, high-intensity, whole-body interval exercise were both increased following training in a recent study (McRae, Payne, Zelt, Scribans, et al., 2012). The effects of HIIT as a treatment of depression has proven to be more effective than low intensity training in older patients with depression in a study on community-dwelling adults <60 years with major or minor depression. The subjects were randomized into one of three groups, supervised high intensity PRT (80% maximum load) or low intensity PRT (20% maximum load) 3 days per week for 8 weeks, or GP care (Singh et al., 2005). In a 12 week HIIT trial on 16 heart transplant recipients depression scores decreased significantly in a HIIT group with no change in patients who did continuous moderate training. Both groups showed improvement in anxiety (Dall et al., in press). Studies on exercise and wellness indicate that moderate exercise has favourable effects on reducing stress, anxiety, and depression, and enhancing mood and self-esteem (Harvey, Hotopf, Øverland, & Mykletun, 2010). A research on the effects of High-Intensity Combined Training on women over 65 years of age concluded that older women can take part in high-frequency, high-intensity training programs with no risk to their health while experiencing improvements to their quality of life, cognitive function, degree of independence and physical fitness (Carral & Perez, 2007).

2 Current study

As mentioned in the introduction the health benefits of exercise have been demonstrated in many studies. Exercise can increase your quality of life considerably but there is no consensus on what type of exercise and what amount is preferred in order to maximize health. Research on HIIT has shown physiological benefits that are similar or even superior to more traditional continuous moderate-intensity exercise (CME) (Boutcher, 2011; Gibala et al., 2012) but more research is needed to identify the optimal length and intensity of a HIIT protocol for achieving varying health outcomes. With regard to modality, little is known about the effects of HIIT modalities such as rowing, walking, running, stair climbing, and swimming since studies have primarily utilized a stationary cycle ergometer. Many of the recent studies also discuss that future studies need to address compliance and efficacy of HIIT in the real world. Not enough is known about the effects of body weight and resistance HIIT on progress among the public. Progress happens to a large extent during rest and it underscores the importance of finding out the appropriate rest and recovery time for individuals engaged in high-intensity exercise. Our goal is to find out if we need to conduct training and rest in a different way than it is done in exercise regimens that focus on fewer elements at a time (Kilpatrick et al., 2014).

The HIIT that we investigated is, like most other HIIT programs, performed at vigorous to maximal intensity but has a different approach and aim than traditional types of HIIT regimens who usually focus on fewer elements at once. Our approach had a more general emphasis, similar to how HIIT is commonly used among the public these days. The program we used in our research study fits the description of bodyweight and resistance HIIT mentioned above (Kilpatrick et al., 2014) and consists of versatile intermittent training where all the metabolic systems are stressed utilizing a wide variety of functional movements. It differs from traditional HIIT in that it often lacks prescribed rest periods, focuses on sustained high power output and uses multiple joint movements (Smith et al., 2013). Functional movements generally use universal motor recruitment patterns, recruit in a wave of contraction from core to extremity, move the body or other objects efficiently and effectively, and are multi-joint. Examples of such functional movements are full range-of-motion squats, deadlifts, pull-ups, jumps, throws and more. Functional movements, when done properly, are very safe and effective in strength training, and as a result, are often used in a rehabilitative environment ((Kiesel, Plisky, & Butler, 2011; Minick et al., 2010). When executed under high intensity, it is vital that proper technique is utilized to ensure success and safety of the overall workout. Therefore, quality and consistent technique must be established prior to increasing the intensity of a workout. Our training does not consist of strictly fixed notions of sets, rest periods, repetitions, exercises, order of exercises, routines, or periodization. To avoid injuries due to a lack of strength, technique, or flexibility, focusing on appropriate progressions within the different modalities and adjusting the resistance and intensity to fit each participant's fitness levels is key.

In the current study, participants were randomized into three groups who exercised either three, four or five sessions each week for 12 weeks. Participants met in supervised 60 minute sessions and the main focus was on bodyweight and resistance HIIT. Each session consisted of a warm up, technical training, a HIIT workout and stretching. See appendix A for a 6 week sample of the exercise program used in this study. The twelve-week HIIT program involved 26 females and 28 males, age 16-56, who had previously taken a four week beginner course in the HIIT regimen investigated and were therefore familiar with the equipment, exercises and technique. Measurements were performed at baseline and after 12 weeks. Body composition (weight, circumference and body fat percentage (BF%)) and physical fitness (endurance, strength, muscle endurance and flexibility) were measured at the beginning and end of the training period (12 weeks) as well as the submission of the DASS questionnaire on mental health.

2.1 The research questions

The research questions were:

1. What is the impact of bodyweight and resistance HIIT on body composition, physical fitness and mental health?
2. Is there a difference in improvements of those that engage in bodyweight and resistance HIIT three, four or five times per week?
3. What is the optimal training frequency of bodyweight and resistance HIIT for healthy adults?

2.2 Objectives

The objectives of this study were:

1. To know and analyse the effects of a high-intensity interval training program on body composition, physical fitness and mental health in healthy adults.
2. To know and analyse the effects of the number of sessions in a high-intensity interval training program on body composition, physical fitness and mental health in healthy adults.

The Manuscript

On the following pages is a manuscript of the current study as it will be submitted for publication. This includes the introduction, method, results, discussion, conclusion, acknowledgements, and references. The reference page and appendices for the entire Thesis follow immediately after the manuscript.

3 A Manuscript of the Study

Optimal training frequency in bodyweight and resistance high-intensity interval training for healthy adults

Introduction

Exercise is a clinically proven, cost-effective, primary intervention that delays and in many cases prevents the health burdens associated with many chronic diseases. However, the precise type and quantity of exercise needed to accrue health benefits is a contentious issue with no clear consensus recommendations for the prevention of inactivity-related disorders and chronic diseases (Gibala, Little, MacDonald, & Hawley, 2012). Current public health recommendations for physical activity for adults aged 18–64 are 30 minutes of moderate-intensity activity each day or at least 150 minutes per week or 75 minutes a week of vigorous-intensity aerobic physical activity. An equivalent combination of moderate- and vigorous-intensity aerobic activity can be performed which provides substantial benefits across a broad range of health outcomes for sedentary adults (U.S. Department of Health and Human Services, 2008). This quantity of exercise may not be enough to prevent unhealthful weight gain for some persons. These persons may need additional exercise or caloric restriction to minimize the likelihood of further weight gain. Those who get 30 min of moderate-intensity exercise per day are likely to achieve additional health benefits if they exercise more (Blair, LaMonte, & Nichaman, 2004). For additional health benefits the World Health Organization (WHO) suggests that adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity (World Health Organization, 2011).

In addition to aerobic exercise, WHO recommends that people should engage in strength training (ST) and flexibility exercises at least twice a week, which will promote the maintenance of lean body mass, improvements in muscular strength and endurance, and preservation of function, all of which enable long-term participation in regular physical activity and promote quality of life (Blair, Kohl, Gordon, & Paffenbarger, 1992). Optimal strength training frequency, the number of workouts per week, depends on several factors such as intensity, volume, type of exercise, level of conditioning, ability to recover and the number of muscle groups trained each workout session. Studies have used frequencies of two to three alternating days per week in previously untrained individuals. American College of Sports Medicine (ACSM) recommendations for ST frequency is 2 to 3 days a week for novice training, 3 to 4 days a week for intermediate training, and 4 to 5 days a week for advanced training (American College of Sports Medicine, 2009).

One Meta-analysis study demonstrates that strength gains in untrained individuals were highest with a frequency of 3 days a week (Rhea et al., 2003). Elements such as speed and agility, balance, coordination, jumping ability, flexibility, and other measures of motor performance may be enhanced by ST. A fitness program which includes ST improves cardiovascular function, prevents osteoporosis, promotes weight loss and maintenance, improves dynamic stability and preserves functional capacity and fosters psychological well-being. Because the human body adapts quickly to a ST program, systematically increasing the demands placed upon the body is necessary in order for continual progression to occur. Variation may take place in many forms and manifests by manipulation of any one or a combination of the acute program variables. It may be accomplished through increasing exercise intensity or the total repetitions performed at the current intensity. Also repetition speed with submaximal loads may be altered according to goals and rest periods may be shortened for endurance improvements or lengthened for strength and power training and finally the training volume may be gradually increased. The two most commonly studied variables have been volume and intensity (American College of Sports Medicine, 2009).

As most adults do not meet current recommendations of physical activity there is a critical need for innovative approaches to increase physical activity across large-scale populations (Thompson, 2009). Elite endurance athletes have long appreciated the role of high-intensity intermittent exercise (HIIE) and high-intensity interval training (HIIT) as part of a comprehensive training program and researchers discuss that recent evidence suggests that, in young healthy persons of average fitness, intense interval exercise is a time-efficient strategy to stimulate a number of skeletal muscle adaptations that are comparable to traditional endurance training. Gibala and McGee (2008) discuss that "fundamental questions remain regarding the minimum volume of exercise necessary to improve physiological well-being in various populations, the effectiveness of alternative, less extreme, interval-training strategies, and the precise nature and magnitude of adaptations that can be elicited and maintained over the long-term. A comprehensive evaluation of the physiological adaptations induced by different interval-training strategies in a wide range of populations will permit evidence-based recommendations that may provide an alternative to current exercise prescriptions for time-pressed individuals" (p.62).

A growing body of evidence demonstrates that HIIT can serve as an effective alternative to traditional endurance-based training, inducing similar or even superior physiological adaptations in healthy individuals and diseased populations, at least when compared on a matched-work basis (Gibala et al., 2012). The time efficiency of a high-intensity interval program may also make it an appealing exercise alternative for increasing exercise adherence (Bartlett et al., 2011).

HIIT it is generally referred to as repeated sessions of relatively brief intermittent exercise, often performed with an "all-out" effort or at an intensity close to that which elicits VO2peak (i.e., ≥90% of VO2peak). Depending on the training intensity, a single effort may last from a few seconds to up to several minutes, with multiple efforts separated by up to a few minutes of rest or low-intensity exercise (Gibala & McGee, 2008). Also HIIT is defined as vigorous exercise performed at a high intensity for a brief period of time interposed with recovery intervals at low-to-moderate intensity or complete rest (Kessler et al., 2012). In contrast to strength training (ST) in which brief intense efforts are usually performed against a heavy resistance to increase skeletal muscle mass, HIIT is normally associated with activities such as cycling or running and does not induce marked fiber hypertrophy (Gibala & McGee, 2008).

Modern fitness programming has adopted the term HIIT as a way to describe this approach to fitness and performance and two categories have emerged. One category is referred to as aerobic HIIT and the other is body weight HIIT or resistance HIIT. Both involve periods of intense effort followed by recovery segments, with the primary difference being the modality of the exercise. Aerobic HIIT training is interval training that uses traditional aerobic exercise modalities, mostly running or cycling, to deliver the desired intensities, for example spinning classes and track based running workouts. In contrast resistance or body weight HIIT training is interval training that uses bodily movements, weighted objects, bars or devices for high-repetition resistance activities. This kind of training makes use of calisthenics, plyometrics and loaded lifts in training programs like Tabata, CrossFit, boot camp training or other similar programs (Kilpatrick, Jung, & Little, 2014). Both types of HIIT programs are used widely and a research indicated the effectiveness of body weight type HIIT programming (McRae, Payne, Zelt, Scribans, et al., 2012). However most research has focused on HIIT that is primarily aerobic because cycling and treadmill running enable more accurate assessment of work to describe the training stimulus. Modern interval training has linkage to military preparedness and athletic competition, but the recent resurgence of interest in interval training can be attributed to potential health related benefits of HIIT (Kilpatrick et al., 2014).

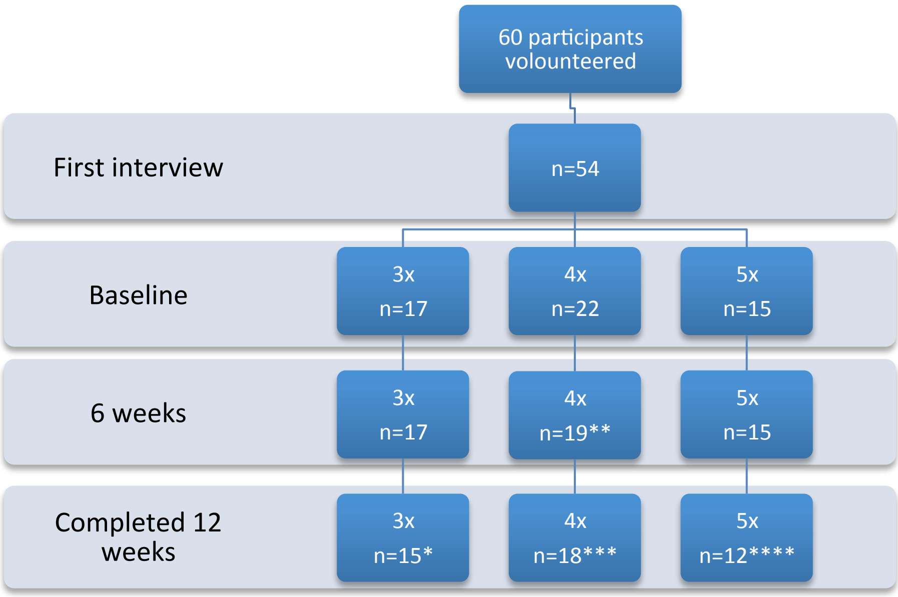
Research on HIIT has shown physiological benefits that are similar or even superior to more traditional continuous moderate-intensity exercise (CME) (Boutcher, 2011; Gibala et al., 2012) but more research is needed to identify the optimal length and intensity of a HIIT protocol for achieving varying health outcomes. With regard to modality, little is known about the effects of HIIT modalities such as rowing, walking, running, stair climbing, and swimming since studies have primarily utilized a stationary cycle ergometer (Hrazdíra, Juránková, & Slámová, 2014; Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010; Whyte et al., 2010). Many of the recent studies also discuss that future studies need to address compliance and efficacy of HIIT in the real world. Not enough is known about the effects of body weight and resistance HIIT on progress among the public. Progress happens to a large extent during rest and it underscores the importance of finding out the appropriate rest and recovery time for individuals engaged in high-intensity exercise (Kilpatrick et al., 2014). The HIIT investigated has a different approach and aim than traditional types of HIIT regimens which usually focus on fewer elements at once. It fits the description of bodyweight and resistance HIIT and consists of versatile intermittent training where all the metabolic systems are stressed utilizing functional movements.

The purposes of the current study were (i) to know and analyse the effects of a high-intensity interval training program on body composition, physical fitness and mental health in healthy adults and (ii) to know and analyse the effects of the number of weekly sessions in a high-intensity interval training program on physical fitness, body composition, physical fitness and mental health and quality of life in healthy adults.

Methods

Participants

In this study 60 healthy individuals (32 males, 28 females) volunteered to participate in a 12 week supervised high-intensity exercise program. Fifty-four subjects (28 males, 26 females 31.78 ± 8.50 years old) showed up for the first measurements. Of the 54 participants, five reported pre-existing injuries that might interfere with the training. A total of 45 subjects (20 males and 25 females, 32.09 ± 6.92 years old) completed the 12 week exercise program. The reasons given for dropouts were as follows: injuries (n = 3), personal reasons (n = 3), no reason given (n = 3). All subjects were then randomly assigned to one of three groups that exercised: Group 1 (three sessions per week) (n=17), Group 2 (four sessions per week) (n=22) and Group 3 (five sessions per week) (n=15) for 12 weeks. The randomization was performed by each subject drawing a number, three, four or five. Therefore all subjects had equal probability to be in every group. Because of this and because of the six "no-shows" the distribution in the groups was not quite equal.



*2 dropouts, pre-existing injury (n=1) and no reason (n=1), **3 dropouts, pre-existing injury (n=1) and personal reasons (n=2), ***1 dropout, personal reasons (n=1), **** 3 dropouts, pre-existing injury (n=1) and no reason (n=2)

Figure 1 - Consort diagram

To be eligible to participate in this study, the volunteers had to have completed a four week beginner course in the HIIT regimen investigated and be familiar with the equipment, exercises and technique. Individuals who attended an initial bodyweight and resistance HIIT course in Sporthúsið gym in January and February 2012 were invited to participate in the study. The study was carried out in 12 weeks from February until May 2012. Participants needed to be older than 16 years of age and if younger than 18 they needed their parents consent. After volunteering every participant met individually with the researcher for a short interview where the experimental protocol was explained orally and in writing before written consent was obtained. The participants signed a consent form approved by the National Bioethics Committee of Iceland (VSNb2012020016/03.7) and the researcher measured participants weight, circumference and body fat percentage and documented their medical history. Participants were made aware that they were free to withdraw at any time.

Study design

The present study was an experimental study where the independent variable is the number of sessions of bodyweight and resistance HIIT a week and the dependent variables are all measurements done in different domains: body composition, physical fitness and mental health. Participants were randomized into three groups who performed either three, four or five bodyweight and resistance HIIT sessions each week for 12 weeks. Each group, group 1 (3x), group 2 (4x) or group 3 (5x), had the same sessions on Mondays, Wednesdays and Thursdays. Subjects in group 1 (3x) could come on Fridays or Sundays if they missed a class. Subjects in group 2 (4x) had their fourth session on Fridays or Sundays. Subjects in group 3 (5x) exercised on all 5 days. If they missed a session they could compensate by joining another group on Tuesdays or Saturdays. Participants always met in supervised 60 minute sessions and the main focus was on bodyweight and resistance HIIT. Each session consisted of a warm-up, technical or strength training, a HIIT workout and stretching. To make it easier for the subjects they could choose from many sessions each day. Mondays, Wednesdays and Thursdays at 6:00, 7:00, 9:15, 12:00, 16:30, 17:30, 18:30 and

19:45. Fridays at 6:00, 7:00, 9:15, 12:00 and 16:30 and Sundays at 10:15 and 11:15. There was always a trainer present and every session was the same throughout the day. The subjects were encouraged to continue their normal lifestyle during the study but to pursue no other high intensity exercise.

Procedures

Measurements were proceeded at baseline and after 12 weeks. Body composition (weight, body fat percentage, BF% and circumference) as well as physical fitness (endurance, strength, muscle endurance and flexibility) were measured at the beginning and end of the training period (12 weeks) as well as the DASS questionnaire on mental health.

Measurements

All subjects were evaluated with the same tests on three domains: body composition, physical fitness and mental health.

Body composition

Body composition was measured by bodyweight, skin fold and circumference. Weight was measured with a digital scale (Tanita HD-314 Digital Weight Scale). It was recorded whether the participant wore their trainers and what type of clothing they were wearing. The measurement was carried out identically in all three measurements, in the beginning and after 12 weeks.

Body fat percentage was calculated with generalized body composition equations (Jackson & Pollock, 1978; Jackson et al., 1979) using skin fold measurements, gender and age specific. The measurement of skinfold thickness was made on 3 sites by the researcher. In males, quadriceps (thigh), pectoralis (chest) and abdomen, and in females, quadriceps (thigh), suprailiac and triceps (Jackson et al., 2009). The measurement was made by grasping the skin and adjacent subcutaneous tissue between the thumb and forefinger, shaking it gently to exclude underlying muscle, and pulling it away from the body just far enough to allow the jaws of a caliper to impinge on the skin. The caliper lever was then released so its spring tension was exerted on the skinfold and the pinch maintained while reading nearest mm on the caliper (Pescatello, 2014). Every measurement was made 3 times at each site and an average was taken.

The skin fold sites were:

- *Quadriceps (Thigh):* A vertical skin fold on the thigh was taken in the front, halfway from the upper part of the knee and the fold above the thigh when the leg is raised.
- *Pectoral (Chest):* A diagonal skin fold was taken between the nipple and the armpit (axilla) but closer to the armpit, approximately 1/3 the distance in the direction of the nipple-armpit line.
- *Abdomen (Belly):* A vertical fold was taken 2 cm to the right of the bellybutton (umbilicus). The vertical pinch was used as the fat folds easier with most people.
- *Suprailiac or Iliac crest (Hip, front):* The skin fold is angled 2 cm right above the iliac crest approx. 45° going up and away from the body. The fold spot was between the top of the hipbone on the side and the bony part on the lower right of the belly, which is still the same hipbone.
- *Triceps (Upper arm, back):* A vertical skin fold was taken halfway up the upper arm. The participants were asked to relax their shoulders and face hand palm forward.

Body density was calculated and converted into BF% using Siri's equations for estimating body density from skinfold thickness (Siri, 1956):

$$Men: BF\% = 495/(1.10938-(0.0008267*s)+(0.0000016*s*s)-(0.0002574*a))-450$$

$$Women: BF\% = 495/(1.089733-(0.0009245*s)+(0.0000025*s*s)-(0.0000979*a))-450$$

s = sum of 3 skinfold mm, , a = age

The circumference was measured with a tape measure at three sites:

- Hips. Maximal circumference of the buttocks above the gluteal fold.
- Waist. Narrowest part of the torso between the xiphoid process and the umbilicus.
- Thigh. Largest circumference of the right thigh below the gluteal fold.

Physical fitness

Physical fitness was measured by anaerobic endurance, strength and muscle endurance. The anaerobic endurance test was carried out on an *Concept 2* indoor rower and took two to three minutes (Vogler et al., 2007). The participant rowed 500 meters as fast as he possibly could and the time it took was registered.

The strength test was a weighted squat and was to find out the maximum weight that a person could lift five times with good technique (5RM). After warming up with an empty barbell each participant performed a few submaximal sets of three to five repetitions, gradually building toward an estimated 5RM load. The participant then attempted the 5RM at the estimated load with a "spotter" on each side. Following each successful 5RM attempt, the load was increased in small increments, 1.25-2.5 kg, until the maximum lift was achieved, resting about 90-120 seconds between sets (Cronin & Hansen, 2005). Squat depth was visually assessed by the investigator for all tests, with the subject being required to descend to a depth where a line between the lateral epicondyle of the femur and the greater trochanter was approximately parallel to the floor and was given an oral signal once they reached the appropriate dept.

For the muscular endurance test participants were paired together with a partner and counted the repetitions out loud for each other, working one at a time with one minute rest between exercises. They recorded the score to the investigator immediately after each minute (Kraemer et al., 1995; O'Hara et al., 2012). The scaling or how the exercise was performed, i.e. push ups done on knees or toes or use of a band in the pull ups, was recorded and exercises performed exactly the same in all tests. The following test were done.

- Maximum repetitions of push ups in 60 seconds. The push ups were performed in a prone position by raising and lowering the body with the straightening and bending of the arms to a 90° angle while keeping the back straight and supporting the body on the hands and toes or knees.
- Maximum repetitions of sit ups in 60 seconds. The sit ups were performed lying flat on the back, with an abmat placed under the lumbar spine and with knees bent. It began by lifting the torso to a sitting position and then returning to the original position without changing the position of the legs.
- Maximum repetitions of pull ups in 60 seconds. The pull ups started in hanging position with straight arms and palms facing forward, then subjects pulled themselves up until the chin passed the bar and lowered back down until the arms were straight again.

- Maximum seconds in ring hold. The ring hold test started by the subject getting into a support position on gymnastic rings with the feet barely off the ground. The subject was then asked to hold their body above the rings with straight arms, shoulders pushed down and the chest up and try to hold the position for as long as possible. The time was registered.

Flexibility

The hamstring muscle flexibility was measured using the active lying straight leg raise test (Muyor et al., 2012). The test started with the participant lying flat on the floor. While the participant was in the supine position with legs extended, the axis of the hip joint was aligned with a large 180° degree measuring instrument drawn on a wall. The participant's leg was lifted passively by the tester into hip flexion. The tester placed one hand under the calcaneus of the tested leg while maintaining the knee joint in the extension with the other hand. The opposite leg was fixed in straight position during the leg raise by an auxiliary tester. The ankle of the tested leg was restrained in plantar flexion to avoid adverse neural tension. The endpoint for straight-leg raise was determined by the participants as they reported pain within their hamstring. To maintain the pelvis in a neutral position and avoid the posterior pelvic tilt, the contralateral leg was held firmly down against the floor by a partner. The criterion score of hamstring flexibility was the maximum angle (degree) read from the measuring instrument at the point of maximum hip flexion. Angles were recorded to the nearest degree for each leg.

Mental health

To assess any possible effects of the program on subjects' mental health, the DASS (Depression, Anxiety and Stress Scale) questionnaire was used in the beginning and after the 12 week program. The DASS is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety and stress. Each of the three DASS scales contains 14 items, divided into subscales of 2-5 items with similar content. The Depression scale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest/involvement, anhedonia, and inertia. The Anxiety scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect. The Stress scale is sensitive to levels of chronic non-specific arousal. It assesses difficulty relaxing, nervous arousal, and being easily upset/agitated, irritable/over-reactive and impatient. Subjects are asked to use 4-point severity/frequency scales to rate the extent to which they have experienced each state over the past week. ("Overview of the DASS and its uses," 2014)

Statistical Analysis

Basic descriptive statistics (mean and standard deviation) were used to characterize the sample. All the variables satisfied the tests of homoscedasticity (Levene variance homogeneity test) and normality (Kolmogorov-Smirnov test) of their distributions. So, the parametric test was used. The t-test was used to know the differences of the variables dependent in each group. The effect sizes (ES) of the differences were calculated by each group (Cohen, 1988). Cohen's categories were used to evaluate the magnitude of the effect size: (i) small if $0 \le |d| \le 0.2$; (ii) medium if $0.2 < |d| \le 0.5$; and (iii) large if $|d| > 0.5$ (Cohen, 1998). One two-way analysis of variance (ANOVA) with repeated measures was used to know the difference between groups. The level of significance for all statistical tests was set at $p \leq 0.05$. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS for Mac, version 22.0).

Results

Descriptive statistics

Table 1 shows the descriptive statistics at baseline of all three groups: Group 1 (three sessions), Group 2 (four sessions) and Group 3 (five sessions). All means and standard deviation on body composition, physical fitness and mental health are similar. ANOVA was carried out to see if there were significant differences between groups at baseline. No significant differences were detected in any of the variables/measures ($p>0.05$). Therefore it can be stated that the groups are homogenus.

Table 1. Differences between groups at baseline.

	Group 1 (3x) (n=17)			Group 2 (4x) (n=22)			Group 3 (5x) (n=15)			ANOVA
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	p-value
Age	34.71 (8.84)	23.0	56.0	32.18 (6.96)	18.0	44.0	27.87 (9.20)	16.0	43.0	.070
Body composition										
Bodyweight (kg)	84.96 (15.06)	61.3	117.0	83.63 (19.64)	57.0	127.9	86.13 (18.84)	55.8	116.1	.918
Body fat (%)	22.81 (6.81)	12.4	36.1	23.47 (6.63)	7.9	32.3	23.05 (7.85)	6.3	36.7	.956
Waist circumference (cm)	94.77 (10.99)	73.5	119.0	94.66 (3.58)	75.0	119.0	93.63 (12.81)	70.0	120.0	.961
Hip circumference (cm)	104.5 (7.67)	93.0	121.5	104.28 (7.82)	91.0	117.0	104.23 (8.65)	89.0	121.0	.996
Thigh circumference (cm)	61.79 (4.05)	55.0	71.5	61.75 (4.34)	55.0	68.5	62.13 (5.44)	54.0	75.0	.966
Physical fitness										
Strength (5RM squat) (kg)	69.71 (22.94)	40.0	100.0	65.34 (31.80)	22.5	120.0	64.00 (27.00)	30.0	130.0	.828
Endurance (500m row) (s)	113.45 (12.65)	92.0	131.7	117.56 (14.00)	90.1	138.2	116.82 (14.41)	100.0	140.1	.631
1 min test push ups (rep)	26.94 (5.97)	18.0	36.0	28.55 (6.96)	17.0	44.0	27.93 (6.14)	21.0	42.0	.743
1 min test pull ups (rep)	13.82 (5.69)	5.0	27.0	14.05 (5.90)	5.0	27.0	14.00 (6.55)	3.0	29.0	.993
1 min test sit ups /rep)	27.59 (3.87)	1.90	35.0	28.50 (6.12)	13.0	44.0	28.20 (5.97)	20.0	37.0	.874
Stability/strength (s)	22.58 (13.35)	0	48.0	26.86 (15.59)	0	52.0	28.00 (17.40)	3.0	62.0	.569
Flexibility left (°)	72.71 (11.83)	50.0	103.0	76.48 (9.33)	55.0	95.0	73.80 (12.87)	55.0	105.0	.568
Flexibility right (°)	73.88 (12.71)	60.0	107.0	78.00 (9.06)	60.0	95.0	72.40 (15.38)	55.0	110.0	.364
Mental health										
Depression	1.69 (2.63)	0	10.0	2.35 (3.17)	0	12.0	2.93 (4.65)	0	16.0	.461
Anxiety	2.38 (3.10)	0	9.0	2.60 (3.32)	0	13.0	2.87 (3.52)	0	14.0	.381
Stress	5.00 (5.54)	0	23.0	5.75 (7.52)	0	25.0	7.07 (8.46)	0	26.0	.533

Intragroup

Tables 2, 3 and 4 show the descriptive statistics for all outcome measures, before the intervention program and after the intervention program and effect sizes. Only the scores of subjects that completed the 12 weeks are used. Table 2 shows the changes in Group 1 (HIIT 3x/week) on body fat, waist circumference, hip circumference and all physical fitness variables. Large effect sizes were found on body fat and all muscle endurance variables (1 min tests of push ups, pull ups and sit ups and in the ring hold). Medium effect sizes were found on the 5RM squat, the 500 meters row and flexibility measures. Finally, small effect sizes were found on circumference measures (waist, hip and thigh).

Table 2 - Difference on scores within Group 1 (HIIT 3x/week) at baseline and after 12 weeks

Group 1 (3x), n=15	Baseline (0 week) Mean (SD)	After (12 weeks) Mean (SD)	T-test	p-value	Cohen´s d
Body composition					
Bodyweight (kg)	84.22 (16.36)	83.16 (15.68)	1.940	.074	0.066
Body fat (%)	23.65 (6.81)	15.20 (7.26)	10.251	<.001	1.201
Waist circumference (cm)	94.67 (11.70)	92.17 (11.33)	4.930	<.001	0.217
Hip circumference (cm)	104.37 (8.07)	102.13 (7.75)	4.367	<.001	0.283
Thigh circumference (cm)	61.90 (4.30)	62.17 (4.18)	-.552	.589	-0.064
Physical fitness					
Strength (5RM squat) (kg)	65.71 (22.61)	77.86 (25.25)	-5.355	<.001	-0.511
Endurance (500m rowing) (s)	115.86 (12.65)	112.14 (12.01)	3.125	.008	0.303
1 min test push ups (rep)	26.67 (6.04)	35.00 (4.68)	-5.897	<.001	-1.542
1 min test pull ups (rep)	13.00 (5.55)	22.13 (6.38)	-7.118	<.001	-1.527
1 min test sit ups /rep)	27.00 (3.57)	31.53 (3.85)	-4.045	<.001	-1.220
Stability/strength (s)	22.60 (14.18)	40.40 (17.73)	-5.074	<.001	-1.109
Flexibility left (°)	72.93 (13.06)	78.86 (15.30)	-4.493	<.001	-0.417
Flexibility right (°)	74.00 (14.05)	79.71 (14.18)	-3.480	.004	-0.405
Mental health					
Depression	1.75 (2.80)	1.08 (2.19)	.697	.500	0.266
Anxiety	2.92 (3.40)	2.00 (2.73)	1.571	.144	0.298
Stress	5.18 (6.54)	4.36 (4.72)	.812	.436	0.144

Table 3 shows the changes in Group 2 (HIIT 4x/week) on body weight, body fat, waist circumference, hip circumference and all physical fitness variables. Large effect sizes were found on body fat and all physical fitness variables except 500m row and 5RM. Medium effect sizes were found on 500m row. Finally, small effect sizes were found on body weight and circumference measures (waist and hip).

Table 3 - Difference on scores within Group 2 (HIIT 4x/week) at baseline and after 12 weeks

Group 2 (4x), n=18	Baseline (0 week) Mean (SD)	After (12 weeks) Mean (SD)	T-test	p-value	Cohen´s d
Body composition					
Bodyweight (kg)	81.09 (20.11)	79.69 (19.08)	2.394	.029	0.071
Body fat (%)	22.72 (6.85)	15.81 (6.13)	12.184	<.001	1.063
Waist circumference (cm)	92.81 (14.34)	90.61 (13.89)	3.626	.002	0.156
Hip circumference (cm)	103.47 (8.34)	101.53 (8.15)	2.880	.010	0.235
Thigh circumference (cm)	61.50 (4.74)	61.39 (5.13)	0.205	.840	0.022
Physical fitness					
Strength (5RM squat) (kg)	63.75 (32.10)	73.03 (30.69)	-4.480	<.001	-0.295
Endurance (500m rowing) (s)	118.22 (14.54)	113.70 (14.06)	3.832	<.001	0.316
1 min test push ups (rep)	29.11 (7.59)	37.56 (6.76)	-7.438	<.001	-1.176
1 min test pull ups (rep)	14.55 (5.88)	26.22 (6.95)	-8.563	<.001	-1.813
1 min test sit ups /rep)	28.28 (6.66)	34.11 (4.07)	-4.150	<.001	-1.056
Stability/strength (s)	26.72 (15.71)	42.94 (16.73)	-5.328	<.001	-0.990
Flexibility left (°)	78.33 (8.06)	84.17 (8.02)	-4.714	<.001	-0.726
Flexibility right (°)	79.22 (8.58)	85.50 (8.71)	-4.349	<.001	-0.726
Mental health					
Depression	2.00 (2.42)	1.08 (2.64)	1.448	.176	0.364
Anxiety	2.21 (2.55)	2.71 (3.43)	-1.073	.303	-0.165
Stress	5.79 (7.93)	5.64 (8.41)	.268	.793	0.018

Table 4 shows the changes in Group 3 (HIIT 5x/week) on body fat, waist circumference, hip circumference and all physical fitness variables except stability/strength. Large effect sizes were found on all endurance strength variables. Medium effect sizes were found on body fat, 5RM, 500m row and flexibility (left side). Finally, small effect sizes were found on circumference measures (waist and hip) and flexibility (right side).

Table 4. Difference on scores within Group 3 (HIIT 5x/week) at baseline and after 12 weeks

Group 3 (5x), n=12	Baseline (0 week) Mean (SD)	After (12 weeks) Mean (SD)	T-test	p-value	Cohen´s d
Body composition					
Bodyweight (kg)	86.30 (22.26)	84.6 (20.21)	1.687	.126	0.080
Body fat (%)	23.94 (8.45)	17.43 (6.70)	5.124	.001	0.854
Waist circumference (cm)	92.63 (14.20)	90.58 (12.82)	2.476	.031	0.152
Hip circumference (cm)	103.50 (9.47)	102.25 (8.78)	2.307	.042	0.137
Thigh circumference (cm)	62.38 (5.89)	62.42 (5.87)	-0.103	.920	-0.007
Physical fitness					
Strength (5RM squat) (kg)	53.64 (19.25)	62.05 (21.12)	-4.867	<.001	-0.416
Endurance (500m rowing) (s)	121.67 (13.86)	115.11 (10.009	3.832	.005	0.541
1 min test push ups (rep)	28.75 (6.50)	35.58 (6.61)	-4.163	.002	-1.042
1 min test pull ups (rep)	13.25 (6.18)	26.22 (6.95)	-8.563	<.001	-1.813
1 min test sit ups /rep)	28.17 (5.89)	34.41 (6.22)	-3.580	.004	-1.031
Stability/strength (s)	25.73 (19.06)	34.00 (18.05)	-1.836	.096	-0.446
Flexibility left (°)	75.18 (14.84)	82.18 (13.72)	-4.442	<.001	-0.490
Flexibility right (°)	73.09 (17.97)	81.45 (15.55)	-6.880	<.001	-0.496
Mental health					
Depression	3.38 (5.60)	1.75 (2.05)	.936	.379	0.387
Anxiety	2.90 (4.15)	2.20 (3.33)	.509	.623	0.186
Stress	7.20 (9.92)	4.20 (5.71)	1.508	.166	0.371

Intergroups

ANOVA was carried out to test if the improvements between groups were different. ANOVA results indicated that no difference is between the groups improvements in terms of these measurements ($p>0.05$). The following variables have a p-value <.500: 5RM squat, push ups, pull ups, sit ups and ring hold and flexibility on both legs, anxiety and stress. Other variables, bodyweight, body fat, waist, hip and thigh circumference, 500 meter rowing and depression have a p-value between .681 and .965.

Discussion

This study examined the effect of a 12 week program with different frequency of sessions per week (three, four or five), on body composition, physical fitness and mental health. 45 participants completed the intervention, 20 males and 25 females, age 16–56 years old. Participants were not required to change their normal habits during the intervention program but were asked not to engage in any other HIIT training. At the beginning of our study, significant difference was not observed between the groups in any variables. It was concluded that the groups were matching. After 12 weeks all groups showed progress but there were no significant differences between the groups in any variables. The major findings of the current study were that bodyweight and resistance HIIT is effective in reducing fat percentage and increasing physical fitness on various measures in healthy adults and that no differences in improvement were found between those that worked out 3x, 4x and 5x a week.

Intragroup differences (Group 1, HIIT 3x/week)

Body composition. The HIIT 3x/week group showed improvement in *body fat* (baseline: 23.65±6.81%, 12 weeks: 15.20±7.26; $p<.001$, ES=1.201) which is similar to findings of a previous study that demonstrated that HIIT three times per week for 15 weeks showed significant reductions in total body fat, subcutaneous leg and trunk fat, and insulin resistance in young women (Trapp et al., 2008). Similarly, a recent study with young overweight men practicing HIIT three times a week for 8 weeks showed a significant reduction in total, abdominal, trunk, and visceral fat and significant increases in fat free mass (Heydari et al., 2012). Furthermore previous literature indicates that HIIT increases the capacity for fat oxidation during exercise in women in a short amount of time (Talanian et al., 2007). Research has shown that it is feasible that HIIT will have an even greater fat reduction effect on the overweight or obese since the greatest HIIT-induced fat loss was found in studies that used overweight type 2 diabetic adults as subjects (Boutcher, 2011).

Additionally, subjects in the HIIT 3x/week group showed a decrease ($p<0.05$) in *waist* (baseline: 94.67±11.70cm, 12 weeks: 92.17±11.33, $p<.001$, ES=0.217) and *hip* (baseline: 104.37±8.07cm, 12 weeks: 102.13±7.75, $p<.001$, ES=0.283) *circumference* measures. Circumference is regularly used to evaluate body composition. Review articles on HIIT that evaluate, among other things, the impact of HIIT on waist circumference and waist-to-hip ratio showed a reduction of waist circumference from 1.0-7.2 cm in 8-16 week interventions (Boutcher, 2011; Kessler et al., 2012; Whyte et al., 2010). A previous study revealed similar findings. Two weeks of HIIT resulted in improved insulin sensitivity, increased resting fat oxidation, and reduced waist circumference and systolic blood pressure in overweight sedentary men (Whyte et al., 2010). On the other hand a 12 week HIIT intervention demonstrated that the major reduction in visceral fat brought about by HIIT occurred within the first six weeks as reduction in waist circumference was significantly correlated with reduction in visceral fat (Heydari et al., 2012).

Physical fitness. Improvements in *endurance* occurred as expected. There was a difference in the 500 meter row in the 3x/week group (baseline:

121.67±113.86 s, 12 week: 115.11±10.09s, $p<.005$, ES=0.541) but the effect size was merely medium. Efforts at moderate to high power and lasting less than several minutes are anaerobic and efforts at low power and lasting in excess of several minutes are aerobic. Since the endurance test (500 meters row) in the current study was performed at an all out effort and only takes around 1:30-3:00 minutes depending on gender and ability, the test can be considered to measure anaerobic endurance. Previous research has demonstrated that regular HIIT significantly increases both aerobic and anaerobic endurance (Kilpatrick et al., 2014). Because the lactate threshold (LT) reflects an onset of anaerobic metabolism and the coinciding metabolic alterations, this in turn determines the fraction of maximal aerobic power that can be sustained for an extended period. LT changes in response to training with the alteration of VO_{2max} and sometimes also as the percentage of VO_{2max}. Accumulation of lactic acid is associated with skeletal muscle fatigue and anaerobic metabolism cannot contribute at a quantitatively significant level to the energy expended (Helgerud et al., 2007). Properly structured, anaerobic activity can be used to develop a very high level of aerobic and anaerobic fitness without the muscle wasting consistent with high volumes of aerobic exercise (Smith et al., 2013). A number of studies have demonstrated that HIIT lasting from 2 to 16 weeks results in significant increases in anaerobic capacity from between 7% to 35% (Kessler et al., 2012; Sloth et al., 2013; Weston et al., 2014). One study (Tabata et al., 1997) used a 20 second work/10 second rest protocol and found that in previously untrained males, anaerobic capacity, measured by maximal accumulated O_2 deficit, was increased by 28%. A recent study (Whyte et al., 2010) carried out a two-week HIIT intervention and found that previously untrained males increased their anaerobic capacity by 8%. It has also been shown that as few as six to seven two hour sessions at 60–70% of VO_2 peak increase aerobic capacity, whole body fat oxidation, and mitochondrial enzyme activities and results in a VO_{2max} increase of 9 to 13% (Perry et al., 2008; Talanian et al., 2007; Whyte et al., 2010).

Regarding *maximal strength and muscular endurance*, subjects that participated in HIIT three times a week experienced improvement in both 5 RM squat (baseline: 65.71±22.61 kg, 12 week: 77.86±25.25 kg, p≤.001, ES=-0.511) and especially in the muscle endurance tests. The indication that bodyweight and resistance HIIT training may improve motor unit recruitment patterns is supported by a group of investigators who reported that heavy strength training (ST) further enhances the function of the nervous system, thereby activating greater movement force by the recruited muscle groups (Glassman, 2002; Kraemer et al., 1995). A study on muscular adaptations in response to three different ST regimens demonstrated that those individuals training with heavier loads improved the most in maximal strength, whereas those who trained with the lighter loads improved the most using 60% of 1RM. The data showed that low and intermediate RM training appears to induce similar muscular adaptations, at least after short-term training in previously untrained subjects and both groups had a similar hypertrophic response (Campos et al., 2002). All subjects increased the number of repetitions in push ups (baseline: 26.67±6.04 rep, 12 week: 35.00±4.68, p<.001, ES=-1.542), pull ups (baseline: 13.00±5.55 rep, 12 week: 22.13±6.38 rep, p≤.001, ES=-1.527) and sit ups (baseline: 27.00±3.57 rep, 12 week: 31.53±3.85, p<.001, ES=-1.220) and the time (seconds) in ring hold in the stability strength test (baseline: 22.60±14.18 s, 12 week: 40.40±17.73, p≤.001, ES=-1.109). The findings compare with previous studies that have found bodyweight and resistance HIIT to improve muscle endurance (McRae, Payne, Zelt, Scribans, et al., 2012; Smith et al., 2013). Although the process underlying this increase in muscle endurance was not investigated in the current study, it is likely that improvements in oxidative capacity typically observed following HIIT in skeletal muscle likely contributed to a decreased PCr breakdown, glycogen turnover, and lactate accumulation and subsequent delays in the development of muscle fatigue (Burgomaster et al., 2006; Gibala et al., 2006; Little et al., 2010).

Furthermore, the subjects in the 3x/week group showed an improvement in *flexibility* on both left (baseline: 72.93°±13.06°, 12 week: 78.86°±15.30°, $p \leq .001$, ES=-0.417) and right (baseline: 74.00°±14.05°, 12 week: 79.71°±14.18°, $p < .004$, ES=-0.405) leg. In the current study stretching was done after each session. In a systematic literature review on the effects of hamstring stretching on range of motion, 28 studies reviewed reported improvements in range of motion (ROM) after stretching (Decoster et al., 2005). On the other hand, in a 12 week HIIT study that measured lower back and hamstring flexibility with the SR test, there were no improvements. It could be because more frequent stretching than three times a week was needed to improve flexibility in these areas (Broadbent et al., 2013).

Mental health. Depression, anxiety and stress scores did not decrease significantly ($p=.500$, $p=.144$, $p=.436$ respectively). Although they did not change significantly, there was a trend towards lower scores in all three measures in the 3x/week group. Previous research has shown that individuals who suffer from mental disorders are unlikely to meet recommended guidelines (Harris & Barraclough, 1998). Therefore time efficient training like HIIT should be suitable for people suffering from depression and anxiety. Perceived enjoyment of and intentions to engage in very low volume, high-intensity, whole-body interval exercise were both increased following training in a recent study (McRae, Payne, Zelt, Scribans, et al., 2012). The effects of HIIT as a treatment of depression has proven to be more effective than low-intensity training in older patients with depression in a study on community-dwelling adults <60 years with major or minor depression. The subjects were randomized into one of three groups, supervised high intensity progressive resistance training (PRT) (80% maximum load) or low intensity PRT (20% maximum load) three days per week for eight weeks, or standard care by a general practitioner (GP) (Singh et al., 2005). In a 12 week HIIT trial on 16 heart transplant recipients depression scores decreased significantly in a HIIT group with no change in patients who did continuous moderate training. Both groups showed improvement in anxiety (Dall et al., in press). Other studies on exercise and wellness indicate that moderate exercise has favourable effects on reducing stress, anxiety, and depression, and enhancing mood and self-esteem (Harvey et al., 2010).

Intragroup differences (Group 2, HIIT 4x/week)

Body composition. The HIIT 4x/week group showed improvement in all variables of body composition except thigh circumference. They were the only group to show improvements in *bodyweight* (baseline: 81.09±20.11 kg, 12 weeks: 79.69±19.08; $p<.029$, ES=0.071). The 4x/week group showed a decrease ($p<0.05$) in *body fat* (baseline: 22.72±6.85%, 12 weeks: 15.81±6.13; $p<.001$, ES=1.063) and in *waist* (baseline: 92.81±14.34cm, 12 weeks: 90.61±13.89, $p<.002$, ES=0.156) and *hip* (baseline: 103.47±8.34cm, 12 weeks: 101.53±8.15, $p<.010$, ES=0.235) *circumference* measures. As mentioned in the discussion for group 1 previous literature on body fat and circumference is consistent with the results of the current study. However, in terms of bodyweight there is little conclusive evidence for more favourable effects on weight loss with HIIT than with continuous moderate-intensity exercise (De Feo, 2013). In the literature only aerobic exercise has solid evidence supporting its efficacy whereas conflicting data regarding the effects of resistance exercise have been produced (Willis et al., 2012). In an eight week protocol, exercising three sessions per week and comparing the effects of aerobic endurance training at different intensities and with different methods matched for total work and frequency there were no group differences on weight loss (Helgerud et al., 2007). Longer studies with individuals possessing moderate elevations in fat mass have resulted in greater weight and fat reduction (Trapp, Chisholm, Freund, & Boutcher, 2008).

Physical fitness. There was a difference in the 500 meter row in the 4x/week group (baseline: 118.22±114.54 s, 12 week: 113.70±14.06, $p<.001$, ES=0.316). Regarding *maximal strength and muscular endurance*, subjects that participated in HIIT four times a week experienced improvement in both 5 RM squat (baseline: 63.75±32.10 kg, 12 week: 73.03±30.69 kg, $p\leq.001$, ES=-0.295) and all variables of muscle endurance, the one minute tests and the strength/stability test performed as maximum seconds in ring hold. All subjects increased the number of repetitions in push ups (baseline: 29.11±7.59 rep, 12 week: 37.56±6.76, $p<.001$, ES=-1.176), pull ups (baseline: 14.55±5.88 rep, 12 week: 26.22±6.95, $p\leq.001$, ES=-1.813) and sit ups (baseline: 28.28±6.66 rep, 12 week: 34.11±4.07, $p<.001$, ES=-1.056) and the time (seconds) in the stability strength test (baseline: 26.72±15.71 s, 12 week: 42.94±16.73, $p\leq.001$, ES=-0.990). These results are in line with studies that have found four sessions of HIIT per week to positively effect increases in muscle endurance. A study on young women observed increases for leg extensions, chest presses, push ups, sit ups, and back extensions in a HIIT group were significantly greater than the changes in both the control and endurance groups (McRae, Payne, Zelt, Scribbans, et al., 2012).

Flexibility improved in the 4x/week group on both left (baseline: 78.33°±8.06°, 12 week: 84.17°±8.02°, $p \leq .001$, ES=-0.726) and right (baseline: 79.22°±8.58°, 12 week: 85.50°±8.71°, $p \leq .001$, ES=-0.726) leg. As mentioned in the discussion for group 1, stretching increases the range of motion and flexibility. Previous literature suggests that flexibility enhances in a linear relationship with stretching, i.e. more stretching increases the flexibility and range of motion (ROM) (Broadbent et al., 2013; Decoster et al., 2005). An eight week program, exercising four days a week, of combined group-based HIIT and conventional training improved various physical fitness parameters including flexibility (Giannaki et al., 2015).

Mental health. Depression, anxiety and stress scores did not decrease significantly ($p=.176$, $p=.303$, $p=.793$ respectively). The reason is most likely the same as in group 1 that the scores were low at baseline and hard to improve.

Intragroup differences (Group 3, HIIT 5x/week)

Body composition. The results of the HIIT 5x/week group were in line with the results of the other groups and previous HIIT studies regarding body fat and circumference measures. Subjects in the HIIT 5x/week group showed a decrease in *body fat* (baseline: 23.94±8.45%, 12 weeks: 17.43±6.70; $p<.001$, ES=0.854) and in *waist* (baseline: 92.63±14.20cm, 12 weeks: 90.58±12.82, $p<.031$, ES=0.152) and *hip* (baseline: 103.50±9.47cm, 12 weeks: 102.25±8.78, $p<.042$, ES=0.137) *circumference* measures. Previous studies show that HIIT is indeed a very time-efficient strategy to induce reduction in waist circumference, total, abdominal, trunk, and visceral fat and significant increases in fat free mass normally associated with endurance training (Heydari et al., 2012; Talanian et al., 2007; Trapp et al., 2008).

Physical fitness. There was a difference in the 500 meter row in the 5x/week group (baseline: 121.67±113.86 s, 12 week: 115.11±10.09s, $p<.005$, ES=0.541). Previous studies indicate that some minimum volume or duration of training may be a key feature in the benefits related to HIIT. Studies in clinical populations have shown that higher volume HIIT programs using longer intervals lead to greater improvements in VO_{2max} when compared with CME of equal volume and time commitment (Guiraud et al., 2012). The 5x/week group improved their scores in *maximal strength and muscular endurance* compared to their baseline values. Subjects that participated in HIIT five times a week experienced improvement in both 5 RM squat (baseline: 53.64±19.25 kg, 12 week: 62.05±21.12 kg, $p\leq.001$, ES=-0.416) and the one minute tests of muscle endurance, push ups (baseline: 28.75±6.50 rep, 12 week: 35.58±6.61, $p<.002$, ES=-1.042), pull ups (baseline: 13.25±6.18 rep, 12 week: 23.25±6.37 rep, $p\leq.001$, ES=-1.593) and sit ups (baseline: 28.17±5.89 rep, 12 week: 34.42±6.23, $p<.004$, ES=-1.031). The results are corresponding with previous literature which suggests that gains in strength and power result from high intensity and low volume training (Hiseada, Miyagawa, Kuno, Fukunaga, & Muraoka, 1996). A recent HIIT study demonstrated that although improvements in cardiovascular fitness are induced by both endurance and extremely low volume interval-style training, whole-body aerobic–resistance training imparted additional benefits in the form of improved skeletal muscle endurance (McRae et al., 2012).

The *flexibility* measures in the 5x/week group improved considerably on both left (baseline: 75.18°±14.84°, 12 week: 82.18°±13.72°, $p \leq .001$, ES=-0.490) and right (baseline: 73.09°±17.97°, 12 week: 81.45°±15.55°, $p \leq .001$, ES=-0.496) leg. Although there was no statistical difference between groups HIIT 4x/week and 5x/week had a greater effect size. Since stretching was done after each session, it comes as no surprise that the groups who had more sessions each week showed greater improvement (Broadbent et al., 2013; Decoster et al., 2005).

Mental health. Depression, anxiety and stress scores did not decrease significantly (p=.379, p=.623, p=.166 respectively). As with the other groups the scores at baseline were low and hard to improve.

Intergroup differences

The results did not show any difference between groups. The current study indicated that the bodyweight and resistance HIIT program examined improved the same in each group. The findings demonstrate that when it comes to bodyweight and resistance HIIT, four or five sessions a week do not provide additional benefits when compared with three times a week. Our study therefore supports previous literature that states that a growing body of evidence demonstrates that HIIT can serve as an effective alternative to traditional endurance-based training, inducing similar or even superior physiological adaptations in healthy individuals and diseased populations, at least when compared on a matched-work basis (Gibala 2012). The findings furthermore underscore the recent interest in HIIT as an alternative to continuous aerobic exercise in adults, mainly because it is perceived as a time efficient method to achieve the health benefits of exercise. Since lack of time has often been cited as a key barrier to exercise participation, HIIT is an excellent way to maximize your health with minimal time (Gibala, 2007).

As for the improvement in flexibility, all groups benefited from the stretching performed in the end of each HIIT session and those who had more sessions stretched more often which should result in more flexibility (Decoster et al., 2005). Furthermore, it has been confirmed that high-intensity strength training can lead to significant improvements in flexibility, perhaps because during resistance training the range of mobility increases, as the exercises use the whole range of movements permitted by the joints, both agonistic and antagonistic muscles being involved (Kalapotharakos, Smilios, Parlavatzas, & Tokmakidis, 2007).

Wherein progress seems to happen to a large extent during rest, it is important to find out the appropriate rest and recovery time for individuals engaged in HIIT (Kilpatrick et al., 2014). Since the improvements of the 4x and 5x/week session groups were not significantly greater than of those who pursue HIIT three sessions a week, perhaps the fourth and fifth session a week in exercise programming should rather be used for recovery purposes, like flexibility or exercises at low to moderate intensities to aid recovery and prevent injuries often linked with HIIT (Thompson, 2014; Watsford et al., 2010). HIIT pushes the body hard, so it is important to be fully recovered between sessions and the literature agrees with our findings. Studies commonly show that three HIIT sessions per week may produce the best results while limiting injury (Daussin et al., 2008; Helgerud et al., 2007; Musa et al., 2009; Perry et al., 2008).

The results of the current study showed no difference in mental health measurements tested with the DASS questionnaire. It can be taken into consideration that the scores in the current study were very low at baseline in all three groups and therefore hard to improve. Furthermore, the sample size was small and if there had been more participants it is possible that the change in depression, anxiety and stress could have reached a statistical significance. There was a trend towards lower scores in depression and stress in all three groups and in anxiety in the HIIT 3x/week group and HIIT 5x/week group. Although not statistically significant the improvements were the greatest for those doing 5 HIIT sessions a week.

Limitations

A number of limitations of this study need to be borne in mind. First, the small sample size in each group. A total of 45 people of the 54 who started completed the study but only 12 people in the 5x/week group. Second, we did not record other daily physical activity performed by each subject during the program and also we did not control nutritional habits during the intervention program. If the daily physical activity and nutritional habits had changed, maybe it could have affected the results. Third, nine subjects dropped out of the study. A total of three subjects, one from each group discontinued due to pre-existing injury. Therefore the number of HIIT sessions a week did not affect the injury rate in this study. All three subjects had a medical history of injuries prior to participating in the study. This information was gathered in the first meeting and their withdrawal was decided with the researcher. Fourth, in retrospect the researcher would have liked to use more than one means to measure endurance in the current study, for example the Cooper 12 minute run (Cooper, 1968) that can easily be used in a group setting and measures VO_{2max} because various factors can affect the progress of the rowing test such as improved technique and increased strength. Finally, another factor that may have affected the results is that on the Friday sessions there was a focus on olympic lifting or running and only a short HIIT bout at the end of the session and in the Sunday sessions there was no weigthlifting. The three sessions that all three groups participated in on Mondays, Wednesdays and Thursdays always included HIIT and sometimes strength training.

Conclusions

The conclusions that may be drawn from this study are:

1. In a 12 week program consisting of bodyweight and resistance high-intensity interval training with three sessions per week, healthy adults achieved improvements on body fat, circumferences (waist and hip) and physical fitness (all variables). On the other hand, the program did not achieve improvements in mental health status. With only three one hour sessions a week a healthy adult can experience many of the health benefits of exercise. Since it is time-efficient and an effective means of accruing health benefits it is likely that a large part of the public will find HIIT a feasible option to use for exercise. Hopefully this will lead to less inactivity among the public and reduce the economic burden associated with an inactive lifestyle.
2. The same program with four sessions per week achieved improvements on bodyweight, body fat, circumferences (waist and hip) and physical fitness (all variables). On the other hand, the program did not achieve improvements in mental health status. This group showed all the same improvements as the 3x/week group but was the only group to show a difference in bodyweight.

This might be because this group had the largest sample and therefore it was easier to measure significant differences.

3. The same program with five sessions per week achieved improvements on body fat, circumferences (waist and hip) and physical fitness (except stability/strength). On the other hand, the program did not achieve improvements in mental health status. This group showed the least statistical difference and as discussed earlier that might be because of the small sample size.
4. There was no difference in advances by weekly frequency (three, four or five sessions) of training on any variables (body composition, physical fitness and mental health). The reason for the lack of difference between the groups might be because progress seems to happen to a large extent during rest and those who had four or five bodyweight and resistance HIIT sessions a week had less time to recover. As previously discussed it is important to be fully recovered between sessions to accrue the health benefits of HIIT. Therefore it might be a good addition to an exercise program with HIIT to utilize the remaining sessions for agility training and recovery.

Future researches

Despite the small sample, the results from the current study provide a good indication of the impact of bodyweight and resistance HIIT on healthy adults and the preferable weekly training frequency. The results can be used as a guideline for health care practitioners and fitness consultants to provide practical, evidence-based recommendations for novel exercise prescription that can easily be incorporated into daily living for the general population. More research is needed on the effects of HIIT on the healthy adults and future research should use larger samples, have more precise measurements and even have a control group and/or a group that engages in continuous moderate exercise to compare the health related improvements. Finally it would be interesting to examine the long-term effects of HIIT, so further studies should focus on longer programs.

The researchers find it interesting that in all groups there was no derease in thigh circumference despite weight loss and decrease in body fat waist and hip circumference and in some cases the average value increased slightly although not nearly enough to achieve statistical significance. Based on the results of a study examining compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations, the investigators concluded that combining high-intensity resistance and aerobic training further enhances skeletal muscle size in comparison to resistance training alone (Kraemer et al., 1995). A classical study (Fiatarone et al. 1990) concluded that high-resistance weight training leads to significant gains in muscle strength, size, and functional mobility among frail residents of nursing homes up to 96 years of age. Since the bodyweight and resistance HIIT program in the current study includes weightlifting and other strength training it is not surprising that thigh circumference increased in 12 weeks. The increase in thigh circumference was similar in all groups and researchers speculate that the reason might be that although the frequency of HIIT varied between groups the strength training was mostly done on the three days that all groups had sessions.

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5 Appendices

Appendix A

Six weeks of the bodyweight and resistance HIIT program used in the current study. (Week 1, 3, 5, 7, 9, and 11). As a reminder: All three groups had sessions on Mondays, Tuesdays and Thursdays. Group 2 (4x/week) had extra sessions on Fridays or Sundays and group 3 (5x/week) had session on all five days.

Week 1	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	General warm up	General warm up and mobility of shoulders and hips	General bodyweight warm up, long duration.	Dynamic warm up to prepare for run or the Burgener warm up with empty barbell for Olympic lifting	General warm up
Skills or strength	7x3 *Hang power clean & jerk* Technique training with light loads. Hang power clean, split jerk	3x5 *Benchpress*, 90% of 5RM 3x3 *Deadlift*. Lift every 3 min with 80-90% of 5 RM		4x3@70% *Snatch* 6x3@70-80% 1RM, 2+1 *C&J* (2 clean, 1 jerk) 5x5 *Snatch Pull*	
Bodyweight and resistance HIIT	*For time 10-9-8-7-6-5-4-3-2-1 of:* Musclesnatch w. dumbbell, (20/12,5kgs) Heavy kettlebell swing (to eye level) Burpees	*As many rounds as possible in 2 min (AMRAP2):* Muscle ups or pull ups. Rest 1 min *AMRAP2* Double unders Rest 1 min *AMRAP2* Wall ball	*As many rounds as possible in 15 min (AMRAP 15)* 10 m Lunge w. 15/10 kg plate overhead 20 tire jumps 10 push press 40/25 kg Extra: 5 burpees every time weights are dropped.	Or running 8 rounds of stair run (190 steps) as fast as possible up and slowly down. 1 min rest between rounds	*Kelly* 5 rounds for time: 450m run 30 box jumps 30 wall ball or *Cindy* AMRAP 20 5 pull ups 10 push ups 15 air squats
Cool down/ stretching	5-10 minute stretching	5-10 minute stretching	5-10 minute stretching	5-10 minute streching. Calves and thighs especially.	5-10 minute stretching

Week 3	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	General warmup with mobility	10 min general warm up and then specific warm up for calves and hamstrings to prepare for sprints	10 min general warm up	10 min general warm up. 10 min Burgener warm up with PVC and empty barbell	10 min general warm up
Skills or strength		10 x 50m *sprints* with 1 min rest between each sprint. Technique: Practice toes to bar. Kettlebell (KB) warm up for workout	*Turkish getup* (TGU) technique. TGU - 15 min to find 3RM (right & left) Starts lying down and ends after 3 repetitions lying down again.	20 min ~8x2 @ 65-95% 1RM of *Snatch.* 90 sec rest between sets. 3x3 *Push Press* 3x3 *Push Jerk* 1x5 *Clean Pull*	
Bodyweight and resistance HIIT	For time: * Run 450m/ 50 sit-ups / 50 push ups, run 900m/ 40 sit-ups / 40 push ups, run 1350m/ 30 sit-ups/ 30 push ups, run 1800m/ 20 sit-ups/ 20 push ups, run 2250m/ 10 sit-ups / 10 push ups *scaling options: shorter run and/or fewer repetitons (reps)	As many rounds as possible (*AMRAP*) in 12 minutes of: 10 box jumps 60/50 cm 10 Toes to bar or 15 hanging leg raises 10 Kettlebell swings to eye level	Team workout 2 males + 2 females For time: 50/35/25 repetitions Backsquat/Front-squat/Over-head squat. Pull ups Shoulders to overhead with bar. Males: 40/30/20 kg* Females: 25/20/10 kg* First women then men, bar can not touch floor during workout. Men can be a „rack" for the ladies and vice versa. *use lighter loads for everyone with unsufficient technique	Or Running: ~~3 x~~ 1800m, rest for 3 min. Start at a good pace and try to increase speed (20-30 sec) in every round.	As many rounds as possible (*AMRAP*) in 20 minutes of: a) Run 300m b) Burpees with jump (8 meters). c) 20 Frontsquats with kettlebell (20/12kgs) d) 20 push press/jerk with kettlebell 20/12kgs e) 20 push ups f) Burpees with jump back to start.
Cool down/ stretching	5-10 min stretching	Stretching and mobility	5-10 min streching	5-10 minute streching	5-10 minute streching

Week 5	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	10 min general warm up	10 min general warm up	10 min warm up and whole body mobility	10 min Burgener warm up, with PVC pipe and empty barbell.	10 min general warm up and active playing
Skills or strength	*5x5 weighted pull ups*, tempo 3-0-1-0 (i.e. 3 sec on the way down) *5x5 Push press,* tempo 3-0-1-0 (i.e. 3 sec on the way down) Alternate between exercises with approx. 1 min rest between sets. Weight in pus press should be about 70% of 1RM.	*5x5squat*. Find 5RM Use break for shoulder mobility and practice the pull up swing	Practice technique and standards in wall ball, sumo deadlift high pull and push press.	6x2@90% of 1RM *Clean & Jerk* 5x3 *Snatch Balance* 3x6 *Romanian deadlift* (RDL)	
Bodyweight and resistance HIIT	*Chipper in pairs*: 80 squats 70 sit ups 60 KB swings 50 push ups 40 burpees 30 jump over and crawl under each other	*Helen* 3 rounds for time: 450m run 21 KB swings (24/16 kg) 12 pull ups	*Fight gone bad* Three rounds of: (1 min rest between rounds) Wall-ball, 8-20 pound WB to 9-10 ft target (Reps) Sumo deadlift high-pull, w. KB (Reps) Box Jump, 50/60cm box (Reps) Push-press, 25/15 kg (Reps) Row (Calories)	*Annie* 50/40/30/20/10 Double unders and Sit ups	4 together in a team complete the following:* 300 squats 450 m run 250 Double unders 450 m run 200 KB swings 450 m run 150 push ups 450 m run 100 burpees 450 m run *One at a time does exercises and everyone runs at the same time.
Cool down/ stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching

Week 7	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	10 min general warm up	10 min general warm up and mobility of the hips	10 min general warm up	5 min general warm up 10 min Burgener warm up, with PVC pipe and empty barbell.	Long warm up. Group fun.
Skills or strength	Skills: Swing in pull ups (kipping) and handstand push ups (HSPU) and handstand. Rule: If you can do a pull up in a band, you can practice the swing in that band. In the HSPU. Be careful, use two spotters if necessary. In handstand: activate shoulders and rotate arms out.	*Heavy squat* 3x5, 2x3 and 1x1 Rest 60-120 sek between sets.	Core strength: Plank and hollow	7x3 *Hang power clean & jerk* Skills: light Hang power clean, split jerk	
Bodyweight and resistance HIIT	EMOM 20 (Every minute on the minute for 20 min) 5 burpees 10 KB-swings to eye level, (16/12kg) If you do not finsh on the minute you rest until the next min starts and do fewer reps next minute (4/8 or 3/6)	AMRAP 8 12 box jump (60/50 cm) 4+4 Clean and jerk with KB (20/12kg) Two and two together, with one box and one KB.	*Tabata* 8 rounds each exercise 20 sec on/10 off, 1 min rest between exercises Rowing Push ups Air squats Pull ups Sit ups	500m row for time (all out effort)	Workout in soccerfield: Burpees w. jump (half field) walking lunges back 20 KB press (r/l) 20 KB swings Sprint over field 20 sit ups 20 push ups Sprint back Work 7 min 2 min rest Work 5 min 2 min rest Work 3 min
Cool down/ stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching

Week 9	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	10 min general warmup with mobility	General warm up and mobility of hips	General warm up and burgener warm up	Mobility exercises for olympic lifting	General warm up, with bodyweight exercises.
Skills or strength	3RM *Shoulder press*, 10 minutes to find the 3RM (repetition maximum)	5x5 *Front squat*. Heavy	Technique: *Power clean*	Mobility for rack and overhead position. Jerk technique (footwork, speed under bar, recovery). Power clean and jerk, work on technique, up to 60-70% of 1RM	
Bodyweight and resistance HIIT	*10 rounds for time:* 5 pull ups 10 push ups 15 air squats max: 15 min	*A chipper*: 500 m row 20 pull ups 20 push ups 20 KB swings (to eye level) 24/16kg 20 Sumo deadlift high pull (SDLHP) 24/16 kg 50 Double unders	*4 rounds for time*: 20 wall ball 20 box jumps 20 sit ups with an abmat	Complete as many burpees as possible in 7 minutes	Max 30 min to finish 300/400 points (reps) Exercises: 1p = 1 Rep Running/rowing: 25 p = 450m, 15 p = 300m Hold position: 1p = 1 sec Jump rope: 1p = 3 Rep Exercises to choose from: Push ups, air squats, high knee lifts, burpees, pull ups, lunges, running, rowing, jump rope, handstand, hollow, ring hold. * max 50 reps per exercise * 100% quality of movements.
Cool down/ stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching	5-10 min stretching

Week 11	Monday	Wednesday	Thursday	Friday	Sunday
Warm up	10 minute general warm up and mobility	5-10 min general warm up	10 min KB warm up with windmill/ TGU/ Lunges /swings/ squats and more	5 min general warm up, mobility and 5 min Burgener warm up.	General warm up
Skills or strength	4x5 *Bench press* 10 x ring row, 3 sec on the way down. Rest 90-120 sec between sets.	3x3 *Shoulder press* 3x3 *Push press*	A: 3 rounds of: Heavy one legged squat (6 on each leg). 15 KB swings (to eye level), Push heavy sled (70/50kg) 10 m. Rest 2 min between rounds. B: 3 rounds of: ring dips (tempo 30X0, i.e. 3 sec on way down). 10 Pull ups (tempo) 30X0 Side plank 30 sec on each side Rest 2 min between rounds	Snatch technique with barbell. Every 90 seconds for 15 min (10 sets) 2 x *Snatch* (NOT touch and go) 1: @ 60% 1 RM Snatch 2: @ 65% 3: @ 70% 4: @ 75% 5 and 6: @ 80% 7 and 8: @ 85% 9 and 10: @ 85-90%	
Bodyweight and resistance HIIT	Benchmark workout: 3 rounds for time: 150 jump rope, 15 push ups, 20 box jumps (60/50 cm) and 25 airsquats.	AMRAP 10 15 Wall ball 15 sit ups Two and two together, not in the same exercise	AMRAP5 Double unders (reps) or running (m)	Or 4 x 800m run (with 2 min rest between sets).	5x AMRAP 3 Buy in: 10 Goblet Squats 20 Clean & Jerk w. KB 10 KB-swings max rep burpees what is left of 3 min. Score: total burpees after 5 rounds.
Cool down/ stretching	5-10 minute stretching	5-10 minute stretching	5-10 minute stretching	5-10 minute stretching	5-10 minute stretching

Appendix B –The questionnaire used in the current study.

DASS

Name: *Date:*

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1	I found myself getting upset by quite trivial things	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I just couldn't seem to get going	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I had a feeling of shakiness (eg, legs going to give way)	0	1	2	3
8	I found it difficult to relax	0	1	2	3
9	I found myself in situations that made me so anxious I was most relieved when they ended	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting upset rather easily	0	1	2	3
12	I felt that I was using a lot of nervous energy	0	1	2	3
13	I felt sad and depressed	0	1	2	3
14	I found myself getting impatient when I was delayed in any way (eg, lifts, traffic lights, being kept waiting)	0	1	2	3
15	I had a feeling of faintness	0	1	2	3
16	I felt that I had lost interest in just about everything	0	1	2	3
17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3
19	I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life wasn't worthwhile	0	1	2	3

Reminder of rating scale:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

22	I found it hard to wind down	0	1	2	3
23	I had difficulty in swallowing	0	1	2	3
24	I couldn't seem to get any enjoyment out of the things I did	0	1	2	3
25	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3
26	I felt down-hearted and blue	0	1	2	3
27	I found that I was very irritable	0	1	2	3
28	I felt I was close to panic	0	1	2	3
29	I found it hard to calm down after something upset me	0	1	2	3
30	I feared that I would be "thrown" by some trivial but unfamiliar task	0	1	2	3
31	I was unable to become enthusiastic about anything	0	1	2	3
32	I found it difficult to tolerate interruptions to what I was doing	0	1	2	3
33	I was in a state of nervous tension	0	1	2	3
34	I felt I was pretty worthless	0	1	2	3
35	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
36	I felt terrified	0	1	2	3
37	I could see nothing in the future to be hopeful about	0	1	2	3
38	I felt that life was meaningless	0	1	2	3
39	I found myself getting agitated	0	1	2	3
40	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
41	I experienced trembling (eg, in the hands)	0	1	2	3
42	I found it difficult to work up the initiative to do things	0	1	2	3

Appendix C - The information letter provided to the in the participants in the study.

Kynningarbréf

Kæri viðtakandi

Um þessar mundir stendur yfir undirbúningur að rannsókn á æskilegri þjálfunartíðni há-ákefðarþjálfunar (high intensity interval training). Rannsóknir benda á marga kosti há-ákefðarþjálfunar en það er lítið um rannsóknarniðurstöður sem gefa vísbendingu um æskilega vikulega þjálfunartíðni há-ákefðarþjálfunar fyrir heilbrigða fullorðna einstaklinga. Þær almennu ráðleggingar sem hafa verð gefnar út varðandi hreyfingu almennings eiga í flestum tilvikum við þjálfun af lágri til miðlungs ákefð. Markmið þessarar rannsóknar er að kanna samband æfingatíðni (fjöldi æfinga á viku) há-ákefðarþjálfunar og líkamlegra framfara þátttakenda. Niðurstöðurnar gefa vísbendingu um æskilega þjálfunartíðni slíkrar þjálfunar fyrir blandaðan hóp heilbrigðra fullorðinna einstaklinga (almennings).

Rannsakendur:
Rannsóknin er meistaraverkefni Erlu Guðmundsdóttur í íþróttavísindum og þjálfun við Háskólann í Reykjavík og er rannsóknin unnin í samvinnu við Atgerviseflingu ehf, rekstraraðila CrossFit Sport. Leiðbeinandi hennar og ábyrgðarmaður rannsóknarinnar er Pétur Sigurðsson, lektor við Háskólann í Reykjavík. Netfang: petursr@ru.is. Aðstoðarleiðbeinandi rannsóknar er dr. Leifur Geir Hafsteinsson, eigandi Atgerviseflingar ehf.

Markmið
Markmið rannsóknarinnar er að komast að æskilegustu æfingatíðni há-ákefðarþjálfunar fyrir almenning til að hámarka líkamlegar framfarir.

Aðferðir
Bera á saman niðurstöður mælinga við upphaf, miðbik og lok þjálfunartímabilsins (12 vikur) og kanna hvort marktækur munur sé á milli hópa sem æfa þrisvar, fjórum eða fimm sinnum í viku. Spurningalisti um heilsutengd lífsgæði verður lagður fyrir og bornar saman niðurstöður til að kanna hvort þjálfunin sé að skila sér í betri heilsutengdum lífsgæðum. Holdafarsmælingar (þyngd, ummál og fituprósenta fyrir og eftir þjálfun verða svo einnig bornar saman.

Rannsóknargögnin munu innihalda eftirfarandi mælingar og upplýsingar: Kyn, aldur, æfingasögu, holdafarsmælingar (þyngd, ummál og fituprósentu), fjölbreyttar líkamlegar mælingar á úthaldi, styrk, sprengikrafti og liðleika og niðurstöður úr spurningalista um heilsutengd lífsgæði. Gera má ráð fyrir að útfylling spurningalista og viðtal taki á bilinu 5-10 mínútur.

Úrtakið verður karlar og konur á aldrinum 18-60 ára sem lokið hafa a.m.k. 4 vikna grunnþjálfun hjá Atgerviseflingu þegar mælingar hefjast.

Persónuöryggi
Við vörslu persónuupplýsinga verður ítrustu öryggisráðstafana gætt og kemur nafn þátttakenda hvergi fram við úrvinnslu eða birtingu rannsóknarinnar. Farið verður með allar upplýsingar sem trúnaðarmál. Þannig fær hver þátttakandi sérstakt kóðanúmer sem rannsóknargögnin verða merkt með. Lykillinn að kóðanum verður í læstri hirslu ábyrgðarmanns rannsóknarinnar, nánar tiltekið í

Háskólanum í Reykjavík. Þátttakandi getur á hvaða stigi rannsóknarinnar sem er hætt við þátttöku, líka eftir að öllum gögnum hefur verið safnað. Gögnum viðkomandi verður þá samstundis eytt. Öllum rannsóknargögnum verður eytt eftir 5 ár.

Áhætta
Þátttaka í hvers kyns líkamsrækt felur í sér einhverja áhættu á meiðslum. Eftir því sem best er vitað eru engar áreiðanlegar tölur til um meiðslatíðni í há-ákefðarþjálfun og því erfitt að leggja mat á það hvort þátttakendur í tilrauninni taki meiri eða minni áhættu en gengur og gerist meðal iðkenda í líkamsrækt.

Við höfum enga ástæðu til að ætla að þátttakendur í þessari rannsókn taki meiri áhættu en gengur og gerist með ástundun annars konar líkamsræktar. Það má meira að segja færa rök fyrir því að þátttakendur búi að einhverju leyti við minni áhættu, þar sem þátttakendur eru undir reglulegu eftirliti rannsakenda, þeir hafa aðgang að rannsakendum Erlu og Leifi Geir meðan á rannsókn stendur og njóta því umtalsvert meiri þjónustu og sérfræðiþekkingar en hinn almenni líkamsræktarneytandi sem kaupir sér aðgang að líkamsræktarstöð.

Til þess að gera iðkendur meðvitaða um ábyrgð sína og áhættuna við há-ákefðarþjálfun skrifa iðkendur hjá Atgerviseflingu undir samning þar sem meðal annars kemur fram að: *Undirrituð/aður tekur þátt í líkamsþjálfun hjá Atgerviseflingu algerlega á eigin ábyrgð, meðvituð/aður um að hvers kyns líkamsrækt getur valdið meiðslum og jafnvel slysum. Þátttakendur í rannsókninni eru ekki sérstaklega tryggðir á vegum rannsakenda eða Atgerviseflingar.*

Ávinningur
Þátttakendur munu fá auknar upplýsingar um stöðu á líkamlegri heilsu og andlegri líðan sem og líkamlegri afkastagetu sem vonandi verður til hvatningar. Að auki fá þátttakendur í rannsókninni afslátt af mánaðargjaldi. Þeir greiða mánaðargjald sem jafngildir 12 mánaða binditíma en eru aðeins samningsbundnir í 3 mánuði.

Eins og áður hefur verið tilgreint mun farið með allar upplýsingar sem trúnaðarmál og mun aðgangur fólks að útskrifuðum gögnum einskorðast við rannsóknarhópinn.
Mikilvægi þessarar rannsóknar er ótvírætt til að meta árangur þjálfunarinnar. Með henni safnast dýrmætar upplýsingar sem gagnast fagfólki og almenning við endurmat á þjálfuninni.

Rannsóknin hefur verið tilkynnt til Persónuverndar og sótt hefur verið um leyfi frá Vísindasiðanefnd fyrir framkvæmd hennar.

Hafir þú spurningar um rétt þinn sem þátttakandi í vísindarannsókn eða vilt hætta þátttöku í rannsókninni getur þú snúið þér til Vísindasiðanefndar, Hafnarhúsinu v/Tryggvagötu, 2. hæð, 101 Reykjavík. Sími: 551-7100, fax: 551-1444.

Með þökk og kærri kveðju,

____
Pétur Sigurðsson, lektor við Háskólann í Reykjavík
Sími: 825-6343. Netfang: peturs@ru.is

____
Erla Guðmundsdóttir, meistaranemi í Íþróttavísindum og þjálfun við Háskólann í Reykjavík
Sími: 615-2121. Netfang: erla@crossfitsport.is

____
Dr. Leifur Geir Hafsteinsson, eigandi Atgerviseflingar ehf.
Sími: 773-1212. Netfang: leifurgeir@crossfitsport.is

Appendix D- Informed consent form for the participants in the study.

HÁSKÓLINN Í REYKJAVÍK
REYKJAVIK UNIVERSITY

CrossFit Sporthúsinu

Ákjósanleg æfingatíðni há-ákefðarþjálfunar fyrir heilbrigða fullorðna einstaklinga. (Optimal training frequency in high-intensity intermittent exercise for healthy adults.)

Samþykkisyfirlýsing fyrir þátttakendur

Ég staðfesti hér með undirskrift minni að ég hef lesið kynningarbréf um rannsóknina sem mér var afhent, hef fengið tækifæri til að spyrja spurninga um rannsóknina og fengið fullnægjandi svör og útskýringar á atriðum sem mér voru óljós. Ég hef af fúsum og frjálsum vilja ákveðið að taka þátt í rannsókninni og samþykki notkun á gögnum um mig sem safnað verður á meðan á rannsókn stendur og tilgreind eru á kynningarbréfinu.

Ávinningur og/eða áhætta samfara rannsókninni hefur verið útskýrð fyrir mér. Mér er ljóst að ég get hvenær sem er dregið þátttöku mína í rannsókninni til baka án útskýringa eða eftirmála. Farið verður með allar upplýsingar sem trúnaðarmál og þær verða ekki persónugreinanlegar í neinum niðurstöðum.

Mér er ljóst að rannsóknargögnum verður eytt að rannsókn lokinni og eigi síðar en eftir 5 ár frá úrvinnslu rannsóknargagna.

Rannsóknin hefur verið tilkynnt til Persónuverndar og sótt hefur verið um leyfi til Vísindasiðanefndar.

____
Staður og dagsetning

____ ____________________
Nafn þátttakanda Kennitala

Undirritaður, starfsmaður rannsóknarinnar, staðfestir hér með að hafa veitt upplýsingar um eðli og tilgang rannsóknarinnar, í samræmi við lög og reglur um vísindarannsóknir.

____
Nafn þess sem leggur samþykkisyfirlýsinguna fyrir

Framkvæmdaaðili:
Erla Guðmundsdóttir, meistaranemi HR.
Sími: 615-2121. Netfang: erla@crossfitsport.is

Ábyrgðarmaður:
Pétur Sigurðsson, lektor við HR
Sími: 825-6343. Netfang: peturs@ru.is

Appendix E- Letter of approval from the National Bioethics Committee of Iceland

VÍSINDASIÐANEFND

Hafnarhúsið, Tryggvagata 17
101 Reykjavík,

Sími: 551 7100, Bréfsími: 551 1444

netfang: visindasidanefnd@vsn.stjr.is

Pétur Sigurðsson, ábyrgðarmaður rannsóknar
Fjarðarási 20
110 Reykjavík

Reykjavík 3. apríl 2012
Tilv.: VSNb2012020016/03.7

Efni: Varðar: 12-044-S1 Ákjósanleg æfingatíðni há-ákefðarþjálfunar fyrir heilbrigða fullorðna einstaklinga.

Vísindasiðanefnd þakkar svarbréf þitt, vegna áðursendra athugasemda við ofangreinda rannsóknaráætlun sbr. bréf nefndarinnar dags. 21.02.2012. Í bréfinu koma fram svör og skýringar til samræmis við athugasemdir Vísindasiðanefndar og því fylgdu endurbætt gögn.

Fjallað var um svarbréf þitt og önnur innsend gögn á fundi Vísindasiðanefndar 03.04.2012.

Rannsóknaráætlunin er endanlega samþykkt af Vísindasiðanefnd.

Vísindasiðanefnd bendir rannsakendum vinsamlegast á að birta VSN tilvísunarnúmer rannsóknarinnar þar sem vitnað er í leyfi nefndarinnar í birtum greinum um rannsóknina. Jafnframt fer Vísindasiðanefnd fram á að fá send afrit af, eða tilvísun í, birtar greinar um rannsóknina. Rannsakendur eru minntir á að tilkynna rannsóknarlok til nefndarinnar. Áréttað er að allar fyrirhugaðar breytingar á þegar samþykktri rannsóknaráætlun þurfa að koma inn til nefndarinnar til umfjöllunar. Jafnframt ber ábyrgðarmanni að láta stofnanir, sem veitt hafa leyfi vegna framkvæmdar rannsóknarinnar eða öflunar gagna vita af fyrirhuguðum breytingum.

Með kveðju,
f.h. Vísindasiðanefndar,

dr. med., Björn Rúnar Lúðvíksson, læknir, formaður