Monica Sinke

Effect of one year of exercise training on sedentary time and total energy expenditure in older adults

Masteroppgave i Physical Activity and Health
Veileder: Dorthe Stensvold
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Masteroppgave

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Infographic poster

Abstract

Background:

Prolonged sedentary time is an independent risk factor for morbidity and increases the risk of functional decline as people age. Therefore, initiatives that increase physical activity and reduce sedentary time have been highlighted as one important strategy to reduce the number of years with disabilities. This study examines the effect of one year of supervised exercise with high-intensity interval training (HIIT) or moderate-intensity continuous training (MICT) and a control group on sedentary time in older adults. Further, this study aims to evaluate if there are group differences in total energy expenditure (TEE) after one year of exercise.

Method and results:

The present study includes a total of 77 participants (37 women) (aged 71.6±1.3 years). Physical activity was measured with objective measurement using the SenseWear activity monitor. The participants in HIIT were asked to participate in two training sessions per week, consisting of 4x4 intervals with heart rate at 90% of peak heart rate (HR_{peak}); MICT participated in two training sessions per week with a continuous training lasting 50 minutes per session with a heart rate of 70% of HR_{peak}; while the control group were asked to exercise according to the guidelines in Norway per 2012 which advise 30 minutes physical activity almost every day.

There was no significant difference between groups in ST after one year of the intervention. However, ST after one year significantly increased from baseline to one year in HIIT (1084±146 and 1313±94 respectively), MICT (1094±126 and 1340±61), and control group (1131±130 and 1346±71, respectively). There was no significance within or between groups in TEE after the intervention.

Conclusion:

The present study gives insight into sedentary behaviour of older adults. Sedentary time increased from baseline to one year in all groups. Thus, our data indicate that introducing exercise may increase sedentary time in older adults.

Sammendrag

Bakgrunn:

Langvarig stillesittende tid er en uavhengig risikofaktor for morbiditet og øker risiko for funksjonsnedsettelse etter som mennesker blir eldre. Intervensjoner som tar sikte på å øke fysisk aktivitet og redusere stillesittende tid har blitt sett på som en av de viktigste strategier for å redusere antall år med nedsatt funksjoner. Denne studien har som mål å evaluere effekten av et års strukturert høy-intensitets intervalltrening (HIIT) versus moderat-intensitets kontinuerlig trening (MICT) i forhold til en kontroll gruppe på stillesittende tid hos eldre voksne. Videre, evaluering av totalt energiforbruk (TEF) etter et års intervensjon.

Metode og resultat:

Totalt 77 eldre voksne (37 kvinner), (71.6±1.3 år ved inklusjon), deltok i studien hvor deltakerne ble tilfeldig randomisert til veiledet trening eller kontroll gruppe. Fysisk aktivitet ble målt objektivt ved bruk av aktivitetsklokken SenseWear. Deltakerne i HIIT ble instruert til å gjennomføre to treningsøkter pr. uke som bestod av 4x4 intervaller ved makspuls på 90% av maksimal hjertefrekvens; MICT gruppen gjennomførte to treningsøkter pr. uke på 50 minutter kontinuerlig trening med en puls tilsvarende 70% av maksimal hjertefrekvens; mens kontrollgruppen ble bedt om å trene i henhold til retningslinjene i Norge for 2012 angående fysisk aktivitet som adviserer 30 minutter av daglig fysisk aktivitet.

Det var ingen signifikante forskjeller mellom de ulike gruppene i stillesittende tid etter et år av intervensjonen, til tross for at stillesittende tid etter et år økte signifikant fra baseline til etter et år i HIIT (henholdsvis 1084±146 and 1313±94), MICT (1094±126 and 1340±61), og kontroll gruppen (henholdsvis 1131±130 and 1346±71). Det var ingen signifikante forskjeller innen eller mellom gruppene i TEF etter et års intervensjon.

Konklusjon:

Denne studien gir innsikt i stillesittende tid hos den eldre delen av befolkningen. Stillesittende tid økte i alle grupper fra start til etter et år i intervensjonen. Derfor, våre data indikerer at introduksjon av fysisk aktivitet kan øke stillesittende tid hos eldre voksne.

Table of contents

Introduction

Background

Demographic projections of the population indicate rapid ageing due to increased longevity, causing a growing concern that the demographic changes will cause pressure on public expenditures not sustainable under the financing arrangements of today (Chatterji et al., 2015). Estimates show that the ageing population will increase from 841 million in 2013 to 2 billion in 2050, where the number of older adults (>65 years old) will exceed the number of children (<5 years old) by 2047 (Chatterji et al., 2015). Due to the ageing population, initiatives that promote health and well-being are warranted, and questions arise about the onset of disabilities. Reports show an increase in years with disabilities, exceeding the total life expectancy (Perenboom et al., 2004). This increase seems to be a consequence of an increase in chronic disease and the number of years with the disease, although the severity of disabilities appears to remain stable (Perenboom et al., 2004). Some factors contribute to age-related disease severity that is non-modifiable as age, sex, and race, although individuals may contribute to modifying age-related physiological health (Pencina et al., 2019). Modifiable risk factors are by others physical inactivity (Sandbakk et al., 2016) and low cardiorespiratory fitness (CRF) (Stensvold et al., 2017), increasing the risk of cardiovascular disease (CVD), all-cause mortality and certain cancer types (Biswas et al., 2015). A sedentary lifestyle is put alongside smoking, obesity, and alcohol use when it comes to reducing healthy life expectancy in developed regions of the world (Wirth et al., 2016) and may apply particularly to older adults (<70) as they are the most sedentary group (Harvey et al., 2015; Sandbakk et al., 2016). Literature shows that the association between sedentary time and risk of CVD is independent of physical activity (Sandbakk et al., 2016; Stensvold et al., 2011), indicating that sedentary time and lack of physical activity may pose a risk of CVD in itself (Sandbakk et al., 2016). Thus, modifying individuals' behaviour toward more PA is one of the most important factors in maintaining and improving physiological and mental health in older age (Hamer et al., 2014).

Physical Activity and Health

Physical fitness is the ability to perform physical activity, and the most used components of physical fitness are CRF, muscular strength and endurance and flexibility (Vanhees et al., 2005). As physical activity is beneficial for health, it is recommended by the World Health Organization (WHO) to partake in moderate-intensity physical activity for 150-300 minutes a week or vigorous-intensity physical activity for at least 75-150 minutes a week. However, any increase in the amount of physical activity is seen as beneficial. It has previously been shown that physical inactivity is responsible for worldwide 6% of CHD, 7 % of type 2 diabetes, 10% of colon cancer, 10% of breast cancer, and 9% of premature mortality (Lee et al., 2012) and neurodegenerative diseases (Hamer et al., 2014). More, partaking in physical activity is associated with risk-reduction of all-cause mortality, cardiovascular incident, cancer incident or mortality as to breast, colon, colorectal, endometrial, epithelial ovarian, and type 2 diabetes in adults (Biswas et al., 2015). In addition, participating in exercise has a significant preventive effect on premature all-cause mortality, and physically fit individuals show up to a 72% reduction in premature mortality compared to inactive individuals (Stensvold et al., 2020). Being physically fit may also largely affect the deleterious association with being overweight or obese (Sandbakk et al., 2017). Importantly, starting physical activity later in life is associated with significant health benefits (Hamer et al., 2014).

Despite the benefits of physical activity, there is a worldwide trend toward a sedentary lifestyle, as only 20% of the United States and 23% of the Norwegian population seem to meet the physical activity guidelines and those aged 70 and older are less active with only 6-10% meeting the physical activity recommendations measured objectively (Zisko, Carlsen, et al., 2015). Sedentary behaviour is defined as behaviour whilst being awake where the energy expenditure is equal to or less than 1,5 metabolic equivalents (METs) whilst sitting or in a reclining position (Wirth et al., 2016). One MET is the resting energy expenditure (REE) during resting/sitting (Strath et al., 2013). Given that total energy expenditure (TEE) consists of activity energy expenditure (AEE), REE and diet-induced thermogenesis (DIT) (Strath et al., 2013), AEE has the greatest potential to influence TEE (Zisko, Stensvold, et al., 2015). Among older adults, the amount of sedentary time per day is high (Harvey et al., 2015). A systematic review of studies from ten countries found that older adults spend, on average, 9.4 hours a day in sedentary behaviour, while some smaller studies have reported up to 18 hours a day for community-dwelling older people when quantified by posture and counts of movement (Harvey et al., 2015). Watching television is the most common reported sedentary behaviour (Grøntved, 2011). In many European countries, 3.5 hours on average per day are reported, Australia 4 hours per day, and the United States 5 hours per day. Moreover, TV time is associated with unhealthy eating in children and adults, a risk factor related to all-cause mortality, and a linear dose-response relation were observed between TV time and CVD and type 2 diabetes (Grøntved, 2011). Also, an increased risk for all-cause mortality was observed per 2 hours of viewing time per day and estimated to be 104 deaths per 100 000 individuals per year for every 2 hours of TV time based on the US mortality statistics (Grøntved, 2011). Due to the high number of older adults that fail to meet the recommended level of physical activity, interventions targeting behaviour change toward a more physically active lifestyle over time, individual-level behaviour change is essential. A systematic review and meta-analysis investigated physical activity interventions and identified an increase in physical activity compared to a control group in steps per/day and minutes spent in moderate and vigorous PA beyond 12 months and sustained up to 4 years (Wahlich et al., 2020). Similar results are observed where a physical activity intervention resulted in a change toward a higher intensity activity and longer bouts, although a decline in TEE was not eliminated (Wanigatunga et al., 2017). Lifestyle interventions and interventions targeting sedentary time may be promising approaches and seem to intervene in a reduction of 24 min/day and 22 min/day of ST (Martin et al., 2015). Findings suggest that interventions with a duration up to 3 months with mixed genders produce a significant reduction in sedentary time (Martin et al., 2015). Moreover, the level of intrinsic motivation in individuals plays an important role in adopting and maintaining health-promoting behaviours. There is a clear association between autonomous types of motivation and the amount of light, moderate and vigorous physical activity (Vancampfort et al., 2015).

Exercise and exercise intensity

High-intensity interval training (HIIT) shows a greater effect on health measures than moderate-intensity training (MICT), even when individuals suffer from chronic heart failure and severely impaired cardiovascular function (Wisløff et al., 2007). This is also seen when a longer training duration is used to compensate for lower-intensity exercise (Helgerud et al., 2007).

Assessing peak oxygen consumption to measure physiological status quo and progression after exercise training is the gold standard (Vanhees et al., 2005). VO_{2max} is defined as a plateau in the final two exercise work rates and implies that a physiological limit is reached and sustained for a specific period (Arena et al., 2007). However, VO_{2max} is affected by age, sex or the presence of disease or medications and typically declines by 10 percent per decade in non-athletic subjects. This decline accelerates with age (Arena et al., 2007). However, VO_{2max} is rarely seen in patients with cardiovascular or pulmonary disease and thus more likely to be used in healthy individuals who are more likely to reach a plateau in VO_2 (Arena et al., 2007). However, a large proportion of healthy individuals will not reach a plateau that defines VO_{2max} (Arena et al., 2007). Therefore, CRF is measured as peak oxygen uptake, VO_{2peak}, the average of the three highest consecutive values of exercise work rates and has shown to be one of the single best predictors for future CVD (Stensvold et al., 2017). CRF has emerged as a strong, independent predictor for all-cause mortality and disease-specific mortality and the prognostic use of CRF is so strong that the American Heart Association advocated for CVF as a routine assessment (Harber et al., 2017).

Wisløff et al., (2007) showed that 12 weeks of exercise training at ~95% and ~75% of HR_{peak} 3 times /week led to an improvement in VO_{2peak} with 46% and 14%, respectively. HIIT elicit a significant change in VO_{2peak} after six weeks of training, which seems to be required to improve VO_{2peak}, which are in line with other research that state improvements after 6 to 8 weeks (Herrod et al., 2020). CRF decline with age and is long established as a strong independent predictor for all-cause mortality and disease-specific mortality (Harber et al., 2017; Herrod et al., 2020) and persists after adjusting for sex, traditional CVD and risk factors such as smoking status, blood pressure, blood glucose and type 2 diabetes (Harber et al., 2017). Each increase in one metabolic equivalent is associated with a lower risk of a 13% reduction in all-cause mortality and a 15% reduction in CHD and CVD mortality (Harber et al., 2017). Aerobically fit older individuals have a higher peak VO_2 and show a higher physical AEE (Brochu et al., 1999). Individuals with a higher level of VO_{2max} seem to be more active, up to two more hours daily (Novak et al., 2009). Moreover, those who report being active report a disability threshold fourteen years later compared to those who are inactive (Stensvold et al., 2015). However, other impairments that are not cardiometabolic in nature are common in older adults and affect the ability to partake in physical activity due to frailty and comorbidity (Lachman et al., 2018). Compared to those who are physically inactive, adding low levels of physical activity reduces the risk for all-cause mortality and CVD (Stensvold et al., 2011).

Physical activity and exercise assessment

Physical activity can be measured in numerous ways, both subjectively with questionnaires and objectively with the use of indirect calorimetry, doubly labelled water method, heart rate monitoring and wearable devices such as motion sensors as accelerometers (Strath et al., 2013).

Questionnaires offer valuable context to identify specific sedentary behaviour, such as time spent sitting and engaging in cognitive behaviour, such as reading or socialising, or mere watching TV (Copeland et al., 2017). However, objective measures, device-based, offer more accuracy and are less prone to biased feedback as it has previously been a reported discrepancy between self-reported questionnaires and objectively measured sedentary time (Harvey et al., 2015). Harvey et al., (2015) reported that self-reported sitting time, on average, was 5.3 hours compared to objectively measured with an accelerometer of 9.4 hours. When self-reported older adults have estimated that 47-51% meet physical activity recommendations, while when assessed using an accelerometer, the prevalence is only 6-10% (Zisko, Carlsen, et al., 2015). The discrepancy between self-reported sitting time and objectively measurements can be explained by that many activities spent sitting are forgotten or interpreted differently, such as time spent sitting and eating or undertaking self-care (Harvey et al., 2015). Moreover, the discrepancy is also seen regarding physical activity, with an overestimation of self-assessed activity level when comparing accelerometers and questionnaires (Walsh et al., 2004). Thus, objective measurements have been considered more accurate than questionnaires assessing physical activity (Harvey et al., 2015).

Indirect calorimetry measure energy expenditure under controlled conditions as in a laboratory, and the most common form of indirect calorimetry is where a participant breathes either room air or a mixture of gasses of known concentration, whereas the expired amount of oxygen and carbon dioxide are analyzed (Strath et al., 2013). Double-labelled water measures TEE in free-living individuals over a period of one to three weeks (Strath et al., 2013; Westerterp, 2017). The disadvantage of this technique is the cost of equipment, dependent on trained personnel and therefore are more suited for smaller groups (Westerterp, 2017).

Heart rate monitoring has increased significantly with the development of small wrist-worn heart rate monitors that receive wireless signals from electrodes attached to a chest strap and store these data for days (Strath et al., 2013). However, assessment of physical activity with the use of a heart rate monitor is problematic at the lower intensities of activity due to that heart rate is also influenced by sympathetic reactive such as caffeine, emotional state, and temperature (Strath et al., 2013).

A growing number of accelerometers are available, validated with gold standard double labelled water or indirect calorimetry, and estimate physical activity by capturing frequency, duration, and intensity of physical movements (Strath et al., 2013). Accelerometers convert the collected data to counts per minute (counts/min), and the higher the counts/min, the higher the acceleration of measured movements (Esliger et al., 2005). However, some accelerometers that use triaxial estimates of EE typically overestimate (12-49%) the measurements made with indirect calorimetry (Fruin & Rankin, 2004). Moreover, triaxial accelerometers overestimate EE for walking and running, and underestimate walking up an incline, cycling exercise and daily living activities (Fruin & Rankin, 2004). The SensWear Armband (SWA; BodyMedia, Inc., Pittsburgh, PA) used in this study makes use of a two-axis accelerometer worn on the upper arm over the triceps with multiple sensor arrays to measure heat flux, galvanic skin response and skin temperature to combined assess intensity and activity. In addition to sensor data, SenseWear uses individuals' characteristics such as age, gender and weight and shows validity and reliability in estimating the physical activity intensity (Plasqui et al., 2013). The multiple sensor arrays were designed to overcome the limitations of other assessment tools that objectively estimate EE (Fruin & Rankin, 2004). SenseWear generated a better estimate for EE for cycling and walking exercises (Fruin & Rankin, 2004). Getting a good representation of PA monitoring needs to be gathered over several days, and in the elderly, it is estimated that two days predict a reliable estimate of TEE (Almeida et al., 2011).

Aims and hypothesis

The primary aim of this study was to examine the effect of different exercise interventions over a one-year period on sedentary time in older adults. The secondary aim was to evaluate the effect of one year of exercise training on TEE.

Methods

Study design

This present study utilizes data collected in a large randomized controlled trial, Generation 100, conducted in Trondheim, Norway. Generation 100 is a phase IIb clinical trial with the main aim to evaluate if exercise over a five-year period had an effect on all-cause mortality in older adults (Stensvold et al., 2015). Participants were stratified by sex and marital status before being randomized 1:1 into a supervised exercise training group or a control group. The exercise group was further randomized 1:1 into high-intensity and moderate-intensity training. The inclusion of participants started in August 2012 and lasted until June 2013. The

Generation 100 intervention ended in June 2018, including follow-up testing after one-, three- and five years (Stensvold et al., 2015).

Participants

All inhabitants born between 1 January 1936 to 31 December 1942, living in Trondheim municipality, were invited to participate in Generation 100 (n = 6966) (Stensvold et al., 2015). Potential participants received invitations containing information regarding the study, a health-related questionnaire and informed consent. Inclusion criteria were individuals born between 1936 and 1942, living in Trondheim municipality and physically able to participate in the exercise program determined by the researchers. A total of 1567 older adults, 777 women and 790 men, were included in the Generation 100 Study. Exclusion criteria before and during that hindered participation and completion of the study were uncontrolled hypertension, symptomatic vascular disease, hypertrophic cardiomyopathy, as stated by Stensvold et al., (2015). Moreover, unstable angina pectoris, primary pulmonary hypertension, heart failure, diagnosed dementia, severe arrhythmia, cancer, chronic communicable infectious diseases, illnesses or disabilities precluded exercises or participation in other studies (Stensvold et al., 2015). This present study included the participants that wore the SenseWear activity monitor at baseline and one-year follow-up. A total of 77 participants (37 women) were included. One was excluded due to missing data at a one-year follow-up. A flowchart of the study is presented in Figure 1.

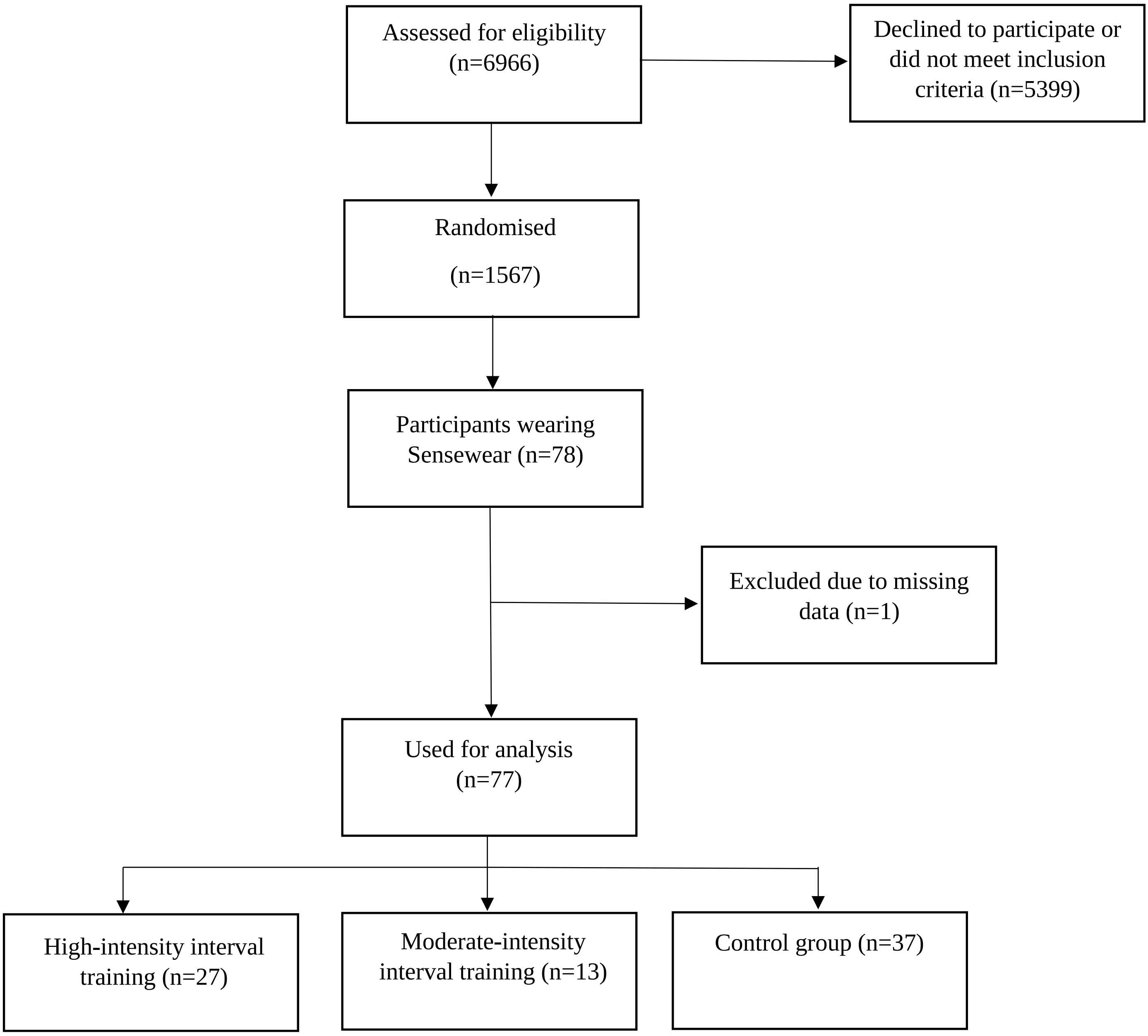

Figure 1. Flow chart of the present study.

Intervention

High-intensity interval training

Participants randomized to HIIT were prescribed to perform two exercise sessions per week lasting ~40 minutes with a ten-minute warm-up followed by a 4x4 minutes interval with 3-minute active breaks (Stensvold et al., 2015). Participants were instructed to exercise according to a Borg scale of 6-20 as guidance for exercise intensity (Borg, 1982). Intensity during intervals corresponded to about 85-95% of peak heart rate, corresponds to 16 on the

Borg scale, while the intensity during the active breaks corresponded to 60-70% of peak heart rate and 12 on the Borg scale (Stensvold et al., 2015). Every sixth week, participants in this group meet up for supervised exercise training using a heart rate monitor to make sure the participants exercised at the recommended intensity. Twice a week, organized training was offered, or participants could choose to perform their exercise training individually (Stensvold et al., 2015).

Moderate-intensity continuous training

Participants randomized to MICT were asked to partake in two weekly sessions consisting of 50 minutes of continuous exercise training corresponding to 70% of peak heart rate corresponding to the rating of exertion of approximately 13 on the Borg scale (Stensvold et al., 2015). Every sixth week, participants in this group meet up for supervised exercise training using a heart rate monitor to make sure the participants exercised at the recommended intensity. Organized exercise training two times a week was offered, or participants could choose to perform their exercise training individually (Stensvold et al., 2015).

Control group

Participants randomized to the control group were asked to follow the Norwegian guidelines for physical activity as of 2012, which correspond to 30 minutes of moderate-intensity physical activity almost every day, with no further supervision (Stensvold et al., 2015).

SenseWear

Objective measurements of activity were obtained using a SenseWear Armband activity monitor (BodyMedia 7, Pittsburg, Pennsylvania, USA). The armband has previously been validated and found accurate in estimating energy expenditure, reported as TEE and AEE, during free-living conditions (Zisko, Stensvold, et al., 2015). The SenseWear is a lightweight monitor worn on the right upper arm to measure galvanic skin response, heat flux, motion, steps, and skin temperatures together with demographic characteristics such as age, sex, smoking status, and handiness to estimate EE. The SenseWear monitor provides information about sedentary time, lying and sleeping time/day, and intensity and duration of PA in metabolic equivalent of tasks (METs). Sedentary is defined as an activity up to 1.5 METs, light activity from 1.5 METs to 3 METs, moderate activity from 3 to 6 METs, vigorous activity from 6 to 9 METs and very vigorous from 9 METs and up (Zisko, Stensvold, et al., 2015). In the present study, the two latter categories are collapsed and called vigorous activity. The participants were instructed to use the armband for seven days, 24 hours a day continuous, except for when in contact with water, as to shower, bath, or swimming. Participants in this study were included if they had used the armband for a minimum of two days and more than 23 hours a day.

Cardiopulmonary Exercise Testing

CRF was measured as peak oxygen uptake (VO_{2peak}) assessed through gold standard cardiopulmonary exercise testing using Cortex MetaMax II (Leipzig, Germany) (Stensvold et al., 2017). Before testing, the ergospirometry systems were calibrated against a standardized motorized mechanical lung (Motorized Syringe with Metabolic Calibration Kit; VacuMed Canada). Before every test, day volume and gas calibration followed by volume calibrations were undertaken according to manufacturer instructions. Gas calibrations were performed before every fourth test or if ambient air measurements were not accepted by the analyzer. Cardiopulmonary exercise testing was performed on a treadmill, and a heart rate monitor (RS100, Polar Electro Oy, Kempele, Finland) was used to measure heart rate. Participants with known heart disease were monitored with 12-led electrocardiography according to the American College of Cardiology/American Heart Association guidelines when performing the cardiopulmonary exercise testing. The exercise test was initiated with a 10-minute warm-up, where an individualized workload was selected based on physical activity level, monitoring of HR and self-reported perceived exertion (Borg scale 6-20). After warming up, participants were instructed to wear a facemask (Hans Rudolph, Germany) connected to the gas analyzer. The cardiopulmonary exercise test, consisting of three steps, started with steady-state measurements lasting three minutes with the inclination and speed on the treadmill at the end of the warm-up. This was followed by step two, a steady state measurement lasting two minutes, where the load was increased with a 2% treadmill inclination or 1 km/h increase. In the third step, the load was gradually increased by approximately everyone and a half minute or when oxygen uptake stabilized. This procedure is maintained until exhaustion (VO_{2peak}) or until the true maximal oxygen uptake (VO_{2max}) is reached. A maximal test is achieved when the respiratory exchange ratio is 1.05 or higher and when the participant continued until exhaustion while oxygen levelled off and did not increase more than 2 ml/kg/min between two 30-s epochs despite increased workload. VO_{2peak} was the average of the three highest consecutive values, peak expiration of carbon dioxide and peak respiratory exchange ratio were the highest among the corresponding three values (Stensvold et al., 2017). As the majority of the tests did not reach true VO_{2max}, the term VO_{2peak} is used in the present study.

Sample size

Few studies have examined the long-term effect of exercise on sedentary behaviour in older adults. However, based on preliminary analysis, the mean sedentary time in this population was 1100±130 min per day. Power calculations were based on the expected difference in sedentary behaviour between HIIT and control. It has previously been reported a 10% difference in sedentary time between the moderate-intensity exercise group and the control group after a 12-week intervention (Kozey-Keadle et al., 2014). To detect a ~10% difference in sedentary time, with a standard deviation (SD) of 130, a significance level of 5% and a statistical power of 80%, each group will need 22 participants.

Statistical analysis

Statistical analyses were performed using SPSS Software version 28 (Statistical Package for Social Science, Chicago, IL, USA). An ANCOVA was run to determine the effect of the different exercise interventions. The changes between the groups Δ-values were used as a dependent factor, pre-intervention activity was used as covariates for the dependent factor, and group affiliation as a fixed factor. P-value ≤0.05 was set as statistically significant. Choosing ANCOVA is related to its greater statistical power to detect treatment effects compared to other methods and adjust follow-up scores with baseline scores without being affected by baseline differences (Vickers & Altman, 2001). An independent t-test was conducted to see any significant mean differences within the groups. Results are presented as means and standard deviation (SD).

Results

The mean age was 71.5 ±1.2 years at the start of the study. Baseline characteristics of the participants in the different intervention groups are presented in Table 1. There were no significant differences between the groups at baseline.

Table 1. Baseline characteristics

	HIIT (n=27)	**MICT (n=13)**	**Control (n=37)**
Age, years	72.3 (1.3)	71.8 (1.5)	72 (1.3)
Female, number	9	9	19
Weight, kilogram	79.3 (15.1)	72.3 (10.6)	79.9 (14.2)
Sleep, min. per day	406 (81)	433 (52)	437 (55)
Steps, per day	7454 (3270)	7796 (1834)	6570 (3652)

Data presented as mean (Standard deviation). HIIT; high-intensity interval training, MICT; moderate-intensity continuous training.

Outcome

There was no significant difference between groups in sedentary time after one year of the intervention (Figure 2). However, all three intervention groups significantly increased sedentary time after one year significantly from baseline to one year. Mean sedentary time in HIIT-, MICT- and control group before the intervention were 1084±146 min/day, 1094±126 min/day, and 1131±130 min/day, respectively. After the intervention, the corresponding number was 1313± 94 min/day, 1340±61 min/day, and 1346±71 min/day for HIIT, MICT, and control group.

Data on TEE, AEE, different zones of physical activity, steps, and sleep before (pre) and after (post) the intervention are presented in Table 2. There was no significance between groups in TEE, measured sleep, the number of steps, light activity, or moderate activity after one year. However, there was a significant between group difference in vigorous activity after one year of intervention. Change in vigorous activity was significantly higher in HIIT compared to MICT (p=.004) and the control group (p=.034). After the intervention, AEE was significant higher in HIIT compared to MICT (p=.02) and the control group (p=.048). There was no difference in AEE between MCT and control. The number of steps in all groups decreased from baseline to one year, although it was not significant, as seen in Table 2.

After one year, there were no between group differences in the change in VO_{2peak}. However, both HIIT and control had a within change in VO_{2peak} from baseline to one year (30.3±8.1 ml/kg/min versus 33.5±8.6 ml/kg/min, p=.002, and in the control 27.6±6.2 ml/kg/min versus 28.9±7.1 ml/kg/min, respectively p=.001). No within group difference was observed, in the MICT group (29.3±8.1 ml/kg/min versus 30.7±8.1 ml/kg/min.)

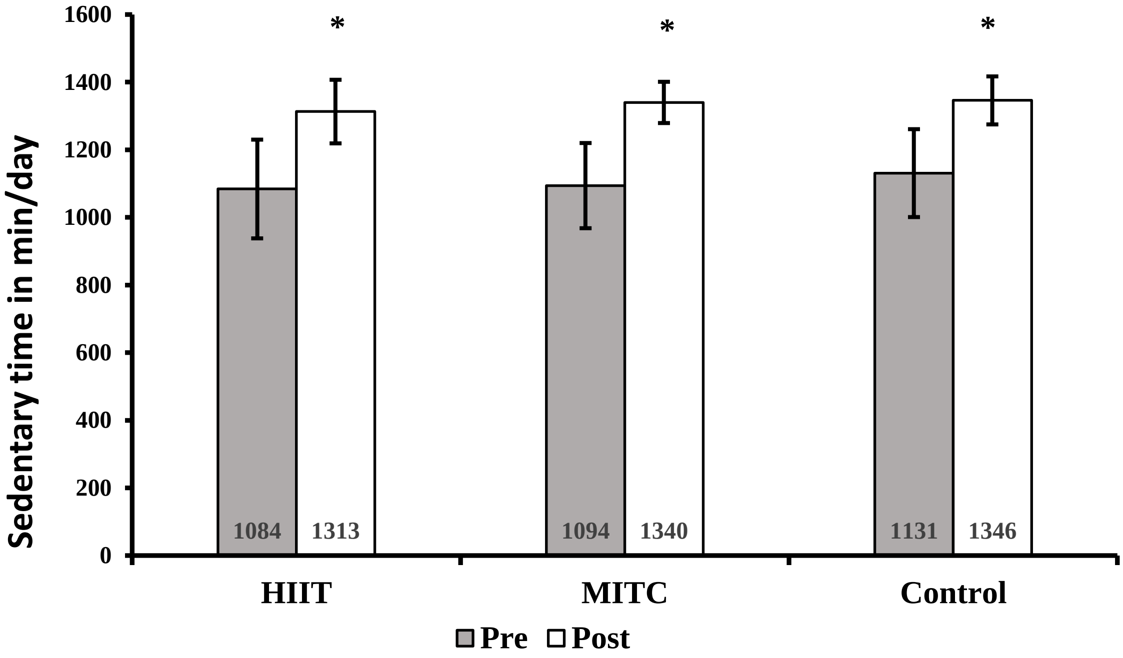

Figure 2. Sedentary time before (pre) and after (post) the intervention. Values in means (Standard deviation) from pre to post in HIIT=High-interval intensity training, MICT=Moderate-intensity continuous training and Control group. *Significant differences within group from pre to post intervention ($p<0.05$).

Table 2. Data from SenseWear monitor before (pre) and after (post) the intervention.

	HIIT		MICT		Control	
Variables	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
TEE, kJ/day	11296 (2193)	11185(2874)	10170 (1935)	9644 (1619)	10443 (2360)	13400 (13602)
AEE, kJ/day	2759 (1836)	3038 (2478) *	2536 (2019)	1820 (1282)	2099 (2209)	1886 (1675)
Vig, min/day	15 (21)	23 (38) *	20 (22)	7 (10) †	9 (21)	8 (15)
Mod, min/day	96 (63)	95 (64)	92 (56)	84 (52)	83 (67)	76 (58)
Light, min/day	255 (82)	240 (95)	228 (65)	226 (81)	210 (76)	196 (72)
Steps/day	7454 (3270)	6984 (3160)	7796 (1834)	7437 (1949)	6570 (3652)	6560 (3021)
Sleep, min/day	406 (81)	420 (78)	434 (52)	420 (59)	437 (55)	431 (58)

Values in means (Standard deviations). TEE=total energy expenditure, AEE=activity related energy expenditure, KJ=Kilojoules. Vig=Vigorous activity, total daily time spent in METS >6, Mod=Moderate activity, time spent in 3-6 METS, Light=Light activity, time spent in 1.5 to 3 METS. Pre=baseline data gathered prior to exercise intervention, Post=data collected post exercise training intervention. HIIT=High-intensity interval training, MICT=Moderate-intensity continuous training. *Significant differences from MICT and Control at $p<0.05$. †Significant difference within group ($p<0.05$).

Discussion

The primary aim of this study was to examine the effect of different exercise interventions over one year on sedentary time in older adults. The main finding is that there is no significant difference between groups in sedentary time after one year of different aerobic exercise interventions. Interestingly, all three intervention groups significantly increased sedentary time after one year. Furthermore, no between group difference were seen in TEE after one year.

After one year, VO_{2peak} was significantly higher in the HIIT- and the control group, but not in the MICT group. Also, there was a significant increase in group difference in vigorous activity and AEE in HIIT group after one year of intervention compared to MICT and the control group. However, a change in AEE does not necessarily translate into a change in TEE (Gomersall et al., 2012). In our study AEE increases in HIIT, with no change in TEE. It has previously been suggested that older persons reduce physical activity compensatory throughout the day after structured exercise of high intensity (Meijer et al., 2001). Our data seem to confirm this hypothesis, as HIIT increased AEE, but also had an increase in sedentary time. Meijer et al., (2001) previously showed that older participants spent relatively more time in low-intensity activities compared to moderate- or high-intensity physical activity. Moreover, time spent in moderate or high-interval physical activity did not impact the overall TEE (Meijer et al., 2001).

The predominantly leisure activity in older adults is television viewing, which has previously been shown to associate with negative health outcomes (Grøntved, 2011). As older adults generally are less physically active than younger age groups (Zisko, Carlsen, et al., 2015), these effects might be more pronounced. Due to the prolonged sedentary time, recommendations arise to break up the sedentary time to have fewer extended periods of inactivity (Chastin et al., 2015). Evidence shows that such breaks have a beneficial effect on glycemic control by lowering the postprandial glucose and insulin response, as well as suggesting that both light and moderate to vigorous physical activity breaks to sedentary time reduce the inflammatory response in adults (Chastin et al., 2015). Taking into mind that only 6-10% of older adults aged above 70 meet the recommended level of physical activity, a small increase in physical activity has benefits (Zisko, Carlsen, et al., 2015).

Due to the decline in physical fitness for older adults, there might be difficult to reach what is defined as a vigorous activity (Evenson et al., 2012). Recommendations of intensities are divided between absolute and relative intensities, where relative intensities consider individual differences, while absolute METS characterize current aerobic recommendations (Zisko, Carlsen, et al., 2015). However, few studies have looked at cut points in older adults, and there are no universally accepted cut points for older adults (Colbert et al., 2014). Due to that age influence cut points, different cut points are used for children and adults (Copeland & Esliger, 2009). For instance, Eslinger et al., (2005) described a 12-year-old male monitored for seven consecutive days who obtained an average of 148 minutes of moderate and vigorous activity when age-specific cut points were used compared to a non-age-specific cut point which showed 64 minutes per day of physical activity. This indicates that applying cut points to specific age populations rather than the population per se may better represent physical activity levels rather than the generalized absolute cut points for the adult population as a whole (Kujala et al., 2017). Evenson et al., (2012) reported that moderate and vigorous physical activity and bouts of physical activity were lower as participants increased in age. In younger adults' moderate intensity physical activity is defined as 3.0-6.0 METs (cut point from 1952 to 5724), and vigorous-intensity physical activity is defined to range between 6.0-9.0 METs (cut point between 5725-9498) (Esliger et al., 2005; Evenson et al., 2012). As a contrast, adults aged 65 to 79 might perceive moderate-intensity physical activity as "somewhat hard", corresponding to 3.2-4.7 METs, whereas vigorous-intensity physical activity is perceived as "hard", corresponding to 4.8-6.7 METs (Evenson et al., 2012). As individuals further increase in age with a decline in CRF, the perceived METs lowers as those older than 80 might perceive moderate intensity PA as 2.0-2.9 METs, while vigorous intensity physical activity is perceived as 3.0-4.3 METs. Similar results are also found by Hall et al., (2014), describing the higher energetic cost of walking and daily activities for the older population compared to the younger population. Moreover, standardized tasks are substantially higher, approximately 30%, for older adults compared to younger ones in caloric cost (Hall et al., 2014). Most large-scale population studies use the absolute intensity for all adults regardless of age and CRF (Zisko, Carlsen, et al., 2015). However, as CRF decline with age and differs between men and women, the accelerometers should take into account the relative intensity of effort required to perform physical activity (Evenson et al., 2012). For instance, 60–69-year-old participants ranged from 14.2 min/day, which is a cut point of ≥2000 counts/min to 130.7 min/day (cut point ≥500 counts/min) compared to those aged ≥70, that ranged from 5.6 min/day (cut point ≥2000 count/min) to 64.0 min/day (cut point ≥500 counts/min) of moderate and vigorous physical activity (Evenson et al., 2012). Similar results have been reported for older adults aged 70±4 with a cut point of 1041counts/min for moderate and vigorous physical activity averaging 68 minutes of activity bouts/day, where most activities occurred in the morning before 12 p.m. more frequently than other times of the day (Copeland & Esliger, 2009).

In the present study, few participants moved on the moderate and vigorous physical activity continuum, and participants ranged on average before training intervention started at 111 min/day in the HIIT group, 122 min/day in the MICT group, and 92 min/day in the control group. After one year of exercise, HIIT, MICT and the control group partook in moderate and vigorous physical activity intensity of 118 min/day, 91 min/day and 84 min/day, respectively. In order to address the difference in CRF, Zisko and Carlsen et al., (2015) established a new Actigraph threshold for light, moderate and vigorous physical activity in older participants aged above 70. This study considers that some older individuals stay fit well into advancing age and may, in some cases, be fitter than younger age groups (Zisko, Carlsen, et al., 2015).

Thus, a cut point that considers VO_{2max} and sex alongside age will allow for a more accurate relative intensity physical activity assessment, as physical activity threshold will vary even when adjusted for specific populations as CRF will vary from individual to individual (Zisko, Carlsen, et al., 2015). Due to that, a large proportion of the older population are not meeting the current guidelines of physical activity it might be problematic for the older population to adjust to meet the guidelines as those with lower CRF will experience challenges to reach METs of 3-6 according to Evenson et al., (2012). CRF is significantly correlated to moderate and vigorous physical activity intensity and ability to reach this level, suggesting that relative intensity physical activity threshold based on CRF could be more appropriate than absolute intensity physical activity threshold when classifying relative intensity of physical activity (Zisko, Carlsen, et al., 2015). In this present study, CRF ranges from baseline for men and women combined from 15.9ml/kg/min to 46.09 ml/kg/min, and after one year, 18.2ml/kg/min to 48.2ml/kg/min. Those on the lower side of CRF will have problems reaching what is commonly defined as the moderate and vigorous intensity threshold, and one can thus argue that a more individualized threshold reflecting CRF variations is warranted. Zisko, Carlsen et al., (2015) advocate for a threshold were cut off values for low, medium, and high fitness were <23.6, 23.6-29.8, >29.8 ml/kg/min for women and <27, 27-35.6, >35.6 ml/kg/min for men. Evenson et al., (2012) concluded that an individualized cut point was more effective than a group-level cut point due to the lack of a consistent cut point for older adults and the variety of CRF.

In our study, HIIT had an increase in VO_{2peak}, which indicate that the VO_2 change occurred as a direct result of the structural exercise intervention training, which are in line with other studies stating the health benefits induced by HIIT (Wisløff et al., 2007). Sandbakk et al., (2016) showed that having a high CRF attenuates the negative health aspects of sedentary time as high levels of CRF is associated with a reduced level of traditional cardiovascular risk factors. The protective role of having a higher CRF was prominent even when participants did not meet the current recommendations of moderate or vigorous physical activity, according to Sandbakk et al., (2016). Moreover, as CRF is interlinked with the level of physical activity and higher levels of activity were associated with a lower risk of CVD, meeting the physical activity recommendations cannot improve the negative associations between sedentary time and cardiovascular risk factors in older adults. However, having a higher CRF improve negative health aspects (Sandbakk et al., 2016). Our data show that both HIIT and the control group had an increase in CRF. As AEE also was significantly higher in HIIT compared to

MICT and control, this study might indicate that one year of HIIT induces some more favourable adaptations compared to the two other groups.

Strength and limitations

A strength of the present study is the long follow-up of the participants, as few studies have followed older adults during a one-year exercise intervention. Another strength of the present study is the use of objectively measured physical activity. Generally, objectively measurements of physical activity using accelerometers are considered more accurate than questionnaires (Copeland et al., 2017). The discrepancy of self-reported questionnaires compared to objective measurements in older participants is susceptible to response bias as to overestimation of physical activity and underestimation of sedentary time, as described by Copeland et al. (2017), which may lead to lower statistical power and underestimations of associations. Moreover, the high wearing time of the activity monitor is a strength. Participants were asked to use the SenseWear continuous for a week, except when in contact with water. Participants wore SenseWear both weekdays and weekends, plus during sleep. The average mean wear of the SenseWear was 5.75 days before the intervention and 5.58 days after the intervention. Two days and more than 23 hours per day of wear time of the SenseWear were included as other studies have shown this was sufficient (Almeida et al., 2011).

A limitation is the group size. The group that participated in MICT failed to reach the number of participants adequate for the power calculations and should be interpreted cautiously. Moreover, due to the decline in older adults' CRF, a too-high cut-point will underestimate moderate and vigorous activity (Evenson et al., 2012; Hall et al., 2014). Future studies may look into adapting a universally cut point that takes into account age, gender and individual CRF for older adults to ensure a more accurate relative intensity in PA assessment for future PA research in the older age group.

Conclusion

Our data shows that there was no difference in sedentary time or TEE between the intervention groups after one year. However, all three intervention groups had an increase in sedentary time from baseline to one year. Thus, our data indicate that introducing structural exercise may increase sedentary time in older adults.

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