Jan-Eivind Holsen

Effect of five years supervised exercise on long-term physical activity levels in older adults

A Generation 100 follow-up study

Master's thesis in M.Sc. Physical Activity and Health
Supervisor: Dorthe Stensvold, ISB, NTNU
Co-supervisor: Ida Berglund, ISB, NTNU
May 2022

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

NTNU
Kunnskap for en bedre verden

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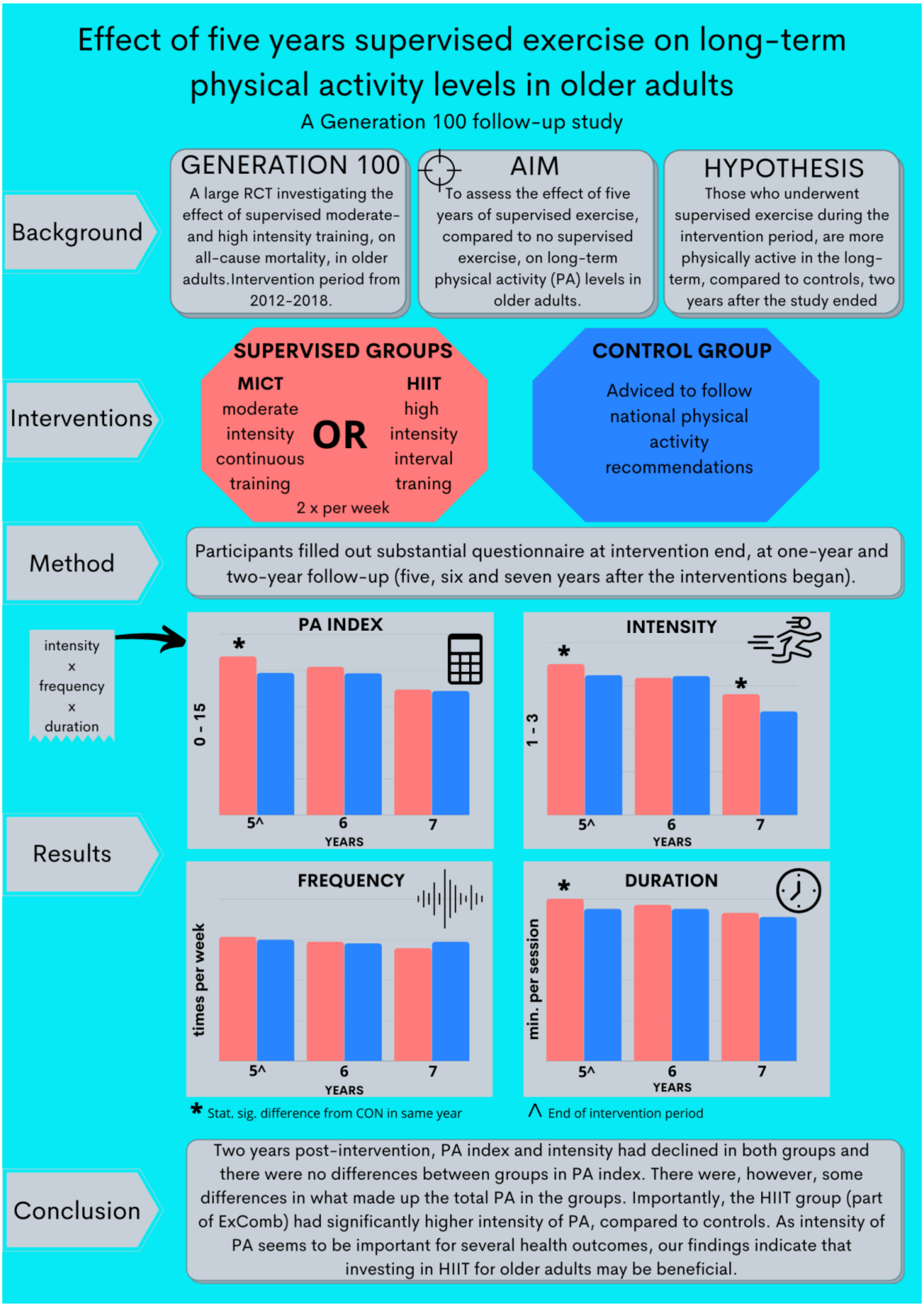
Infographic



Abstract

Background: There is a lot of research regarding health benefits of physical activity and exercise for older adults. However, there is scarce knowledge about long-term adherence to physical activity and exercise in this population, following intervention periods. The present study aimed to assess the effect of five years of supervised exercise (either as MICT; moderate intensity continuous training or as HIIT; high intensity interval training), compared to no supervised exercise, on long-term physical activity levels in older adults.

Method: All participants from the Generation 100 study still attending at study end in 2018 (n=870) were invited to answer a substantial questionnaire, as well as at one- and two years after the intervention ended. For the present study, questions regarding physical activity were of interest. Physical activity was assessed for the outcomes *frequency*, *duration*, *intensity*, and *BORG*, as well as through a *physical activity index* - a product of frequency, duration and intensity.

Results: There were significant declines in physical activity index and intensity in all groups, two years after the intervention of the original study ended. However, there were no significant difference in change between the groups over the two years. Frequency was reduced in the supervised groups, while duration and BORG only declined in controls and the HIIT group. Interestingly, the HIIT group had higher intensity of physical activity, compared to controls, two years post intervention.

Conclusion: The present study finds that there was no difference in physical activity levels between groups, when assessed as an index, two years after the interventions. However, the HIIT group still exercised at a higher intensity compared to controls, after two years.

Sammendrag

Bakgrunn: Det finnes mye forskning på helsefordelene ved å være fysisk aktiv hos eldre voksne. Imidlertid finnes det lite kunnskap om hvordan fysisk aktivitet og trening kan opprettholdes i denne populasjonen. Denne studien ønsker å undersøke effekten av fem år med veiledet trening (enten som MICT; moderat intensitet kontinuerlig trening eller som HIIT; høy intensitet intervalltrening), sammenlignet med en kontrollgruppe som ble bedt om å følge helsemyndighetenes råd for fysisk aktivitet, for langsiktig fysisk aktivitetsnivå hos eldre voksne.

Metode: Alle deltakerne fra Generasjon 100-studien som fortsatt var med etter 5-års intervensjon (n=870) ble invitert til å svare på en omfattende spørreundersøkelse ved intervensjonens ende, samt ved ett- og to år etter intervensjonen. For denne studien var det spørsmålene om fysisk aktivitet og trening som var av interesse. Fysisk aktivitet ble undersøkt med utfallsmålene *frekvens*, *varighet*, *intensitet* og *BORG*, samt som en *fysisk aktivitet-indeks* – et produkt av frekvens, varighet og intensitet.

Resultat: Det var signifikant nedgang i fysisk aktivitets-indeks og intensitet i alle gruppene, to år etter at intervensjonene i den opprinnelige studien endte. Det var imidlertid ingen forskjeller i endring mellom gruppene over de to årene. Frekvens gikk ned i de veiledede gruppene, mens varighet og BORG bare viste nedgang i kontroll- og HIIT-gruppen. Interessant nok, viste HIIT-gruppen høyere intensitet av fysisk aktivitet sammenlignet med kontrollgruppen, to år etter intervensjonen.

Konklusjon: Denne studien finner at det er ingen forskjeller mellom gruppene i fysisk aktivitetsnivå målt som en fysisk aktivitet-indeks, to år etter at intervensjonene endte. Våre data viser likevel at HIIT-gruppen trener med høyere intensitet, sammenlignet med kontrollgruppen.

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Introduction

According to the World Health Organization (WHO), the world's population is aging (1). A phenomenon first associated with wealthier countries, due to improved living standards, nutrition, and medicine, is now also seen in low-income countries. WHO estimate that by 2050, the amount for people over the age of 80, will have tripled world-wide. They underline that all countries must be ready for this shift in demography and prepare their health services in order to meet the challenges of the coming decades (1).

In Norway, the number of people above the age of 65 will exceed the number of children and adolescents aged 0-19 by 2030 and by 2060, every fifth person will be above the age of 70 (2).

Sustainable health care

With an increasing number of older adults, comes the challenge of age-related diseases. Thus, there is a need for ways to evolve and streamline how resources are used.

The United Nations' "Sustainability Agenda" consists of 17 main goals for sustainable development (3). These goals focus on "good health and well-being", and aims to "Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks" (4), with one major health risk being the aging population (1). WHO state that their goal is to specifically enhance opportunities and services to increase physical activity levels in older adults (5).

WHO focuses on "healthy life expectancy" rather than "life expectancy", meaning how many years of good health can a person have, not just how many years total (6). The key question is; how can people worldwide maintain the current quality of life and healthcare, with less resources available?

Physical activity and exercise to reverse ageing and prevent illness

The ageing process in humans is inevitable and starts as early as the mid-twenties. Ageing is associated with decreases in muscle- and bone mass – as well as reductions in pulmonal-, cardiovascular-, endocrine- and neural functions (6). There are also changes in body composition, with more fat mass compared to fat free mass (6). Along with these changes, there is a significant decrease in physical activity (PA) levels and -intensity (6-8). It may seem like the physiological changes seen with age, are both age- and behaviour-related, as we are less physically active with age.

Emerging body of evidence has shown that physical activity and exercise is a feasible, affordable and effective tool for successful aging (1, 6, 9). WHO have recently updated their guidelines for PA, recommending adults to be physically active for at least 150-300 minutes of moderate intensity aerobic PA, or 75-150 minutes of vigorous intensity aerobic PA. Additionally, they recommend doing muscle strengthening exercise two or more times per week, as well as minimizing sedentary behaviour. Adults above the age of 65 are recommended to follow the same guidelines as other adults, but to incorporate some PA as sessions of functional balance and strength training 3 or more times per week, to enhance functional capacity and prevent falls (9).

Cardiovascular disease (CVD) is one of the most common causes of death among older adults (10). With age, our cardiovascular system becomes less efficient, but studies show that PA may improve cardiovascular function and reduce the risk of CVD and death (10).

Many older adults die of cancer, with about 3 out of 5 cancer incidents occurring above the age of 65, with most deaths by cancers also happening in older adults (11). PA has been shown to reduce risk of many cancer types (12). In a systematic review by McTiernan and colleagues published in 2019, they found that those who attained recommended PA levels were at a lower risk of both being diagnosed with cancer and dying of cancer (12).

Another factor which is very costly both to the person it affects, and society, is falls**.** Falls combined with decreased bone mineral density, often cause bones to break, with the most common being hip fractures (13). Luckily, several types of exercise and PA, including aerobic exercise, have been shown to significantly reduce the risk of falling among older adults (14, 15).

Interestingly, a systematic review from 2021 found that although many fall-prevention interventions are effective in reducing falls, they often cost so much that little is saved from an economic standpoint (16). One would still argue that it is worth it, as prevention of falls is not just for economic gains, but to maintain older adults´ quality of life.

PA has also been shown to be a great tool in preventing loss of cognitive function, especially with moderate-to-vigorous intensity (17). Quality of life is likely enhanced by all the aforementioned benefits of PA. Not only could PA be a relatively cheap, effective, and feasible preventive strategy, but it could also yield great gains in people’s quality of life, increase their “healthy life expectancy”, and decrease healthcare reliance (18).

To summarize, there are many health benefits from being physically active for older adults. In addition to benefiting quality of life, it may reduce risk of all-cause mortality, cardiovascular disease, cancer, falls and fractures, as well as prevent declines in physical- and cognitive function (18).

Adherence to physical activity in older adults

While the benefits of PA are widely known and promoted, more knowledge is needed on how to maintain or improve adherence to PA in the world's population. WHO states that there has not been an increase in PA levels globally since 2001, and that those in high-income countries are less physically active than those in low-income countries (9). They estimated that 28% of all adults above the age of 18 did not meet the recommendations for PA in 2016 (9). When looking at older adults specifically, studies show even lower adherence to PA, with as many as 79% of older adults not meeting PA recommendations (8, 19).

In light of the demographical changes, initiatives that promote PA in older adults seems pivotal. In an umbrella review published by Collado-Mateo and colleagues in 2021, they report that adherence to physical activity and exercise in older adults is multifactorial (20). Among many factors, they emphasise the importance of supervision and involvement of professionals, social support, progress information and monitoring, as well as the participants' active role and goal setting (20).

Adherence to supervised exercise in controlled settings is often quite high (21). However, less is known about long-term PA levels after the intervention periods. Moholdt and colleagues found that patients who had undergone cardiac rehabilitation for twelve weeks saw improvements in aerobic capacity for both *usual care exercise* and *HIIT*, with HIIT seeing the greatest gains of the two (22). However, at 6- and 30-month follow-up post-intervention, they found that aerobic capacity, as an indirect measure of PA levels, had declined substantially in both groups (22). The HIIT group displayed a slower decline compared to the usual care group and this may in part be explained by the higher aerobic capacity in the HIIT group initially post-intervention (22).

In a randomized study on long-term PA levels following twelve weeks of cardiac rehabilitation, Aamot and colleagues found that aerobic capacity, again as an indirect measure of PA levels, had declined at one-year follow-up (23). They did, however, find that PA levels and aerobic capacity was higher compared to baseline, and that especially home-based high-intensity exercise was beneficial for long-term PA levels (23).

A systematic review and meta-analysis published in 2013 by Hobbs and colleagues, found that there were signs of sufficient PA levels until 12 months post-intervention, from interventions aiming to increase PA in older adults (24). Furthermore, they found that these effects were not statistically significant after the first 12 months (24). A drop-off in PA levels 12 months post-intervention in older adults was also found in the "Choose to move" follow-up study by McKay and colleagues in 2021 (25). They found that PA levels were the same as at baseline, one year after the 6-month intervention ended (25).

In contrast, Harris and colleagues have found that pedometer-based walking interventions improve long-term levels of moderate-to-vigorous physical activity (MVPA) (26). Both 45-75 and 60–75 year-olds showed greater MVPA levels compared to controls at 3- and 4 years follow-up respectively (26). Thus, data on the long-term physical activity levels post-intervention, in older adults, are inconsistent.

Physical activity in older adults and Covid-19

Since late 2019 and early 2020, the spread of the Covid-19 virus has caused a world-wide pandemic, leading to millions of deaths, in addition to turning many lives upside down with social distancing and closed societies (27). About two years on, there are increasing concerns as to which consequences the restrictions may have had on the population, especially with regards to older adults (28).

As previously mentioned, older adults are at risk of having lower levels of PA in non-pandemic times (7, 8). Recent studies indicate that the pandemic and its restrictions may have caused further decreases in PA levels among older adults, which may further reduce their quality of life and increase the burden on healthcare (28, 29).

There are some studies emerging, indicating that there are interventions that may help maintain or increase PA levels during periods of social restriction (30, 31). The use of social media, technology such as virtual reality and home-based exercise programs have been suggested as effective strategies to increase levels of PA in older adults (28, 30-32).

Aims and hypothesis

The primary aim of this study is to assess the effect of five years of supervised exercise, compared to no supervised exercise, on long-term physical activity levels in older adults.

The study hypothesizes that the older adults who underwent supervised exercise during the intervention period, are more physically active two years after the intervention, compared to controls who only were asked to follow physical activity guidelines.

Method

Study design

The present study is based on data from a larger scale randomized controlled trial (RCT), Generation 100, which is based in Trondheim, Norway (33). The study aimed to assess the long-term effects of regular aerobic exercise on all-cause mortality in older adults. The intervention period for the RCT was five years to 2018. Participants were routinely tested after one-, three- and five years. After the trial period ended, participants have been asked to answer a questionnaire yearly (2018-2020).

Generation 100 was preregistered as a clinical trial in August 2012, identifier: NCT01666340. It was conducted to the principles of the Helsinki Declaration and the SPIRIT statement. The present project has been approved by the Regional Committee for Medical Research Ethics (REK 2012/381 B). All participants have given written informed consent.

Participants

Original study

In 2012, all permanent inhabitants of Trondheim, Norway, born between January 1st 1936 and December 31st 1942 were invited to partake in the Generation 100 study (n=6966). Every participant received information regarding the study itself, a response sheet with a written consent form and a health-related questionnaire. They were asked to return it, regardless of whether they were to partake or not (33).

Inclusion criteria outside of residing permanently in Trondheim and being born between 1936 and 1942, was being able to perform the exercise programme as determined by the researchers (34).

Exclusion criteria, both before and during the study, were uncontrolled hypertension (untreated systolic blood pressure >220mmHg, or diastolic blood pressure >110mmHg); symptomatic valvular disease; hypertrophic cardiomyopathy; unstable angina pectoris; primary pulmonary hypertension; heart failure; severe arrythmia; diagnosed dementia; cancer that made participation impossible; chronic communicable infectious diseases, illness, or disabilities that preclude exercise; or participation in other exercise trials (34).

A total of 1567 (777 males, 790 females) older adults were included in the study (34). The participants were randomized 1:1:2 to either High Intensity Interval Training (HIIT), Moderate Intensity Continuous Training (MICT) or a control group. The randomization was stratified by sex and cohabitation. The study protocol has been described thoroughly previously (33, 34).

Present study

In the present study, only participants who filled out the questionnaire at five-year follow-up were included. In addition, participants had to answer the questionnaire at minimum one of the time points for follow-up at six and/or seven years, to be included.

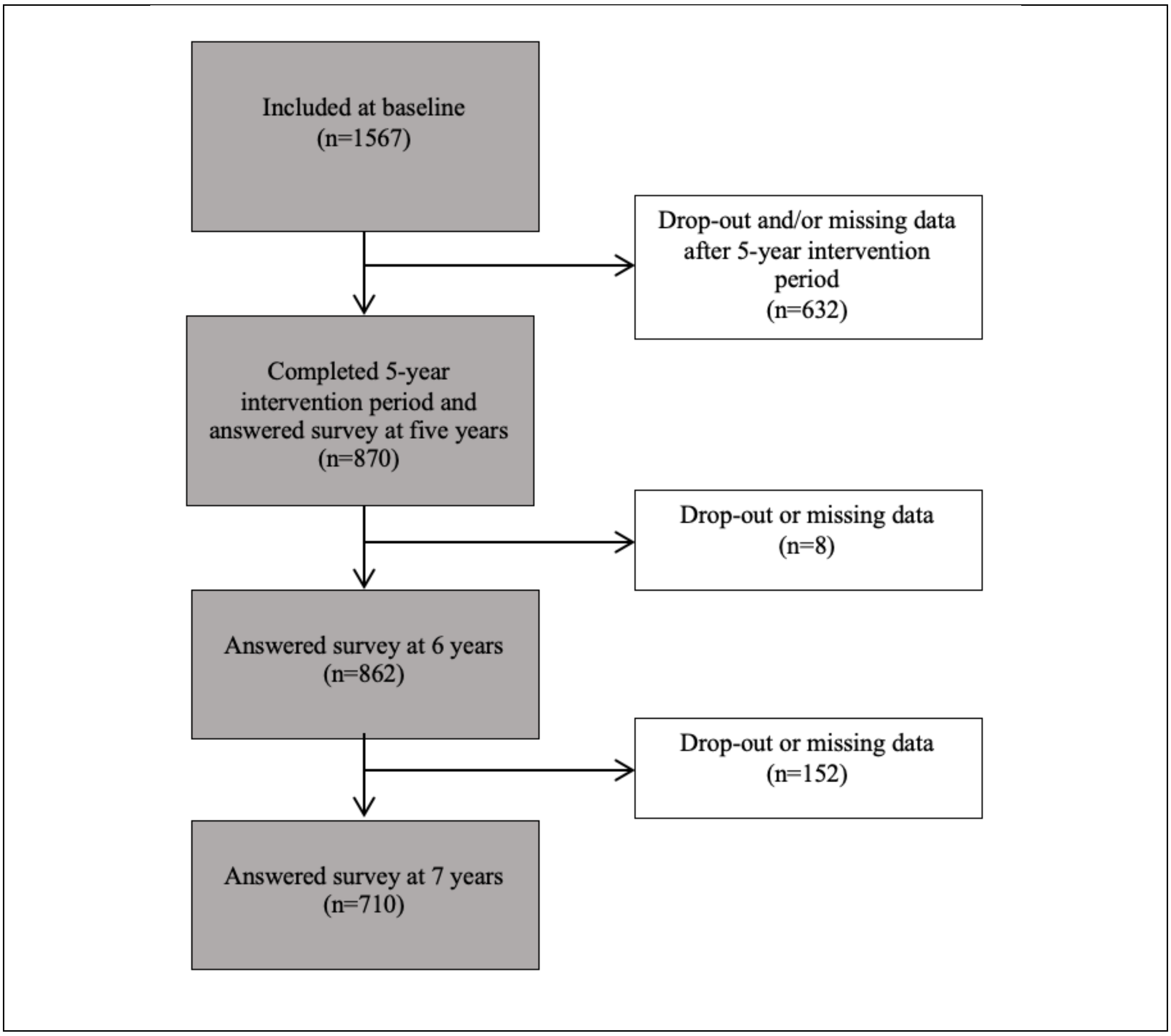

Figure 1: Flow chart showing number of participants at study end after five years, as well as after six and seven years.

Interventions

High Intensity Interval Training

Those randomized to the HIIT intervention (n=400) were prescribed to replace two of their weekly 30-minute physical activities, with exercise sessions containing 4x4minute intervals. The sessions consisted of a ten-minute warm-up, followed by four bouts of four-minute working intervals at 85-95% of peak heart rate (HR_{peak}) or about 16 on the BORG scale for rate of perceived exertion (6-20 scale) (35). These intervals were interspersed by three-minute active breaks at 60-70% HR_{peak} or about 12 on the BORG scale.

The sessions could be performed in their activity mode of choice, be it running, walking, skiing, cycling, rowing, or others. However, every six weeks, the participant had to meet for a mandatory session – supervised and performed on an ergometer bicycle while wearing a heart rate monitor (RS100, Polar Electro Oy, Kempele, Finland). This was to ensure that the participants exercised at the prescribed intensity (34).

For all five years during the intervention period, the participants had the opportunity of partaking in two weekly supervised sessions, arranged different places across Trondheim, led by exercise physiologists (34). These sessions were also afforded after the intervention period ended in 2018 until the pandemic started in March 2020.

Moderate Intensity Continuous Training

Those randomized to the MICT intervention (n=387) were prescribed to replace two of their weekly 30 minute physical activities, with exercise sessions containing 50 minutes at 70% HR_{peak}, corresponding to about 13 on the BORG scale (35). As with the HIIT group, they were offered two supervised sessions per week for the five-year period, as well as being asked to partake in a mandatory session every six weeks, using ergometer bicycles and heart rate monitors (RS100, Polar Electro Oy, Kempele, Finland). The rest of the sessions could be performed in their activity mode of choice, be it running, walking, skiing, cycling, rowing, or others (34).

Combined training group

For the analysis in both the original- and the present study, the supervised exercise groups (MICT and HIIT) have been combined to form one group, called *ExComb* (34).

Control group

The control group were instructed to follow the 2012 guidelines for PA in Norway. In 2012, these guidelines recommended 30 minutes of PA every day, corresponding to 210 minutes per week (36). No further supervision was given, other than testing at one- three- and five years (33).

Self-Reported Physical Activity

In the present study, validated questionnaires were used to assess self-reported PA at one- and two years after the intervention period ended. PA levels post-intervention were measured in terms of frequency of PA per week, average intensity of PA per week, as well as duration of PA per session. In addition, PA levels were assessed through a physical activity index (PA index).

Frequency of PA

The participants were asked "How many times are you physically active per week?", in which the alternatives to answer were; (1) never; (2) less than once per week; (3) once per week; (4) two-three times per week; (5) every day.

Intensity of PA

Intensity was assessed in two ways;

I) Through verbal alternatives: "When you exercise; as often as once or more per week, how hard do you exercise?", with the alternatives; (1) "Easy without being out of breath or sweaty"; (2) "So hard that I become out of breath and sweaty"; (3) "I exhaust myself".

II) With scaled numbers (BORG): "On a scale from 6-20: how hard are the activities that you regularly perform when you exercise? (take an average of the last week)", with alternatives 6 through 20.

Duration of PA

Duration of PA was measured by asking the question: "What is the usual duration (average)?". The alternatives were: (1) less than 15 minutes; (2) 15-29 minutes; (3) 30 minutes – 1 hour; (4) more than 1 hour.

Physical Activity Index

In addition to assessing PA levels in terms of frequency, intensity and duration, the present study assessed PA levels through a summary index. The index is a product of frequency, duration and intensity. This has previously been used in several studies related to the HUNT-study (Nord-Trøndelag Health Study), with some difference in weighting of the factors (37, 38). The present study aimed to use the same weighting as Kurtze and colleagues, see Table 1 (37). Lowest possible PA index score was 0, with 15 being the highest possible score.

Table 1: Survey answers and their score

Answer	Score
Frequency	
Never	0
Less than once a week	0,5
Once a week	1
2 or 3 times per week	2,5
Nearly every day	5
Intensity	
No sweat or heavy breath	1
Heavy breath and sweat	2
Push myself to exhaustion	3
Duration	
Less than 15 minutes	0.10
15-29 minutes	0.38
30 minutes - 1hour	0.75
More than 1 hour	1

Statistical analysis

Baseline descriptive characteristics in Table 2 are presented as mean ± standard deviation (SD) for continuous variables, with numbers and percentages for categorical variables. It is underlined that baseline characteristics in this study are based on data retrieved at the end of the Generation 100 study and must not be confused with baseline data from the original study. Because the baseline data in the present study is no longer randomized, statistically significant differences between the groups at baseline were assessed through a One-Way ANOVA test. A premise for performing a One-Way ANOVA is that the data must be normally distributed.

All data included in the analysis fulfilled the assumption of normal distribution, based on visual inspection of histograms and Q-Q plots based on residuals.

To adjust for baseline differences, a linear mixed model (LMM) was performed in accordance with recommendations from Twisk and colleagues (39), which was also done in the original study by Stensvold and colleagues (34). This method allows for direct interpretation of the between-group treatment effects for the estimate of group*time (39). Sex and cohabiting status were used in the randomization stratification in the original study (33). Therefore, we adjusted for these factors, as well as age, in the LMM.

To assess treatment effect between groups at different time points, LMM analysis was performed for all five outcomes (frequency, intensity, BORG, duration, and PA index), one at a time, as dependent variables. Participants were included as a random effect. *Intervention groups* were included in the analyses (CON vs ExComb, CON vs MICT, CON vs HIIT, MICT vs HIIT), as well as *time* and their 2-way interaction (time*group).

Assessment of differences in mean values at all time points for the outcomes was performed through a One-Way ANOVA (Bonferroni) test for between-group differences, both for CON vs. ExComb and CON vs. MICT vs. HIIT. This analysis does not adjust for baseline differences.

All statistical analysis was performed in IBM SPSS Statistics, Version 27 (SPSS Inc, Chicago, USA).

Results

Baseline descriptive characteristics are presented in Table 2. There were no statistically significant differences in characteristics between groups at baseline (5 years after the intervention began). Females accounted for about 50% in each group.

Table 2: Baseline characteristics by intervention group

	CON (n=452)	ExComb (n=418)	MICT (n=208)	HIIT (n=210)
Females (%)	401 (51.4)	389 (49.4)	199 (51.4)	190 (47.5)
Living alone (%)	136 (17.4)	112 (14.2)	63 (16.3)	49 (12.3)
Uses medication (%)	239 (30.6)	217 (27.6)	122 (31.5)	95 (23.8)
Age (years)	72.8 ± 2.1	72.9 ± 2.1	72.8 ± 2.0	72.9 ± 2.1
Height (cm)	169.6 ± 8.8	170.2 ± 9.2	170.9 ± 9.1	169.5 ± 9.3
Weight (kg)	74.5 ± 12.9	74.4 ± 13.3	75.3 ± 13.2	73.6 ± 13.3
Body mass index (kg/m^2)	25.8 ± 3.5	25.6 ± 3.5	25.7 ± 3.7	25.5 ± 3.2
VO_2peak (L/min)	2.1 ± 0.6	2.2 ± 0.6	2.1 ± 0.6	2.2 ± 0.6
VO_2peak (mL/kg/min)	28.4 ± 6.7	29.2 ± 6.5	28.9 ± 6.6	29.5 ± 6.5
Waist circumference (cm)	94.9 ± 10.9	94.3 ± 11.2	94.8 ± 11.7	93.9 ± 10.6
Waist-to-hip ratio	1 ± 0.1	1 ± 0.9	0.9 ± 0.1	1 ± 0.1
Fat percentage (%)	31.1 ± 8.3	30.1 ± 7.5	30 ± 8.1	30.2 ± 6.9
Fat mass (kg)	23.3 ± 8.3	22.6 ± 7.6	22.9 ± 8.3	22.3 ± 6.8
Muscle mass (kg)	27.8 ± 5.7	28.2 ± 5.8	28.6 ± 5.7	27.9 ± 5.9

Data is presented as total numbers, percentages or as mean ± SD. VO_2peak, Peak oxygen uptake; CON, controls; ExComb, MICT and HIIT combined; MICT, moderate intensity continuous training; HIIT, high intensity interval training.

Exercise patterns at baseline

The exercise patterns at baseline are presented in Table 3. At baseline, PA index was higher in the ExComb group compared to controls (p=0.011). The difference was mainly driven by the HIIT group, as HIIT, but not MICT had significantly higher PA index compared to controls (p=0.026). There was no difference between CON and MICT in terms of PA index at baseline. There were also higher values in ExComb for intensity (p=<0.001) and BORG (p=<0.001) compared to controls, again with the HIIT group being the main contributor, as HIIT, but not MICT, had significantly higher levels compared to controls (p=<0.001 and <0.001, respectively). There were significant differences between HIIT and MICT for BORG at baseline (p=<0.001). Duration was longer in ExComb compared to controls (p=<0.001), with both MICT (p=0.002) and HIIT (p=0.017) having significantly longer sessions than CON. No between group differences were found in PA frequency at baseline.

Table 3: Exercise patterns at five, six and seven years

	CON	ExComb	MICT	HIIT
Year 5 (baseline)	**n=452**	**n=418**	**n=208**	**n=210**
PA index (0-15)	3.93 ± 2.82	4.39 ± 2.48*	4.26 ± 2.41	4.52 ± 2.56*
Frequency (days/week)	2.99 ± 1.55	3.06 ± 1.32	3.04 ± 1.28	3.08 ± 1.35
Duration (hours/session)	0.75 ± 0.21	0.80 ± 0.19*	0.81 ± 0.18*	0.80 ± 0.19*
Intensity (1-3)	1.62 ± 0.55	1.75 ± 0.51*	1.70 ± 0.48	1.81 ± 0.53*
BORG (6-20)	13.26 ± 2.01	13.77 ± 1.87*	13.21 ± 1.66	14.34 ± 1.90*°
Year 6	**n=450**	**n=412**	**n=208**	**n=204**
PA index (0-15)	3.92 ± 2.86	4.10 ± 2.69	3.93 ± 2.64	4.27 ± 2.73
Frequency (days/week)	2.90 ± 1.51	2.94 ± 1.44	2.95 ± 1.44	2.93 ± 1.45
Duration (hours/session)	0.75 ± 0.22	0.77 ± 0.21	0.78 ± 0.21	0.77 ± 0.21
Intensity (1-3)	1.61 ± 0.54	1.69 ± 0.54	1.60 ± 0.52	1.78 ± 0.55*°
BORG (6-20)	13.22 ± 2.19	13.60 ± 1.99*	13.18 ± 1.84	14.04 ± 2.05*°
Year 7	**n=370**	**n=340**	**n=168**	**n=172**
PA index (0-15)	3.43 ± 2.56	3.47 ± 2.41	3.46 ± 2.49	3.47 ± 2.35
Frequency (days/week)	2.94 ± 1.55	2.78 ± 1.43	2.71 ± 1.42	2.85 ± 1.44
Duration (hours/session)	0.71 ± 0.24	0.73 ± 0.23	0.76 ± 0.21	0.70 ± 0.24
Intensity (1-3)	1.49 ± 0.52	1.59 ± 0.52*	1.56 ± 0.52	1.63 ± 0.52*
BORG (6-20)	12.78 ± 2.13	13.27 ± 2.07*	13.08 ± 1.80	13.48 ± 2.31*

Data is presented as mean ± SD. CON, control; MICT, Moderate Intensity Continuous Training; HIIT, High Intensity Interval Training; PA, Physical Activity.
*Sig. difference from CON at the 95% level ° Sig. difference from MICT at the 95% level

Changes in PA index over time

The mean value of each group, per time, is presented in Table 3. Between-group changes are presented in Table 4. Between-group differences and changes within groups over time are presented in Figure 2. From year five to six, PA index was reduced in ExComb by 6.6% (p=0.035) and in the MICT group by 7.7% (p=0.05), but there were no between-group differences in PA index at this time. CON and HIIT did not see changes in PA index from year five to six.

From year five to seven, there were reductions in PA index for all groups. PA index fell by 12.7% (p=<0.001) in CON, 21% (p=<0.001) in ExComb, 18.8% (p=<0.001) in MICT, and 23.2% (p=<0.001) in HIIT. There were no statistically significant differences in change between groups and there were no differences in PA index between groups at year seven.

Changes in frequency over time

The mean value of each group, per time, is presented in Table 3. Between-group changes are presented in Table 4. Between-group differences and changes within groups over time are presented in Figure 2. From year five to six, there were no significant reductions in frequency of PA for any group, and there were no differences between groups.

From year five to seven, there was a significant reduction of 9.2% for ExComb (p=<0.001), with reductions of 10.9% in MICT (p=<0.001) and 7.5% in HIIT (p=0.016). CON saw no significant changes in frequency over the two years. There were no statistically significant differences in change between groups and there were no differences in frequency between groups at year seven.

Changes in duration over time

The mean value of each group, per time, is presented in Table 3. Between-group changes are presented in Table 4. Between-group differences and changes within groups over time are presented in Figure 2. There was a statistically significant reduction in duration in ExComb by 3.8% (p=0.028), with the HIIT group being the main contributor with a 3.8% reduction (p=0.031) from year five to six. There were no significant reductions in duration in CON or MICT from year five to six. There were no between-group differences in terms of duration at year six.

From year five to seven, there were reductions in duration in CON by 5.3% (p=<0.001), as well as in ExComb (8.8%, p=<0.001) and HIIT (12.5%, p=<0.001). MICT saw no statistically significant reductions in duration across the two years. However, both CON and MICT saw a larger reduction in duration than HIIT from year six to seven. At year seven there were no significant differences between groups in terms of duration.

Changes in intensity over time

The mean value of each group, per time, is presented in Table 3. Between-group changes are presented in Table 4. Between-group differences and changes within groups over time are presented in Figure 2. From year five to six, there was a significant 5.9% (p=0.005) decline in intensity in MICT, but no change was observed in CON, ExComb or HIIT. MICT saw a smaller reduction in intensity, compared to HIIT from year five to six. However, at year six, the HIIT group had significantly higher intensity compared to both CON and MICT (p=0.001 and 0.002, respectively).

From year five to seven, all groups reduced the intensity, and no between-group differences in change were observed. CON reduced intensity by 8% (p=<0.001), ExComb by 9.1%

(p=<0.001), MICT by 8.2% (p=0.003), and HIIT by 9.9% (p=<0.001). The HIIT group had a higher intensity level compared to CON at year seven (p=0.022).

Changes in BORG over time

The mean value of each group, per time, is presented in Table 3. Between-group changes are presented in Table 4. Between-group differences and changes within groups over time are presented in Figure 2. There were no significant reductions or between-group differences in change concerning BORG from year five to six in any group. The HIIT group still had higher BORG compared to CON and MICT, at year six (p=<0.001 for both).

From year five to seven, there were statistically significant declines in CON by 3.6% (p=<0.001), ExComb by 3.6% (p=<0.001) and HIIT by 6% (p=<0.001). No change was observed in MICT. From year six to year seven, there was a smaller change in HIIT than in MICT, but CON saw larger changes than MICT. The HIIT group had significantly higher BORG compared to CON at year seven (p=0.002).

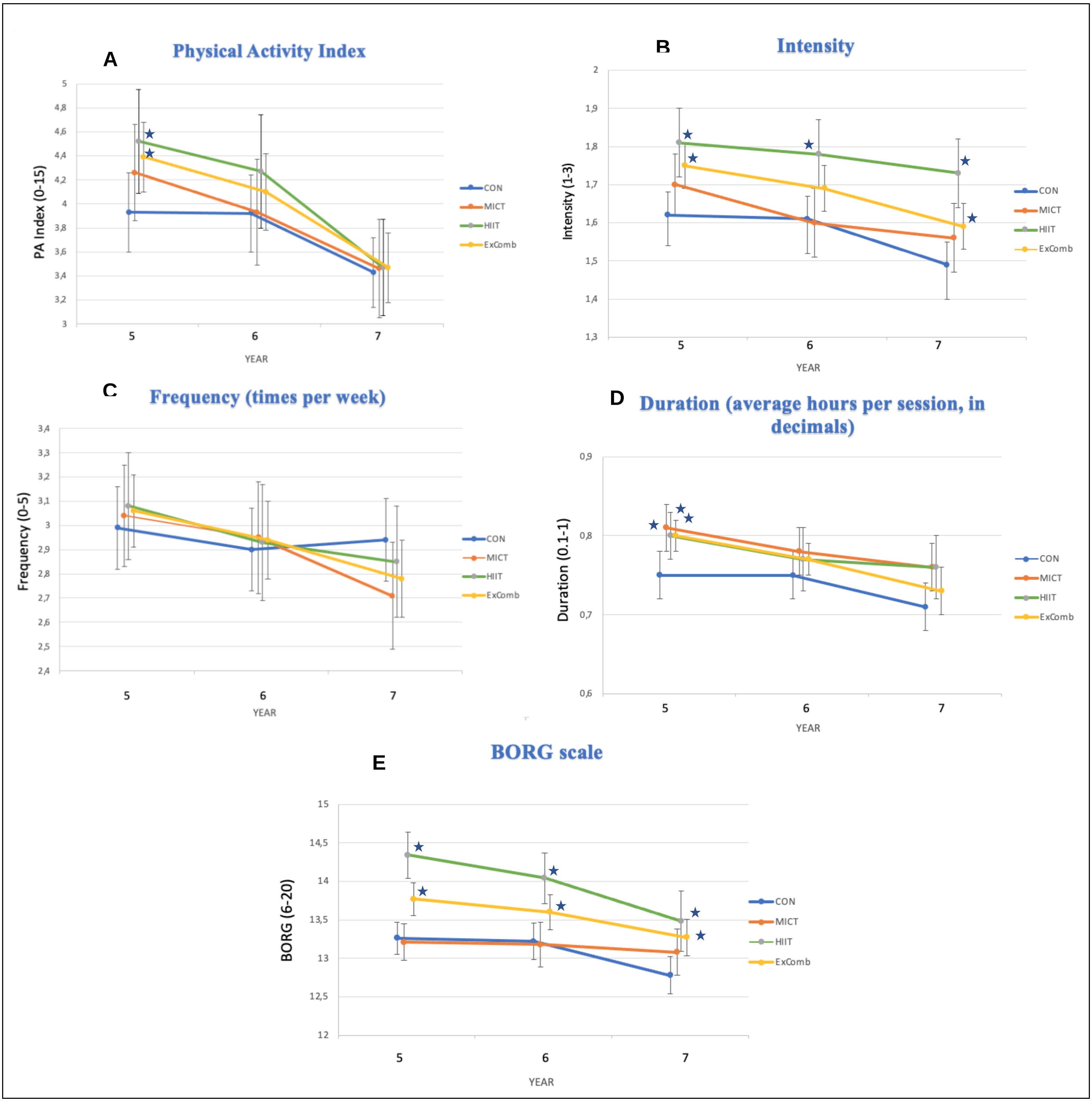

Figure 2: Changes in A; PA index, B; intensity, C; frequency, D; duration, E; BORG.
Results are presented as means and 95% confidence intervals for each outcome at study years five, six and seven, by group (CON, MICT, HIIT and ExComb).

CON, control (blue line); MICT, moderate intensity continuous training (orange line); HIIT, high intensity interval training (green line); ExComb, MICT and HIIT combined (yellow line).

★ Significant difference from CON at the 95% level

Table 4: Results from the linear mixed model showing estimated treatment effect

Outcome	Year	Control	ExComb vs control		MICT vs control		HIIT vs control		HIIT vs MICT	
		Mean (SD)	**Estimate (95% CI)**	**P-value**	**Estimate (95%CI)**	**P-value**	**Estimate (95% CI)**	**P-value**	**Estimate (95% CI)**	**P-value**
PA-index	**5**	3.93 (2.82)								
	6	3.92 (2.86)	-0.13 (-0.42 to 0.17)	0.395	-0.19 (-0.55 to 0.17)	0.292	-0.058 (-0.42 to 0.3)	0.753	0.14 (-0.29 to 0.56)	0.532
	7	3.43 (2.56)	-0.17 (-0.49 to 0.15)	0.305	0.03 (-0.36 to 0.42)	0.880	-0.38 (-0.77 to 0.02)	0.063	-0.41 (-0.88 to 0.06)	0.087
Intensity	**5**	1.62 (0.55)								
	6	1.61 (0.54)	-0.01 (-0.07 to 0.05)	0.756	-0.06 (-0.14 to 0.013)	0.105	0.045 (-0.03 to 0.12)	0.247	0.107 (0.02 to 0.2)	0.018*
	7	1.49 (0.52	0.035 (-0.032 to 0.1)	0.300	0.06 (-0.03 to 0.14)	0.178	0.013 (-0.07 to 0.096)	0.786	-0.044 (-0.14 to 0.05)	0.378
BORG	**5**	13.26 (2.01)								
	6	13.22 (2.19)	0.09 (-0.13 to 0.31)	0.430	0.009 (-0.26 to 0.28)	0.950	0.18 (-0.1 to 0.46)	0.213	0.17 (-0.16 to 0.49)	0.309
	7	12.78 (2.13)	0.24 (-0.008 to 0.48)	0.058	0.41 (0.11 to 0.71)	0.007*	0.05 (-0.26 to 0.36)	0.752	-0.36 (-0.72 to -0.0001)	0.050*
Duration	**5**	0.75 (0.21)								
	6	0.75 (0.22)	-0.012 (-0.038 to 0.013)	0.352	-0.004 (-0.04 to 0.03)	0.787	-0.02 (-0.05 to 0.01)	0.216	-0.016 (-0.05 to 0.02)	0.406
	7	0.71 (0.24)	-0.006 (-0.034 to 0.022)	0.669	0.03 (-0.007 to 0.06)	0.113	-0.04 (-0.08 to -0.007)	0.019*	-0.069 (-0.11 to -0.03)	<0.001*
Frequency	**5**	2.99 (1.55)								
	6	2.90 (1.51)	0.014 (-0.15 to 0.18)	0.875	0.03 (-0.18 to 0.23)	0.782	0.003 (-0.21 to 0.20)	0.976	-0.03 (-0.28 to 0.21)	0.795
	7	2.94 (1.55)	-0.17 (-0.35 to 0.01)	0.065	-0.22 (-0.44 to 0.007)	0.057	-0.12 (-0.35 to 0.11)	0.295	0.096 (-0.17 to 0.37)	0.483

The table shows year*group interaction with 95% confidence interval for ExComb, MICT (moderate intensity continuous training) and HIIT (high intensity interval training) compared to control, as well as mean (standard deviation) for control.

*Statistically significant at the 95% level

Discussion

This follow-up study is the first to assess long-term physical activity levels in older adults, one and two years after a five-year intervention period. Our data show that from when the supervised exercise stopped in 2018, until 2020, there were statistically significant reductions in PA index and intensity in all three groups. Further, our data show that frequency was reduced only in the supervised groups (ExComb), while duration and BORG decreased in all groups except for MICT. At study end, there were no significant differences between groups in terms of PA index, frequency, or duration. However, in terms of intensity and BORG, the HIIT group had significantly higher values compared to controls.

The present study hypothesized that those who underwent supervised exercise during the Generation 100 study, had higher levels of physical activity, compared to controls, during the follow-up period. The hypothesis is not supported by the analyses in the present study, although there are some differences in what makes up the PA index in the groups. The summary PA index was not statistically different between groups at study end. However, as the index is a product of frequency, duration, and intensity, these three variables may contribute differently. Interestingly, although intensity and BORG fell in all three groups from year five to seven, the HIIT group had higher intensity and BORG compared to CON, two years post-intervention.

The results of the present study are in line with the systematic review by Hobbs and colleagues, in that PA levels decrease when assessed long-term after an intervention (24). Likewise, in the previously mentioned studies by Aamot- and Moholdt and colleagues, they found that PA levels decline at long-term follow-up (12- and 30 months, respectively) (22, 23).

In contrast, the results of the present study oppose the results from the pedometer-based walking interventions presented by Harris and colleagues, where they found that MVPA levels were greater in intervention groups after 3- and 4 years, compared to controls (26). These differences were of clinical importance, as the intervention groups had about 30 minutes more physical activity per week compared to controls. It is important to note that the participants in Harris' study were younger than those in the present study (26). A possible explanation for successful adherence to PA in the intervention groups of Hobbs' trial, could be the simplicity of the interventions (24).

The present study adds more insight into how five years of supervised and unsupervised exercise influences long-term PA levels in older adults. Finding effective initiatives to maintain or increase PA levels in the older population is highlighted as an important strategy to increase quality of life and self-reliance, as well as reduce the risk of chronic diseases and healthcare utilization as people age (9). This is the first study to evaluate long-term PA levels following a high intensity aerobic intervention for such a long time. Our data adds knowledge that five years of supervised aerobic exercise does not improve long-term PA levels in older adults, compared to controls.

Clinical significance

Many studies emphasize the importance of statistical significance, as does the present study. However, statistical significance only shows whether the results are likely to be due to chance or not, meaning if we can trust that the results reflect reality. In medical research, the p-value indicating statistical significance, has been viewed as important, but to clinicians and patients, the *clinical significance* may be more interesting.

Clinical significance, also called “minimal important difference” or “clinical relevance”, means the significance the results have for the stakeholders, such as patients and clinicians. An effect may be statistically significant, but that does not mean that the patient finds the intervention effective or worthwhile (40).

In terms of physical activity, there is scarce knowledge about how much change is needed, for it to be clinically significant. In a recent systematic review by Ramsey and colleagues regarding the clinical value of change in PA among older adults, they found that an increase of just 1000 steps per day, led to 11% higher odds of survival and 34% odds of better performance in daily activities (41).

Although the declines in PA dimensions were statistically significant two years post-intervention in the present study, that does not mean they are of clinical relevance. Intensity fell by about 0.1-0.2 on the 1-3 scale across groups, while it fell approximately 0.5 on the BORG scale. If these declines are of clinical importance, is not certain, but does not seem likely.

Importantly, the HIIT group had 0.14 (9.4%) and 0.7 (5.5%) higher intensity and BORG respectively, compared to controls at two years post-intervention. These differences are not substantial but could perhaps yield slightly greater health benefits for the HIIT group.

PA index fell 12.7 to 23.3% across groups, with there being no differences between groups at two years post-intervention. As mentioned, even small changes in PA may be of clinical importance (41). It seems plausible that this decline in PA could affect health and risk of premature death in the participants, though that is merely speculation.

The importance of intensity

The PA guidelines presented by WHO largely focuses on total time spent being physically active (9). These guidelines are in accordance with Ramsey and colleagues, who emphasise that "every step counts" (41). The PA recommendations presented by WHO state that PA may be performed as longer duration at lower intensity, or as shorter duration with higher intensity (9). While it may seem like which intensity one chooses does not matter, WHO do in fact recommend that some of the weekly PA should be performed at vigorous intensity for even greater health benefits. I.e. intensity is of importance, according to WHO (9).

The present study indicates that although PA index is not different between groups at two years post-intervention, there were some differences in intensity, with the HIIT group maintaining a higher exercise intensity compared to controls. As was shown in the Generation 100 original study, there were larger health benefits from performing mainly HIIT, compared to performing mainly MICT (34). Therefore, the difference in intensity seen two years after the study ended, may be of importance.

As has been shown previously, performing aerobic exercise at a higher intensity yields greater gains in peak oxygen uptake compared to moderate intensity, and greater peak oxygen uptake yields greater health benefits (6, 34, 42). Exercise intensity therefore seems important and should be a part of weekly PA among older adults.

Potential explanations for declines in PA levels

Ageing

It is well established that the global older population are less physically active compared to younger counterparts (9). In a cross-sectional study from 2014 by Lohne-Seiler and colleagues, they assessed PA in older adults (65-85 years old) using accelerometers. The study found that among older adults in Norway, only 21% fulfilled the national physical activity recommendations at the time. More interestingly, they found that the "oldest" older adults (80-85 years) had 50% lower PA levels compared to the "youngest" (65-70 years), with only 6% meeting the recommended PA level in the oldest group (19).

Data from the U.S show that there is about a 10% decline in PA levels from 65 to 75 year-olds and older (8). The decline in PA levels seem steady from young age, with more people becoming inactive with increasing age, and less people being sufficiently active (8).

Of note, the participants in Lohne-Seiler's study spent only 3% of their waking hours, in moderate-to-vigorous physical activity, with 66% spent sedentary. Furthermore, the authors found that higher PA levels were associated with better self-reported health (19).

The participants in Generation 100 were 70-77 years old in 2012 (34). In 2020, when the last questionnaires were answered, they were about 78-85 years old. Based on previous studies assessing PA levels in older adults, it is plausible and expected that ageing in itself is a possible explanation for the fall in PA levels after the intervention period (8, 19). Accordingly, the results of the present study may only be generalizable to older adults, as the decline in PA levels perhaps would not be seen in younger adults.

In the present study, PA levels fell by 12.7 to 23.3%, measured as a PA index. Compared to the aforementioned 10% decline seen in U.S citizens across ten years of ageing (65 to 75) (8), the reduction is higher in the present study. However, PA was assessed through a summary PA index in the present study, following a substantial intervention period, while Schoenborn and colleagues measured PA as how many people of a certain age fulfilled the national recommendations at a given time (8). Thereby, it is difficult to compare the results.

As stated by Collado-Mateo and colleagues, there are a variety of potential factors that may have caused a decrease in PA levels among the participants of the present study (20).

During the Generation 100 intervention period, participants experienced involvement of professionals, supervision, social support, communication and feedback as well as progress information and monitoring (34). After the intervention period, many of these factors were no longer as strong as they had been. Still, they were invited to answer a yearly questionnaire and were encouraged to continue exercising has they had done, but the constant monitoring and supervision had stopped. Whether they continued to have social support is unknown, but it is probable that there is some variance in this factor. Summarized, many of the factors associated with higher adherence to exercise and PA in older adults, were not fulfilled to a great degree after the interventions ended. This may well be part of the explanation as to why PA levels dropped during the first two years since the intervention period.

A global pandemic

While ageing may explain some of the decline of PA levels in the present study, there is another factor which may also contribute. The global Covid-19 pandemic that broke out in late 2019 and early 2020, may have severely impacted PA levels among older adults. While observing a great deal of variance, early research suggests that increased age may be a risk factor for Covid-19 related hospitalization (43). In addition, comorbidity has been shown to be a strong risk factor for Covid-19 related hospitalization and as ageing increases the risk of comorbidity, there were clear indications for older adults to be especially careful (43). Early research indicates that PA levels in older adults with comorbidities were negatively affected by lockdown (28, 29). However, there are indications of strategies that may aid in maintaining or increasing these levels (30-32). Interestingly, frequent use of social media was linked to increases in PA among older adults in the UK during lockdown (30), while Chaabene and colleagues suggest using home-based exercise programs to improve physical fitness among older adults, as such strategies have proven to be effective (32).

Although there is a lack of substantial research on the topic of PA levels in older adults during the pandemic, it is plausible it may have impacted the results of the present study. However, the declines in PA in the present study were not significantly different from year five to six and year six to seven. This may imply that the pandemic did not affect PA levels substantially in the present population.

Implications for practice

For clinicians, the result of the present study produces some interesting perspectives. While PA levels were high while supervision was provided during the Generation 100 study, the PA levels decreased when supervision was taken away. Clinicians should carefully consider which intervention is suited to their patient or participant, how much supervision they need, and perhaps explore how to make them more independent with regards to PA. As suggested in the original paper by Stensvold and colleagues, there might be value in yearly physiological testing, as this seems to motivate subjects in adhering to PA recommendations (34).

Moreover, there may be implications for gradual reductions of supervision following studies such as Generation 100. Perhaps gradually decreasing communication and supervised exercise sessions would allow participants to continue their exercising habits with greater success.

The study may also yield some political implications. Policies concerning PA in older adults, and the population as a whole, are important. The present study may help inform decision makers in how important supervision seems to be for older adults with regards to maintaining or increasing PA levels. In the coming decades, providing older adults with enough resources to attain recommended PA levels may in turn relieve healthcare services in the long run. However, as there were no differences between CON and MICT in terms of intensity or BORG at two-year follow-up, there may be implications that using resources on moderate intensity interventions is not a worthwhile investment.

Informed by the fact that levels of PA and exercise seems negatively affected by age, as well as the results of the present study showing declines in PA, it seems appropriate to provide this population with opportunities for supervised exercise and social support. Older adults may be at greater need for more substantial follow-up when it comes to PA, compared to younger adults, who to a larger extent fulfil PA recommendations (8).

Limitations and strengths

The present study has some limitations that must be addressed. Firstly, as mentioned in the original study, the included participants were physically active and resourceful, with 80% of participants reporting medium to high PA levels at baseline (in 2012), which does not reflect this population generally (8, 34). Therefore, both the results of the original- and the present study, must be interpreted with caution – with regards to the general older population.

Using questionnaires as a way of assessing PA levels in older adults, may have been a limitation. Ryan and colleagues found that the International Physical Activity Questionnaire (IPAQ), was not reliable when assessing sedentary behaviour and physical activity in older adults, compared to accelerometers (44). IPAQ was not used in the present study, but the questionnaires share similarities.

Accelerometers are generally considered more accurate than questionnaires (45), but such measurements are prone to be effected by fitness level, activity mode and gender (46). As stated in the original study, in a real-life setting, with heterogenous fitness levels, daily activities and preferred activity modes, there are strong arguments for using questionnaires for this study. The questions regarding PA used in the present study have been validated by Kurtze and colleagues during the HUNT-study and were found to correlate moderately with peak oxygen uptake (37).

Another compelling argument, and a strength of the present study, is the ability to attain a lot of information from participants, with less resources required. For a study such as the present one, where resources are limited, the use of questionnaires strengthen the study by yielding large data. Additionally, the questionnaire used in the present study, has previously shown sensitivity in predicting current and future cardiovascular health (37, 47). It is important to note that the present study is the largest known study to assess PA levels among older adults for such a long follow-up period, which must be considered a major strength.

While the questionnaire may be valid and reliable in assessing physical activity, the data that has been analysed in the present study does not consider more subtle forms of physical activity. It is unknown to the author, but it seems plausible that participants did not consider activities such as gardening, tidying and grocery shopping as physical activity. Additionally, the results do not show which activity modes the participants chose.

Recommendations

With research moving forward there is a need avoid selection bias when recruiting participants to studies regarding PA in older adults. Since higher intensity of PA and exercise is beneficial for many health outcomes, it seems important to aid and encourage older adults in incorporating HIIT as part of their weekly PA.

As mentioned, adherence to PA is multifactorial. Adjusting exercise mode to the individual's preferences, aiding them in integration of PA in daily living, giving them ownership, while still providing support, seems important in improving PA levels. Results from the present study indicate that older adults seem to benefit from HIIT when it comes to long-term exercise intensity. Therefore, it may be beneficial to invest in HIIT for the present population.

Another interesting topic in need of further exploration is the use of social media for increasing PA levels in older adults. While recent studies suggest there is value in social media (28, 30), more research is needed, particularly targeting those who need it most.

Conclusion

In terms of physical activity index, the present study did not find any differences between the groups, two years after the Generation 100 intervention period ended. There were, however, some differences in what made up the total PA in the groups. Importantly, the HIIT group had significantly higher intensity of PA, compared to controls, two years post-intervention. As intensity of PA seems to be important for several health outcomes, our findings indicate that investing in HIIT for older adults may be beneficial. Future research should avoid selection bias, and focus on how exercise and PA can be sustained long-term, and how social media and technology can be used for this purpose.

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