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Effects of aquatic high-intensity interval training on aerobic capacity in adults with rheumatic and musculoskeletal diseases: the AquaHigh randomised controlled trial

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ABSTRACT

Objectives To examine the effects of 12 weeks aquatic high-intensity interval training (AHIIT) compared with aquatic moderate-intensity continuous training (AMICT) on aerobic capacity and lower limb functional strength in adults with rheumatic and musculoskeletal diseases (RMDs).

Design An assessor-blinded randomised controlled trial.

Setting Community-based setting.

Participants 89 participants (91% female, mean age 62 (SD 13) years) with RMDs were randomly allocated to AHIIT (n=44) or AMICT (n=45).

Interventions Both groups participated in group-based peer-led exercise programmes two times per week for 12 weeks. The AHIIT group included four intervals of 4 min at high intensity (Borg scale 14–18). The AMICT group maintained moderate continuous intensity level (Borg scale 12–13).

Main outcome measures Peak aerobic capacity (VO_2peak) was estimated by time to exhaustion and lower limb functional strength with the 30-second sit-to-stand test (30sSTS) at baseline, 3 months and 6 months. A linear mixed model for repeated measures estimated the mean difference with 95% CI in VO_2peak and 30sSTS.

Results Mean exercise intensity was Borg scale 15 (SD 2) and 13 (SD 2) in the AHIIT and AMICT, respectively. Mean improvement in VO_2peak in AHIIT was 1.9 mL·kg^{-1}·min^{-1} (95% CI 0.045 to 3.77) compared with AMICT after 12 weeks ($p<0.05$). There was no statistically significant difference between groups in VO_2peak after 6 months or in 30sSTS at either 3 or 6 months ($p>0.05$). No adverse events during exercise were reported.

Conclusions AHIIT demonstrated significant improvements in aerobic capacity after 12 weeks, and the intervention was well tolerated with no adverse events reported. However, there was no maintenance of aerobic capacity at 6 months.

Trial registration number NCT05209802.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The main strength of the present study is the randomised controlled trial design and intention-to-treat strategy with linear mixed models for repeated measures.
⇒ The impact of training intensity was assessed by comparing two exercise interventions.
⇒ Using peers as instructors applied the intervention to real-world practices, though the lack of professional supervision may have impacted its effectiveness.
⇒ Outcome assessors were blinded, but the lack of blinding for participants and instructors could introduce bias.
⇒ Small sample size and high dropout rates, likely related to the COVID-19 pandemic, are limiting factors, increasing the risk of type II error.

INTRODUCTION

Rheumatic and musculoskeletal diseases (RMDs) affect a considerable number of adults, and their global incidence is increasing.[1–3] Conditions such as osteoarthritis (OA), fibromyalgia (FM), rheumatoid arthritis (RA), psoriatic arthritis (PsA) and axial spondylarthritis (AxSpA) are common RMDs exhibiting a range of symptoms arising from inflammatory, degenerative or autoimmune processes that affect muscles, joints, tendons and other bodily tissues and organs.[4] These symptoms include pain, fatigue, stiffness,[4] decreased aerobic capacity, reduced quality of life[5 6] and increased risk of cardiovascular diseases.[7] Both inflammation from the condition and commonly used medications, such as corticosteroids and non-steroidal anti-inflammatory drugs (NSAIDs), elevate the risk of cardiovascular disease.[8] Despite medical advancements like biological therapy,[9] managing symptoms and optimising health for individuals with RMDs remain complex.

While symptoms and physical limitations vary for people living with RMDs, there are many common challenges in participating in

exercise therapy due to their condition. Beyond disease-related barriers like pain and fatigue, people living with RMDs often experience pain in joints during weight-bearing activities.[10] There has been a longstanding interest in aquatic exercise for people with pain and weakness to enable successful exercise as buoyancy reduces weight-bearing load on joints.[11] In addition, alteration of pain perception due to the warmth of (thermoneutral) water, along with reduced swelling from compression by hydrostatic pressure and lowered sympathetic nervous system activity,[11] may facilitate movements that are challenging on land. This, in turn, can contribute to a sense of overall well-being. These beneficial aspects of the environment may also contribute to the high compliance and preference for aquatic exercise in people with chronic conditions including those with RMDs.[12 13] However, aquatic programmes have been criticised for mainly being conducted at low or moderate exercise intensity,[14] and this may limit gains in cardiorespiratory fitness. Consequently, the potential benefits of applying high-intensity interval training (HIIT) in an aquatic environment merit further exploration.

Improved aerobic capacity is associated with improved cardiovascular disease risk profile,[15 16] improved health-related quality of life[17] and reduced overall mortality.[15 16] Moreover, exercise plays a central role in the management of RMDs[18] because of the multitude of benefits to the physiological systems and physical function,[18] and its association with improved disease control.[19] HIIT demonstrates greater improvements in aerobic capacity compared with moderate-intensity exercise in middle-aged, older adults and clinical populations.[20] There are a limited number of studies of HIIT, including people with RMDs,[21–27] and to our knowledge, no studies investigate the effectiveness of HIIT in an aquatic environment in improving aerobic capacity.

The aquatic environment can offer additional physiological benefits for cardiopulmonary exercise, such as central hypervolemia, increased stroke volume and cardiac output due to hydrostatic pressure.[11] Lower lung volumes when immersed in water are due to hydrostatic pressure, which forces abdominal contents and the diaphragm upward, and increased blood volume in pulmonary vessels. Additionally, the compression of the chest wall and upwards displacement of the diaphragm require more effort during inspiratory work of breathing, and thereby, the inspiratory muscles will be strengthened.[11] A recent systematic review evaluating the effectiveness of aquatic high-intensity interval training (AHIIT) on exercise capacity in people with chronic conditions[28] only included three studies conducted in people with RMDs.[29–31] Among these, two studies from Brazil focused on FM[29 30] and one from Finland targeted mild knee OA.[31] Conflicting evidence exists regarding the effect of exercise intensity on aerobic capacity in these studies. One showed no clinical improvements,[29] while two demonstrated only small beneficial improvements in AHIIT.[30 31] However, in these studies, AHIIT was either compared with a non-exercising control group[29 31] or with land-based HIIT.[30] Further research, particularly comparing AHIIT to aquatic moderate-intensity continuous training (AMICT), is needed to fully understand its impact on aerobic capacity in a broader population with RMDs. Additionally, it is crucial to design studies that are not only effective but also feasible to integrate by existing user organisations that already provide aquatic exercise programmes, so they can offer effective interventions.

Therefore, the primary aim was to examine the effects of 12 weeks AHIIT compared with AMICT on VO_2peak, estimated by time to exhaustion in adults with RMDs. The secondary aim was to examine the effect of AHIIT compared with AMICT on lower limb functional strength and to monitor adverse events.

METHODS

A supporting Consolidating Standards of Reporting Trials (CONSORT) checklist[32] for this trial is available as supplementary information (see online supplemental file 1).

Study design

The study was designed as an assessor-blinded pragmatic multisite randomised controlled trial (RCT) comparing the effect of AHIIT with AMICT after 12 weeks intervention. Participants were examined at baseline, at 3 months and further at 6 months. The study protocol was registered at ClinicalTrials.gov (NCT05209802).

Participants

Adults with RMDs (inclusive of hip and knee OA, FM, RA, AxSpA, systemic sclerosis, Sjogren's syndrome, systemic lupus erythematosus, large vessel vasculitis, mixed connective tissue disorder and all diagnoses confirmed by a general medical practitioner or specialist) were recruited from three municipalities in Eastern Norway. Local chapters (locations) from the user organisation of the Norwegian Rheumatism Association (NRF) recruited members through emails, local web pages and flyers. In one municipality, participants were recruited from the Healthy Life Centres and local physiotherapy services. Prescreening was performed via telephone. Inclusion criteria were individuals ≥18 years, diagnosed with any kind of RMDs, capable of walking with or without a walking aid and able to understand Norwegian. Exclusion criteria were medical contraindications to high-intensity exercise, current or recent participation (within the last 3 months) in AHIIT or land-based HIIT programmes or trials.

Patient and public involvement

The project, initiated by the NRF, was developed based on user preferences and experiences with aquatic exercise. Peer involvement was central, incorporating feedback from users who tested and experienced the AHIIT programme, as well as insights from an unpublished feasibility study. Representatives from local NRF chapters

actively participated in the planning, development and recruitment phases of the research project. Peers also served as instructors, having completed instructor training through NRF. Additionally, a reference group was used to discuss outcome measures and evaluate the test protocol. The results were disseminated to the user organisation.

Interventions

All sessions were group-based exercise led by experienced volunteer peer instructors affiliated with the local chapters of the NRF, at five local pool facilities within the three municipalities. All instructors were gathered for a half-day theoretical and practical workshop, and underwent the AHIIT programme, received guidance, reviewed the Borg Ratings of Perceived Exertion (RPE) scale as well as explored various methods to encourage intensity increase. This included visually displaying the RPE scale during training (on a big poster with colours) and instructing participants on how the peak interval should feel (ie, breathless without stiffness in the muscles). Additionally, this AHIIT programme differed from AMICT in its focus on HIIT and its specific emphasis on perceived exertion levels during HIIT. Throughout the intervention period, instructors received both digital and in-person supervision from a qualified physiotherapist (HB-N), who visited each location every other week. During four of the visits, heart rate was monitored for exercise intensity using Garmin Swim 2 monitors. A random sample of 30 individuals distributed across all locations was measured with monitors to verify that heart rate increased or remained consistently at the same intensity according to the protocol and to guide in RPE during the project. Sessions were both led from the pool or on land, primarily with music.

Each group comprised 5–15 participants who exercised in water with a temperature of 32–34 °C, maintaining an immersion to a level of xiphoid process. Both groups completed training sessions lasting for 45–60 min, conducted two times per week on non-consecutive days for 12 weeks. Exercise intensity was monitored by RPE by the Borg 6–20 scale.[33] During the subsequent 12 weeks, participants did not receive any intervention but were encouraged to maintain an active lifestyle and continue participation in aquatic exercises at the local chapters of the NRF if they wanted.

Details of the AHIIT intervention are illustrated in figure 1. The programme consisted of a warm-up followed by four intervals of 4 min at high intensity (RPE 14–18) of exercises activating large muscles in the lower and upper limbs. Between high-intensity intervals, there were 2–3 min bouts of light recovery exercises. The AMICT group intervention followed the usual format of the aquatic exercise sessions within the local chapters and included warm-up, then alternated among flexibility, endurance, strength and balance exercises to ensure moderate continuous intensity (RPE 12–13).

Exercise intensity, adherence to programme

At the start of the intervention, during baseline assessment and testing, participants were familiarised with the Borg RPE scale.[33] Participants were encouraged to document their training participation and RPE in a diary. They were also instructed to keep a record of any other physical activities they engaged in during the intervention period. Adherence to the intervention was assessed based on both attendances to exercise sessions and adherence to the prescribed intensity levels. Attendance (the number of completed sessions reported in diaries) was counted and calculated as the percentage of the total number of sessions completed (24 sessions, 100%). The per-protocol criteria and the lower limit for appropriate adherence to the intervention were defined as follows: participants needed to complete ≥70% of the sessions (≥ 17 out of 24 sessions) and report a Borg RPE of ≥15 in the AHIIT group (or <15 in the AMICT group).

Adverse events

All instructors were instructed to report any adverse events or abnormal exercise-related symptoms during exercise to the principal investigator (HB-N) and participants were asked to report any pain or other symptoms related to the exercise sessions in a diary.

Outcome measures

Primary outcome and end criteria

Peak oxygen uptake (VO_2peak) was estimated using an indirect maximal test on a treadmill, where participants walked uphill until exhaustion,[34] following a modified Balke protocol.[35] The protocol started with habituation at a pace of 2–3 km/h (2–7 min), followed by a gradual increase to 3.8 or 4.5 km/h with an incline of 4%. Participants≥55 years initiated the protocol at a speed of 3.8 km/h, whereas those<55 years started at 4.8 km/h for the initial 4 min. Thereafter, the inclination was increased by 2% every minute until 20% inclination was reached (at 9 min). The speed was thereafter increased by 0.5 km/h from the 11th minute (if inclination stopped at 15%, the acceleration in speed commenced at the 8th minute by 0.5 km/h). The test was continued until exhaustion and was considered valid if the Borg RPE was>16. Heart rate was measured every minute, with a heart rate belt (Polar H10 Bluetooth) connected to the Polar Beat application, and the Borg RPE scale (graded 6–20) was noted every 2 min throughout the test. Different treadmills were used at different locations; however, the same equipment was used at all three measurement points. The estimated VO_2peak is simpler to administer than cardiopulmonary exercise testing and has superior feasibility.[34] For those not able to conduct a treadmill test, a similar protocol was used on a stationary bike. The calculated VO_2peak was then based on watt workload at the end of the test multiplied by 1000 to obtain millilitres per minute, plus 500 (resting metabolism), divided by body weight. For example, at the end of the test, if the workload was 200 watts (W), the calculation was: 200 W=2× 1000 (to get

Drills and intervals	Descriptions of the Movements	Intensity	Purpose
Warm-up: 10-15 min			
First movement drill General warmup	-Different movements of the wrist, elbows, and fingers (rolling both ways) -work around with fingers (fingertips) -Shoulder joints-roll up and down, make different movements	**Borg RPE** 7→11	Warm up joints, ligaments and muscles to be ready for larger movements and loads.
Second and third movement drills Specific warmup	- Switch between swimming and walking in the pool (detects the participants skills in shallow and deep water) - Squat jumps with dynamic tuck jumps at different depths (to determine their load or if they need assistance by their side) - Frog jumps (different levels) - Kick backwards and forwards - Touch feet with the opposite arm and leg (touch hip or knee to adapt)	**Borg RPE** 10→15	Specific warmup to large muscle groups and joints. The intensity of the movements should be increasing during this warmup because the main workout is of high intensity. Each participant should be encouraged to "taste" the intensity in the last part of the warmup before the main workout. They will be encouraged to adapt at their own pace.
Active Recovery Active recovery for 2-3 minutes, instructions and demonstrations of next part of the session			
Part 1			
Interval 1: 4 minutes	**Cycling with floating noodle** The participant is sitting in an upright position while cycling using both feet and hands. The participant has to individually adapt to use one or two noodles, make as much movement as possible, and work the core as a stabilizer. **Alternative:** High knee raise jumps or jog while clapping under legs	**Borg RPE** 14→17	Offloading movements for the body to float while moving most of the body. The participant uses knees, legs, hips, arms, and shoulders. The core is also active to ensure steady balance
Active Recovery Active recovery for 2-3 minutes, instructions and demonstrations of next part of the session			
Interval 2: 4 minutes	**Running frog jumps** The participant jumps with both legs to the surface as their arm touches their feet. They do not need to jump over the surface/water. Their hands are supposed to touch their feet. **Alternative:** The participant runs with high knees and their arms are touching each leg as it is lifted.	**Borg RPE** 14→17	The exercise gives the participant some load to the skeleton and muscles, but there is still much less load to the joints. Most of the joints are active.
Active Recovery Active recovery for 2-3 minutes, instructions and demonstrations of next part of the session			
Interval 3: 4 minutes	**Jumping Jacks** Typical jumping jacks where the participant jumps with arms and legs out to the side, lands in a "X," and jumps back. To activate most of the body, the participant should start the exercise with water at shoulder height. It can be more demanding it in the shallow part of the pool. **Alternative:** Running or cycling	**Borg RPE** 14→17	A perfect exercise to activate the whole body. It is individually adapted (how broad and fast the jumps are). Very active shoulders and hips.
Active Recovery Active recovery for 2-3 minutes, instructions and demonstrations of next part of the session			
Interval 4: 4 minutes	**Exercise with the best intensity** The participant chooses which of the three exercises they want to do. The highest intensity exercise is recommended. **Alternative:** The participant chooses a lower intensity exercise.	**Borg RPE** 14→18	Individually adapted – hopefully with the highest intensity possible within the recommended intensity.
Active Recovery, Hydrate Active recovery for 2-3 minutes, instructions and demonstrations of the part 2 of the session			
Part 2 – Muscular endurance			
Muscular endurance 20 sec work 10 sec rest	**Part 1:** 20 seconds work and 10 seconds' rest: **1. Bent over flies/reverse flies.** The participant will stand on the waterboard/floating board. **2. Push and pull of board.** Similar to bench press and rowing.		Upper body muscular endurance.
Active Recovery between Part 1 and Part 2			
20 sec work 10 sec rest	**Part 2:** 20 seconds work and 10 seconds rest **- Lateral pull down** With straight arms holding one or two noodles, press the noodle from the surface down to the hips. Arms should stay straight both ways. **Alternative:** One arm swing at the edge of the pool with a straight arm up and down. **- Core exercises** (individually adapted)		Upper body muscular endurance.
Part 3 – Stretch and Cooldown			
Stretch and cooldown	Participants return the equipment, besides those who need floating devices to do the exercises. The participants find a spot to do muscle stretching and optional floating.		Cool down and relax for the participants. Feedback from the instructor if needed.

Figure 1 The AHIIT intervention. AHIIT, aquatic high-intensity interval training; RPE, ratings of perceived exertion; sec, seconds.

millilitre uptake) + 500 (resting metabolism) divided by body weight in kilograms (90 kg) = 27.8 mL·kg^{-1}·min^{-1}.

Secondary outcomes: clinical measures

Lower limb functional strength was measured by the 30-second sit-to-stand test (30sSTS).[36] Beginning from a seated posture with arms folded across their chests, participants were directed to perform as many full stands as possible within a 30-second timeframe.[36] Due to logistical considerations, chairs of standard height (44–45 cm) were used across various test sites. The quantity of full stands completed was documented. The test correlates well with other functional tests, such as walking speed and balance, and is deemed reliable and responsive in patients with RMDs.[37] A major clinically important improvement is suggested to be equal to or greater than 2 and 2.6.[37]

Background variables, such as demographic information (including body mass index (BMI) was calculated as weight in kg/height in m^2, age, sex, educational status, employment and marital status, along with details on disease-related variables, were collected at baseline.

Sample size

Sample size was determined based on the primary outcome variable, with a between-group difference in VO_2peak of 15% or 3.5 mL·kg^{-1}·min^{-1} deemed clinically relevant.[15 16 38] Since both groups were receiving an exercise intervention, we estimated a between-group difference to be 2.0 mL·kg^{-1}·min^{-1}. With a reported SD of change in VO_2peak of 3[39] and 80% power to detect this difference, approximately, 35 participants were needed in each group. To account for a potential 20% dropout rate, we aimed to include 42 participants in each group.

Randomisation and blinding

Participants were randomised to either the intervention group (AHIIT) or the control group (AMICT) in a 1:1 ratio using a computer-generated random sequence, generated by an external statistician. Block randomisation was employed to ensure a sufficient number of participants across three different locations. An independent researcher, not involved in participant recruitment, testing or intervention, prepared concealed envelopes. Allocation to groups was conducted by a researcher not involved in assessments.

The outcome assessors, consisting of eight trained physiotherapists or personal trainers, were blinded to group allocations. Following the initial baseline testing, the participants contacted the researcher by phone, who was blinded to the test results. The researcher then opened sealed envelopes and randomly assigned the participants to their respective groups.

Statistical analysis

Descriptive statistics were summarised using means and SD or percentages and frequencies. We used histograms and Q–Q plots to visually inspect the data for normal distribution. The student's t-test and the χ^2 test were used to compare mean values and proportions among completers versus non-completers and those who exercised per protocol or not. The main analyses for primary and secondary outcomes were conducted according to an intention-to-treat strategy using all available data at all timepoints. We used a linear mixed model for repeated measures to estimate the mean difference with 95% CI. Treatment, time, interaction between treatment and time, location and baseline value of outcome variable included as fixed effects. Mean differences postintervention and at 6 months were estimated with associated 95% CIs and p values. Sensitivity to missing data was evaluated using multiple imputations (pooled estimates of five imputed datasets) based on a multivariate regression model (with age, group and time).

A per-protocol analysis was conducted at the 12-weeks follow-up (postintervention).[40] This analysis included only those who reported to exercise on the prescribed intensity for AHIIT in diaries. We excluded participants from both groups who did not attend the assessment following the intervention (postintervention) and those who reported failing to complete the prescribed exercise sessions (defined as <17 sessions, less than 70% attendance) or those who reported to exercise on a lower intensity than prescribed in the AHIIT group or at a higher intensity than prescribed in the AMICT group.

Statistical analyses were performed with IBM Statistical Package for the Social Sciences Statistics V.29. A significance level of 5% was used throughout the analyses.

RESULTS

Participant flow and characteristics

A total of 102 participants with RMDs were eligible after screening for inclusion and exclusion criteria and 89 were randomised to an AHIIT group (n=45) or an AMICT group (n=44) from three different local chapters of the NRF between February 2022 and June 2022. Participants were evenly distributed across local chapters. The mean age was 62 years (SD 13). 9 participants (20%) in the AHIIT group and 14 participants (31%) in the AMICT group dropped out prior to the postintervention assessment (3 months). At 6 months, six (14%) in the AHIIT group and seven (16%) in the AMICT group dropped out. The flow of the participants is shown in figure 2. Two participants in the AMICT group were not able to perform a modified Balke protocol on treadmill and underwent the tests on a stationary bike.

The characteristics at baseline are presented in tables 1 and 2. No statistically significant differences were observed between the groups in any of the baseline characteristics (tables 1,2). The participants had one or more diagnoses of RMDs, including OA (60%), FM (38%), RA (27%), PsA (12%) and AxSpA (7%) systemic sclerosis, similarly distributed across groups. Sjogren's syndrome, systemic sclerosis, systemic lupus erythematosus, large vessel vasculitis and mixed connective tissue disorder, either individually or in combinations, were represented among the participants.

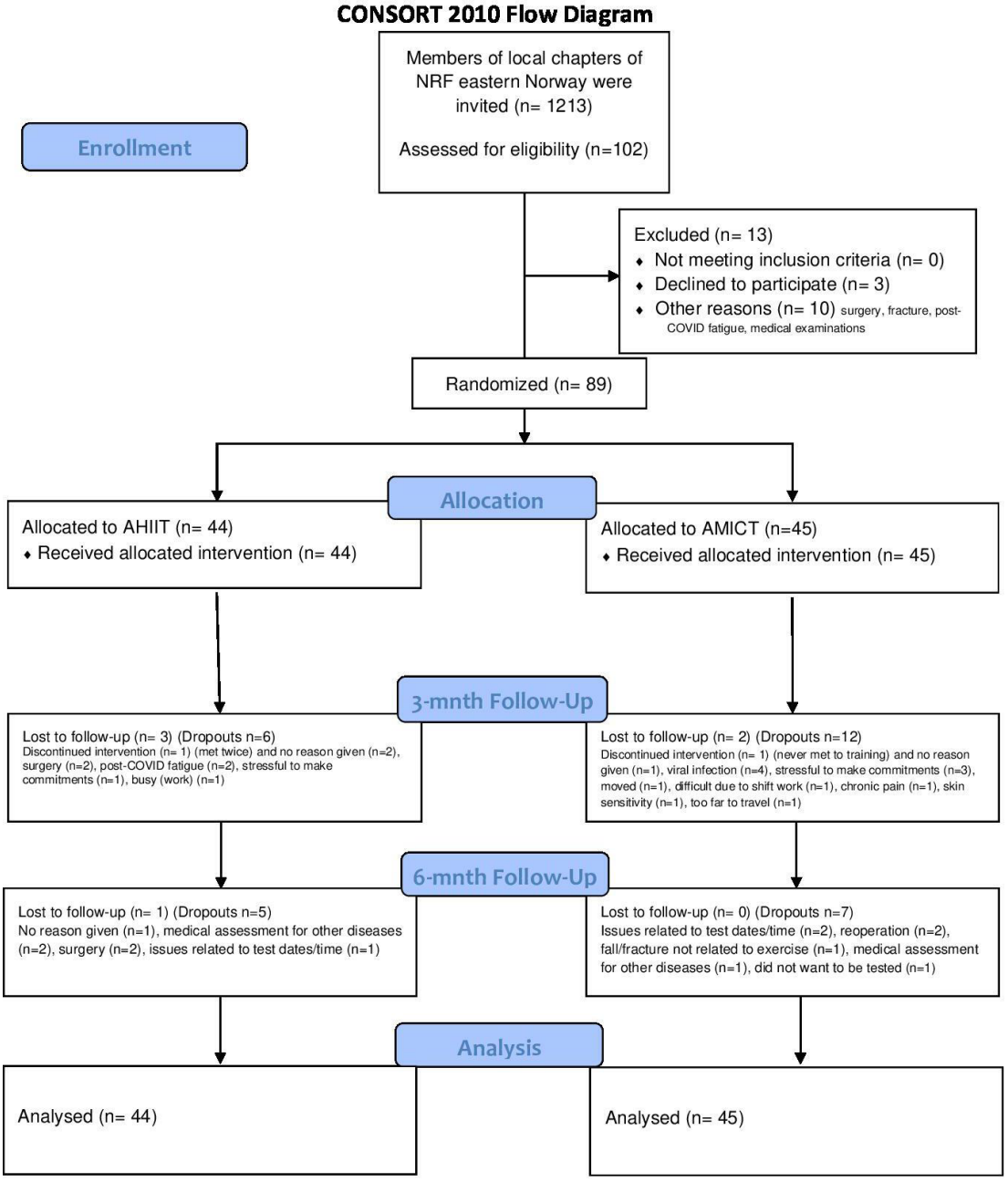

Figure 2 Flow (CONSORT) of participants through the RCT. AHIIT, aquatic high-intensity interval training; AMICT, aquatic moderate-intensity continuous training; CONSORT, Consolidating Standards of Reporting Trials; NRF, Norwegian Rheumatism Association; RCT, randomised controlled trial.

Adherence

A total of 66 (74%) participants completed the intervention. Of these, 48 (73%) participants submitted their diaries. According to the diaries, 22 out of 28 participants in the AHIIT group completed 70% of the sessions, while 18 out of 21 participants in the AMICT group completed 70% of the sessions (online supplemental file 3). Throughout the study period from baseline to 3 months, 16 cases of SARS-CoV-2 infection (AHIIT n=11 and AMICT n=5) were reported in diaries, leading to periods off the intervention due to a positive SARS-CoV-2 test, rest symptoms or long COVID (table 9, online supplemental file 2). There was no significant group difference in the number of completed training sessions; mean completion in AHIIT group was 19.1 (SD 3.3) and 20.3 (SD 3.1) in the AMICT group. The mean reported training intensity in the AHIIT and AMICT groups was Borg RPE 15 (SD 2) and 13 (SD 2), respectively. The between-group difference was 2.5 (95% CI 1.39 to 3.5, p<0.001). In the AHIIT group, seven participants (26%) reported exercising at a lower intensity than prescribed by the exercise protocol, while three participants (14%) assigned to the AMICT group reported training at a high intensity (RPE >15) in their diaries. Only four participants in the AHIIT group provided comments in their diaries regarding why they did not reach the intended intensity. These participants

Table 1 Baseline characteristics of the participants*

	Total n=89	AHIIT n=44	AMICT n=45
Gender, Women, n (%)	81 (91)	41 (93)	40 (89)
Men	8 (9)	3 (7)	5 (11)
Age, y (mean, SD)	62 (13)	60 (12)	64 (13)
BMI	29 (4.9)	28.5 (5)	29.6 (5)
Marital status, n (%)			
Living with partner	47 (53)	24 (55)	23 (51)
Living without partner	24 (27)	12 (27)	12 (27)
Widow/widower	9 (10)	4 (9)	5 (11)
Living with children	9 (10)	4 (9)	5 (11)
Smoker, yes, n (%)	8 (9)	3 (7)	5 (11)
Work status, n (%)			
Full-time job	17 (19)	11 (25)	6 (13)
Part-time job	11 (12)	6 (14)	5 (11)
Retired	33 (37)	11 (25)	22 (49)
Disabled	28 (32)	16 (36)	12 (27)
Educational status, n (%)			
Elementary school	17 (19)	6 (14)	11 (24)
High school	34 (38)	21 (48)	13 (29)
Bachelor's degree	21 (23)	9 (20)	12 (27)
Master's degree or higher	17 (19)	8 (18)	9 (20)
Inflammatory disease, yes n (%)	42 (47)	21 (48)	21 (47)
Joint replacement,† yes n (%)	17 (19)	7 (16)	10 (22)

*There were no statistically significant differences between the AHIIT and the AMICT group on any of the descriptive variables at baseline.
†The distribution was similar between groups, including hips, knees and right and left sides.
AHIIT, aquatic high-intensity interval training; AMICT, aquatic moderate-intensity continuous training; BMI, body mass index; y, years.

reported an average Borg RPE ranging from 12.8 to 13.5 and reported variations in encouragement levels among instructors as a part of the reason why they did not reach intended intensity. One participant commented that they were unable to reach the desired intensity due to difficulty in increasing the speed of movements and not feeling adequately breathless according to the Borg RPE.

Effect of the exercise programme at 3 months and 6 months on aerobic capacity (primary outcome)

There was a statistically significant increase in VO_2peak in the AHIIT group compared with the AMICT group after the 12 weeks intervention, with a mean difference of 1.9 mL·kg^{-1}·min^{-1} (95% CI 0.05 to 3.8, p=0.045). See table 3 for adjusted means (SDs) and figure 3 for the graph of results.

There was no statistically significant difference between groups in VO_2peak from baseline to 6 months (1.1 mL·kg^{-1}·min^{-1} (95% CI −1.051 to 3.165, p=0.322)) (table 3 and figure 3).

Effect of the exercise programme at 3 months and 6 months on lower limb functional strength (secondary outcome)

Number of repetitions raising from a chair increased in both groups (30sSTS) at 3 months and at 6 months; however, there were no statistically significant differences between groups at any timepoint (table 3).

Adverse events

No adverse events were reported during the intervention, either by participants or from the instructors.

Sensitivity analysis

No statistically significant difference on any outcomes was found between responders and non-responders at 3 months (postintervention) or at 6 months (tables 5 and 6, online supplemental file 2). A higher number of participants with FM were categorised as non-responders at 6 months, suggesting that the missing data can be considered as missing at random, as the likelihood of missingness is related to the observed variable rather than the missing values themselves. Both model-based multiple imputations and a per-protocol analysis strengthened our results showing a mean difference of 3.3 mL·kg^{-1}·min^{-1} (95% CI 0.27 to 6.2, p=0.033) and a mean difference of 2.8 mL·kg^{-1}·min^{-1} (95% CI 0.832 to 4.726, p=0.006), respectively (see tables 7 and 8, online supplemental file

Table 2 Descriptive statistics of the participants' aerobic capacity and lower limb functional strength at baseline, 3 months and 6 months*

Aerobic capacity and lower limb functional strength (mean, SD)							
	Total n=88	AHIIT n=43	AMICT n=45	AHIIT 3 months n=32	AMICT 3 months n=30	AHIIT 6 months n=28	AMICT 6 months n=22
VO_2peak (mL/kg/min) (mean, SD)	24.6 (7)	25.5 (6.2)	24.0 (7.7)	27.0 (6)	23.0 (7)	24.6 (5.8)	21.0 (5.1)
	Total n=88	AHIIT n=44	AMICT n=44	AHIIT 3 months n=32	AMICT 3 months n=30	AHIIT 6 months n=28	AMICT 6 months n=23
30sSTS	13.5 (4.2)	14.2 (4.5)	12.8 (3.7)	15.3 (5.3)	14.1 (3.9)	16.18 (5.56)	15 (4.95)

*There were no statistically significant differences between the AHIIT and the AMICT group on 30sSTS or VO_2peak at baseline.
AHIIT, aquatic high-intensity interval training; AMICT, aquatic moderate-intensity continuous training; 30sSTS, 30-s sit-to-stand test; VO_2peak, peak oxygen consumption.

Table 3 Efficacy results from baseline to 3 months and 6 months follow-up

	3 months Adjusted mean (95% CI)		6 months Adjusted mean (95% CI)		3 months		6 months	
	AHIIT n=32	AMICT n=30	AHIIT n=28	AMICT* n=22	Mean difference AHIIT–AMICT (95% CI)	P	Mean difference AHIIT–AMICT (95% CI)	P
Aerobic capacity and lower limb functional strength								
VO_2peak (mL/kg/min)	26.0 (24.7 to 27.3)	24.1 (22.8 to 25.4)	23.6 (22.3 to 25.0)	22.6 (21.0 to 24.1)	1.91 (0.05 to 3.77)	0.045	1.06 (–1.05 to 3.17)	0.322
30sSTS	15.0 (13.8 to 16.2)	14.4 (13.2 to 15.7)	16.0 (14.7 to 17.2)	15.4 (14.1 to 16.7)	0.55 (–1.17 to 2.27)	0.528	0.55 (–1.25 to 2.36)	0.543

*n=23 was tested for the 30sSTS in the AMICT group. Adjusted means and 95% CI at 3 months (postintervention) and at 6 months and mean difference between groups with 95% CI and p value at postintervention (3 months) and 6 months assessed with longitudinal analysis of covariance.
AHIIT, aquatic high-intensity interval training; AMICT, aquatic moderate-intensity continuous training; 30sSTS, 30-s sit-to-stand test; VO2peak, peak oxygen consumption.

2 for more details). For additional sensitivity analysis on the mean difference between groups, see table 4 in the online supplemental file 2.

DISCUSSION

This study found a significant difference in aerobic capacity in favour of the AHIIT group compared with AMICT, suggesting potential improvements in functional capacity and health benefits. As far as we are aware, this is the first study to examine the effect of AHIIT on VO_2peak for people with RMDs. Nevertheless, the long-term benefits in VO_2peak were not sustained, raising questions about sustaining improvements over time. The impact on the secondary outcome suggests that AMICT was equally effective in increasing lower limb functional strength as AHIIT. This is important for individuals with RMDs and clinicians, as it indicates the potential for benefits of different exercise intensities in improving physical function. The AHIIT intervention was well tolerated with no adverse events, which is important for adherence and long-term engagement in higher intensity exercise programmes. Additionally, the intervention involved a patient organisation with volunteer peers as instructors and highlighted the potential of using peers to administer effective interventions, such as AHIIT. This peer-led intervention may also offer a way to enhance community engagement in supporting cost-effective interventions, although this needs further investigation.

Significant increases in VO_2peak in the AHIIT group compared with AMICT in this study support the prescription of higher intensities in aquatic environments to improve aerobic capacity for individuals with RMDs. Greater improvements in aerobic capacity may lead to enhanced function,[41] thereby making daily tasks easier to perform. The improvement in aerobic capacity was less than has been considered clinically meaningful in previous studies ($3.5\,mL{\cdot}kg^{-1}{\cdot}min^{-1}$) comparing HIIT with a non-exercising control group.[15 16] However, a difference of $1\,mL{\cdot}kg^{-1}{\cdot}min^{-1}$ is also shown to be clinically meaningful, with a 15% reduction in all-cause mortality.[42] The difference of $1.9\,mL{\cdot}kg^{-1}{\cdot}min^{-1}$ in the present study may, thus, be considered significant. AHIIT should be further explored to lead to greater improvements in aerobic capacity in this population.

The observed increase in VO_2peak is in line with previous studies on HIIT. However, RCTs investigating land-based HIIT in adults with RMDs are still limited,[24–26] and only two studies have evaluated change in aerobic

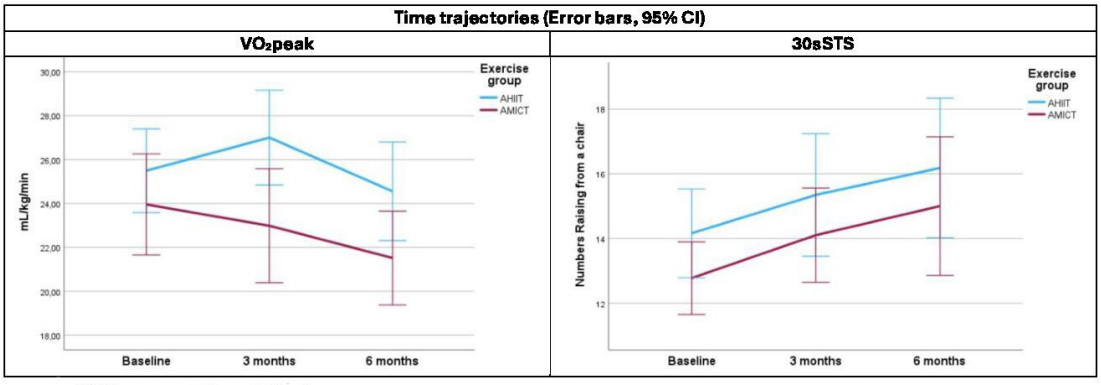

Figure 3 Time trajectories: mean VO_2peak and mean numbers raising from a chair for AHIIT and AMICT. AHIIT, aquatic high-intensity interval training; AMICT, aquatic moderate-intensity continuous training; 30sSTS, 30-second sit-to-stand test; VO_2peak, peak aerobic capacity.

capacity as primary outcome.[24 26] Previous RCTs involve participants with inflammatory RMDs,[23 25 26] whereas the present study has added variation to the cohort under investigation, more similar to a real-world setting, with participants presented with a diverse range of RMD diagnoses. Prior RCTs, mainly conducted in specialised healthcare settings, showed significant exercise effects with oxygen uptake increases of approximately 3.5–3.7 mL·kg^{-1}·min^{-1}.[23 25–27] This could be due to factors like one-on-one training or physiotherapist instruction. A recent study by Nordén *et al* in a primary care setting also found significant, although smaller, increases in VO_2peak (2.5 mL·kg^{-1}·min^{-1})[24] consistent with our results. However, in the present study, participants underwent group-based sessions, led by peers. Findings from a systematic review suggest a small beneficial effect of AHIIT over AMICT.[28] Our two weekly sessions closely aligned with most previous studies.[28] Adjusting the session frequency to three times per week, as endorsed by EULAR,[18] could potentially further improve aerobic capacity.

Influencing cardiovascular risk in a clinically meaningful way is an important goal of exercise for people with inflammatory RMDs and could be explored further using AHIIT. The presence of inflammatory RMDs in the present study was high, 47%. When comparing the baseline VO_2peak values in our sample to age-matched norms, they were notably lower.[43] Following 12 weeks of AHIIT, the mean VO_2peak increased to mean 27 mL·kg^{-1}·min^{-1}, bringing the AHIIT group closer to population norms.[34] Most of the participants in this study were women (81%), a significant factor considering that the average population norm for women aged 60–69 years is 28.7 mL·kg^{-1}·min^{-1}.[43] This finding suggests that AHIIT has a potential role in reducing the cardiovascular risk associated with inflammation.

Longer term benefits in VO_2peak were not found in this study. This could be related to the 3-month closure of the organised aquatic exercise programme during the summer, which may have disrupted participants' regular exercise routines. The implication for future service provision is ongoing participation to achieve necessary intensity for sustaining improvements in aerobic capacity,[44] as the effects of exercise depend on regular participation.[45] However, it could also be argued that the changes in VO_2peak were not substantial enough to be sustained over time, suggesting that ongoing, group-based exercise may be necessary to maintain the effect.

Functional lower limb strength was improved in participants in this study regardless of the group intensity of exercise they were included in, indicating that the intensity level was not crucial for improvements in functional strength. Although higher intensity and greater speeds of limb movement, along with resistance from drag, have been shown to improve strength,[46] we did not demonstrate this in the present study. Therefore, if improved aerobic capacity is not the primary aim of the intervention, AMICT may be equally valuable.

No adverse events were reported, indicating that the exercise interventions were well tolerated by participants, which is important for better compliance with exercise programmes. Although data were limited, these findings on adverse events are comparable to results from a systematic review,[28] where AHIIT had few adverse events (compared with land-based HIIT). However, we cannot rule out that the absence of adverse events could be linked to the fact that some participants in the AHIIT group did not achieve higher intensities, despite evidence indicating that the average RPE exceeded 15. Furthermore, not all participants assigned to AHIIT did achieve the intensity in the HIIT protocol as intended. Several factors may have contributed to this lack of adherence, including unfamiliarity with HIIT in general, challenges associated with performing HIIT in a water environment or difficulties accurately reporting their perceived exertion on the RPE scale. With extensive RPE training for instructors and comprehensive RPE instructions for participants, adherence to the correct intensity could have been improved. However, considering disease-related barriers in traditional exercise settings, the aquatic environment emerges as a valuable and accessible option for HIIT.

Strengths and limitations

The strengths of this study included an RCT design, an intention-to-treat strategy using all available data in a linear mixed model for repeated measures and the comparison of two exercise interventions to assess the impact of intervention intensity. However, there were limitations to consider. Both interventions lacked supervision by healthcare professionals, potentially affecting the achievement of high intensity. Despite this, the pragmatic design enhanced the study's generalisability to real-world practices. However, variations in disease management across countries may limit the generalisability of our findings. We believe that our sample represents adults with RMDs who seek or prefer water-based exercise and are interested in trying high-intensity exercise. While outcome assessors were blinded, the lack of blinding of participants and instructors could introduce bias. Nonetheless, the primary treatment effect was observed on an objective outcome measure like aerobic capacity, reinforcing result validity. Additionally, small numbers and dropouts are limiting factors, which could lead to a type II error. This insufficient power may be attributed to a low completion rate. Furthermore, dropout rates were higher and the attendance and adherence rates in this study were less than ideal due to the COVID-19 pandemic. However, non-responders (dropouts) were statistically comparable to responders, suggesting it did not influence the results of this study.

Currently, there is a lack of studies on peer-led interventions and patient-reported outcome related to AHIIT, limiting our understanding of the effectiveness and impact on patients' quality of life. Future studies should examine the feasibility of peer-led aquatic exercise programmes.

Practical implications and feasibility considerations

By using volunteer peers as instructors, healthcare systems can reduce the financial burden while maintaining high-quality care. Based on our research and the integration of AHIIT into the Norwegian NRF's advanced instructor course, we recommend standardising training protocols, implementing comprehensive instructor training and adapting programmes to local conditions. Continuous evaluation and feedback may be crucial. Scaling up will require assessing resource availability, securing funding and establishing local partnerships. Assessment of the use of a digital support system for instructors may enhance feasibility.

CONCLUSION

12 weeks of group-based AHIIT is effective to improve aerobic capacity in participants with RMDs. There was no maintenance of aerobic capacity at 6 months, suggesting that ongoing, group-based exercise may be necessary to maintain the effect. The intervention was well tolerated with no adverse events suggesting that people with RMDs were capable of successfully completing an AHIIT programme and may experience beneficial improvements. These findings support the potential for user-delivered AHIIT to be applied and integrated into the existing organisations in volunteer settings within the municipality.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This trial was approved by the Regional Committee for Medical and Health Research Ethics (272749), Sikt's Data Protection Services and the data protection officer at Oslo Metropolitan University. All participants provided written informed consent, and all procedures followed the Declaration of Helsinki.

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