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Effects of high intensity resistance aquatic training on body composition and walking speed in women with mild knee osteoarthritis: a 4-month RCT with 12-month follow-up

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SUMMARY

Objective: To investigate the effects of 4-months intensive aquatic resistance training on body composition and walking speed in post-menopausal women with mild knee osteoarthritis (OA), immediately after intervention and after 12-months follow-up. Additionally, influence of leisure time physical activity (LTPA) will be investigated.
Design: This randomised clinical trial assigned eighty-seven volunteer postmenopausal women into two study arms. The intervention group ($n = 43$) participated in 48 supervised intensive aquatic resistance training sessions over 4-months while the control group ($n = 44$) maintained normal physical activity. Eighty four participants continued into the 12-months' follow-up period. Body composition was measured with dual-energy X-ray absorptiometry (DXA). Walking speed over 2 km and the knee injury and osteoarthritis outcome score (KOOS) were measured. LTPA was recorded with self-reported diaries.
Results: After the 4-month intervention there was a significant decrease ($P = 0.002$) in fat mass (mean change: −1.17 kg; 95% CI: −2.00 to −0.43) and increase ($P = 0.002$) in walking speed (0.052 m/s; 95% CI: 0.018 to 0.086) in favour of the intervention group. Body composition returned to baseline after 12-months. In contrast, increased walking speed was maintained (0.046 m/s; 95% CI 0.006 to 0.086, $P = 0.032$). No change was seen in lean mass or KOOS. Daily LTPA over the 16-months had a significant effect ($P = 0.007$) on fat mass loss ($f^2 = 0.05$) but no effect on walking speed.
Conclusions: Our findings show that high intensity aquatic resistance training decreases fat mass and improves walking speed in post-menopausal women with mild knee OA. Only improvements in walking speed were maintained at 12-months follow-up. Higher levels of LTPA were associated with fat mass loss.
Trial registration number: ISRCTN65346593.

Introduction

Knee osteoarthritis (OA) is a common cause of pain and activity limitations causing significant burden on healthcare services[1]. While there is no known treatment that prevents or reverses OA, traditional management of OA focuses on reducing the symptoms, i.e., pain and activity limitations, associated with the disease. Recently focus has shifted from treatment of end-stage OA to

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preventing progression of the disease, especially in early knee OA[2]. One possible approach could be to use interventions that address known risk factors for progression of OA. Risk factors predicting worsening in symptoms and activity limitations include slow walking speeds, obesity, older age and decreased leisure time physical activity (LTPA)[3,4]. Obesity is associated with knee OA progression through sub-optimal biomechanical loading and low-grade systematic inflammation related to high body fat-mass[2,5]. Further, people with knee OA have been shown to walk slower and adapt their gait patterns in order to avoid pain and to redistribute joint loading[6,7].

Exercise has been shown to evoke positive changes on symptoms and functional capacity as well as facilitate weight loss[8,9] and is therefore strongly recommended in the management of knee OA[1,10]. However, pain is a major modulator for activity avoidance in patients with OA and may limit compliance with land-based exercise[11]. The aquatic environment allows the individual to exercise with reduced weight bearing and impact on the affected joints[12]. Recent studies have shown that individuals with lower-limb OA experience significantly less pain during aquatic compared to land-based exercise of equivalent intensity[13,14]. Our recent systematic reviews revealed that aquatic exercise evokes both a small and a moderate effect on physical functioning in people with lower limb OA[15] and healthy older people[16], respectively. The difference in effect size is thought, in part, to be due to the higher intensity of training implemented with the healthy older adults[17]. Further, lack of reporting of actual training intensities achieved in all the included aquatic exercise studies, limits interpretation of the results. Moreover, higher levels LTPA can have a positive impact on body composition and also predict a slower progression of OA related symptoms and activity limitations[3,4]. LTPA levels have not been reported in any previous aquatic exercise studies and therefore the effect of this important cofounding factor has not been previously investigated.

In order to prevent knee OA progression, the exercise intervention should be prescribed early in the disease progression[2]. To the authors knowledge only one previous study has investigated the effect evoked by aquatic exercise in the early stage of knee OA development[18]. Our study, a randomised controlled trial (RCT), indicated that 4-months of aquatic resistance training improved estimated cardiovascular fitness and had a small significant impact on tibiofemoral cartilage as measured with quantitative magnetic resonance imaging (qMRI)[18]. Therefore, aims of this study are to report the effect of 4-months intensive aquatic resistance training program on body composition and functional capacity in postmenopausal women with mild knee OA, and whether possible changes are maintained after 12-months' follow-up. The effect of LTPA on the results and the training intensities achieved during the aquatic resistance training will also be investigated.

Materials and methods

Study design

This study uses previously unreported outcome data collected from the registered AquaRehab research project (ISRCTN65 346593), a RCT consisting of a 4-month aquatic intervention with a 12-month follow-up period. Data was collected from January 2012 to April 2014. The full description of the protocol can be found on open access[19], which was followed without changes and a full report of participant recruitment can be found from our previous study[18]. This study has two experimental arms: (1) aquatic resistance training and (2) control. Included participants were women aged 60–68 years old with mild knee OA. In this study we classify mild knee OA as experiencing knee pain on most days, not exceeding 5/10 VAS, with radiographic changes in tibiofemoral joint grades I (possible osteophytes) or II (definite osteophytes, possible joint space narrowing) according to the Kellgren–Lawrence (K/L) classification[20]. Pre- and post-intervention results for the qMRI outcomes and patient reported symptoms have been previously reported[18]. This current study, in addition to patient reported symptoms, will report the outcomes for body composition and walking speed taken pre- and post-intervention as well as after the 12-months follow-up[18]. The study design and reporting follows the CONSORT recommendations for the conducting and reporting of randomized controlled trials[21]. The study protocol (Dnro 19U/2011) was approved by the Ethics Committee of the Central Finland Health Care District and conforms to the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Subject recruitment

Participants were recruited from the county of Central Finland using newspaper advertisements and telephone recruitment methods. Eligibility criteria was female aged 60–68 years old, body mass index (BMI) <35, experiences knee pain almost daily, K/L grades I or II and no medical reason preventing full participation in intensive exercise. Full eligibility criteria are described elsewhere[19].

Randomisation and blinding

The subjects were randomly allocated into one of the two arms of the study by a blinded external statistician, provided only with randomisation number and OA severity, using a computer generated block randomization of size of ten, stratified according to K/L grading. The first author performed the dual-energy X-ray absorptiometry (DXA) imaging but analysis was performed using the manufactures' in-built software without modification. Physical therapists providing the intervention also performed the physical performance measures. Principal investigators were blinded to group allocation.

Interventions

Those participants in the intervention group participated in an aquatic resistance training sessions lasting 1 h, 3 times a week for 16 weeks (48 sessions in total). Variable resistance equipment was used to progress training intensity with three resistance levels; barefoot, small resistance fins (Theraband products, The Hygienic Corporation, Akron, OH 44310 USA) and large resistance boots (Hydro-boots, Hydro-Tone Fitness Systems, Inc. Orange, CA 92865-2760, USA). Training intensity was set at as “hard and fast as possible”: A full description of the training program, its progression and daily training program can be found elsewhere[18]. The control group maintained usual care and were asked to continue their usual leisure time activities. They were offered the possibility of participating in two sessions consisting of 1 h of light stretching, relaxation and social interaction during the 4-month intervention period.

Measures of exercise intensity and perceived exertion

Maximum training intensity was ensured by measuring the maximum and average heartrates and rating of perceived exertion (RPE) for every training session using heart rate monitors (Polar Oy, Kemble. Finland). Maximum heartrate was estimated using the Karvonen formula (220 − age = maxHR) with no adjustments made for the possible effects of immersion. During the twelfth week capillary blood lactates and repetitions completed for all three training situations were measured. Self-reported emotional state felt during the aquatic resistance training was measured with a 1–5 Likert scale (1-Poor, 2-Tolerable, 3-Satisfactory, 4-Good, 5-Excellent).

Outcome measures

Outcomes for this study are body composition, walking speed and self-reported symptoms. Body composition (total body fat and lean body mass (kg)) was measured with dual-energy X-ray absorptiometry (DXA, Lunar Prodigy; GE Lunar Healthcare, Madison, WI, USA). All full body and regional images were analysed as per manufacturers' protocols using enCORE software (enCORE 2011, version 13.60.033). *In vivo* precision of these measurements has been reported to be high (CV 1.3–2.2%)[22]. Walking speed was calculated from the UKK 2 km walking test. This test requires the subject to walk 2 km around a 200 m flat track as quickly as possible without running[23]. Walking speed was calculated in metres per second (m/s) and describes walking ability and is a surrogate for aerobic fitness. Self-report pain (Pain), symptoms (Sym), activities of daily living (ADL), sports and recreation (Sport&Rec) and quality of life (QoL) were measured using be the five domains of the Finnish version of the knee injury and osteoarthritis outcome score (KOOS)[24]. Scores are transformed into a score 0–100 with a score of 0 indicating extreme knee problems and 100 no knee problems[25].

LTPA

LTPA for each participant was calculated for the whole 4-month intervention and 12-month follow-up period using a daily physical activity diary. Participants recorded type of activity and self-perceived intensity of each activity, i.e., low, moderate or high, from which metabolic equivalent task hours (MET/h) per month was calculated[26]. The LTPA for the intervention group was calculated by combining the MET/h calculated from the aquatic resistance training and the physical activity diary.

Statistical methods

Results are displayed as mean and standard deviation (SD) unless otherwise stated. Between group baseline comparisons were performed using a bootstrap type *t*-test and Chi-squared. Repeated measures for walking speed, body composition and all domains of the KOOS were analysed using generalised linear mixed-models with unstructured correlation structure. Fixed effects were group, time and group-time interaction. Effect size, standardised beta coefficient (Beta (β)) adjusted for baseline values, was calculated for post intervention and at 12-month follow-up. Cohen's standard for Beta values above 0.10, 0.30 and 0.50 represent small, moderate and large effects respectively[27]. Between group differences in average monthly LTPA during the 4 month intervention and 12-months period was tested using a Fisher–Pitman permutation test for two independent samples. The relationship between average monthly LTPA and body composition and walking speed, after removal of group allocation, was calculated using a mixed-effects regression model and represented as Cohen's f^2, were 0.02, 0.15 and 0.35 indicate a small, moderate and large effect respectively[28]. Repeated analysis of variance (ANOVA) was used to compare the differences between the three training intensities (barefoot, small fins and large boots) and measures of training response i.e., RPE, heart rates, blood lactates, number of repetition performed per session and emotional state. Statistical analyses were performed using statistical software (Stata, release 13.1, StataCorp, College Station, Texas).

This study is a *post hoc* analysis of original data thus the target sample size ($n = 70$, 35 per research arm) was calculated based on expect change in the qMRI outcome[18].

Results

In total, 87 participants fulfilled the eligibility criteria and after attending baseline measurement were randomised into the two treatment arms of the study. There were no significant differences between the groups in any descriptive variables at baseline (Table I). Eighty five participants completed the intervention and 84 agreed to participate in the 12-month follow-up. In total 76 participants attended measurement at 12-months follow-up. Participant recruitment and reasons for loss to follow-up are shown in Fig. 1.

Training intensities achieved during aquatic resistance training

Adherence to the aquatic training program was high (88%), with only three subjects attending less than 70%. Pain during aquatic resistance training in the affected knee was reported more frequently during the first month (37 times), followed by a gradual decrease in frequency as the training progressed, with a three-fold reduction in the frequency (12 times) by the fourth month. Pain experienced in affected knee during the intervention was mild 14 (16) (visual analogue scale (VAS) 0–100 mm). Training intensity recorded from each complete training session is shown in Table II. There was a gradual increase in RPE when progressing from barefoot to large resistance boots while no significant differences in heart rates were measured. A full description of the daily training intensities measured and pain experienced during training can be found from the Supplemental material Appendix A. The attendance for the control group sessions was 68%.

Treatment effects and maintenance at 12-months

Summaries of the treatment effects after 4-months and their maintenance at 12-months follow-up are presented in Fig. 2 and Table III. After 4-months aquatic resistance training there was a significant ($P = 0.002$) moderate (Beta (β): 0.32; 95% CI: 0.14 to 0.51) decrease in fat mass (−4.7% and 0.25% in training and control

Table I
Baseline demographic and clinical characteristics

	Exercise group ($n = 43$)	Control group ($n = 44$)
Age (years)	63.8 (2.4)	63.9 (2.4)
Height (cm)	161.7 (5)	161.6 (5)
Body mass (kg)	69.6 (10.3)	71.0 (11.2)
BMI (kg/m^2)	26.6 (3.8)	27.1 (3.5)
Affected knee (right/left)	36/7	34/10
K/L grade, *n* (%)		
Grade 1	23 (53.5)	24 (54.5)
Grade 2	20 (46.5)	20 (45.5)
Analgesia, *n* (%)*	11 (26)	9 (20)
LTPA (MET/h/week)	29 (31)	36 (33)
Smoker *n* (%)		
Never	17	13
Current	3	3
Previous	23	28
Blood pressure, *n* (%)		
Normal	23	14
Elevated	9	11
Medical management	11	19

Values are means (SD) unless otherwise noted.
* Number of participants using analgesia for knee pain on inclusion to study.

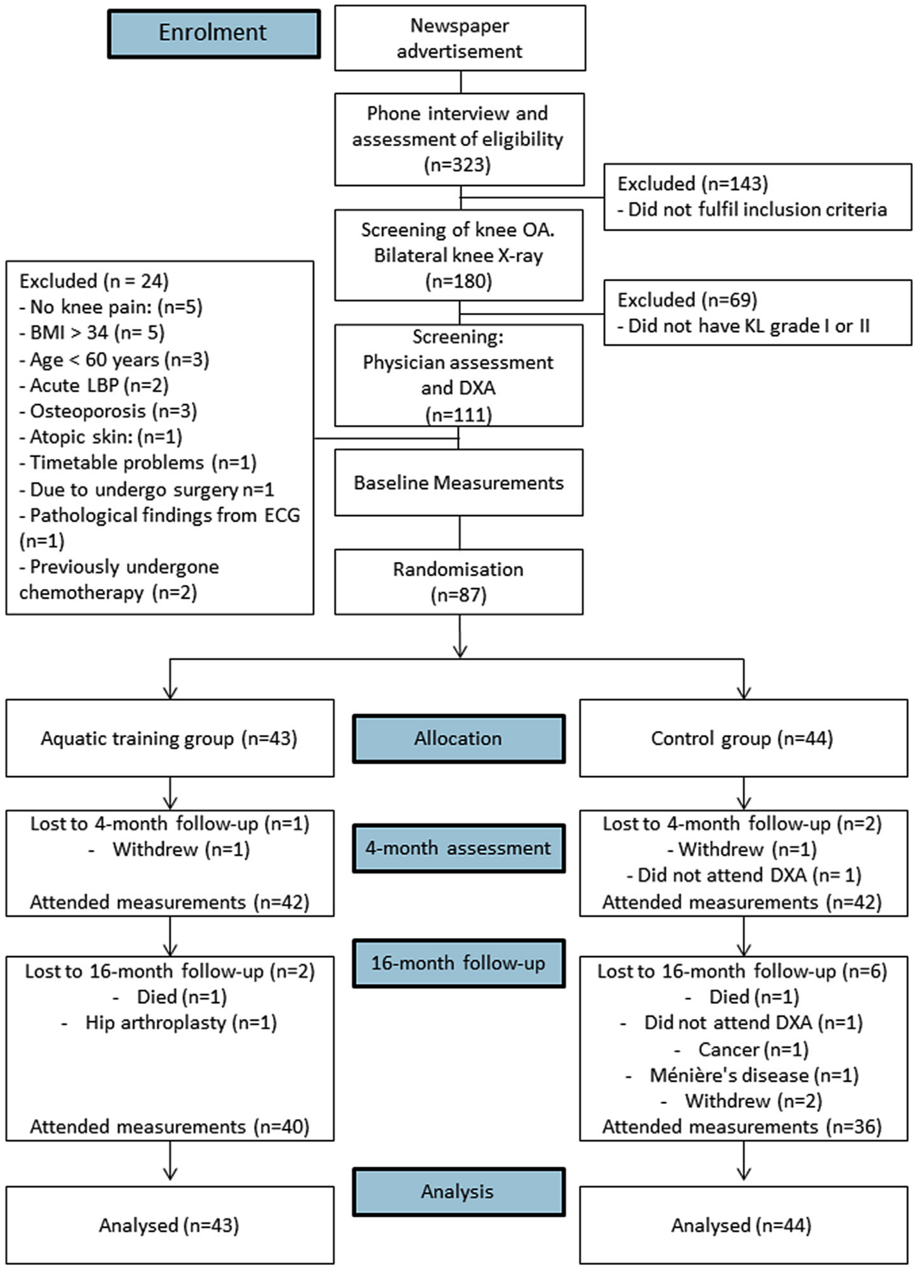

Fig. 1. Flow chart showing participant recruitment, randomisation and retention.

Table II
Description of training intensities achieved during the aquatic resistance training and psychological feelings experienced per progression

	Barefoot	Small Fins	Large boots
No. Sessions	8	14	26
RPE*	13.7 (1.0)	14.9 (1.3)	15.0 (1.5)‡
Average HR (%)	61 (5.9)	61 (5.3)	61 (6.3)
Max HR (%)	85 (7.8)	84 (8.9)	84 (8.0)
Blood lactates (mmol/L)†	4.9 (2.1)	4.5 (1.9)	4.0 (1.8)
Repetitions per session	481 (66)	408 (71)	376 (65)‡
Self-reported emotional state	4.2 (0.33)	4.2 (0.36)	4.3 (0.40)

Mean and (SD) unless otherwise stated.
* RPE = Rating of perceived exertion (BORG 6–20).
† Measured directly after sessions 35–37.
‡ Bare vs Large ($P < 0.001$).

group respectively) and over-all moderate (β: 0.34; 0.15 to 0.52) decrease (−1.4% and 0.21%) in body weight ($P = 0.004$), both in favour of the intervention group. There was a significant ($P < 0.001$) decrease in fat mass in both legs −0.47 kg (−0.74 to −0.20) or a loss of −4.5% in the training group compared to 1.1% increase in the control group. There was a similar significant change ($P = 0.007$) in the trunk −0.63 kg (−1.1 to −0.17) or a loss of −3.1% compared to a 1.0% increase in the control group. Both significant findings were lost at 12-months follow-up. No localised change in lean mass was seen at any time point. After the intervention, a significant increase in walking speed ($P = 0.002$) was observed in favour of the intervention group (β: 0.3; 0.12 to 0.50). At 12-months follow-up walking speed ($P = 0.032$) in the intervention group remained significantly faster compared to the control group (β: 0.2; 0.01 to 0.44). No other significant between group differences could be seen in any domain of the KOOS questionnaire.

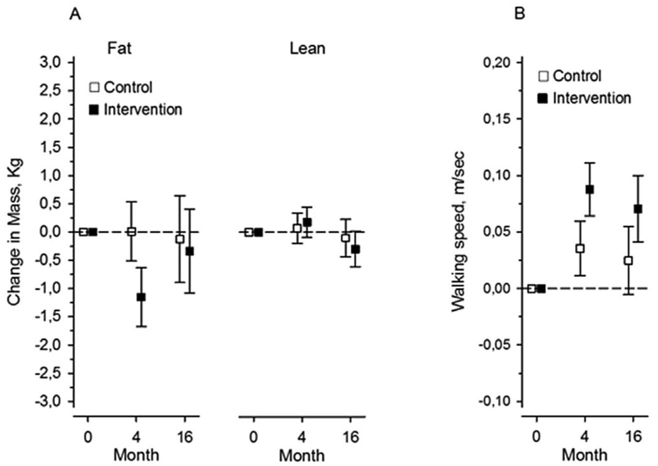

Fig. 2. Changes in A) fat and lean mass (kg) and B) walking speed (m/s) following a 4-months aquatic resistance training and 12-month follow-up period.

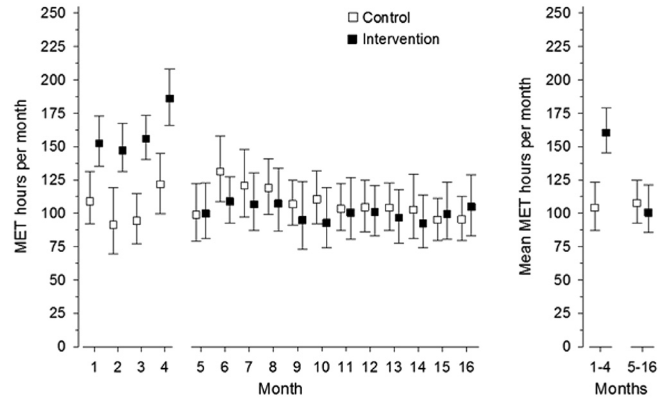

Fig. 3. Monthly leisure time physical activity (MET/h).

Effects of physical activity

There was a significant ($P < 0.001$) between group difference in average monthly LTPA during the intervention period 160 (53) vs 104 (63) MET/h for intervention and control groups respectively. This difference was immediately lost following cessation of the aquatic training (Table III), monthly group averages are depicted in Fig. 3. After removal of group allocation there was a small (Cohen's $f^2 = 0.05$) statistically significant ($P = 0.007$) relationship between higher average monthly LTPA (MET/h) and greater loss of fat mass. There was no relationship between LTPA ($P = 0.52$) and lean mass ($f^2 = 0.002$) and a small ($f^2 = 0.02$) but non-significant ($P = 0.25$) relationship with walking speed. While walking was the most popular form of LTPA (40.1%) there was no difference seen in activity type or intensities between the control and intervention group at any time point.

Harms

As previously reported[18], one subject stopped the intervention following pain experienced after the first use of the large resistance boot (session 16). One subject complained of dyspnoea. After education training the participant was able to complete the intervention and attend follow-up measurements. The results of both participants are included as per intention-to-treat analysis. No subjects at pre- or post-intervention measurements were unable to walk the 2 km. At 12 months' follow-up two subjects, one from each group could not complete the 2 km; both due to a lower-limb injury unrelated to their knee OA.

Discussion

Our study indicates that an intensive aquatic resistance training program is effective at decreasing fat mass as well as improving walking speed in post-menopausal women with mild knee OA. This is the first randomised controlled study investigating the effects of aquatic resistance training on individuals with mild knee OA with a 12-month follow-up period. While, our results show that the improvements in body composition are lost at 12-months' follow-up, the improvements in walking speed were maintained. Importantly, higher average monthly LTPA was related with greater loss of fat mass over the 16-month study period. Further, this is the first study to report the actual training intensities achieved by the subjects during an aquatic exercise intervention and the effect of LTPA during the intervention and follow-up period.

Increased fat mass is linked to knee OA through biomechanical[29] and low-grade inflammatory mechanisms[30], and is associated with an increased risk of suffering from knee OA as well as a more rapid progression of the disease[31–33]. A change of −1% in body weight has

Table III
Effect of aquatic resistance training on walking speed, body composition and clinical symptoms

Variable	n	Aquatic training (AT)		Control		Mean difference (95% CI)	P-value*	n	AT	Control	Mean difference (95% CI)	P-value**
		BL mean (SD)	FU mean (SD)	BL mean (SD)	FU mean (SD)				12-FU mean (SD)	12-FU mean (SD)		
Walking speed (m/s)	87	1.74 (0.15)	1.83 (0.16)	1.73 (0.17)	1.76 (0.17)	0.052 (0.018 to 0.086)	0.002	73	1.82 (0.14)	1.77 (0.13)	0.046 (0.006 to 0.90)	0.032
Body composition												
Body mass (Kg)	87	69.2 (10.3)	68.2 (10.4)	70.8 (11.2)	70.9 (11.3)	−1.11 (−1.85 to −0.42)	0.004	76	68.6 (10.6)	70.8 (11.5)	−0.39 (−1.51 to 0.64)	0.543
BMI	87	26.6 (3.8)	26.2 (3.9)	27.1 (3.5)	27.1 (3.6)	−0.46 (−0.74 to −0.19)	0.001	76	26.4 (4.0)	26.9 (3.7)	0.001 (−0.47 to 0.47)	0.892
Lean mass (kg)	87	40.3 (3.9)	40.6 (3.9)	41.4 (4.4)	41.7 (4.4)	0.083 (−0.29 to 0.45)	0.590	76	40.1 (4.0)	41.9 (4.2)	−0.30 (−0.79 to 0.12)	0.410
Fat mass (Kg)	87	26.0 (8.6)	24.8 (8.8)	26.5 (8.0)	26.4 (8.1)	−1.17 (−2.00 to −0.43)	0.002	76	25.7 (8.8)	26.1 (8.5)	−0.14 (−1.24 to 0.90)	0.700
KOOS (0–100)												
Pain	87	80.6 (10.4)	84.3 (10.5)	82.1 (11.8)	83.3 (11.7)	2.3 (−1.93 to 6.31)	0.184	76	86.8 (10.5)	85.1 (12.4)	1.45 (−2.72 to 5.66)	0.187
Symptoms	87	74.4 (12.9)	80.9 (12.1)	74.8 (14.1)	77.5 (14.9)	4.07 (−0.43 to 8.54)	0.091	76	81.4 (11.4)	77.9 (14.5)	3.31 (−1.19 to 7.30)	0.119
ADL	87	84.5 (10.4)	87.7 (9.7)	85.2 (11.0)	86.0 (14.6)	3.36 (−0.38 to 7.118)	0.105	74	89.2 (11.2)	88.3 (11.0)	0.97 (−2.64 to 4.32)	0.397
Sport&Rec	87	63.6 (20.5)	70.6 (21.7)	64.8 (22.2)	67.6 (26.5)	4.81 (−3.00 to 12.61)	0.223	76	71.0 (20.7)	68.7 (24.6)	2.45 (−4.76 to 8.96)	0.396
QoL	87	66.0 (17.5)	72.6 (18.1)	70.6 (20.1)	74.1 (23.1)	2.76 (−3.51 to 8.66)	0.248	75	75.0 (18.2)	76.4 (24.4)	1.21 (−5.97 to 7.98)	0.308
LTPA (MET/h)	85	–	160 (53)	–	104 (63)	56 (−81.4 to −31.1)	<0.001†	76	100 (57)	107 (56)	−7.3 (−31.5 to 16.9)	0.56†

BL = baseline, FU = post-intervention (4-months), 12-FU = 12-months follow-up, *post-intervention follow-up compared to baseline (mixed model), **12-month follow-up compared to baseline (mixed-model).
LTPA = average monthly total leisure time physical activity. †Fisher–Pitman permutation test.

been shown to have a significant association with slower loss of tibial cartilage volume and improvement in symptoms suggesting our 1.4% weight change could have a meaningful impact on both cartilage health and OA related symptoms[34]. Our findings indicate a superior improvement in body composition compared with the two previous studies investigating the effects of aquatic exercise on body and fat mass in persons with OA[17,35]. The respective −1.17 kg and −1.1 kg decreases in fat and body mass evoked in our study are larger than the non-significant decrease in fat mass (−0.7 kg) reported by Lim *et al.*[17] and significant reduction in body mass (−0.76 kg) reported by Kim *et al.*[35]. While this could be due our slightly longer duration i.e., 4 weeks longer, we also utilised a much higher training intensities. Lim *et al.*[17] set intensity at 65% Max HR, while Kim *et al.*[35] set intensity at RPE 12–13 (Borg 6–20), approximately 60% Max HR[36]. In our study, average maximum heartrates during the main set were close to 85% with measured maximum HR up to 105%. Further, our finding demonstrate that high intensity aquatic exercise, appears to have similar effects as land-based exercise programs on body and fat mass. Messier *et al.*[9], for example, reported that an 18-month, 3 times a week land-based exercise-only program produced a (−1.8 kg) loss in total body weight. However, the decrease in fat mass was only 1% (−0.4 kg) and loss of lean mass was 1% (−2.6 kg) in the exercise-only group. A loss of lean-mass and therefore reduction in muscle strength, is a common negative side effect of weight loss. Reduction in muscle mass and strength is associated with the development and faster progression of knee OA[37,38], therefore preserving muscle mass during periods of weight loss is vital in this population[33]. Our study showed no change in lean mass and previously reported muscle strength[18], indicating that while the training was intensive enough to evoke a decrease in fat mass it was also sufficient to preserve strength and lean mass.

Improvements in walking speed after 4-months aquatic resistance training, and its maintenance, after a 12-month follow-up period, are in contrast to the results for body composition changes. Slower walking speeds are associated with faster progression of OA related symptoms and activity limitations and the small but sustained improvement of 0.05 m/s achieved in our study indicate a meaningful and lasting improvement in functional capacity[39]. Given that the weight lost during the intervention was regained during follow-up, our findings suggest that the effect on walking speed may not have been weight related. The results could indicate an improvement in cardiovascular fitness; however, the lack of between group differences in LTPA over the 12-months' follow-up period and at a level that had no effect on cardiovascular fitness in controls during the intervention period, suggests that this alone cannot explain the maintenance of walking speed. While there were no improvements in muscle strength of the knee extensors and flexors (previously reported[18]), we cannot rule out improvements in the un-measured ankle plantar flexors or hip abductors which could improve gait biomechanics and efficiency[40]. Further, strength alone is not a marker of improved gait biomechanics with efficient gait requiring co-ordination between agonist and antagonist muscles[7,41,42]. Immersion results in a decrease in nociceptor stimulation and afferent feedback[43,44], and reduces the sensation of pain[13,14,45,46]. These conditions may create a suitable training condition for improving gait biomechanics[14]. Alternatively, the high intensity intervention exposed the subjects to the sensation of high physical exertion. This could have taught the participants that it was safe for them to exert themselves at a higher intensity than previously thought. It is feasible to speculate that this exercise pedagogy was retained 12-months after intervention cessation. However, walking frequency and intensity as part of the monthly LTPA did not differ between groups suggesting the improvement in walking speed was not utilised. Ultimately, the mechanisms behind the effect of aquatic resistance training on walking speed, deserves further investigation.

Education on life-style changes has been suggested as a vital part of management of both early and late-stage OA, in order to sustain improved levels of physical activity following an intervention study[47]. Participants in the training group did not have higher LTPA after the intervention than the control group therefore it is plausible to conclude that they returned back to pre-intervention level. Therefore, the increased walking speed may only describe improved functional capacity and may not be associated with increased walking speeds utilised in daily life. In combination with the possible exercise pedagogical effect of the high intensity exercise and implementation of a life-style education program, including dietary and advice, may have maintained or even continued the improvements in body composition and walking speed. Importantly, our results showed an association between higher levels LTPA and loss of fat mass irrespective of group allocation. Our results suggest that involvement in the intervention did not increase LTPA during the 12-months' follow-up period. However, LTPA was measured using self-reported questionnaires and it is plausible to hypothesise that after the intervention the participants in the training group may have changed their perception of activity intensities. Further, inclusion in a study may have caused a general increase in LTPA explaining the results. No acute worsening of clinical symptoms, as measured with the KOOS, was seen, possibility a result of the low impairment at baseline, the fluctuating nature of OA symptoms and the relatively short follow-up period[2].

The strengths of this study included the randomised control design. The high adherence to the intervention and small number of drop-outs optimised the treatment response and shows motivation to participate in such an aquatic resistance exercise intervention. This is the first study to monitor LTPA, in addition to the exercise intervention, during an aquatic exercise intervention in participants with knee OA[15], controlling an important confounding factor. The main limitation of this study was the use of strict inclusion criteria, essential for the original primary qMRI outcomes, which resulted in a homogeneous sample limiting direct application of our results to persons with more severe knee OA. However, it is conceivable to assume that, adapted, this program, would be suitable to improve functional capacity and decrease weight in subjects with more severe knee OA. Further studies are needed to confirm its efficacy in subjects with hip OA. The use of un-equal interventions i.e., only two sessions in the control group, introduces at least some degree of bias in favour of the intervention. Therefore, these results only indicate that aquatic resistance training is effective compared to no intervention and not more effective than another intervention. The lack of assessor blinding to the intervention may have resulted in bias, however, assessors had no vested interest in the results of this study and primary investigator was blinded throughout. Dietary intake was not measured or controlled for. Inclusion in a study has been shown to affect participants' dietary habits as well as physical activity and therefore we cannot directly attribute all the changes as a pure effect of the intervention. Diet alone, however, would not have accounted for the maintenance of lean body mass[9]. Further, greater increases in lean mass and decreases in fat mass may have occurred with appropriate diet[48]. Intensity of the self-reported LTPA may have been affected after the intervention therefore use of objective measure after the intervention, e.g., accelerometers, would have given more accurate information[49]. It is not known if the mechanisms improving walking ability occurred earlier during the intervention therefore, future studies could look at the effectiveness of a shorter intensive aquatic exercise intervention.

Conclusion

To conclude, our findings show that a relatively short high intensity aquatic resistance training program decreases fat mass and improves walking speed in post-menopausal women with mild knee OA. Only improvements in walking speed were maintained at 12-months follow-up. Further, LTPA appeared more important for controlling body composition than walking speed. Therefore, future research should investigate if lifestyle education following an intensive aquatic resistance training intervention optimises long term benefits for people with knee OA. Additionally, research is needed to discover through which mechanism aquatic resistance training improves walking speed.

Author contributions

Waller, Benjamin: Analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article, obtaining of funding, collection and assembly of data.

Munukka, Matti: Analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article, obtaining of funding, collection and assembly of data.

Rantalainen, Timo: Analysis and interpretation of the data, critical revision of the article for important intellectual content, final approval of the article, administrative, technical, or logistic support, collection and assembly of data.

Lammentausta, Eveliina: Conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, final approval of the article, administrative, technical, or logistic support.

Nieminen, Miika: Conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, final approval of the article, administrative, technical, or logistic support.

Kiviranta, Ilkka: Conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, final approval of the article.

Kautiainen, Hannu: Conception and design, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article, statistical expertise, collection and assembly of data.

Häkkinen, Arja: Conception and design, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article.

Kujala, Urho: Conception and design, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article.

Heinonen, Ari: Conception and design, analysis and interpretation of the data, drafting of the article, critical revision of the article for important intellectual content, final approval of the article, obtaining of funding.

Conflict of interest

There is no conflict of interest for any authors.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.joca.2017.02.800.

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