Effects of progressive aquatic resistance training on symptoms and quality of life in women with knee osteoarthritis : A secondary analysis

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Effects of progressive aquatic resistance training on symptoms and quality of life in women with knee osteoarthritis: a secondary analysis

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Abstract

Objective: To conduct a secondary analysis to study the effects that four months of aquatic resistance training has on self-assessed symptoms and quality of life in postmenopausal women with mild knee osteoarthritis (OA), after the intervention and after a 12-month follow-up period.

Methods: 87 postmenopausal volunteer women, aged 60–68 years, with mild knee OA were recruited in a randomised, controlled, 4-month aquatic training trial (RCT) and randomly assigned to an intervention (n=43) and a control (n=44) group. The intervention group participated in 48 supervised aquatic resistance training sessions over four months while the control group maintained their usual level of physical activity. Additionally, 77 participants completed the 12-month post-intervention follow-up period. Self-assessed symptoms were estimated using the OA-specific Western Ontario and McMaster University Osteoarthritis Index (WOMAC) and Health-related Quality of life (HRQoL) using the generic Short-form Health Survey (SF-36).

Results: After four months of aquatic resistance training, there was a significant decrease in the stiffness dimension of WOMAC -8.5mm (95% CI= -14.9 to -2.0, p=0.006) in the training group compared to the controls. After the cessation of the training, this benefit was no longer observed during the 12-month follow-up. No between-group differences were observed in any of the SF-36 dimensions.

Conclusions: The results of this study show that participation in an intensive aquatic resistance training program did not have any short- or long-term impact on pain and physical function or

quality of life in women with mild knee OA. However, a small short-term decrease in knee stiffness was observed.

Key Words: Osteoarthritis; Aquatic resistance training; Randomised Controlled Trial; Follow-up study

INTRODUCTION

Osteoarthritis (OA) is the most common form of arthritis and a major source of pain, disability, and socioeconomic costs worldwide.[1] OA develops slowly over years and is thus referred to as a slowly progressive degenerative joint disease.[2] With no cure for the disease, the focus of OA management has been on pain relief, improving physical function, and reducing the symptoms.[3] Despite the modality (land- or water-based) or type (aerobic or strength), therapeutic exercise has been shown to have positive post-treatment effects on achieving these goals[4-7] and in the estimated quality of knee articular cartilage.[8-11]. However, these studies have focused on the later stage of the disease, and there is a need to investigate the role of therapeutic exercise in the earlier stages of the disease. Therapeutic aquatic exercise has been shown to have a positive effect on neuromuscular function and improve muscle mass and strength in healthy women. It is therefore a possible option to prevent the progression of the clinical symptoms and reduced quality of life associated with knee OA.[12]

Therapeutic aquatic exercise (TAE) can offer several benefits over land-based exercise for the OA population because of the reduced loading across joints due to buoyancy.[5,13] It has been shown that people with lower limb OA can safely, comfortably, and most importantly intensively exercise in water while utilising a full joint range of motions not possible or normally recruited on land.[10,14]. In our recent systematic review[5], we found that TAE has a similar short-term effect on pain and self-reported functioning compared to land-based training, but pooling the long-term effects was not possible. In another review, Bartels et al.[7] measured the long-term effects of TAE but did not observe any statistically significant effects of TAE on pain or physical function after the cessation of training. Overall, only three trials[15-17] in TAE reviews[5,7] included participants with knee OA alone. Furthermore, the Kellgren-Lawrence grading of knee OA severity was 2 or higher in Lim et al.[15] whereas it was not reported in the other two.[16,17]

The effect of exercise on health-related quality of life (HRQoL) is still not well understood.[18] Recent systematic reviews with meta-analysis have shown that land-based exercise[6] and TAE[5,7] have a small but significant effect on HRQoL. Because of the limited number of studies reporting follow-up HRQoL outcomes, a meta-analysis of treatment sustainability for HRQoL could not be performed for land-based training[6] or TAE[5]. Further, Bartels et al.[7] did not find any statistically significant long-term effect of TAE on HRQoL after the cessation of training.[7] Moreover, out of

the three trials investigating knee OA alone in TAE reviews[5,7], one used SF-36[15] and two the KOOS questionnaire[16,17] to measure quality of life. Only Lund et al.[16] reported sustainability results with a 3-month follow-up. All this highlights the lack of short- and long-term follow-up TAE studies in early knee OA investigating the effects of TAE on self-assessed symptoms and quality of life. Especially in the long-term, the effects of different types of exercise on OA are scarce, and further well-designed and adequately powered studies are urgently needed.

Therefore, the aim of this study was to investigate the effects of a 4-month aquatic resistance training on self-assessed symptoms of OA and quality of life in postmenopausal women with mild knee osteoarthritis (OA) immediately after the intervention and after a 12-month follow-up period.

MATERIALS AND METHODS

Study design

To achieve the aims of this study we conducted a secondary analysis on data from a previously conducted and registered RCT (ISRCTN65346593).[10] This 4-month RCT with a 12-month follow-up period investigating biochemical composition of tibiofemoral cartilage had two experimental arms: 1) aquatic resistance training and 2) control. Secondary Recruitment and data collection took place between January 2012 and July 2014 and followed the published protocol without changes. The full description of the protocol can be found on open access.[19] Included participants were women aged 60–68 years with mild knee OA. In this study we classify mild knee OA as 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 and as experiencing knee pain on most days.[20] 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

A multistage recruitment process was implemented. Initially, postmenopausal women experiencing knee pain on most days from the Jyväskylä region in Central Finland were voluntarily recruited through advertisements in local newspapers. Inclusion criteria were: postmenopausal female aged 60–68 years, experiences knee pain on most days, body mass index (BMI) <35, radiographic changes in tibiofemoral joint K/L grades I or II, and no medical contraindications preventing full participation in progressive aquatic resistance training program. After the 4-month intervention period, each participant's willingness to participate the 12-month follow-up period was asked for (Figure 1). Full eligibility criteria can be found elsewhere.[10]

Figure 1 here.

Randomisation and blinding

After baseline measurements, all participants were randomly allocated into one of the two arms of the intervention part of the study with a three-digit identification number to blind principal investigator (AH) to group allocation. A blinded statistician (HK), who was only provided with the participants' ID and K/L grades, performed the computer-generated block randomisation of the size of 10, stratified according to K/L grade I or II, and conducted all statistical analyses. The allocation was kept in a locked cabinet, which only the authors (MM and BW) had access to. Outcomes used in this study are patient-reported outcomes, and therefore assessor blinding was not possible.

Intervention

The participants in the intervention group participated in supervised lower limb aquatic resistance training lasting one hour three times a week for four months (with a total of 48 training sessions). The intervention was completed in small groups of 6–8 participants, and two experienced physiotherapists, who had been trained to instruct this program, supervised all training sessions. Training intensity was ensured by using three resistance levels: barefoot, small fins (Theraband products, The Hygienic Corporation, Akron, OH 44310 USA), and large resistance boots (Hydro-boots, Hydro-Tone Fitness Systems, Inc. Orange, CA 928652760, USA), and the training leg performed all the movements without contact with the pool walls or bottom i.e. non-weight bearing. To ensure maximal muscle contraction, the intensity of the training sessions was set at "as hard and fast as possible". Training intensity was monitored using heart rate monitors (Polar Electro Ltd, Kempele, Finland), the rate of perceived exertion (RPE) using the Borg 6–20 scale[22] and the number of repetitions achieved per movement. Full description of the exercises and training program can be found from the online supplemental material.

Training compliance was measured using a combination of training sessions attendance and training intensity measured using heart rate monitors, the rate of perceived exertion (RPE), and repetitions completed per set. These have been reported in depth in our previous article (Waller et al. 2017 supplementary material).[23]

Control

The participants in the control group maintained usual care and were asked to continue their habitual leisure time activities. They were offered the possibility of participating in two sessions consisting of one hour of light stretching and relaxation during the 4-month intervention period.

Follow-up

After the post intervention measurements, all participants were advised to continue their spontaneous leisure time physical activities (LTPA). No other specific instructions were given to the participants. Each participant marked their LTPAs each day for 12 months in a LTPA diary and were instructed only to mark the duration, type, and intensity of the activity. LTPAs were then converted into MET-hours. More detailed description of the LTPA diaries can be found elsewhere.[11]

Outcomes measurements

The outcomes for this study are the self-reported symptoms (WOMAC) and health-related quality of life (SF-36) documented at the baseline and the 4-month and 12-month follow-ups. Self-reported symptoms, i.e. pain, stiffness, and physical functional difficulty, were assessed by using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) questionnaire. Scores for each dimension range from 0 to 100 mm in the visual analogue scale (VAS), with a score of 0 indicating the best symptom status and 100 the worst symptom status.[24] Self-reported quality of life, i.e. physical functioning, role limitations due to physical problems, bodily pain, general health perception, vitality, social functioning, role limitations due to emotional problems, and mental health, were assessed by using the Short Form Health Survey (SF-36). Scores for each dimension range between 0 and 100, with a score of 0 indicating the worst overall health status and 100 the best health status.[25] Version 1.0 of SF-36 was used in this study.

Statistical analyses

Data are presented as the means with standard deviations (SD). Between-group baseline comparisons were performed using a bootstrap type t-test and Chi-squared. Changes in all

outcomes were analysed using the bootstrap type analysis of covariance (ANCOVA); confidence interval (CI) were obtained by bias-corrected boot-strapping (5,000 replications) due to the violation of distributions assumptions. Data were included in the analyses if the participant had data from all measurement points (i.e. baseline, end of intervention at 4-months, and 12-month follow-up). Comparative analyses were not adjusted for randomisation/stratification variables as baseline values were used as covariates. Between-group changes in all outcomes are reported in text as mean difference (95% CI, P-value).

The sample size calculations were based on the primary outcomes of our previous study (Munukka et al. 2016). Target sample size of 70 (35 per research arm) was required to ensure the power of at least 80% to detect a difference of 40 ms effect in dGEMRIC between the groups at two-side $\alpha=0.05$. Predicting a dropout rate of about 10% we aimed to recruit at least 80 participants at baseline. Statistical analyses were performed using statistical software (Stata, release 14.1, StataCorp, College Station, Texas).

RESULTS

In total, 87 participants met the inclusion criteria and were randomised into the aquatic training group (n=43) and control group (n=44). Table 1 shows that the demographic and clinical characteristics of both groups were similar at baseline. 85 participants completed the 4-month intervention, and 84 participants were willing to continue to the 12-month post-intervention follow-up. During the 12-month follow-up period, seven participants dropped out of the study. Therefore 77 participants attended measurements at the 12-month follow-up. Participant recruitment and reasons for loss to follow-up are shown in figure 1.

As previously reported[10], there were two medical consultations (bilateral knee pain and dyspnoea) as a result of the aquatic training. One subject from the control group required a medical consultation for knee pain after the baseline physical performance measures. All three subjects continued their participation in the study and attended the follow-up measurements. During the 12-month follow-up period, no harms related to physical activity were registered.

Table 1 here.

Table 2 here.

Intervention program feasibility

Drop-out rate during the 4-month intervention period for each group was 2.3% (n=1 per group). Training compliance was high (88%) with only three subjects attending less than 70%. The average intensity of each training session (RPE) was 15 (range, 12–17) and average (SD) maximum heart rate was 144 (12) beats per minute. A detailed description of the training intensities achieved during the aquatic resistance training and psychological feelings experienced can be found elsewhere.[23]

Outcomes

There were no between-group differences in self-reported symptoms at baseline (table 2). After the 4-month aquatic training, there was a significant decrease in the WOMAC stiffness dimension -8.5mm (-14.9 to -2.0, p=0.006) in the training group compared to the controls (Figure 2). After the cessation of the training, this benefit was no longer observed in the 12-month follow-up. No between-group differences were observed in WOMAC pain or physical function immediately after the intervention or after the 12-month follow-up.

Figure 2 here.

Table 2 shows that the values of the health-related quality of life dimensions of both groups were similar at baseline. No between-group differences were observed in any of the HRQoL dimensions immediately after the intervention or after the 12-month follow-up (Figure 3).

Figure 3 here.

DISCUSSION

This is the first randomized controlled study to examine the effects of 4-month aquatic resistance training on self-assessed symptoms and quality of life in postmenopausal women with mild knee osteoarthritis (OA) with a 12-month follow-up period. After the 4-month aquatic resistance training, we did not find any statistically significant between-group differences in any measured outcomes except for the small improvement in self-assessed knee stiffness. After the cessation of the training, this benefit was not maintained on long-term.

In this study, there was a significant decrease in WOMAC knee stiffness in the training group compared to the controls. This improvement might be due to the fact that during the intervention, full knee range of motion was ensured in every repetition whereas gait on level surface during LTPAs requires knee ROM from nearly full extension to 60–65 degree flexion.[26] During the intervention period, there was a significant between-group difference in the average monthly LTPA due to the aquatic resistance training. However, this difference was lost after the cessation of the aquatic resistance training.[23] This can be, at least partly, explained by the fact that the former participants of the intervention group went back to their normal level and type of LTPAs[23], suggesting that participants should be recommended to continue TAE at some level. As mentioned in our previous study[11], the most common LTPA during the follow-up period was walking which does not require full-range knee motions as described above. This finding is also in line with a previous systematic review showing that directly after the intervention, TAE had a small, but significant effect on knee stiffness.[5] Furthermore, there was a trend, though not statistically significant, showing a possible pain reduction in the aquatic resistance training group, which might partly support the observed reduction in knee stiffness.

Unlike in previous systematic reviews of TAE[5,7] and land-based therapeutic exercise in osteoarthritic population[6], no between-group differences were observed in any of the quality of life (SF-36) dimensions. The effect size was found small in all review studies.[5-7] The outcome measures used may not accurately represent the true changes in the HRQoL in these patients as involved studies used a variety of continuous scales to evaluate the quality of life outcomes.[5-7] It needs to be noted that in both TAE reviews[5,7] only three trials included participants with knee OA alone and two of the studies used KOOS quality of life[16,17] and one SF-36[15]. Furthermore, the Kellgren-Lawrence grading of knee OA severity was 2 or higher in Lim et al.[15] whereas it was not

reported in the other two[16,17]. Also, only Lund et al.[16] reported sustainability results with a 3-month follow-up. Thus, because of the small amount of knee OA studies and varying methods together with the small effect sizes found, authors of both reviews[5,7] raised caution in the interpretation of the results.

Although there was no significant change in the self-assessed pain, physical function, or HRQoL, it must be remembered that the participants in this study had only mild knee OA with low WOMAC and high SF-36 scores at baseline, meaning there was a strong likelihood of floor and ceiling effects in both measurement points respectively. Means of all SF-36 domains at baseline in this study were at the same level as or above the means of age matched healthy general population in Finland[27] and Norway.[28] Positive finding in the knee stiffness dimension of WOMAC questionnaire aside, these results suggest that the symptoms from early knee OA are not detected by self-assessed symptoms and HRQoL in postmenopausal women and the impact of these symptoms may also only be slight. Furthermore, these results indicate that the WOMAC and SF-36 dimensions might not be the best outcomes or focus for interventions in this study population. Moreover, as this study reports secondary outcomes of our previously published RCT[10], these analyses are under-powered to detect changes in the measured outcomes. However, based on the previous research and aims for possibly slowing down the progression of symptoms, people at risk of developing knee OA or in the early stages of knee OA would be encouraged to consider the benefits of TAE. These benefits include decreasing pain and stiffness, maintaining functional capacity, correcting lower limb/gait biomechanics, controlling weight, and increasing physical activity.[12,29,30] On the other hand, the results of this study show that high intensity progressive aquatic resistance training has no adverse effects on self-assessed symptoms and HRQoL in postmenopausal women with mild knee OA, and there was a trend, though not significant, showing a possible bodily pain reduction in SF-36. It has been suggested that more attention should be paid in early stage OA as the literature shows clear improvements in OA symptoms in patients participating in exercise programs.[31]

STRENGTHS AND LIMITATIONS

The strengths of this exercise intervention study include the high adherence to a highly intensive 4-month aquatic resistance training program and a 12-month follow-up period with a small number of drop-outs. This indicates that postmenopausal women with mild knee OA were able to

withstand progressive aquatic resistance and they were highly motivated. As a limitation, this trial was underpowered to detect changes in the secondary outcomes. The secondary analyses are hypothesis-driven, and even though we did not find significant between-group differences except for knee stiffness, it was worthwhile to observe these outcomes, since self-assessed symptoms and HRQoL are important factors for people with even a mild knee OA diagnosis. This study was designed to fulfill all the important quality criteria in RCT, except for blinding the participants to exercise therapy, which is a common limitation in exercise therapy studies[32]. Due to the strict inclusion criteria in the original intervention study[10], the study sample was homogeneous. Therefore, the results of this study cannot be directly applied to people with progressed OA or older or extremely obese women and men.

PERSPECTIVE

The results of this study suggest that after four months of intensive aquatic resistance training, no statistically significant between-group differences were found in any measured outcomes except for self-assessed knee stiffness (WOMAC). This small positive finding suggests that aquatic resistance training may alleviate self-assessed stiffness of the knee joint which is in line with previous literature.[5] However, one year after the cessation of the training this benefit is no longer observed. Unlike in previous systematic reviews[5-7], this study did not find any between-group differences in any of the SF-36 HRQoL dimensions. Together with only a small positive finding in the knee stiffness dimension of WOMAC questionnaire these results suggest that early stages of knee OA may have only a small or no effect on self-assessed symptoms and HRQoL in postmenopausal women as measured with WOMAC and SF-36 respectively. Importantly, high intensity aquatic resistance training was well tolerated and did not increase clinical symptoms or decrease health–related quality of life, suggesting that postmenopausal women with mild knee OA are able to train hard and safely in an aquatic environment. Therefore, progressive high intensity aquatic resistance training can be recommended to people with mild knee OA.

Contributors

AHeinonen, AHäkkinen, MTN, EL, UMK, HK, and IK conceived and designed this study. AHeinonen obtained the funding for the study. MM and BW managed the trial and were responsible for data collection and the assembly of data. MTN and EL were responsible of

administrative, technical, or logistic support. HK was responsible for statistical expertise. MM takes responsibility for the integrity of the data and the accuracy of the data analysis. MM, AHeinonen, and AHäkkinen drafted the manuscript. All authors contributed to the design; the analysis and interpretation of the data, the critical revision of the article for important intellectual content, and the final approval of the article. AHeinonen was the principal investigator and will act as the guarantor for the paper. All authors had full access to all of the data in this study.

Conflict of interest

Professor Ari Heinonen is a senior section editor for the Scandinavian Journal of Medicine and Science in Sports. No potential conflict of interest was reported by any of the other authors.

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TABLES:

Table 1. Baseline demographic and clinical characteristics of the participants

	Exercise group (n=43)	Control group (n=44)
Age (years)	64 (2)	64 (2)
Height (cm)	162 (5)	162 (5)
Body mass (kg)	69.6 (10.3)	71.0 (11.3)
Body mass index (kg/m^2)	26.6 (3.8)	27.1 (3.5)
Time from menopause (years)	14 (6)	14 (6)
Medication for knee pain, n (%) of users	11 (25.6)	9 (20.5)
Glucosamine use occasionally, n (%)	12 (28)	8 (18)
Kellgren Lawrence grade, n (%)		
Grade 1	23 (53.5)	24 (54.5)
Grade 2	20 (46.5)	20 (45.5)
Knee pain during last week, (VAS, mm)[a]		
• Affected leg	28 (25)	24 (19)
• Non-affected leg	24 (19)	23 (18)
Habitual physical activity (METh/week)	29 (31)	36 (33)

Values are means (SD) or n (%)

METh = metabolic equivalent task hour.

[a] Range, 0-100 mm

Table 2. Baseline values of self-assessed symptoms and health-related quality of life

	Exercise group (n=43)	Control group (n=44)	P-value
WOMAC [a]			
Pain	13 (12)	13 (13)	0.88
Stiffness	18 (18)	22 (22)	0.42
Physical Function	9 (9)	10 (12)	0.89
SF-36			
Physical Functioning	79 (13)	81 (13)	0.40
Role-Physical	83 (26)	85 (31)	0.73
Bodily Pain	69 (17)	73 (15)	0.34
General Health	71 (16)	75 (13)	0.21
Vitality	71 (17)	76 (17)	0.20
Social Functioning	90 (18)	92 (15)	0.70
Role-Emotional	84 (29)	92 (22)	0.17
Mental Health	81 (14)	83 (17)	0.61

Values are means (SD)

[a] Scale 0-100 mm

FIGURE LEGENDS:

Figure 1. Flow chart showing enrolment, allocation, and four month end measurements.

Figure 2 Immediate (4-month) and long-term (12-month follow-up) effects of aquatic resistance training on self-assessed symptoms (WOMAC).

Figure 3. Immediate (4-month) and long-term (12-month follow-up) effects of aquatic resistance training on self-assessed quality of life (SF-36).

Enrollment

Phone interview with assessment of eligibility (n=   )

Excluded (n=   )
- Not meeting inclusion criteria (n=   )
- age <18 (n=   )
- age >65 (n=   )
- BMI <27 (n=   )
- BMI >40 (n=   )
- Pregnant (n=   )
- Breastfeeding (n=   )
- Declined to participate (n=   )
- Other reasons (n=   )

Baseline Assessment

Randomization (n=   )

Allocation

Appetite training group (n=   )
- Received allocated intervention (n=   )
- Did not receive allocated intervention (n=   )

Control group (n=   )
- Received allocated intervention (n=   )
- Did not receive allocated intervention (n=   )

3-month measurements

Attended measurements (n=   )
- Lost to follow-up (n=   )

Attended measurements (n=   )
- Lost to follow-up (n=   )

6-month measurements

Attended measurements (n=   )
- Lost to follow-up (n=   )

Attended measurements (n=   )
- Lost to follow-up (n=   )