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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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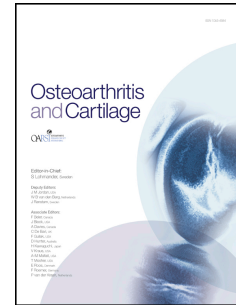
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1 **Effects of high intensity resistance aquatic training on body composition and walking**
2 **speed in women with mild knee osteoarthritis: a 4-month RCT with 12-month follow-up**
3

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36

37 **Running title:** Aquatic training improves walking speed in knee OA

38 **ABSTRACT**

39 **Objective:** To investigate the effects of 4-months' intensive aquatic resistance training on
40 body composition and walking speed in post-menopausal women with mild knee
41 osteoarthritis, immediately after intervention and after 12-months follow-up. Additionally,
42 influence of leisure time physical activity (LTPA) will be investigated.

43 **Design:** This randomised clinical trial assigned 87 volunteer postmenopausal women into
44 two study arms. The intervention group (n=43) participated in 48 supervised intensive aquatic
45 resistance training sessions over 4-months while the control group (n=44) maintained normal
46 physical activity. 84 participants continued into the 12-months' follow-up period. Body
47 composition was measured with dual-energy X-ray absorptiometry. Walking speed over 2km
48 and the knee injury and osteoarthritis outcome score (KOOS) were measured. LTPA was
49 recorded with self-reported diaries.

50 **Results:** After the 4-month intervention there was a significant decrease ($p=0.002$) in fat
51 mass (mean change: -1.17kg ; 95%CI: -2.00 to -0.43) and increase ($p=0.002$) in walking speed
52 (0.052m/sec ; 95%CI: 0.018 to 0.086) in favour of the intervention group. Body composition
53 returned to baseline after 12-months': In contrast, increased walking speed was maintained
54 (0.046m/sec (95%CI 0.006 to 0.086 , $p=0.032$). No change was seen in lean mass or KOOS.
55 Daily LTPA over the 16-months had a significant effect ($p=0.007$) on fat mass loss ($f^2=0.05$)
56 but no effect on walking speed.

57 **Conclusions:** Our findings show that high intensity aquatic resistance training decreases fat
58 mass and improves walking speed in post-menopausal women with mild knee OA. Only
59 improvements in walking speed were maintained at 12-months' follow-up. Higher levels of
60 LTPA were associated with fat mass loss.

61 **Keywords:** Osteoarthritis; Aquatic Exercise; Body Composition; Walking speed

62 **Trial registration number:** ISRCTN6534659

1 INTRODUCTION

2 Knee osteoarthritis (OA) is a common cause of pain and activity limitations causing
3 significant burden on healthcare services¹. While there is no known treatment that prevents or
4 reverses OA, traditional management of OA focuses on reducing the symptoms, i.e. pain and
5 activity limitations, associated with the disease. Recently focus has shifted from treatment of
6 end-stage OA to preventing progression of the disease, especially in early knee OA². One
7 possible approach could be to use interventions that address known risk factors for
8 progression of OA. Risk factors predicting worsening in symptoms and activity limitations
9 include slow walking speeds, obesity, older age and decreased leisure time physical activity
10 (LTPA)^{3,4}. Obesity is associated with knee OA progression through sub-optimal
11 biomechanical loading and low-grade systematic inflammation related to high body fat-mass²,
12 ⁵. Further, people with knee OA have been shown to walk slower and adapt their gait patterns
13 in order to avoid pain and to redistribute joint loading^{6,7}.

14

15 Exercise has been shown to evoke positive changes on symptoms and functional capacity as
16 well as facilitate weight loss^{8,9} and is therefore strongly recommended in the management of
17 knee OA^{1,10}. However, pain is a major modulator for activity avoidance in patients with OA
18 and may limit compliance with land-based exercise¹¹. The aquatic environment allows the
19 individual to exercise with reduced weight bearing and impact on the affected joints¹². Recent
20 studies have shown that individuals with lower-limb OA experience significantly less pain
21 during aquatic compared to land-based exercise of equivalent intensity^{13,14}. Our recent
22 systematic reviews revealed that aquatic exercise evokes both a small and a moderate effect
23 on physical functioning in people with lower limb OA¹⁵ and healthy older people¹⁶,
24 respectively. The difference in effect size is thought, in part, to be due to the higher intensity
25 of training implemented with the healthy older adults¹⁷. Further, lack of reporting of actual

26 training intensities achieved in all the included aquatic exercise studies, limits interpretation
27 of the results. Moreover, higher levels LTPA can have a positive impact on body composition
28 and also predict a slower progression of OA related symptoms and activity limitations^{3, 4}.
29 LTPA levels have not been reported in any previous aquatic exercise studies and therefore the
30 effect of this important cofounding factor has not been previously investigated.

31

32 In order to prevent knee OA progression, the exercise intervention should be prescribed early
33 in the disease progression². To the authors knowledge only one previous study has
34 investigated the effect evoked by aquatic exercise in the early stage of knee OA
35 development¹⁸. Our study, a randomised controlled trial (RCT), indicated that 4-months of
36 aquatic resistance training improved estimated cardiovascular fitness and had a small
37 significant impact on tibiofemoral cartilage as measured with quantitative magnetic
38 resonance imaging (qMRI)¹⁸. Therefore, aims of this study are to report the effect of 4-
39 months intensive aquatic resistance training program on body composition and functional
40 capacity in postmenopausal women with mild knee OA, and whether possible changes are
41 maintained after 12-months' follow-up. The effect of leisure time physical activity on the
42 results and the training intensities achieved during the aquatic resistance training will also be
43 investigated.

44 MATERIALS AND METHODS

45 Study design

46 This study uses previously unreported outcome data collected from the registered AquaRehab
47 research project (ISRCTN65346593), a RCT consisting of a 4-month aquatic intervention
48 with a 12-month follow-up period. Data was collected from January 2012 until April 2014.
49 The full description of the protocol can be found on open access¹⁹, which was followed
50 without changes and a full report of participant recruitment can be found from our previous
51 study¹⁸. This study has two experimental arms: 1) aquatic resistance training and 2) control.
52 Included participants were women aged 60-68 years old with mild knee OA. In this study we
53 classify mild knee OA as experiencing knee pain on most days, not exceeding 5/10 VAS,
54 with radiographic changes in tibiofemoral joint grades I (possible osteophytes) or II (definite
55 osteophytes, possible joint space narrowing) according to the Kellgren Lawrence (K/L)
56 classification²⁰. Pre- and post-intervention results for the qMRI outcomes and patient reported
57 symptoms have been previously reported¹⁸. This current study, in addition to patient reported
58 symptoms, will report the outcomes for body composition and walking speed taken pre- and
59 post-intervention as well as after the 12-months follow-up¹⁸. The study design and reporting
60 follows the CONSORT recommendations for the conducting and reporting of randomized
61 controlled trials²¹. The study protocol (Dnro 19U/2011) was approved by the Ethics
62 Committee of the Central Finland Health Care District and conforms to the Declaration of
63 Helsinki. Written informed consent was obtained from all participants prior to enrolment.

64

65 Subject recruitment

66

67 Participants were recruited from the county of Central Finland using newspaper
68 advertisements and telephone recruitment methods. Eligibility criteria was female aged 60-68

69 years old, body mass index (BMI) <35, experiences knee pain almost daily, K/L grades I or II
70 and no medical reason preventing full participation in intensive exercise. Full eligibility
71 criteria are described elsewhere¹⁹.

72

73 **Randomisation and blinding**

74

75 The subjects were randomly allocated into one of the two arms of the study by a blinded
76 external statistician, provided only with randomisation number and OA severity, using a
77 computer generated block randomization of size of ten, stratified according to K/L grading.

78 The first author performed the DXA imaging but analysis was performed using the
79 manufactures' in-built software without modification. Physical therapists providing the
80 intervention also performed the physical performance measures. Principal investigators were
81 blinded to group allocation.

82

83 **Interventions**

84

85 Those participants in the intervention group participated in an aquatic resistance training
86 sessions lasting 1 hour, 3 times a week for 16 weeks (48 sessions in total). Variable resistance
87 equipment was used to progress training intensity with three resistance levels; barefoot, small
88 resistance fins (Theraband products, The Hygienic Corporation, Akron, OH 44310 USA) and
89 large resistance boots (Hydro-boots, Hydro-Tone Fitness Systems, Inc. Orange, CA 92865-
90 2760, USA). Training intensity was set at as "hard and fast as possible": A full description of
91 the training program, its progression and daily training program can be found elsewhere¹⁸.

92 The control group maintained usual care and were asked to continue their usual leisure time
93 activities. They were offered the possibility of participating in two sessions consisting of 1

94 hour of light stretching, relaxation and social interaction during the 4-month intervention
95 period.

96

97 **Measures of exercise intensity and perceived exertion**

98

99 Maximum training intensity was ensured by measuring the maximum and average heartrates
100 and rating of perceived exertion (RPE) for every training session using heart rate monitors
101 (Polar Oy, Kemble, Finland). Maximum heartrate was estimated using the Karvonen formula
102 ($220 - \text{age} = \text{maxHR}$) with no adjustments made for the possible effects of immersion. During
103 the twelfth week capillary blood lactates and repetitions completed for all three training
104 situations were measured. Self-reported emotional state felt during training was measured
105 with a 1-5 Likert scale (1-Poor, 2-Tolerable, 3-Satisfactory, 4-Good, 5-Excellent).

106

107 **Outcome measures**

108

109 Outcomes for this study are body composition, walking speed and self-reported symptoms.
110 Body composition (total body fat and lean body mass (kg)) was measured with dual-energy
111 X-ray absorptiometry (DXA, Lunar Prodigy; GE Lunar Healthcare, Madison, WI, USA). All
112 full body and regional images were analysed as per manufacturers' protocols using enCORE
113 software (enCORE 2011, version 13.60.033). In vivo precision of these measurements has
114 been reported to be high (CV 1.3-2.2%)²². Walking speed was calculated from the UKK 2km
115 walking test. This test requires the subject to walk 2km around a 200m flat track as quickly as
116 possible without running²³. Walking speed was calculated in metres per second (m/sec) and
117 describes walking ability and is a surrogate for aerobic fitness. Self-report pain (Pain),
118 symptoms (Sym), activities of daily living (ADL), sports and recreation (Sport&Rec) and

119 quality of life (QoL) were measured using be the five domains of the Finnish version of the
120 Knee Injury and Osteoarthritis Outcome Score (KOOS)²⁴. Scores are transformed into a score
121 0-100 with a score of 0 indicating extreme knee problems and 100 no knee problems²⁵.

122

123 **Leisure time physical activity (LTPA)**

124

125 LTPA for each participant was calculated for the whole 4-month intervention and 12-month
126 follow-up period using a daily physical activity diary. Participants recorded type of activity
127 and self-perceived intensity of each activity, i.e. low, moderate or high, from which metabolic
128 equivalent task hours (MET/h) per month was calculated²⁶. The LTPA for the intervention
129 group was calculated by combining the MET/h calculated from the aquatic resistance training
130 and the physical activity diary.

131

132 **Statistical Methods**

133

134 Results are displayed as mean and standard deviation (SD) unless otherwise stated. Between
135 group baseline comparisons were performed using a bootstrap type t-test and Chi-squared.
136 Repeated measures for walking speed, body composition and all domains of the KOOS were
137 analysed using generalised linear mixed-models with unstructured correlation structure. Fixed
138 effects were group, time and group-time interaction. Effect size, standardised beta coefficient
139 (Beta (β)) adjusted for baseline values, was calculated for post intervention and at 12-month
140 follow-up. Cohen's standard for Beta values above 0.10, 0.30 and 0.50 represent small,
141 moderate and large effects respectively²⁷. Between group differences in average monthly
142 LTPA during the 4 month intervention and 12-months' period was tested using a Fisher-
143 Pitman permutation test for two independent samples. The relationship between average

144 monthly LTPA and body composition and walking speed, after removal of group allocation,
145 was calculated using a mixed-effects regression model and represented as Cohen's f^2 , where
146 0.02, 0.15 and 0.35 indicate a small, moderate and large effect respectively²⁸. Repeated
147 ANOVA was used to compare the differences between the three training intensities (barefoot,
148 small fins and large boots) and measures of training response i.e. RPE, heart rates, blood
149 lactates, number of repetition performed per session and emotional state. Statistical analyses
150 were performed using statistical software (Stata, release 13.1, StataCorp, College Station,
151 Texas).

152

153 This study is a post hoc analysis of original data thus the target sample size (n=70, 35 per
154 research arm) was calculated based on expect change in the qMRI outcome¹⁸.

155 **RESULTS**

156

157 In total, 87 participants fulfilled the eligibility criteria and after attending baseline
158 measurement were randomised into the two treatment arms of the study. There were no
159 significant differences between the groups in any descriptive variables at baseline (Table 1).
160 85 participants completed the intervention and 84 agreed to participate in the 12-month
161 follow-up. In total 76 participants attended measurement at 12-months' follow-up. Participant
162 recruitment and reasons for loss to follow-up are shown in Figure 1.

163

164

Table 1 here.

165

166

Figure 1 here.

167

168 **Training intensities achieved during aquatic resistance training**

169

170 Adherence to the aquatic training program was high (88%), with only three subjects attending
171 less than 70%. Pain during aquatic resistance training in the affected knee was reported more
172 frequently during the first month (37 times), followed by a gradual decrease in frequency as
173 the training progressed, with a three-fold reduction in the frequency (12 times) by the 4th
174 month. Pain experienced in affected knee during the intervention was mild 14(16) (VAS 0-
175 100mm). Training intensity recorded from each complete training session is shown in Table
176 2. There was a gradual increase in RPE when progressing from barefoot to large resistance
177 boots while no significant differences in heart rates were measured. A full description of the
178 daily training intensities measured and pain experienced during training can be found from

179 the supplemental material Appendix A. The attendance for the control group sessions was
180 68%.

181

182 *Table 2 here.*

183

184 **Treatment effects and maintenance at 12-months**

185

186 Summaries of the treatment effects after 4-months and their maintenance at 12-months
187 follow-up are presented in Figure 2 and Table 3. After 4-months aquatic resistance training
188 there was a significant ($p=0.002$) moderate (Beta (β): 0.32; 95% CI: 0.14 to 0.51) decrease in
189 fat mass (-4.7% and 0.25% in training and control group respectively) and over-all moderate
190 (β : 0.34; 0.15 to 0.52) decrease (-1.4% and 0.21%) in body weight ($p=0.004$), both in favour
191 of the intervention group. There was a significant ($p<0.001$) decrease in fat mass in both legs
192 -0.47kg (-0.74 to -0.20) or a loss of -4.5% in the training group compared to 1.1% increase in
193 the control group. There was a similar significant change ($p=0.007$) in the trunk -0.63kg (-1.1
194 to -0.17) or a loss of -3.1% compared to a 1.0% increase in the control group. Both
195 significant findings were lost a 12-months follow-up. No localised change in lean mass was
196 seen at any time point. After the intervention, a significant increase in walking speed
197 ($p=0.002$) was observed in favour of the intervention group (β : 0.3; 0.12 to 0.50). At 12-
198 month follow-up walking speed ($p=0.032$) in the intervention group remained significantly
199 faster compared to the control group (β :0.2; 0.01 to 0.44). No other significant between group
200 differences could be seen in any domain of the KOOS questionnaire.

201

Figure 2 here

202

Table 3 here

203

204 **Effects of physical activity**

205

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

216

217 *Figure 3 here.*

218

219 **Harms**

220

221 As previously reported¹⁸, one subject stopped the intervention following pain experienced
222 after the first use of the large resistance boot (session 16). One subject complained of
223 dyspnoea. After education training the participant was able to complete the intervention and
224 attend follow-up measurements. The results of both participants are included as per intention-
225 to-treat analysis. No subjects at pre- or post-intervention measurements were unable to walk
226 the 2km. At 12 months' follow-up two subjects, one from each group could not complete the
227 2km; both due to a lower-limb injury unrelated to their knee OA.

228 **DISCUSSION**

229

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

240

241 Increased fat mass is linked to knee OA through biomechanical²⁹ and low-grade
242 inflammatory mechanisms³⁰, and is associated with an increased risk of suffering from knee
243 OA as well as a more rapid progression of the disease³¹⁻³³. A change of -1% in body weight
244 has been shown to have a significant association with slower loss of tibial cartilage volume
245 and improvement in symptoms suggesting our 1.4% weight change could have a meaningful
246 impact on both cartilage health and OA related symptoms³⁴. Our findings indicate a superior
247 improvement in body composition compared with the two previous studies investigating the
248 effects of aquatic exercise on body and fat mass in persons with OA^{17,35}. The respective -
249 1.17kg and -1.1kg decreases in fat and body mass evoked in our study are larger than the
250 non-significant decrease in fat mass (-0.7kg) reported by Lim et al.¹⁷ and significant
251 reduction in body mass (-0.76kg) reported by Kim et al.³⁵. While this could be due our
252 slightly longer duration i.e. 4 weeks longer, we also utilised a much higher training

253 intensities. Lim et al.¹⁷ set intensity at 65% Max HR, while Kim et al.³⁵ set intensity at RPE
254 12-13 (Borg 6-20), approximately 60% Max HR³⁶. In our study, average maximum heartrates
255 during the main set were close to 85% with measured maximum HR up to 105%. Further, our
256 finding demonstrate that high intensity aquatic exercise, appears to have similar effects as
257 land-based exercise programs on body and fat mass. Messier et al.⁹, for example, reported
258 that an 18 month, 3 times a week land-based exercise-only program produced a (-1.8kg) loss
259 in total body weight . However, the decrease in fat mass was only 1% (-0.4 kg) and loss of
260 lean mass was 1% (-2.6kg) in the exercise-only group. A loss of lean-mass and therefore
261 reduction in muscle strength, is a common negative side effect of weight loss. Reduction in
262 muscle mass and strength is associated with the development and faster progression of knee
263 OA^{37,38}, therefore preserving muscle mass during periods of weight loss is vital in this
264 population³³. Our study showed no change in lean mass and previously reported muscle
265 strength¹⁸, indicating that while the training was intensive enough to evoke a decrease in fat
266 mass it was also sufficient to preserve strength and lean mass.

267

268 Improvements in walking speed after 4-months aquatic resistance training, and its
269 maintenance, after a 12-month follow-up period, are in contrast to the results for body
270 composition changes. Slower walking speeds are associated with faster progression of OA
271 related symptoms and activity limitations and the small but sustained improvement of
272 0.05m/sec achieved in our study indicate a meaningful and lasting improvement in functional
273 capacity³⁹. Given that the weight lost during the intervention was regained during follow-up,
274 our findings suggest that the effect on walking speed may not have been weight related. The
275 results could indicate an improvement in cardiovascular fitness; however, the lack of between
276 group differences in LTPA over the 12-months' follow-up period and at a level that had no
277 effect on cardiovascular fitness in controls during the intervention period, suggests that this

278 alone cannot explain the maintenance of walking speed. While there were no improvements
279 in muscle strength of the knee extensors and flexors, (previously reported¹⁸) we cannot rule
280 out improvements in the un-measured ankle plantar flexors or hip abductors which could
281 improve gait biomechanics and efficiency⁴⁰. Further, strength alone is not a marker of
282 improved gait biomechanics with efficient gait requiring co-ordination between agonist and
283 antagonist muscles^{7, 41, 42}. Immersion results in a decrease in nociceptor stimulation and
284 afferent feedback^{43, 44}, and reduces the sensation of pain^{13, 14, 45, 46}. These conditions may
285 create a suitable training condition for improving gait biomechanics¹⁴. Alternatively, the high
286 intensity intervention exposed the subjects to the sensation of high physical exertion. This
287 could have taught the participants that it was safe for them to exert themselves at a higher
288 intensity than previously thought. It is feasible to speculate that this exercise pedagogy was
289 retained 12-months after intervention cessation. However, walking frequency and intensity as
290 part of the monthly LTPA did not differ between groups suggesting the improvement in
291 walking speed was not utilised. Ultimately, the mechanisms behind the effect of aquatic
292 resistance training on walking speed, deserves further investigation.

293

294 Education on life-style changes has been suggested as a vital part of management of both
295 early and late-stage OA, in order to sustain improved levels of physical activity following an
296 intervention study⁴⁷. Participants in the training group did not have higher leisure time
297 physical activity after the intervention than the control group therefore it is plausible to
298 conclude that they returned back to pre-intervention level. Therefore, the increased walking
299 speed may only describe improved functional capacity and may not be associated with
300 increased walking speeds utilised in daily life. In combination with the possible exercise
301 pedagogical effect of the high intensity exercise and implementation of a life-style education
302 program, including dietary and advice, may have maintained or even continued the

303 improvements body composition and walking speed. Importantly, our results showed an
304 association between higher levels LTPA and loss of fat mass irrespective of group allocation.
305 Our results suggest that involvement in the intervention did not increase LTPA during the 12-
306 months' follow-up period. However, LTPA was measured using self-reported questionnaires
307 and it is plausible to hypothesise that after the intervention the participants in the training
308 group may have changed their perception of activity intensities. Further, inclusion in a study
309 may have caused a general increase in LTPA explaining the results. No acute worsening of
310 clinical symptoms, as measured with the KOOS, was seen, possibility a result of the low
311 impairment at baseline, the fluctuating nature of OA symptoms and the relatively short
312 follow-up period².

313

314 The strengths of this study included the randomised control design. The high adherence to the
315 intervention and small number of drop-outs optimised the treatment response and shows
316 motivation to participate in such an aquatic resistance exercise intervention. This is the first
317 study to monitor leisure time physical activity, in addition to the exercise intervention, during
318 an aquatic exercise intervention in participants with knee OA¹⁵, controlling an important
319 confounding factor. The main limitation of this study was the use of strict inclusion criteria,
320 essential for the original primary qMRI outcomes, which resulted in a homogeneous sample
321 limiting direct application of our results to persons with more severe knee OA. However, it is
322 conceivable to assume that, adapted, this program, would be suitable to improve functional
323 capacity and decrease weight in subjects with more severe knee OA. Further studies are
324 needed to confirm its efficacy in subjects with hip OA. The use of un-equal interventions i.e.
325 only 2 sessions in the control group, introduces at least some degree of bias in favour of the
326 intervention. Therefore, these results only indicate that aquatic resistance training is effective
327 compared to no intervention and not more effective than another intervention. The lack of

328 assessor blinding to the intervention may have resulted in bias, however, assessors had no
329 vested interest in the results of this study and primary investigator was blinded throughout.
330 Dietary intake was not measured or controlled for. Inclusion in a study has been shown to
331 affect participants' dietary habits as well as physical activity and therefore we cannot directly
332 attribute all the changes as a pure effect of the intervention. Diet alone, however, would not
333 have accounted for the maintenance of lean body mass⁹. Further, greater increases in lean
334 mass and decreases in fat mass may have occurred with appropriate diet⁴⁸. Intensity of the
335 self-reported LTPA may have been affected after the intervention therefore use of objective
336 measure after the intervention, e.g. accelerometers, would have given more accurate
337 information⁴⁹. It is not known if the mechanisms improving walking ability occurred earlier
338 during the intervention therefore, future studies could look at the effectiveness of a shorter
339 intensive aquatic exercise intervention.

340

341 **Conclusion**

342

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

351 **Author contributions**

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386

387 **Conflict of interest**

388 There is no conflict of interest for any authors.

389

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540

541 **TABLES****Table 1** 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)
Body mass index (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 (METh/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

542 Values are means (SD) unless otherwise noted.

543 *Number of participants using analgesia for knee pain on inclusion to study

544 LTPA = leisure time physical activity, METh = metabolic equivalent task hour.

545

546 **Table 2** Description of training intensities achieved during the aquatic resistance training and
547 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)

548 Mean and (SD) unless otherwise stated. *RPE = Rating of perceived exertion (BORG 6-20)

549 [‡] Measured directly after sessions 35-37, [†]Bare vs Large (p<0.001)

550

551 **Table 3** Effect of aquatic resistance training on walking speed, body composition and clinical symptoms.
 552

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/sec)	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†

553 BL = baseline, FU = post-intervention (4-months), 12-FU = 12-months follow-up, *post-intervention follow-up compared to baseline (mixed
 554 model), **12-month follow-up compared to baseline (mixed-model),

555 LTPA = average monthly total Leisure Time Physical Activity, MET/h = metabolic equivalent task hour. †Fisher-Pitman permutation test

556

557 **FIGURE LEGENDS**

558 **Figure 1** Flow chart showing participant recruitment, randomisation and retention

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

561 **Figure 3** Monthly leisure time physical activity (METH)

