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Efficacy of progressive aquatic resistance training for tibiofemoral cartilage in postmenopausal women with mild knee osteoarthritis: a randomised controlled trial

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SUMMARY

Objective: To study the efficacy of aquatic resistance training on biochemical composition of tibiofemoral cartilage in postmenopausal women with mild knee osteoarthritis (OA).
Design: Eighty seven volunteer postmenopausal women, aged 60–68 years, with mild knee OA (Kellgren–Lawrence grades I/II and knee pain) were recruited and randomly assigned to an intervention ($n = 43$) and control ($n = 44$) group. The intervention group participated in 48 supervised aquatic resistance training sessions over 16 weeks while the control group maintained usual level of physical activity. The biochemical composition of the medial and lateral tibiofemoral cartilage was estimated using single-slice transverse relaxation time (T2) mapping and delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC index). Secondary outcomes were cardiorespiratory fitness, isometric knee extension and flexion force and knee injury and OA outcome (KOOS) questionnaire.
Results: After 4-months aquatic training, there was a significant decrease in both T2 −1.2 ms (95% confidence interval (CI): −2.3 to −0.1, $P = 0.021$) and dGEMRIC index −23 ms (−43 to −3, $P = 0.016$) in the training group compared to controls in the full thickness posterior region of interest (ROI) of the medial femoral cartilage. Cardiorespiratory fitness significantly improved in the intervention group by 9.8% ($P = 0.010$).

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Conclusions: Our results suggest that, in postmenopausal women with mild knee OA, the integrity of the collagen-interstitial water environment (T2) of the tibiofemoral cartilage may be responsive to low shear and compressive forces during aquatic resistance training. More research is required to understand the exact nature of acute responses in dGEMRIC index to this type of loading. Further, aquatic resistance training improves cardiorespiratory fitness.
Trial registration number: ISRCTN65346593.

Introduction

Knee osteoarthritis (OA) is a common cause of pain and limitations in physical function globally and represents a significant burden on healthcare costs[1]. The development of knee OA progresses slowly over years[2]. In the early phase of OA development, changes are seen in the biochemical composition of the cellular matrix of the cartilage. These include a decrease in glycosaminoglycan (GAG) content, responsible for hydrophilic properties of the collagen matrix, and loss of integrity of the collagen matrix, responsible for restraining hydrostatic pressure and maintaining cartilage stiffness[3]. As cartilage degeneration progresses its biomechanical properties are altered, reducing its ability to resist and distribute tensile, shear and compressive forces, causing further degradation and joint failure[4].

There is no known cure or treatment that prevents or reverses the biochemical changes in the cartilage, therefore, the current management of OA focuses on reducing the symptoms and decreased function associated with the disease[1]. Exercise, irrespective of modality (land or water) or type (strength or aerobic), has been shown to be effective in achieving these aims[5,6]. Moreover, an active life style with participation in exercise has been shown to be beneficial for maintenance of the biochemical properties of cartilage in both animals[7,8] and humans[9,10]. Further, exercise has been shown to reverse cartilage atrophy seen in disuse and immobilisation studies[11,12] and slow down progression of OA in animals[13]. Therefore, exercise could be an effective intervention for the maintenance of cartilage health. However, studies investigating the effect of exercise interventions on healthy and degenerated human cartilage are sparse[14–17]. Only two previous studies have investigated the effects of land based exercise on the biochemical composition of cartilage in postmenopausal women with mild knee OA, i.e., Kellgren–Lawrence grades I/II and knee pain[15,16]. We found an improvement in the collagen matrix in the patella cartilage of women with mild knee OA following a 1-year, three times a week, high-impact exercise intervention[15] while we did not see any worsening or improvement in the collagen matrix or GAG concentration of the tibiofemoral cartilage in the same study[16]. Therefore, there is sufficient evidence to show cartilage health is maintained by appropriate mechanical stimulus and environment[9,18].

Pain is a major modulator for activity avoidance in people with knee OA[19]. Water is a facilitating environment in which persons with lower limb OA can safely and comfortably exercise at high intensities utilising full joint range of motions[20]. Our recent systematic review showed that aquatic exercise has a similar effect on pain and self-reported functioning compared to land-based training[6]. Moreover, in our previous studies Pöyhönen *et al.*[21] and Valtonen *et al.*[22] both showed significant benefits of a progressive aquatic resistance training program for physical functioning in healthy women and following knee arthroplasty, respectively. Regular cyclic movements performed during aquatic exercise may provide sufficient mechanical stimulus and facilitate improved exchange of nutrients thus increasing chondrocyte activity[4,18]. Therefore, the aim of this study was to investigate if progressive, intensive and high volume aquatic resistance training affects the biochemical composition of tibiofemoral cartilage in postmenopausal women with mild knee OA.

Materials and methods

Study design

This study was a 4-month registered randomised controlled trial (ISRCTN65346593) with two experimental arms: (1) aquatic resistance training and (2) control. Recruitment and data collection took place between January 2012 and May 2013 and followed the published protocol without changes[23]. 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 experiencing knee pain on most days[24]. 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 enrollment.

Subject recruitment

A multistage recruitment process was implemented (Fig. 1). Initially, postmenopausal women from the Jyväskylä region in Central Finland were voluntarily recruited through advertisements in local newspapers. Preliminary eligibility was assessed using a structured telephone interview ($n = 323$), followed by evaluation of OA severity in the tibiofemoral joint with radiographs ($n = 180$) and finally through medical screening ($n = 111$). Inclusion criteria were: postmenopausal woman aged 60–68 years, experiencing knee pain on most days, participates in intensive exercise $\leq$twice a week, radiographic changes in tibiofemoral joint K/L I or II, no previous cancer or chemotherapy, no medical contraindications or other limitations to full participation in an intensive aquatic training program and complete transverse relaxation time (T2) data. Exclusion criteria included a T-score <-2.5 (indicating osteoporosis)[25] measured from the femoral neck using dual-energy X-ray absorptiometry (DXA), resting knee pain visual analogue scale (VAS) >50/100, surgery of the knee due to trauma or knee instability, meniscectomy within the last 12 months, inflammatory joint disease, intra-articular steroid injections in the knee during the previous 12 months, contraindications to MRI and allergies to contrast agents or renal insufficiency. Due to confounding factors related to obesity, a body mass index (BMI) of >34 kg/m^2 was an exclusion criterion.

Randomisation and blinding

After baseline measurements, all participants were randomly allocated with a three digit identification number (ID) to blind