

Effects of 12-week aquatic exercise on cardiorespiratory fitness, knee isokinetic function, and Western Ontario and McMaster University osteoarthritis index in patients with knee osteoarthritis women

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The purpose of this study is to investigate the risk factors of metabolic syndrome, cardiorespiratory fitness, knee isokinetic function, and osteoarthritis index in patients with knee osteoarthritis women. Subjects were divided into the exercise group (n=9, aged 60.89±5.06), and the control groups (n=8, aged 61.25±1.91). Aquatic exercise was performed for 12 weeks, 3 times a week, 60 min a day. The changes of metabolic syndrome risk factors, cardiorespiratory fitness, knee isokinetic function, and WOMAC index (Western Ontario and McMaster University osteoarthritis index) were measured and analyzed at pre- and post-exercise program for verifying exercise effectiveness. As a result, fasting blood glucose ($P<0.05$), glycosylated hemoglobin ($P<0.01$), and triglyceride ($P<0.05$) were significantly decreased in the risk factors of

metabolic syndrome. The maximum oxygen uptake in cardiorespiratory fitness was not significantly different. The left and right extensor muscles of knee isokinetic function increased significantly ($P<0.01$, $P<0.01$, respectively). There was no significant difference in flexor muscles. Osteoarthritis index was significantly improved in stiffness ($P<0.01$) and physical function ($P<0.05$). In conclusion, aquatic exercise can be regarded as an effective exercise program for managing metabolic syndrome risk factors, increasing muscle function, and improving osteoarthritis index in patients with osteoarthritis of the knee.


Keywords: Aquatic exercise, Osteoarthritis, Metabolic syndrome, Cardiorespiratory fitness, Knee isokinetic function, WOMAC index

INTRODUCTION

The incidence of musculoskeletal diseases due to population aging is increasing, and the most prevalent disease is osteoarthritis (Niu et al., 2009). Osteoarthritis, in particular, is considered a serious health problem that increases the burden of disease (Grazio, 2005). Osteoarthritis is a disease in which articular cartilage is worn or damaged, resulting in functional impairment due to repeated pain, stiffness and deformity of the joint (Arden and Nevitt, 2006; Tanaka et al., 1998). Symptoms such as pain and stiffness in osteoarthritis restrict activity and interfere with daily life (Dieppe and Lohmander, 2005). According to the WHO Sci-

entific Group on the Burden of Musculoskeletal Conditions at the Start of the New Millennium (2003), 80% of osteoarthritis patients report mild activity limitation and 25% have difficulty performing daily activities. Thus, osteoarthritis is not a disease that leads to death, but it causes social and psychological problems caused by limitation of activity, which is a significant deterioration of quality of life.

Recent studies have shown a high prevalence of metabolic syndrome in osteoarthritis patients (Puenpatom and Victor, 2009; Yoshimura et al., 2011). Metabolic syndrome is a major risk factor for cardiovascular disease, including obesity, high blood pressure, impaired fasting glucose, dyslipidemia, and inflammatory respons-

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es (Libby et al., 2002). The cause of metabolic syndrome in osteoarthritis patients is the limitation of physical activity due to osteoarthritis symptoms. In addition, physical activity limitations in patients with osteoarthritis result in cardiorespiratory fitness and decreased myocardial function (Lankhorst et al., 1985). According to previous studies, the maximum oxygen uptake (VO_{2max}), which is an index of cardiorespiratory fitness in osteoarthritis patients, is only 73% of normal people (Minor et al., 1988). In a study of muscle function, quadriceps muscle strength in osteoarthritis patients was found to be weaker than normal subjects (Hurley et al., 1997; Tan et al., 1995; Wessel, 1996).

Treatment of osteoarthritis is fundamentally difficult, but it is aimed at minimizing symptoms such as pain, stiffness, and movement disorders and promoting activity (Altman, 2010). In addition, it is important to manage metabolic syndrome, improve cardiorespiratory fitness, and improve muscle function in order to lower the risk of cardiovascular disease in patients with osteoarthritis. This study was supported by a review of the literature on osteoarthritis and osteoarthritis in the elderly. However, it has been suggested that exercise with high weight-bearing may exacerbate osteoarthritis (Miyazaki et al., 2002). Therefore, it is recommended that aquatic exercise with low weight loss and low joint pressure is used in prevention or treatment of osteoarthritis (Batterham et al., 2011; Rahmann, 2010).

Aquatic exercise uses buoyancy and resistance at the same time. Because buoyancy is a force acting in the opposite direction of gravity, aquatic motion has less load than actual weight. As a result, aquatic exercise is effective in improving the pain and functional ability by lowering the mechanical burden on the knee and hip joint of osteoarthritis patients (Lim et al., 2010; Wilder and Brennan, 1993). This increase in physical activity can also affect cardiovascular disease prevention.

However, studies on cardiorespiratory fitness and muscle function, which are directly related to metabolic syndrome risk factors and activities of daily living, which are a complex of cardiovascular diseases in women with osteoarthritis of the knee, are somewhat lacking. The purpose of this study was to investigate the effect of aquatic exercise on metabolic syndrome risk factors, cardiorespiratory fitness, knee isokinetic function, and osteoarthritis index of knee osteoarthritis women.

MATERIALS AND METHODS

Subjects

The subjects of this study were middle-aged women in Seoul

Table 1. Characteristics of subjects

Variable	Exercise group (n=9)	Control group (n=8)	P-value
Age (yr)	60.89±5.06	61.25±1.91	0.846
Height (cm)	156.89±6.99	154.14±5.04	0.364
Weight (kg)	61.79±9.94	58.20±10.95	0.493
BMI (kg/m ²)	25.18±4.31	24.63±5.33	0.894

Values are presented as mean ± standard deviation.
BMI, body mass index.

region who were diagnosed with osteoarthritis of knee. The subjects were selected voluntarily for participation in aquatic exercise programs, those who were diagnosed with osteoarthritis of the knee, those who received a doctor's consent to participate in the exercise program, and those who did not participate in regular exercise or other exercise programs for the past 6 months. Exercise group (n=9) and control group (n=8) were randomly selected from 17 subjects. The physical characteristics of the subjects were as shown in Table 1.

Anthropometric and metabolic syndrome risk factors

Height and weight were measured using an automatic anthropometric instrument (SH-9600A, O2run, Seoul, Korea). Body mass index (BMI) using height and weight was calculated as (body weight [kg]/height [m]²). The waist circumference was measured according to the WHO recommendation in a comfortable upright posture midway between the lowest rib and the upper extremity of the pelvic iliac crest. Body fat percentage was measured using a body fat analyzer based on bioelectrical impedance method (X-Scan, Jawon Medical, Gyeongsan, Korea). Systolic and diastolic blood pressures were measured using an automatic blood pressure monitor (FT-700R, Jawon Medical) after a stable state for more than 10 min. Blood samples were collected from the brachial artery after fasting for at least 8 hr. After collecting the blood, centrifugation was carried out at 3,000 rpm for 15 min. Analysis of fasting blood glucose, glycosylated hemoglobin (HbA_{1c}), triglyceride, high-density lipoprotein cholesterol (HDL-C), and C-reactive protein (CRP) was performed with the use of a biochemical analyzer (Selecta XL, Vital Scientific, Newton, MA, USA).

Cardiorespiratory test

The cardiorespiratory fitness test was carried out using an automatic breathing gas analysis system (Q4500, Quinton, Bothell, WA, USA) to determine the VO_{2max} . The protocol for testing exercise loads was the modified Balke protocol. The end of criteria for

exercise testing was defined as rating of perceived exertion (RPE) of 17 or greater, a maximum heart rate of 5 or greater, and a respiratory exchange rate of 1.15 or greater.

Knee isokinetic function test

The knee isokinetic function of the knee was measured using the Biodex System 3 (Biodex, New York, NY, USA). After placing the subject in the measuring device chair, the axis of the knee joint and the axis of the knee joint were aligned. To prevent shaking of the body and legs during measurement, the scope of test subjects was determined after fixing the chest, abdomen, and femur with straps and fixing the legs on the resistance pads. The subject's isokinetic knee joint test protocol was performed after two exercises at an angular velocity of 60°/sec. Before the measurement, the test method was explained to the subject.

Osteoarthritis index test

In this study, we used the Korean-WOMAC index (Bae et al., 2001) as a tool to evaluate the functional improvement of patients with osteoarthritis (WOMAC index). The Korean-WOMAC index is divided into three areas of pain, stiffness, and physical function, and consists of 24 questions. Each item is scored on a 5-point scale, and the higher the score, the worse the symptoms. The range of points in each area is 0–20 points of pain, 0–8 points of hardness, and 0–68 points of physical function. The WOMAC index showed higher reliability ($r=0.86$) in assessing osteoarthritis. The Cronbach of this study was 0.95.

Aquatic exercise program

The 12-week aquatic exercise program was conducted in the K indoor pool 3 times a week for 60 min a day, followed by a preparation exercise, a main exercise, and a healing exercise. The preparation exercise and the grooming exercise were performed for 10 min each for jumping, walking, and stretching. This exercise can be performed by swimming underwater in front of the arms, swimming back and forth in the water, raising and lowering in the water, raising the arms under the water, walking forward underwater, walking underwater, underwater squat, lifting the underwater bridge, and was performed for 40 min. Exercise intensity was applied at 13–14 (slightly hard) level using RPE.

Statistical analysis

All data in this study were calculated using the IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA) and presented as mean and standard deviation. Two-way analysis of variance was performed by repeated measures to verify the effect of 12-week aquatic exercise. The significance level (α) of the statistical test was set at $P < 0.05$.

RESULTS

Changes of metabolic syndrome risk factors and CRP

As shown in Table 2, there was no significant difference in the body weight, BMI, body fat percentage, waist circumference, systolic blood pressure, diastolic blood pressure, HDL-C, and CRP

Table 2. Change of metabolic risk factors and CRP

Variable	Exercise group		Control group		Group	Time	Interaction
	Pre	Post	Pre	Post			
Weight (kg)	61.79±9.94	60.67±8.87	58.20±10.95	58.16±11.17	0.548	0.100	0.122
BMI (kg/m ²)	25.18±4.31	24.76±3.96	24.63±5.33	24.69±5.36	0.894	0.195	0.088
Body fat (%)	33.59±5.83	32.63±5.47	32.83±5.45	32.49±5.41	0.877	0.073	0.607
WC (cm)	81.56±10.58	81.50±11.10	83.98±10.81	84.50±10.32	0.607	0.742	0.685
SBP (mmHg)	116.67±17.31	113.22±20.04	124.88±9.72	118.63±12.83	0.360	0.075	0.588
DBP (mmHg)	71.11±6.64	70.44±7.40	70.44±7.40	70.44±7.40	0.927	0.661	0.902
FBG (mg/dL)	105.33±13.01	101.00±13.81	114.63±20.51	110.00±18.19	0.258	0.032*	0.940
HbA _{1c} (%)	6.07±0.63	5.71±0.59**	6.33±1.28	6.28±1.34	0.409	0.001**	0.005**
TG (mg/dL)	127.44±36.97	111.11±33.71	118.75±31.90	107.50±26.26	0.702	0.000***	0.195
HDL-C (mg/dL)	46.33±4.53	46.78±5.72	45.13±4.52	46.25±3.92	0.704	0.169	0.541
CRP (mg/L)	0.17±0.16	0.14±0.11	0.18±0.25	0.14±0.06	0.975	0.493	0.905

Values are presented as mean ± standard deviation.

BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; HbA_{1c}, glycosylated hemoglobin; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; CRP, C-reactive protein.

* $P < 0.05$. ** $P < 0.01$. *** $P < 0.001$; paired *t*-test.

Table 3. Change of cardiorespiratory fitness and knee isokinetic function

Variable	Exercise group		Control group		Group	P-value	
	Pre	Post	Pre	Post		Time	Interaction
VO _{2max} (mL/kg/min)	24.38±6.29	27.90±2.84	25.46±7.41	25.19±4.44	0.733	0.219	0.154
Rt Knee EX TQ/BW (Nm)	126.97±26.74	148.36±25.50**	130.75±18.32	133.39±18.00	0.608	0.001**	0.005**
Lt Knee EX TQ/BW (Nm)	137.12±40.28	151.71±43.24**	128.78±27.91	130.88±30.16	0.420	0.000***	0.004**
Rt Knee FX TQ/BW (Nm)	55.11±27.12	57.78±27.74	51.75±18.19	52.13±16.57	0.687	0.596	0.689
Lt Knee FX TQ/BW (Nm)	58.88±26.61	60.78±22.10	54.86±18.55	55.63±21.62	0.671	0.651	0.846

Values are presented as mean ± standard deviation.

VO_{2max}, maximum oxygen uptake; Rt Knee EX TQ/BW, right knee-extensor peak torque/body weight; Lt Knee EX TQ/BW, left knee-extensor peak torque/body weight; Rt Knee FX TQ/BW, right knee-flexion peak torque/body weight; Lt Knee FX TQ/BW, left knee-flexion peak torque/body weight.

* $P < 0.05$. ** $P < 0.01$. *** $P < 0.001$; paired t -test.

Table 4. Change of WOMAC index

Variable	Exercise group		Control group		Group	P-value	
	Pre	Post	Pre	Post		Time	Interaction
Pain (score)	10.89±3.62	9.22±3.60	12.50±6.32	11.50±4.63	0.371	0.101	0.668
Stiffness (score)	4.56±1.81	3.56±1.59*	4.38±1.85	5.38±2.83*	0.393	1.000	0.013*
Physical function (score)	34.78±13.63	29.33±12.65**	34.88±11.59	33.63±11.11	0.716	0.003**	0.003**
Total (score)	50.22±17.74	42.11±16.14**	51.75±19.23	50.38±18.06	0.573	0.007**	0.042*

Values are presented as mean ± standard deviation.

WOMAC index, Western Ontario & McMaster Universities Osteoarthritis index.

* $P < 0.05$. ** $P < 0.01$; paired t -test.

between the two groups according to the treatment. Fasting blood glucose significantly decreased after exercise in both exercise and control groups ($P < 0.05$). However, the interaction effect did not appear. HbA_{1c} significantly decreased after exercise in the exercise group compared to the control group ($P < 0.01$), but there was no significant difference in the control group compared to the control group. Interaction effects also appeared ($P < 0.01$). Triglyceride was decreased after exercise in both exercise and control groups ($P < 0.01$), but no interaction effect was observed.

Changes of cardiorespiratory fitness and knee isokinetic muscle function

As shown in Table 3, there was no significant difference in maximal oxygen uptake as a cardiovascular fitness index according to treatment. The left extensor muscle was significantly increased after exercise in the exercise group ($P < 0.01$). However, there was no significant difference in the control group. Interaction effects also appeared ($P < 0.01$). In the exercise group, the right extrinsic muscle increased significantly ($P < 0.01$). However, there was no significant difference in the control group. Interaction effects also appeared ($P < 0.01$). There was no significant difference between the two groups according to the treatment. No interaction effect was seen.

Changes of osteoarthritis index (WOMAC index)

As shown in Table 4, osteoarthritis index did not show any significant difference between the two groups according to the treatment. Stiffness decreased significantly after exercise in the exercise group ($P < 0.05$). However, the control group was significantly increased ($P < 0.05$). Interaction effects also appeared ($P < 0.01$). Physical function was significantly decreased after exercise ($P < 0.01$) in the exercise group compared to the control group. However, there was no significant difference in the control group. Interaction effects also appeared ($P < 0.01$). The overall score of osteoarthritis index decreased significantly after exercise in the exercise group ($P < 0.01$). However, there was no significant difference in the control group. Interaction effects also appeared ($P < 0.05$).

DISCUSSION

This study was conducted to investigate the risk factors of metabolic syndrome, cardiorespiratory fitness, knee isokinetic function and osteoarthritis index in patients with knee osteoarthritis women. To summarize the results of this study, 12-week aquatic exercise in women with osteoarthritis was found to be effective in improving fasting blood glucose, HbA_{1c}, triglyceride reduction, knee extensor promotion, and osteoarthritis index.

Metabolic syndrome is characterized by abdominal obesity, impaired fasting glucose, hypertension, dyslipidemia, and is known to increase the risk of cardiovascular disease and type 2 diabetes due to atherosclerosis (Lakka et al., 2002; Malik et al., 2004). Wang et al. (2016) studies have shown a link between osteoarthritis and metabolic syndrome. The results of this study showed that the HbA_{1c} was decreased in the exercise group, but the control group was not changed, reflecting the fasting blood glucose level and the 2–3 month average blood glucose control status in the metabolic syndrome indicator. The triglyceride was significantly decreased before and after treatment. On the other hand, there was no significant difference in obesity index, systolic and diastolic blood pressure, and HDL-C. Although not osteoarthritis patients, Kasprzak et al. (2014) reported that aquatic exercise is partially effective in altering the metabolic syndrome in obese middle-aged and elderly women. More future clinical studies are needed for the aquatic and metabolic syndrome indicators in patients with osteoarthritis later. In addition, it is necessary to examine various experimental variables such as dietary intake and stress, which affect the index of metabolic syndrome when applying aquatic exercise to osteoarthritis patients.

Osteoarthritis is a noninflammatory arthritis, but it is known that inflammation-related changes occur when cartilage destruction occurs (Myers et al., 1992). CRP reflects biological markers of inflammatory response, metabolic syndrome, and cardiovascular disease risk (Cesari et al., 2003; Ridker, 2001; Wilson et al., 2006). Exercise has been shown to have anti-inflammatory effects (Panagiotakos et al., 2005; Pedersen, 2006). The results of this study showed no significant difference in CRP. The CRP of osteoarthritis patients in this study is in the normal range. Therefore, it is considered that the change is not caused by the aquatic exercise. Pain, joint function limitation, and muscle weakness, which are the main symptoms of osteoarthritis, complicate restraint and discomfort in life, such as walking and stair climbing (Creamer et al., 2000). As a result, a decrease in physical activity lowers cardiorespiratory fitness and muscle function. Particularly low cardiorespiratory fitness increases the risk of cardiovascular disease (Carnethon et al., 2003). As a result of this study, VO_{2max}, an index of cardiorespiratory fitness, was increased but no significant difference was observed. On the other hand, in the exercise group, the extensor muscles of knee isokinetic muscular function were significantly increased, but the control group did not change. Wang et al. (2007) also found that aquatic exercise was effective in increasing strength in osteoarthritis patients. In this way, aquatic exercise can be effectively applied to increase the strength

of the knee joint while reducing the mechanical burden on the joints having a high weight. However, there was no difference in flexor muscles in this study. Baratta et al. (1988) reported that cooperative activity between the main and antagonistic muscles of the knee plays an essential role in maintaining joint stability and supporting ligaments. Hortobágyi et al. (2005) also suggest that it is important for patients with osteoarthritis to enhance the balance between quadriceps muscle strength and hamstring muscle strength. This suggests that additional programs are needed to improve the function of the flexor muscles as well as the extensor muscles of the knee during aquatic exercise.

Pain and stiffness in osteoarthritis patients are the main limiting factor in everyday life (Jakobsson and Hallberg, 2006). In this study, the osteoarthritis index (WOMAC index) was used to test the efficacy of aquatic exercise in osteoarthritis women. Osteoarthritis index is useful in clinical evaluation of pain, stiffness and physical function status in osteoarthritis patients. A meta-analysis of exercise programs and pain assessment tools in osteoarthritis patients showed that exercise was effective in pain relief (Lu et al., 2015). The results of this study also showed that the osteoarthritis index of the exercise group improved joint stiffness and physical function, but the control group remained unchanged. Previous studies have also shown that aquatic exercise in osteoarthritis patients is effective in improving osteoarthritis index (Foley et al., 2003; Lin et al., 2004; Silva et al., 2008). Because osteoarthritis dysfunction is related to weakness of the quadriceps muscle, improvement in muscle function is important (O'Reilly et al., 1998). Therefore, improvement of osteoarthritis index can be regarded as a result of reducing mechanical load on the knee joint due to extensor muscle strength enhancement shown in this study.

In conclusion, aquatic exercise can be regarded as an effective exercise program for the management of metabolic syndrome, improvement of muscle function, and improvement of osteoarthritis index in osteoarthritis women.

CONFLICT OF INTEREST

No potential conflict of interest to this article was reported.

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