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Comparison of Three Exercise Modalities on Patient Reported Symptoms of Knee Osteoarthritis: A Randomized Prospective Study

Matthew Silvis[1,2], Jillian Sylvester[3], Brittney Hacken[2]*, John Wawrzyniak[2], Robert Kelly[2], Scott Lynch[2], Timothy Mosher[2,4], Vernon Chinchilli[5] and Kevin Black[2]

[1]Department of Family and Community Medicine, Penn State Milton S. Hershey Medical Center, Hershey, PA, USA
[2]Department of Orthopedics and Rehabilitation, Penn State Milton S. Hershey Medical Center, Hershey, PA, USA
[3]NCC-Family Medicine Residency, Fort Belvoir Community Hospital, Fort Belvoir, VA, USA
[4]Department of Radiology, Penn State Milton S. Hershey Medical Center, Hershey, PA, USA
[5]Department of Public Health Sciences, Penn State Milton S. Hershey Medical Center, Hershey, PA, USA

Abstract

Objective: The ACSM recommends healthy adults aged 18-65 participate in 30 minutes of moderate-intensity exercise 5 times per week. The benefits of exercise in patients with osteoarthritis (OA) is known, but the best exercise modality to accomplish this is not. This study compared the effect of three exercise modalities on patient reported symptoms of knee OA.

Methods: 61 participants with radiographically evident, symptomatic bilateral OA were randomized into exercise modalities: upright cycle, land treadmill, or water treadmill. Participants completed an 8-week exercise program, progressing to achieve 30 minutes moderate exercise per session. WOMAC, KOOS, and SF-12 health surveys were completed at baseline and then weekly throughout the study.

Results: All groups improved in regard to WOMAC scores. No statistically significant difference was noted between groups. Using greater than 25% improvement in WOMAC as a threshold for significant change, 80% of the water treadmill group improved vs 60% upright cycle and 62% land treadmill. Study completion rates were highest for the water treadmill group (80%) compared to the land treadmill (62%) and upright cycle (65%), although not statistically significant (p=0.33).

Conclusion: An 8 week exercise program improved symptoms in participants with knee OA with no difference based on training device. Moderate aerobic exercise is beneficial for participants with knee OA.

Keywords: Aqua therapy; Water aerobics; Water treadmill; Land treadmill; Cycle

Introduction

Osteoarthritis (OA) is the most common joint disorder in the United States. The most common cause of disability in the United States [1], the overall prevalence of OA is estimated at 26.9 million adults greater than 25 years of age [2] and continues to increase [3]. One study estimated the lifetime risk of developing symptomatic knee OA to be 44.7%, increasing if one has a history of a knee injury (56.8%) or obesity (66%) [4]. Other studies estimate prevalence of radiographically apparent OA in adults over age 45 to be 19.2%-27.8% [5]. Knee pain alone led to 36 million ambulatory care visits in 2008 [3].

In addition to direct health care expenditures related to diagnosis and treatment, knee OA is an important confounding morbidity in many other chronic conditions such as cardiovascular disease, diabetes, and obesity. This is primarily driven by the limited ability to exercise secondary to pain and loss of function. The American College of Sports Medicine (ACSM) recommends healthy adults ages 18-65 participate in moderate-intensity aerobic physical activity for a minimum of 30 minutes/session, 5 days per week or vigorous-intensity aerobic physical activity for a minimum of 20 minutes/session 3 days per week in order to promote and maintain health [6,7]. The benefit of exercise in all individuals is well supported [8-10], including those with knee OA [11-15]. However, the best method of reaching current ACSM goals in patients with knee OA is not known. A Cochrane review on aquatic exercise provided gold level evidence that aquatic exercise likely reduces pain and increases function over 3 months; however, the review stated that more research was needed to understand which type of aquatic exercise, how often, and for how long might be beneficial [16].

The purpose of this study is to compare the effect of three exercise modalities (underwater treadmill, land treadmill, and upright cycling) on patient reported symptoms of knee OA while exercising at moderate intensity exercise for a goal of 30 minutes three times a week.

Methods and Study Design

Design

In this randomized, prospective study we evaluated the knee symptoms of a participant with knee OA when exercising at the current American College of Sports Medicine recommendations of 30 minutes of moderate intensity exercise during underwater treadmill walking, land based treadmill walking, and cycling.

***Corresponding author:** Brittney Hacken, MD, Departments of Orthopedics and Rehabilitation, Penn State Milton S. Hershey Medical Center, EC089, 30 Hope Drive, Hershey, PA 17033, USA, Tel: 717-531-8521; Fax: 717-531-0498; E-mail: bhacken@hmc.psu.edu

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Enrollment and randomization

Upon obtaining University Institutional Review Board (IRB) approval, participants were recruited via radio advertisements, newspaper ads, and fliers posted in local clinics. Participants were screened via telephone interview to meet eligibility criteria:

Inclusion criteria: Ages 30-70 and knee pain with radiographically confirmed knee OA.

Exclusion criteria: Medical conditions contraindicating moderate aerobic exercise (as determined through prescreening questions, i.e., heart condition, asthma, history of stroke), inability to exercise via treadmill or exercise cycle, contraindication to radiography, pregnancy, history of recent joint injection (steroid, hyaluronic acid, etc.) within 6 weeks of study, history of previous joint arthroplasty, history of inflammatory joint disease, and inability to sign informed consent.

After obtaining informed consent, participants underwent bilateral AP standing knee radiographs to confirm the presence and degree of knee OA. X-rays were graded using the Kellgren and Lawrence (K/L) scale for knee OA severity [17]. Subjects with K/L level ≥ 1 were enrolled.

Each eligible participant was then randomized and prospectively assigned into one of three exercise groups: underwater treadmill (Hydroworx 2000 series pool), land based treadmill (True CS 6.0 or Nautilus NTR 700), or upright exercise cycle (Schwinn Windsprint), by drawing a card, with their respective study arm named, out of a bucket.

Exercise sessions

Exercise sessions were completed three times weekly for 8 weeks. Exercise sessions were directly monitored by a member of the research team with licensed medical professionals in close proximity. Automated external defibrillators were present in the Department of Physical Therapy and ready for use if needed. Each participant participated in three monitored exercise sessions per week and completed between 10 to 40 minutes of exercise with a goal of achieving 30 minutes of moderate aerobic exercise. While recognizing the ACSM goal of 30 minutes moderate exercise per session 5 day/week, limiting exercise to 3 days per week was chosen to avoid increasing exercise in the study participants too quickly. The exercise progression is presented in Table 1. All participants participated in no more than routine activities only for the 8-week study period outside of the study protocol (no strength training, cardio training, etc.). Participants were compensated $100 for completion of this research. Participants who failed to complete the study were compensated in proportion to their duration of participation. Participants were progressed according to their symptoms and cardiovascular endurance.

Exercise intensity

The goal of the exercise progression was to achieve 30 minutes of moderate aerobic exercise by week 4 of the program. Participants progressively increased exercise time over the first 3 weeks; participants who were not inhibited by pain or increased symptoms reached a training level of up to 5 minutes of warm-up, 30 minutes of moderate aerobic exercise, and 5 minutes of cool down for a total of 40 minutes of exercise 3 times per week for the final 5 weeks of the program (Table 1).

Moderate aerobic exercise has been objectively defined as activity that generates energy expenditure of 3.0 to 6.0 Metabolic Equivalents (METs) [6]. In this study, moderate aerobic exercise was also defined by a participant's subjective Rate of Perceived Exertion (RPE) of 4-6 on a 10-point scale. For the purpose of this study, METs and RPE were used as guidelines to determine exercise intensity. A participant may have an RPE of 4-6 with METs outside the 3.0 to 6.0 range. Participants were permitted (vs. encouraged) to exercise to tolerance (RPE) even if MET intensity was outside the preferred range due to possible cardiovascular limitations or high exercise tolerance. From a conditioning standpoint, the goal was to have participants capable of exercising at a moderate aerobic exercise level (METs) by week 4 of the study through a gradual progression over the first 3 weeks. Modality-specific exercise instructions and measurements of associated Metabolic Equivalents (METs) were determined based upon previous studies and presented in Table 2 [18].

Participants in each group were asked whether or not they have unusual/persistent fatigue, increased weakness, stiffness, or excessive joint swelling/pain lasting for >24 hours after their previous exercise session. If a participant answered "yes" to any of these questions, they were not permitted to exercise that day [19]. If they were unable to exercise for 2 consecutive sessions, they were asked to see their primary care provider prior to continuing with the research study. Subjects were asked to discontinue exercise by the supervising health care provider during a session if they developed any type of musculoskeletal disorder that prohibited their ability to exercise. In addition, any symptoms of chest pain or excessive shortness of breath prompted discontinuation of exercise.

Data collection

Each participant completed three health status measurement

Session	Warm-Up	Training	Cool Down	Total Time	Time at Moderate Intensity
1	5 min	0 min	5 min	10 min	0 min
2	5 min	0 min	5 min	10 min	0 min
3	5 min	5 min	5 min	15 min	5 min
4	5 min	5 min	5 min	15 min	5 min
5	5 min	10 min	5 min	20 min	10 min
6	5 min	10 min	5 min	20 min	10 min
7	5 min	20 min	5 min	30 min	20 min
8	5 min	20 min	5 min	30 min	20 min
9	5 min	20 min	5 min	30 min	30 min
10-24	5 min	30 min	5 min	40 min	30 min

Table 1: Exercise Progression: Duration of time spent exercising per session. All participants exercised three days per week for a previously determined amount of time. Participants gradually increased exercise duration over first 3 weeks of study to achieve target METs (3-6) and RPE (4-6) in "Training" period of exercise session by Week 4 (Session 10).

Exercise Modality	Exercise Intensity Determinants
Exercise Cycle	Resistance set to level 1; METs calculated by computer and based upon participant's body weight and RPM. Subjects instructed to maintain RPM's within a determined range to maintain moderate exercise intensity.
Land Treadmill	Previous studies determined that walking on a level surface at 3.0 (MPH) equates to 3.3 METs and walking at 4.5 MPH generates 6.3 METs. Participants walked at a pace of 3.0 to 4.5 MPH on a treadmill with zero incline. Participants were instructed to walk at a pace that neither caused pain nor increased symptoms even if below target METs range. METs and speed were recorded.
Water Treadmill	Previous studies determined water aerobics /calisthenics equates to 4.0 METs and aqua jogging is 8.0 METs. Participants in this study walked at a below-jogging pace on the underwater treadmill. Treadmill depth was set so water level met participant's mid-chest.

Table 2: Exercise progression per modality. Methods for completing exercise sessions for each modality. Baseline METs criteria for exercise modalities based upon previous studies [7,18].

questionnaires: the Western Ontario and McMaster Universities (WOMAC) Index of Osteoarthritis, the Knee Osteoarthritis Outcome Score (KOOS), and the SF12 Health Survey based on their more symptomatic knee. Questionnaires were completed at the time of randomization and then weekly. Reviewers and the statistician were blinded to subject group assignment. An intention to treat paradigm was utilized. Descriptive statistics were constructed for changes in the WOMAC and KOOS subscales in the form of means and standard deviations. The three groups were compared via a one-way analysis of variance (ANOVA). Pairwise comparisons of the three groups were performed via the ANOVA standard error and a Bonferroni correction to the significance level (0.05/3=0.01667).

Results

Demographics and participation

Seventy-four adults ages 30 to 70 were recruited over 9 months to participate in this study. Six were deemed ineligible, as their radiographs did not demonstrate OA. Seven subsequently withdrew prior to initiating exercise. Sixty-one participants initiated the exercise program, randomized into one of three exercise modalities (Figure 1). The basic demographics of these cohorts are presented in Table 3. Of these 61 participants, 60 (98%) demonstrated OA in their knees bilaterally, with an average K/L score of 2.17. Ultimately, 42 participants (70%) completed the 8-week program. Study completion was highest for the water treadmill cohort (80%) as compared to the land treadmill (62%) and upright cycle (65%) cohorts, though this difference was not statistically significant (p=0.33). No adverse events occurred during the exercise sessions (Table 4).

One individual in the land treadmill cohort withdrew due to severe gastroenteritis and was subsequently re-enrolled from the start of the exercise progression, bringing their cohort total to 21 participants. Causes of program withdrawal by exercise modality are detailed in Table 4. Participant withdrawal due to pain did not correlate with K/L scores. Enrolled participants based their survey responses on the more symptomatic knee at baseline and no participant in this study reported increasing pain in the opposite knee during this study.

Outcome measures

All participants were encouraged to exercise at a "moderate" level, defined as 3.0-6.0 METs and a subjective Rate of Perceived Exertion (RPE) of 4-6, deferring to RPE if both ratings could not be simultaneously satisfied. Overall, all participants exercised to a moderate level as defined by RPE; however, 4 participants (3 cycle, 1 land treadmill) failed to reach a moderate exercise level as defined by METs. Similarly, 5 individuals (2 cycle, 3 water treadmill) exercised above a standard METs level in order to reach a moderate level on RPE.

In comparing weekly survey results, all cohorts demonstrated an improvement in WOMAC scores; however, there was no statistically

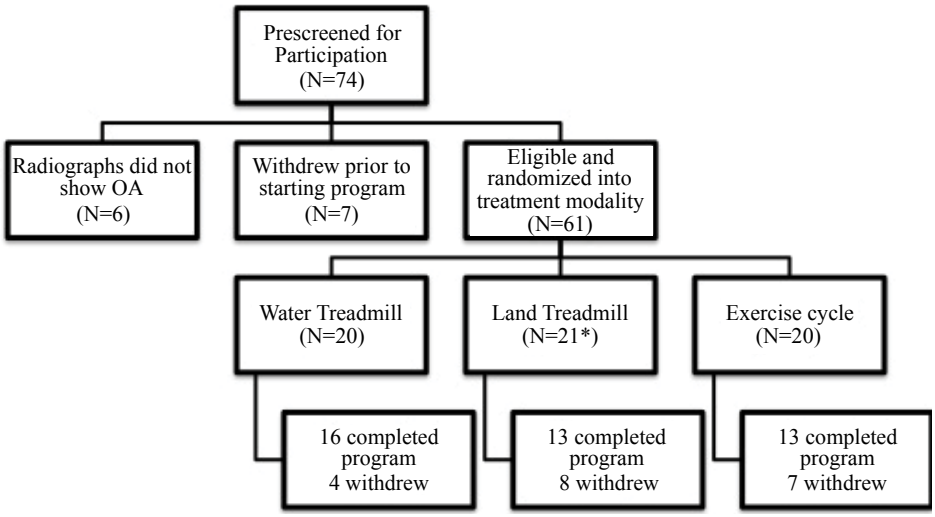

Figure 1: Participant flow study diagram. Flow of participants from pre-screening and study enrollment through completion of the study.

	Land Treadmill (n=21)	Water Treadmill (n=20)	Exercise Cycle (n=20)
Average Age at Enrollment (years)	58.1	59.0	57.6
Male	8	4	11
Female	13	16	9
Average BMI	31.5	32.7	30.8
K/L 0	0	1	0
K/L 1	12	8	10
K/L 2	16	11	15
K/L 3	10	14	14
K/L 4	4	4	1
Average K/L score	2.25	2.10	2.15
Number withdrawn from program	8	4	7

Table 3: Baseline participant demographics by exercise cohort.

Exercise Modality	Percent Completion	Reasons for withdrawal
Land Treadmill	62%	• 3 increased knee pain • 1 increased leg pain • 2 sustained falls at home • 1 migraines • 1 contracted gastroenteritis, restarted program
Upright Cycle	65%	• 1 increased knee pain • 1 increased hip pain • 1 increased back pain • 2 opted for alternative treatment methods (surgery and joint injection) • 2 lost to follow-up
Water Treadmill	80%	• 4 increased knee pain

Table 4: Causes of study withdrawal: Participant-provided reasons for study withdrawal.

	WOMAC				KOOS		
	Baseline	Change in Score	P-Value	95% CI	Estimate	P-Value	95% CI
Water Treadmill	74.8	-46.36	**<0.0001**	-65.32, -27.39	-13.05	**<0.0001**	-18.98, -7.11
Land Treadmill	60.2	-31.21	**0.002**	-50.66, -11.74	-7.26	0.03	-13.60, -0.92
Upright Cycle	71.9	-30.28	**0.004**	-50.37, -10.20	-9.71	**0.004**	-16.13, -3.28
WT vs LT		-15.16	0.27	-42.32, 12.01	-5.79	0.19	-14.47, 2.90
WT vs Cycle		-16.07	0.25	-43.69, 11.55	-3.34	0.45	-12.09, 5.41
LT vs Cycle		-0.92	0.95	-28.88, 27.05	2.45	0.54	-6.58, 11.47

Table 5: KOOS and WOMAC survey results: Statistically significant P-values presented in bold. WT=Water Treadmill, LT=Land Treadmill.

significant difference noted between exercise groups. Baseline WOMAC and change in score (95% confidence interval) at completion of the exercise program was 74.8 and -46.4 (-65.3, -27.4) for the water treadmill; 60.2 and -31.2 (-50.7, -11.7) for the land treadmill; 71.9 and -30.3 (-50.4, -10.2) for the upright cycle (Table 5). Using greater than 25% improvement in WOMAC as a threshold for clinically significant change, 80% of the water treadmill group improved by the conclusion of their participation in the study (either at point of drop-out or at study completion), compared with 60% cycle and 62% land treadmill.

Likewise, an improvement in KOOS scores was observed over baseline for each exercise modality, but none exhibited statistically significant improvement in comparison to other modalities. Change from baseline KOOS score (95% confidence interval) at the completion of the study was -13.05 (-18.98, -7.11) for the water treadmill, -7.26 (-13.60, -0.92) for the land treadmill, and -9.71 (-16.13, -3.28) for the upright cycle (Table 5). Neither physical nor mental component summary scales demonstrated statistical significance between baseline and end of study values (Table 6).

Discussion

This study showed that an 8-week exercise program improved symptoms in participants with knee OA. Mean changes in KOOS scores were -13.05, -7.26, and -9.71 for the water treadmill, land treadmill, and upright cycle respectively, indicative of improvements in OA symptoms, pain, stiffness, and daily functionality. These results are consistent with other studies [16,20], which found that exercise is beneficial in alleviating symptoms of osteoarthritis. However, there was no statistically discernable difference noted based on training device

Though other studies have compared aquatic- versus land-based exercise for patients with knee OA, this study differed from those studies both in types of exercises performed and in outcomes measured. In one study [21], participants performed both resistance and aerobic exercises either in a pool or on land, and researchers evaluated the changes in knee range of motion, thigh girth, subjective pain, and time for a 1-mile walk. Another study evaluated the effects of land- and aquatic-based walking on gait kinematics and overall pain levels with movement [22]. Lastly, a third study studied cohorts of land- and water-based participants who participated in 60-minute group exercise sessions that focused on both resistance and aerobic methods of full-body conditioning over a 12-week period. Researchers primarily evaluated changes in pain levels in these two groups, as well as changes in activities of daily life, knee range of motion, and ability to perform the six-minute walk test [23]. The results of these studies were mixed; two studies found that subjective pain levels were lower in aquatic exercise groups when compared with land cohorts, while one showed no significant difference between land and aquatic groups. Both studies that demonstrated a documented difference in subjective pain scales utilized a continuous visual analog scale, while the one that did not show a statistically significant change utilized the KOOS score. None of these studies investigated the relative benefit of the exercise cycle in comparison to the water- and land-based treadmill.

Our study evaluated individuals as they participated in moderate aerobic exercise as recommended by ACSM guidelines, comparing the outcomes between land-based treadmill walking, water-based treadmill walking, and cycling. Evaluation was based on outcomes measurements involving exercise ability, effects upon markers such as pain, stiffness, and functions of daily living, and participants' ability to sustain an exercise regimen for 8 weeks.

Study limitations

This study had several limitations. First, there was no control group to with which to compare the effects. Participants' improvement was compared against their baseline survey findings, but may have been more markedly differentiated when compared to a non-exercising control group. Additionally, the conclusion that these three separate means of exercise were not statistically different may be Beta (Type II) error. Conversely, this conclusion may be accurate with no statistically significant difference. Increasing the sample size and the duration of the study may aid in the differentiation of the exercise modality and therefore yield a more statistically significant result. The study had a sizable dropout rate (30%). This group was not found to be statistically different from those who completed the 8-week program in terms of gender, BMI, and K/L score. While this attenuation rate may speak to the difficulty in encouraging individuals with OA to commit to regular exercise, it may have impacted the ability of this study to

	SF-12 PCS				SF-12 MCS			
	Estimate	**Std Error**	**P-Value**	**95% CI**	**Estimate**	**Std Error**	**P-Value**	**95% CI**
Water Treadmill	3.40	1.77	0.06	-0.14, 6.93	1.66	1.74	0.34	-1.84, 5.15
Land Treadmill	0.57	1.83	0.75	-3.08, 4.22	5.48	1.77	**0.003**	1.94, 9.03
Upright Cycle	2.35	1.89	0.22	-1.43, 6.13	3.04	1.83	0.10	-0.62, 6.69
WT vs LT	-2.82	2.54	0.27	-2.26, 7.90	-3.82	2.49	0.13	-8.79, 1.15
WT vs Cycle	1.05	2.59	0.40	-4.13, 6.22	-1.37	2.53	0.59	-6.42, 3.68
LT vs Cycle	-1.77	2.63	0.50	-7.03, 3.48	2.45	2.55	0.34	-2.65, 7.54

Table 6: SF-12 results PCS=Physical composite score MCS=Mental composite score.

reach statistical significance among exercise modalities. Lastly, each subject participated in three monitored exercise sessions per week and completed between 10 to 40 minutes of exercise with a goal of achieving 30 minutes of moderate aerobic exercise. While recognizing the ACSM goal of 30 minutes moderate exercise per session 5 days/week, limiting exercise to 3 days per week was chosen to avoid increasing exercise in the study participants too quickly. Further progression towards the ACSM goal of 5 days per week should be considered for future study, although advancement of exercise is known to be highly variable across individuals [6].

Conclusion

Though it cannot be "cured", the symptoms of OA can be effectively managed by regular moderate exercise, regardless of modality. Regardless of type, performance of 30 minutes of moderate exercise three times weekly is beneficial in the management of knee OA. However, it may be difficult to encourage individuals with OA to continue regular exercise to the point of noticeable benefit. Medical practitioners should encourage their patients with OA to reach these exercise goals set forth by the ACSM by whatever means they are able to sustain exercise.

Financial Disclosure/Conflict of Interest Statement

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IRB Statement

Institutional Review Board at Penn State Hershey Medical Center approved the study protocol.

Public Trials Registry

Trial was registered at Clinicaltrials.gov, study number NCT01359124.

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