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ABSTRACT

Background and purpose: One of the main risk factors for knee osteoarthritis is overweight. The purpose of this study is to determine the effectiveness of yoga exercise in reducing the risk of knee osteoarthritis and fibulin-3 levels in overweight populations.

Methods: This study was a randomized controlled trial involving 24 participants who met the inclusion and exclusion criteria. Participants were randomly divided into two groups: group one was given yoga exercise intervention and group two was given neuromuscular coordination exercise as the control group. Risk of knee osteoarthritis measurements were carried out using The Western Ontario and McMaster University Osteoarthritis Index (WOMAC). Fibulin-3 measurement used ELISA technique using human fibulin-3 kit, FBLN3 BT-LABkit 96T E4667Hu.

Results: Participants of both groups were comparable, except for age where the control group is slightly older. Pre and post-test comparison showed improvement in pain, stiffness, physical function, total WOMAC score, and fibulin-3 levels in both groups. While, the post-test comparison between the two groups showed that yoga group has better scores on all indicators compared to the control groups which was statistically significant ($p \leq 0.001$).

Conclusion: Both interventions are effective in reducing the risk of knee osteoarthritis and fibulin-3 levels, but yoga showed better result. We recommend yoga training to reduce the risk of knee osteoarthritis compared to conventional training. Future research is needed to measure other knee osteoarthritis biomarkers that describe the pathological process of knee osteoarthritis.

Keywords: Yoga, fibulin-3, knee osteoarthritis, neuromuscular coordination

INTRODUCTION

Knee osteoarthritis is a degenerative joint disease which is becoming an increasing concern with the aging population.¹ Based on WHO data, the prevalence of osteoarthritis in the world is 9.6% in men and 18% in women aged over 60 years. In Indonesia, the prevalence of knee osteoarthritis remains high, namely 15.5% in men and 12.7% in women out of the total population in Indonesia, amounting to 255 million people. Osteoarthritis is one of the ten diseases that cause disability in developing countries and has other health impacts as well as socio-economic impacts.²

One of the main risk factors for knee osteoarthritis is obesity.³ Obesity and osteoarthritis are two inter-related health problems that affect most of the world's adult population. Excessive mechanical load on joints due to excess body weight and activation of various metabolic factors that play a role in joint tissue damage are mechanisms underlying how obesity can increase the risk of knee osteoarthritis.³ A cohort study states that individuals who are obese have a 1.5 to 2 times greater risk of developing knee osteoarthritis. An increase of 5 kg/m² in body mass index increases the risk of knee osteoarthritis by 32%.¹

One of the factors that play a role in increasing the progression of knee osteoarthritis is muscle weakness.⁴ People who are obese tend to have lower muscle strength compared to those with normal weight. The relative muscle weakness that occurs in obese people is due to reduced mobility, neural adaptations and changes in muscle morphology.⁵ The onset, progression and severity of knee osteoarthritis are associated with decreased muscle strength. Decreased muscle strength and changes in the pattern of muscle activation greatly affect joint kinematics during movement. Changes in joint kinematics that occur chronically cause degenerative changes in joint cartilage causing osteoarthritis.⁶

Leg muscle weakness contributes in the initiation and development of knee osteoarthritis, so physical exercise is needed to increase leg muscle strength to prevent knee osteoarthritis. One of the main muscles that play a role in the stability of the knee joint is the quadriceps muscle. Weakness of the quadriceps muscles can increase the risk of developing knee osteoarthritis. Weakness of the quadriceps causes poor neuromuscular control which can lead to pathological joint movement. Sensorimotor disturbances of the quadriceps muscles can lead to degeneration of joint structures such as the meniscus, ligaments, cartilage and bone.⁷ Neuromuscular exercise is a conventional exercise that has been shown to reduce the risk of knee osteoarthritis in the obese population. Neuromuscular exercise improves sensorimotor control and helps achieve compensatory functional stability.⁸

Yoga exercise is also a physical exercise that has been proven to prevent knee osteoarthritis. Yoga exercise can reduce the load on the knee joint on the frontal plane. It can minimize the knee joint exposure to adduction movements (knee adduction moment) so that it can strengthen the knee joint.⁹ The effectiveness of yoga exercise in reducing the risk of knee osteoarthritis was associated with knee adduction moment (KAM). KAM describes the magnitude of the medial lateral distribution of the load across the tibial plateau. KAM during walking correlates with the process of cartilage degradation among people with knee osteoarthritis. KAM peaks can be minimized by increasing muscle strength around the knee. Yoga exercise can minimize KAM peaks, because yoga exercise can maximize quadricep muscle activation. EMG analysis of yoga exercise which focuses on lower extremity exercise shows an isometric contraction of 7.3% to 31% of maximum muscle contraction, this shows that the muscle contractions that occur during yoga exercise can be a stimulus that can improve muscle strength around the knee.¹⁰

To prevent the occurrence of osteoarthritis of the knee, objective early detection is needed which describes the initiation of degeneration in the knee joint. Fibulin-3 protein is a biomarker that can monitor early changes in subchondral metabolism, hence it can be used as a biomarker in early detection and monitoring the progression of knee osteoarthritis. The fibulin-3 is found in the urine and is increased in the serum of patients with osteoarthritis. Basal concentrations of the fibulin-3 epitope are associated with the incidence of radiologically and clinically diagnosed knee osteoarthritis in overweight and obese middle-aged women.¹¹ Effective prevention method is urgently needed to provide optimal results in preventing knee osteoarthritis in the overweight population, so this study aims to determine the differences in the effectiveness of yoga exercise with conventional exercise in reducing the risk of knee osteoarthritis and fibulin-3 levels.

METHOD

Study design and Setting

This was an experimental study with the pre-test and post-test control group design, conducted in Denpasar City, Bali Province, Indonesia from September to December 2022.

Population, sample, and source of data

The reachable population in this study are people registered in *banjar* (hamlet) in Denpasar. The research sample selection was started with randomization of 2 of 4 sub-districts in Denpasar (West Denpasar and East Denpasar were selected), followed by selection of one village in each sub-district (Padangsambian Kelod Village and Sumerta Kelod Village). Then, one *banjar* was selected in each village (Banjar Tegal Buah and Banjar Sebudi). We randomly selected potential respondents from the list of names available in Banjar. The participants of this study were adult population with eligibility criteria: age 30-50 years; BMI 23-29.9 kg/m² (based on Asia Pacific criteria); willing to participate in the research; able to follow exercise and carry out according to instructions; and were not pregnant. The exclusion criteria were those with a history of injuries to the upper or lower extremities, heart disease, with physical disabilities, and participating in other physical exercise programs. Participants were dropped out of the study if they did not attend exercise more than 3 times, withdrew or suffered an injury.

The number of individuals assessed for eligibility was 39 people, 9 were excluded because they refused to join and participate in the study. Then, 30 participants were randomized into two arms, the yoga group and control group with permuted block randomization. The block size was not stated in the protocol, so the investigators were blinded. Participants allocated to yoga group (n=13) and control group (n=17). There were 6 participants who discontinued intervention because they were withdrew from the study. The number of final participants in the yoga group was 13 while the control group was 11 people. An explanation of the procedures and benefits of the study was conducted to all participants before the study commenced. Participants' agreement was provided by signing an informed consent.

Yoga exercise in this study was Suryanamaskar which consisted of 12 postures prayer pose, raised arms pose, standing forward bend, equestrian pose, mountain pose, salute with eight parts pose, cobra pose, mountain pose, equestrian pose, standing forward bend pose, raised arms pose, and prayer pose. All postures performed rhythmically with controlled breathing in one round without any pause in between. Suryanamaskar is yoga

exercise that is identical to moderate intensity aerobic exercise because it reaches 80% VO2 max.

Data collection techniques and instruments

The guidelines used for body mass index (BMI) classification is BMI criteria of Asia Pacific. Weight measurements were carried out using digital body weight scale by Omron. Height measurements were carried out using stature meter by One Med. Fibulin-3 examination was carried out before and after treatment. Fibulin-3 measurement was using ELISA technique with human fibulin-3 96T ELISA kit ® (FBLN3 BT-LAB kit, catalog no E4667Hu). Risk of knee osteoarthritis were measured using The Western Ontario and McMasters University Osteoarthritis Index (WOMAC). WOMAC score was interpreted as higher scores indicated worse pain, stiffness, and functional limitations. The WOMAC measures five items for pain (score range 0–20), two for stiffness (score range 0–8), and 17 for functional limitation (score range 0–68).

Training was carried out 2 times a week for 12 weeks. Blood samples were taken at the beginning, which was one day before training started (pre-test) and at the end, which was one day after the last training in the twelfth week of training. Blood sampling was taken twice, the day before yoga and conventional exercise (pre-test) begins and the day after (post-test). Venous blood that had been taken using a syringe was left standing for 1-2 hours, so that serum/plasma and other blood components was separated. After 1-2 hours, a new 300 rpm centrifuge was carried out for 10 minutes. Seen and observed formed supernatant (serum/plasma) were separated from other blood components. The supernatant was put in a 1.5 ml microcentrifuge tube and stored in the freezer -20/-80°C. Preparation of reagents, samples, standard solutions and assay procedures had been carried out according to standard fibulin-3 measurement procedures.

Fibulin-3 levels was measured using the ELISA technique with human fibulin-3 96T ELISA kit ® (FBLN3 BT-LAB kit, catalog no E4667Hu). Risk of knee osteoarthritis measurement were conducted using The Western Ontario and McMasters University Osteoarthritis Index (WOMAC).

Data analysis

The collected data were processed using the SPSS version 25. Descriptive analysis was performed, normality test was carried out using the Saphiro Wilk test, and homogeneity test was carried out using Levene's test. Paired test using the Wilcoxon Sign Rank test on several parameters before and after the intervention in both groups with $p < 0.05$ indicating statistical significance. The difference test between groups using the Mann Whitney U test with $p < 0.05$ indicating statistical significance.

The research has been approved by the research ethics commission of the Faculty of Medicine, Udayana University with Grant number 363/UN14/HK/2022, dated September 27, 2022.

RESULT

Table 1 shows the comparison of the two intervention groups' characteristics before the intervention. For all variables, both groups are comparable except for the age, the control group was slightly older on average at 36.91 years than the yoga group at 32.64 years.

Table 1. Characteristics of participants

Characteristics	Yoga Group	Control Group	p
Age (years), mean $\pm$ SD	32.64 $\pm$ 4.90	36.91 $\pm$ 3.61	0.029
BMI (kg/m ²), mean $\pm$ SD	29.47 $\pm$ 1.47	30.57 $\pm$ 2.19	0.192
Pre-test pain, mean $\pm$ SD	15.64 $\pm$ 1.50	16.45 $\pm$ 0.688	0.265
Pre-test stiffness, mean $\pm$ SD	7.00 $\pm$ 0.894	7.27 $\pm$ 0.647	0.597
Pre-test physical function, mean $\pm$ SD	32.36 $\pm$ 1.56	32.73 $\pm$ 1.19	0.569
Pre-test total WOMAC score, mean $\pm$ SD	55.00 $\pm$ 1.89	56.45 $\pm$ 1.86	0.120
Pre-test fibulin-3 (ng/mL), mean $\pm$ SD	13.17 $\pm$ 1.96	13.22 $\pm$ 7.17	0.957

Table 2 shows the comparison of the WOMAC scores and level of fibulin-3 pre and post intervention for the yoga and control group. Both the yoga and control groups show significant reduction in the pain score, stiffness score and physical function score. Similarly for the total WOMAC scores which reduced by 20 points for yoga groups ($p < 0.001$) and by around 10 points for the control group ($p < 0.001$). While for the fibulin-3 level, it was improved by almost 4 units for the yoga group and there was a decrease of almost 3 units for the control group.

Table 2. Comparison of pre and post intervention of WOMAC scores and fibulin-3 levels

Variable	Pre-Test		Post-Test		p
	Mean	95%CI	Mean	95%CI	
Pain score					
Yoga Group	15.64	14.63-16.65	7.82	7.09-8.54	<0.001
Control Group	16.45	15.99-16.92	11.00	9.96-12.04	0.003
Stiffness score					
Yoga Group	7.00	6.40-7.60	4.36	3.82-4.91	<0.001
Control Group	7.27	6.84-7.71	5.55	5.08-6.01	0.004
Physical function Score					
Yoga Group	32.36	31.31-33.42	22.09	19.59-24.59	<0.001
Control Group	32.73	31.93-33.53	29.55	28.58-30.51	0.003
Total WOMAC score					
Yoga Group	55.00	53.73-56.27	34.27	31.34-37.20	<0.001
Control Group	56.45	55.20-57.71	46.09	44.80-47.38	<0.001
Fibulin-3					
Yoga Group	13.17	11.83-14.50	17.12	16.42-17.81	<0.001
Control Group	13.22	12.74-13.71	10.94	10.23-11.65	<0.001

The post-test comparison of both intervention shows that participants from the yoga group has better scores for all indicators compared to the control group. The pain score, stiffness score, physical score and total WOMAC scores were significantly lower than the control group ($p < 0.001$), while the fibulin-3 score is significantly higher in the yoga group compared to the control group.

Table 3. Comparison of post-test pain score, stiffness score, physical function score, total WOMAC score, fibulin-3 levels

Variable	Yoga Group		Control Group		p
	Mean	95%CI	Mean	95%CI	
Pain score					
Post Test	7.82	7.09-8.54	11.00	9.96-12.04	<0.001
Stiffness score					
Post Test	4.36	3.82-4.91	5.55	5.08-6.01	0.001
Physical function score					
Post Test	22.09	19.59-24.59	29.55	28.58-30.51	<0.001
Total WOMAC score					
Post Test	34.27	31.34-37.20	46.09	44.80-47.38	<0.001
Fibulin-3					
Post Test	17.12	16.42-17.81	13.22	12.74-13.71	<0.001

DISCUSSION

Knee osteoarthritis is increasingly occurred and is preventable by routine exercise. Our study found that both yoga and conventional exercise were effective in improving the indicators for knee osteoarthritis, where yoga showed a significantly better results.

Respondents of our study are classified as young adults, which is an age group that is very appropriate for interventions to prevent knee osteoarthritis. One study concluded that the prevalence of symptomatic knee osteoarthritis recently occurred earlier, namely younger age groups so that earlier detection and prevention interventions are needed in younger age groups, namely the middle age group.¹²

Respondents' BMI ranged from 29 kg/m² to 30 kg/m² which based on the Asia Pacific BMI category was classified as obese. Obesity is one of the main risk factors for knee osteoarthritis. Excessive mechanical load on joints due to excess body weight and activation of various metabolic factors that play a role in joint tissue damage are the mechanisms underlying how obesity can increase the risk of knee osteoarthritis.³ The degree of obesity is a factor that is directly related to the functional and clinical conditions of knee osteoarthritis. A meta-analysis study showed that a 5-unit increase in body mass index was associated with a 35% increased risk of knee osteoarthritis. Body mass index is positively associated with an increased risk of knee osteoarthritis which is clarified by radiographic examination and/or clinical diagnosis.¹³

Yoga exercise and conventional exercise, were effective in reducing fibulin-3 levels. Both interventions could prevent further degradation of joint structures so as to prevent further damage of joints in the obese population. One of the underlying mechanisms is that the two interventions in this study can increase the strength of the quadriceps muscles. The quadriceps muscle is the main muscle that plays a role in the functional stability of the knee joint and loading on the knee joint. Weak quadriceps muscles can lead to an inability to maintain translational control of the tibia during movement, thereby increasing the risk of damage to the joint structure. Disturbances in the quadricep muscles can cause excessive loading on the knee and cause physical stress on the knee joint, so that by increasing the strength of the quadricep muscle it can reduce the load on the knee joint and the process of tissue degradation can be minimized.⁷

Yoga exercise can increase the strength of the quadriceps muscles. A study reports that yoga exercise combined with aerobic exercise is effective in increasing peripheral muscle strength, one of which is the

quadriceps muscle.¹⁴ Another study also proved the effectiveness of yoga exercise in increasing quadricep muscle strength in populations with knee osteoarthritis, where the increase in quadricep muscle strength after yoga exercise ranged from 2% to 21%.¹⁵

Neuromuscular exercise is proven to increase quadriceps muscle strength. Neuromuscular exercise trains functional weight bearing positions so as to improve the quality and efficiency of movement as well as the alignment of the body and joints in the lower extremities. Neuromuscular exercise can increase the activation of various muscle groups that can produce an internal moment to counteract the external knee adduction moment during functional weight-bearing movements. Some of the muscle groups that activated are the hip adductor, tensor fascia lata, lateral hamstring, quadricep and lateral gastrocnemius.¹⁶

Neuromuscular exercise can affect the functional performance of the knee joint, knee biomechanics, and patterns of activation of the muscles around the knee joint so that neuromuscular exercise is often used in rehabilitation of knee joint disorders such as injuries.¹⁷

The results of the independent test also showed a significant difference between the yoga group and the conventional exercise group, meaning that yoga exercise was more effective than conventional exercise in reducing fibulin-3 levels. The mechanism underlying these results is that yoga exercise not only increase the quadriceps muscles, but it involves exercise isometric contractions of the lower extremities and hips combined with stretching.

A study with modified yoga movements focused on strengthening the lower extremity muscles, one of which is the quadriceps using the principles of squats and lunges. Exercise modification through various yoga postures that require changes in the range of motion of the knees and the ability to support body weight. During the cool down, stretches that focus on the hip, knee and ankle muscles in the supine position. To balance the strengthening of the quadriceps muscles, exercise is also combined with supine bridges and heel raises which increase the strength of the hamstring and plantar flexor muscles.¹⁰

We recommend yoga training to reduce the risk of knee osteoarthritis compared to conventional training, because yoga training not only trains muscle strength, it is also combined with stretching training and increasing range of motion. Each pose in yoga training is accompanied by breathing control which can improve blood flow in the contracted muscle area. Yoga movements that are done slowly with concentration on the movement being done can train the proprioceptive stimulation of the movement system.¹⁰ Future research is needed to measure other knee osteoarthritis biomarkers that describe the pathological process of knee osteoarthritis.

The limitation of this study was we could not control the respondents' daily physical activity which could affect muscle strength, flexibility and proprioceptive stimulation in movements carried out in daily activities.

CONCLUSION

Yoga exercise in this study, namely Suryanamaskar, was more effective than neuromuscular coordination exercise in reducing the risk of knee osteoarthritis and fibulin-3 levels among overweight population. This difference in effectiveness occurs through a mechanism that we concluded through various literature because yoga exercise can maximize quadricep muscle activation so that it can improve quadricep muscle strength. We recommend yoga training to reduce the risk of knee osteoarthritis compared to conventional training. Future research is needed to measure other knee osteoarthritis biomarkers that describe the pathological process of knee osteoarthritis and researchers should be able to control respondents' daily physical activity.

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AUTHOR CONTRIBUTION

NW: concepts, literature search, experimental studies, data acquisition, data analysis, statistical analysis, manuscript preparation; IPGA: concept, manuscript review; GV: literature search, clinical studies, experimental studies, manuscript preparation, manuscript editing; ANM: data acquisition, data analysis, statistical analysis.

CONFLICT OF INTEREST

The author reports no conflicts of interest in this work.

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