ORIGINAL ARTICLE

Effectiveness of Adding Lower Extremity Isotonic Exercise on Hamstring Flexibility for Hajj Pilgrims Who Received Walking Aerobic Exercise

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ABSTRACT

Introduction: Hajj is a pilgrimage that is primarily undertaken by walking. The hamstring muscles play an important role in walking activities. They often experience shortening (tightness), so exercises should be performed to increase their flexibility. The goal of this study was to investigate the effect of adding lower extremity isotonic exercise on hamstring flexibility in Hajj pilgrims who perform walking aerobic exercise.

Method: We performed a randomised controlled trial with a total of 36 individuals divided equally into the control and treatment groups. Both groups received walking aerobic exercises five times a week; the treatment group also received lower extremity isotonic exercise twice a week. We used the sit-and-reach test to assess hamstring flexibility both before and after the 6-week treatment programme.

Results: After 6 weeks, there was a significant increase in hamstring flexibility in both the treatment group ($p = 0.0000$) and the control group ($p = 0.0001$). The treatment group showed a significantly greater improvement in hamstring flexibility (5.39 ± 3.47) compared with the control group (2.17 ± 1.79; $p = 0.001$).

Conclusion: Adding lower extremity isotonic exercise could significantly increase hamstring flexibility higher than aerobic walking exercise alone in Hajj pilgrims.

Keywords: Hajj pilgrims, hamstring flexibility, aerobic walking exercise, lower extremity isotonic exercise

ABSTRAK

Pendahuluan: Haji merupakan ibadah yang sebagian besar dilakukan dengan berjalan kaki. Otot hamstring memainkan peran penting dalam aktivitas berjalan. Otot ini sering mengalami pemendekan, sehingga latihan diperlukan untuk meningkatkan fleksibilitas. Tujuan penelitian ini adalah untuk mengetahui efektivitas penambahan latihan isotonik ekstremitas bawah terhadap fleksibilitas hamstring calon jemaah haji yang mendapat latihan aerobik berjalan.

Metode: Kami menggunakan uji coba acak terkontrol dengan total 36 peserta yang dibagi secara merata ke dalam kelompok kontrol dan perlakuan. Kedua kelompok mendapat latihan aerobik berjalan sebanyak lima kali dalam satu minggu dan kelompok perlakuan mendapat penambahan latihan isotonik ekstremitas bawah dua kali dalam satu minggu. Kami menggunakan sit and reach test untuk menilai fleksibilitas hamstring sebelum dan sesudah enam minggu perlakuan.

Hasil: Fleksibilitas hamstring meningkat secara signifikan pada kedua kelompok dengan p=0,0000 untuk kelompok perlakuan dan (p=0,0001) untuk kelompok perlakuan setelah enam minggu. Peningkatan fleksibilitas hamstring pada kelompok perlakuan (5,39 ± 3,47) lebih tinggi secara signifikan dibandingkan kelompok kontrol (2,17 ± 1,79) (p=0,001).

Kesimpulan: Penambahan latihan isotonik ekstremitas bawah secara signifikan dapat meningkatkan fleksibilitas hamstring lebih tinggi dibandingkan latihan aerobic berjalan saja pada calon jemaah haji.

Kata kunci: calon jemaah haji, fleksibilitas hamstring, latihan aerobik berjalan, latihan isotonik ekstremitas bawah.

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INTRODUCTION

There are five pillars of Islam. It is mandatory for all Muslims who meet the requirements to perform the fifth pillar, the Hajj, at least once in their lifetime. The requirements for Hajj are maturity; sanity; independence; and istithaah (capacity), namely physical condition (health), assets, and security.[1] The health condition is critical because the Hajj pilgrimage is very physical. Hajj pilgrims must fulfil this requirement so that they can carry out the series of Hajj activities effectively and smoothly.[2] Most of the physical activities in Hajj involve walking, including tawaf, sa'í, and throwing jumroh. In addition to these activities, Hajj pilgrims require good walking skills for daily tasks, such as traveling to and from their

accommodation to the mosque. Hajj pilgrims have to walk a minimum of 12 km to carry out these activities.[3,4,5]

The hamstrings are muscles that play an important role in various human activities such as walking, running, ascending and descending stairs, and also transitioning from sitting to standing. They are also needed in knee flexion, hip extension, and external and internal rotation during the walking phase.[6] The ability of muscles to stretch or extend to their maximum extent, allowing the body to move through its full range of motion, is known as flexibility. Flexibility is an important factor for carrying out daily activities.[7] The benefits of hamstring flexibility for Hajj pilgrims are increased physical fitness; a reduction in the chance of injuries to the muscles and joints; and improved balance, coordination, speed, agility, and effectiveness and efficiency of power or energy. Adequate hamstring flexibility allows Hajj pilgrims to move more freely and comfortably so that they can walk for long distances, perform rituals, and navigate crowded areas during the physically demanding Hajj pilgrimage. Hamstring flexibility can be measured using the sit and reach test.[8]

According to the American College of Sports Medicine (ACSM), exercises that contribute to cardiovascular endurance are rhythmic, involve large muscle groups, and are sustained. Resistance training is performed to improve cardiovascular health and can increase muscle strength, improve balance and mobility, depending on the type and intensity.[9] Isotonic training could increase strength and power production at the speed used in these exercises. Isotonic exercises are standard in sports programmes, but with varying loads and speeds. This exercise consists of both concentric and eccentric contractions. It can affect the hamstrings, enabling them to generate more strength and power, thereby supporting performance. The length of the muscle changes during eccentric and concentric contractions, which produce force. The flexibility and rigidity of muscles are also impacted. As a result, engaging in isotonic exercise can help strengthen the hamstrings, enhance performance, and lower the chance of injury.[10]

The level of participation and implementation of structured training activities among prospective Hajj pilgrims is still low.[5] In one study, researchers evaluated the level of physical exercise of Hajj pilgrims before departure and reported the level of physical exercise. There were 110 people (61.8%) in the lack category and 45 people (25.3%) in the low category. The authors concluded that while Hajj pilgrims have implemented health recommendations for exercise during the waiting and departure periods, their level of physical exercise is still inadequate. Moreover, monitoring and attention from officers regarding training is also still lacking.[11]

The effectiveness of adding lower extremity isotonic exercises on hamstring flexibility in Hajj pilgrims who receive aerobic walking training has never been studied. Thus, we evaluated the effect of adding lower extremity isotonic exercises on hamstring flexibility in prospective Hajj pilgrims who received aerobic walking training.

METHODS

This research used a pre- and post-test control group design in a randomised controlled trial to compare the effects of adding lower extremity isotonic exercises on hamstring flexibility in Hajj pilgrims who received aerobic walking training. The study population was Hajj pilgrims departing from the city of Salatiga, Indonesia, in 2023. The study was performed in February and March 2023. The Diponegoro University Faculty of

Medicine approved the study (number 83/EC/KEPK/FKUNDIP/III/2023). The researchers were responsible for all costs related to the study.

The inclusion criteria were age 40–59 years old, able to walk without assistive devices, fulfil the Hajj health and istithaah requirements, had a smartphone with WhatsApp to monitor exercise, no cognitive impairment (based on a score of ≥ 26 points on the Indonesian Version of Montreal Cognitive Assessment), and able to understand instructions. The subjects were excluded if they experienced pain in the lower extremities, based on a visual analogue scale (VAS) score ≥ 5; uncontrolled diabetes mellitus (Random Blood Glucose<70 mg/dl or > 250 mg/dl); excessive blood pressure without control (≥ 160/100 mmHg); hypotonus and laxity on the lower extremities; an manual muscle testing score < 5 for upper and lower extremities; refused to take part in a training programme or participating in other research; underwent a cardiac surgical procedure or percutaneous coronary intervention during the research period; and diseases such as severe chronic obstructive pulmonary disease, stage III–IV heart failure, stage IV chronic kidney failure with peritoneal dialysis/regular haemodialysis; stage IV acquired immunodeficiency syndrome with opportunistic infections, extensive haemorrhagic stroke, end-stage malignancy, tuberculosis total drug resistance (TDR), cirrhosis or decompensated hepatoma, severe schizophrenia, severe dementia, severe mental retardation, leg fractures, and spinal fractures. Subjects were removed from the study if they did not follow an aerobic exercise programme running more than six times, did not participate in the lower extremity isotonic exercise program more than four times, or did not come to the initial and/or final assessments.

The minimum sample size was obtained by using equation below.[12]

$$n1 = n2 = 2\,[(1.96 + 0.84)\,0.9 / 0.92]^2 = 15$$

Thus, the minimum number of research subjects per group was 15. Considering a potential dropout rate of 20%, 19 subjects would be required for each group, for a total of 38 subjects.

We considered 214 Hajj pilgrims who departed from Salatiga, Indonesia. We excluded 150, leaving 64 participants. Of them, we used simple random sampling to distribute 38 participants equally into the control and treatment groups. We explained the goals, advantages, and potential outcomes of the study, and each participant signed an informed consent form before starting the exercise programme. Their exercise was monitored via smartphone and a diary. After one participant in each group dropped out, there were 18 participants per group (Figure 1).

The control and treatment groups received moderate intensity walking aerobic exercise with the Borg scale 12–13 (100 steps/minute) five times a week (30 min per session) for 6 weeks. The treatment group also performed lower extremity isotonic exercises with ankle weight cuffs twice a week at a moderate intensity of 40%–50% 1-repetition maximum for 2–4 sets and 20 repetitions for a total of 6 weeks. Hamstring flexibility was measured before and after the 6-week exercise programme using the sit and reach test.

Isotonic training focused on improving flexibility of the hamstrings and also included movements involving knee extension and foot dorsiflexion. These movements engaged interconnected muscles that worked in conjunction with the hamstrings to support overall lower body flexibility. By strengthening and stretching the muscles around the knee and ankle joints, these exercises helped improve hamstring

flexibility, balance, stability, and proper alignment in everyday movements to enhance movement efficiency and to reduce the risk of injury or muscle imbalance. There were five movements.

- Knee extension
  In a sitting position, place a weighted cuff on the right ankle. With the elbows in the straight position, lift the leg forward to the top slowly with the back straight and leaning against the chair, and then return to the original position slowly. Repeat the movement for the other leg.
- Knee flexion
  In the standing position holding onto a chair or table, place a weighted cuff on the right ankle. Lift the leg back slowly until it is at 90 degrees, and then return to the original position slowly. Repeat the movement for the other leg.
- Hip abduction
  In the standing position holding onto a chair or table, place a weighted cuff on the right ankle. Lift the leg to the side slowly until it is at 45 degrees, and then return to the original position slowly. Repeat the movement for the other leg.
- Ankle plantarflexion
  In the standing position holding onto a chair or table, lift both heels slowly until standing on the tips of the toes, and then return to the original position slowly.
- Ankle dorsiflexion
  In the standing position holding onto a chair or table, lift the toes of both feet slowly to the maximum, and then return to the original position slowly.

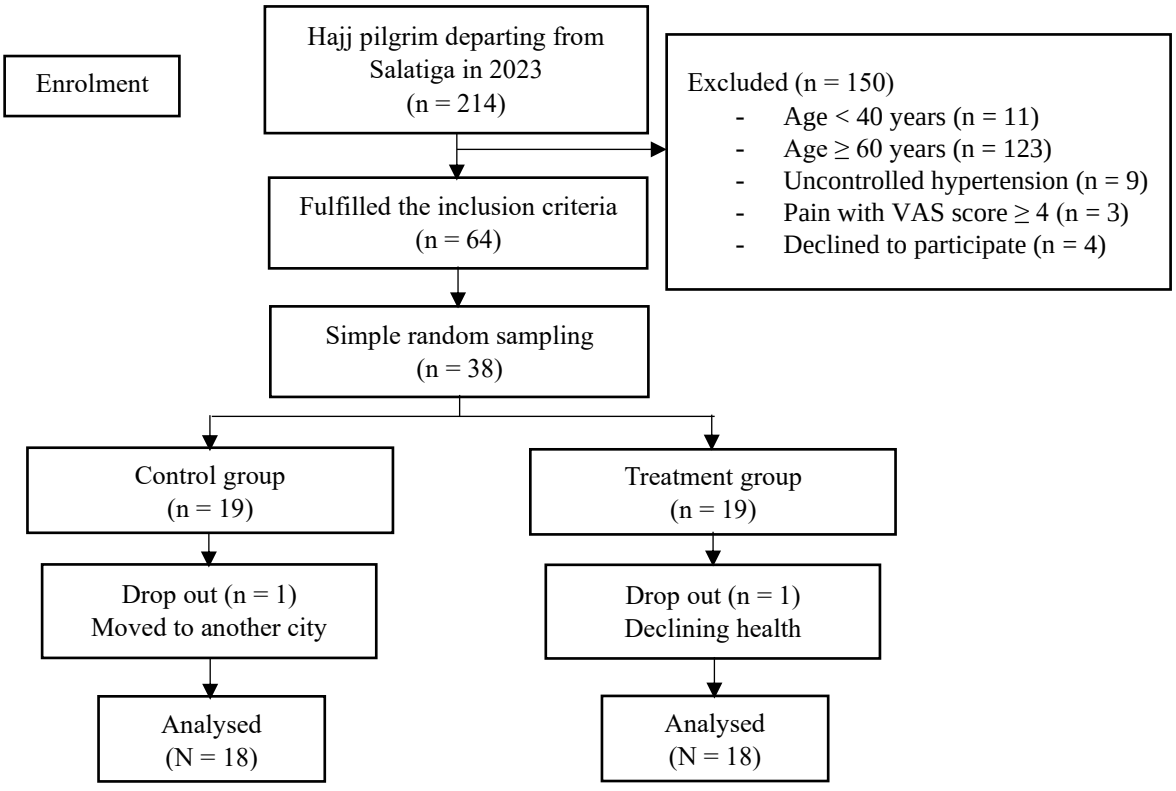

Figure 1. The CONSORT Flowcart

We used Stata version 13.1 to process the data. We used the Shapiro–Wilk test to determine whether the data were normally distributed. We analysed normally distributed data a t-test, and non-normally distributed data with the chi-square test of Fisher's exact test. We considered a p-value < 0.05 was considered to be statistically significant.

RESULT

Table 1 presents the baseline characteristics of the participants. There were no significant differences between the control and treatment groups.

Table 2 shows the results of the sit and reach test, which has been used previously.[13-15] Prior to the exercise programme, the mean sit and reach test result was 23.78 ± 5.26 cm for the control group, longer compared with the treatment group (22.67 ± 5.12 cm), but the difference was not significant (unpaired t-test, p = 0.526). After the 6-week programme, there was a significant improvement for the control group (2.17 ± 1.79 cm; unpaired t-test, p = 0.001) and the treatment group (5.39 ± 3.47 cm; paired t-test, p < 0.001). The treatment group showed a significantly greater improvement compared with the control group (paired t-test, p = 0.001; Table 2).

Table 1. Baseline Characteristics

Variable	Group		P
	Control (n=18)	Treatment (n=18)	
Gender			0,502¥
Male	7 (38,89%)	9 (50%)	
Female	11 (61,11%)	9 (50%)	
Age (years old)	53,33 ± 4,06	52,28 ± 5,31	0,507§
Weight (kg)	66,06 ± 8,29	68,61 ± 13,50	0,498§
Height (cm)	160,72 ± 7,66	162,28 ± 6,41	0,513§
Body mass index (kg/m^2)	25,50 ± 1,83	25,92 ± 4,06	0,692§
International Physical Activity Questionnaire			0,790±
Low	3 (16,67%)	1 (5,56%)	
Moderate	9 (50%)	10 (55,56%)	
High	6 (33,33%)	7 (38,89%)	
School Grade			0,101±
Elementary School	4 (22,22%)	1 (5,56%)	
High School	5 (27,78%)	3 (16,67%)	
Diploma	2 (11,11%)	2 (11,11%)	
Bachelor	2 (11,11%)	12 (52,2%)	
Master	5 (27,78%)	8 (44,44%)	
Doctor	0 (0%)	2 (11,11%)	
Work			0,791±
Housewife	4 (22,22%)	2 (11,11%)	
Teacher	1 (5,56%)	1 (5,56%)	
Pedagang	1 (5,56%)	2 (11,11%)	
Farmer	0 (0%)	1 (5,56%)	
Government employees	5 (27,78%)	8 (44,44%)	
Police	2 (11,11%)	0 (0%)	
Employees	3 (16,67%)	2 (11,11%)	
Self-Employed	2 (11,11%)	2 (11,11%)	

The symbols indicate the statistical test used for analysis: §independent t-test, ¥chi-square test, and ±Fisher's exact test.

Tabel 2. The sit and reach test results.

Measurement	Group		P
	Control (n=18)	Treatment (n=18)	
Before the exercise programme	23,78± 5,26	22,67 ± 5,12	0,526§
After the exercise programme	25,94 ± 4,30	28,06 ± 4,88	0,178§
p	0,0001¶*	0,0000¶*	
Difference	2,17 ± 1,79	5,39 ± 3,47	0,001§*

*p < 0.05. The symbols indicate the statistical test used for analysis: §independent t-test and ¶paired t-test.

DISCUSSION

The length of a muscle changes during isotonic exercise. Concentric and eccentric contractions can strengthen muscles and increase their endurance and flexibility. The treatment group performed lower extremity isotonic exercise with ankle weights to strengthen muscles and improve flexibility. The hamstrings are used to flex the knee and extend the hip joint. Eccentric contraction increases the flexibility and plasticity of connective tissues, which improves joint range of motion. The maximal force generated by eccentric muscular contractions is approximately 50% greater than that of concentric contraction and 25% greater than that of isometric contraction. Hamstring flexibility can be improved through resistance training due to several physiological mechanisms. Resistance training strengthens muscles, allowing them to handle greater loads and reducing stiffness. This type of training involved eccentric contractions, which lengthen muscle fibres and increase the length of the muscle–tendon unit and add sarcomeres, leading to greater muscle extension. Additionally, resistance training enhances neuromuscular coordination and proprioceptive awareness, enabling more effective and safer muscle stretching. Connective tissues such as tendons, ligaments, and fascia also became more pliable and resilient, improving overall muscle elasticity and flexibility. This is the basis for the increased flexibility in the treatment group compared with the control group.[16]

The flexibility of the control group increased significantly, although it was significantly lower than the treatment group. Aerobic walking exercise focuses on cardiovascular health and overall fitness, but it also engages the lower body muscles, including the hamstrings, in a repetitive, low-impact manner. While walking does not directly target muscle strength like resistance training does, it promotes blood circulation, joint mobility, and neuromuscular coordination, all of which can contribute to improve flexibility over time. During walking, the gait cycle comprises the stance phase (60%) and the swing phase (40%). During most of the gait cycle, the hamstrings contract eccentrically. During the stance phase (first contact and loading reaction) and swing phase, eccentric hamstring contractions are seen during the initial, mid, and terminal swings. The hamstrings stretch at the proximal attachment as the hip flexes forward during the leg swing and at the distal attachment when the knee extends before ground contact throughout the gait cycle. The hamstrings are most active when the knee reaches full extension, just before the foot makes contact with the ground during the initial phase of the gait cycle. The hip is flexed and the knee is extended during the leg-swing phase of the gait cycle, resulting in the lengthening of both the proximal and distal attachments of all three hamstring muscles. Hence, there is maximum eccentric

tension in the hamstrings before contacting the ground. Indeed, the main function of the hamstrings during the leg swing phase, to store elastic energy.[17]

Both resistance training and aerobic walking exercise represent effective strategies to increase hamstring flexibility. The treatment group received a combination of both types of exercise, so it got comprehensive benefits for overall flexibility and muscle health. The total amount of physical activity is positively associated with the flexibility of the hamstrings.[13] In a previous study, two different aerobic exercises, namely circuit and traditional, increased hamstring flexibility.[14] Agustiyawan and Hendrawan[15] performed research on prospective Umrah pilgrims in Jakarta using aerobic exercise interventions in the form of brisk walking and measuring flexibility using the sit and reach test method. Tien et al.[10] stated that isotonic training could increase flexibility. Delvaux et al.[18] reported an increase in passive hamstring flexibility in amateur athletes who participated in a 6-week eccentric contraction programme in the form of four column exercises for hamstring muscles. Blackburn and Norcross[16] showed that hamstring stiffness increased significantly for isometric training; the benefits were equal to isotonic training. Liang et al.[19] found that eccentric training could effectively improve the flexibility and strength of the hamstrings in dance students when compared with stretching exercise. Vatovec et al.[20] showed that training the hamstrings eccentrically significantly increased hamstring flexibility. Nordic hamstring and glider exercises were used in the study to examine the effects of hamstring passive stiffness and hip flexion flexibility.

This study has several limitations. First, the study population was relatively small. Second, we only evaluated the measurements once after the intervention. We did not reevaluate Hajj pilgrims once they returned to Indonesia, so we cannot say how long the increased hamstring flexibility lasts. Future research can be carried out to evaluate this increase in flexibility on the condition of Hajj pilgrims after returning to Indonesia.

CONCLUSION

We found a significant increase in hamstring flexibility in Hajj pilgrims who participated in aerobic walking training. Moreover, the addition of lower extremity isotonic training further improved this flexibility. Our findings support previous studies such as Ozer et all that showed aerobic exercise could increase hamstring flexibility.[14] They indicate that lower extremity isotonic exercises should be considered for Hajj pilgrims who perform aerobic walking exercises.

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