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EFFECTIVENESS OF ADDING STRENGTHENING LOWER EXTREMITY EXERCISE ON GAIT SPEED OF HAJJ PILGRIMS WHO RECEIVE WALKING AEROBIC EXERCISES

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ABSTRACT

Background: In the Hajj pilgrimage, the daily activities of Hajj Pilgrims also require good walking skills. Walking is the most common physical activities. Individuals with limited mobility have been found to have greater energy costs related to daily life tasks. Resistance training is a type of exercise that can increase muscular speed, power, strength, hypertrophy, and coordination. The decreased muscle strength leads to decrease in walking ability. **Objective:** Researchers want to compare that adding strengthening lower extremity exercise can improve the gait speed on Hajj Pilgrims more than control group who receive walking aerobic exercise only. **Methods:** A randomized controlled trial was used for this research. There were 36 participants divided into an 18-person intervention group and an 18-person control group. The groups received walking aerobic exercises five times a week and the intervention group were added strengthening lower extremity exercise twice a week. A 4-meter gait speed test was used to evaluate gait speed both pre- and post- a six-week course of intervention. **Results:** After six weeks, there was a significant increase in gait speed in both the intervention group (p=0.000) and the control group (p=0.000). There's no significant difference between the interventions of each group (0.86 ± 0.58) compared to the control group. (0.87 ± 0.66) (p=0.968). **Conclusion:** Walking aerobic exercise and adding strengthening lower extremity exercise can increase gait speed significantly. However, walking aerobic exercise with or without strengthening lower extremity exercise addition there is an increase in gait speed.

INTRODUCTION

Walking is a complex activity that involves interactions between the brain system[1] and the most common physical activities and also central carrying out various life activities independently.[2]

Small changes in walking ability have been associated with falls, impaired walking, and activities of daily living. Walking speed is influenced by physical conditions, such as: age, gender and height, presence or absence of disease and cardiorespiratory fitness. Apart from that, muscle strength and balance are factors that play a role.[1] Difficulty walking, poor gait endurance, and slow gait speed constitute a strong prognosis of functional dependence and death, especially in older adults.[2]

Apart from fitness being an important component in carrying out physical activity, increased energy requirements when walking are also commonly observed, especially in older people. Energy expenditure is an important component in functional task performance. Across species, the preferred degree of energy expenditure correlates with speed of movement. If an activity's energetic cost is too high, it may be abandoned or undertaken with less exertion, according to the energy reduction theory. Populations with reduced mobility have greater energy costs associated with daily activities.[2]

In the Hajj pilgrimage there are several sequences for carrying out the Hajj pilgrimage and apart from these activities, the daily activities of Hajj Pilgrims

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also require good walking skills. Because the Hajj pilgrimage has a time limit that regulates the sequence of the Hajj pilgrimage itself, Hajj pilgrims must have good mobility and walking speed to move from one place to another independently. Besides, the high physical activity of Hajj Pilgrims often has side effects in the form of fatigue due to excessive activity without good endurance preparation so that the risk of fatigue is high, which can also be one of the factors causing increased morbidity and mortality in Hajj Pilgrims.[1,3-7]

Mobility is an essential component of health at all ages, but it is especially important in older individuals to retain functional independence and autonomy.[14] Walking speed is the most typical marker of mobility.[15]

Resistance training is a type of exercise that has risen in popularity over the last two decades, notably because of its ability to improve athletic performance by developing muscle strength, power and speed, hypertrophy, and coordination.[17] Reduced muscle strength and balance in the elderly cause a decline in walking capacity, which leads to falls.[16]

Researchers want to compare that adding strengthening lower extremity exercise can improve the gait speed on Hajj Pilgrims more than control group who receive walking aerobic exercise only.

METHODS

Subjects

The research was carried out in the Hajj Pilgrims, Salatiga, Indonesia and was carried out from April to May 2023. There were sixty-four Hajj Pilgrims that fulfill the criteria and signing the informed consent and then thirty-eight participants were taken by simple random sampling, divided into 2 groups: walking aerobic exercise group as a control group (n=19) and walking aerobic and lower extremity strengthening exercises group as a intervention group (n=19).

Using a pre- and post-test control group design in a randomized controlled trial to compared the effects of adding strengthening lower extremity exercises on gait speed of Hajj Pilgrims who received aerobic walking training.

The inclusion criteria were age 40-59 years old, able to walk without assistive devices, fulfill the Hajj health *istitha'ah* requirements, have a communication tool in the form of an application WhatsApp (order and video calls) to monitor exercise home program, no cognitive impairment ((MoCa-Ina) normal (≥26), and able to understand instructions.

The subjects excluded while there were pain in the lower extremities with assessment of Visual Analog Scales (VAS) ≥5, uncontrolled diabetes mellitus (GDS<70mg/dl or >250 mg/dl), excessive blood pressure without control (BP ≥ 160/100 mmHg), hypotonus and laxity on the lower extremities, MMT score for upper and lower extremities is lower than 5, refusing to take part in a training program or taking part in other research, undergoing a cardiac surgical procedure or percutaneous coronary intervention during the research period, diseases, such as: severe chronic pulmonary obstruction (COPD), stage III-IV heart failure, stage IV chronic kidney failure with peritoneal dialysis/regular hemodialysis, stage IV AIDS 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 dropped out if they were not following an aerobic exercise program running more than six times, not participating in the strengthening lower extremity exercise program more than four times, not coming at the initial and/or final assessment of the research.

The research has received approval for ethical clearance from the Health and Medical Research Ethics Commission of Diponegoro University, Semarang, Indonesia.

Intervention

Simple random sampling was implemented for dividing the subjects into two groups. They were intervention and control group (figure 1). Both groups received given moderate intensity walking aerobic exercise with the Borg scale 12-13 (100 steps/minute), frequency five times a week for six weeks, exercise duration 30 minutes. The intervention group was also given strengthening lower extremity exercises. The training dose was given twice a week for six weeks, moderate intensity 40-50% 1-RM 2-4 sets, 20 repetitions with ankle weight cuffs. Before and after the exercise, the patient did warming up and cooling down. There were five movements.

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- Knee Extensors
  In sitting position, place a weight cuff on the right ankle, elbows in 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 another leg.
- Knee Flexors
  In standing position when held into a chair or table, place a weight cuff on the right ankle, lift the leg back slowly until they were up at 90 degrees, and then return to the original position slowly. Repeat the movement for another leg.
- Hip Abductors
  In standing position when held into a chair or table, place a weight cuff on the right ankle, lift the leg to side slowly until they were up at 45 degrees, and then return to the original position slowly. Repeat the movement for another leg.
- Ankle Plantar flexors
  In standing position when held into a chair or table, lift both heels of the feet slowly until reach maximum tiptoe, and then return to the original position slowly.
- Ankle Dorso flexors
  In standing position when held into a chair or tables, lift both tip toes of both feet slowly to the maximum, and then return to the original position slowly.

Exercise monitoring via smartphone and involving Hajj program holders at each Community Health Center during training and recorded in a diary which was distributed to research subjects. On training days, researchers monitored via WhatsApp group and participants were asked to send photos of the pedometer and exercise diary that had been shared previously. Then the researcher would check one by one the number of steps listed on the pedometer according to the exercise dose given and also information from the exercise diary. Apart from that, periodically there were also nearby health officers who were assigned to come and monitor the training of prospective Hajj pilgrims.

Measurements

Participants' 4-meter gait speed was measured both before and after therapy. 4-meter gait speed is a performance metric for functional mobility and gait speed. The participant was asked to "walk as quickly as possible" for 4 metres (with a moving start); the space to accelerate and decelerate was 2 metres before and after the designated distance. The distances (0-2-6-8 m) were marked on the floor with tape stripes. The test was repeated three times, with a two-minute gap between each. The study was based on the fastest time to complete the 4-meter walk.[8]

Statistical Methods

Data analysis consists both descriptive analysis and hypothesis testing. Prior to testing the hypothesis, descriptive statistics were employed to describe the demographic features of the participants. The Shapiro-Wilk test was done to see if the distributions within the groups were normal. The independent t-test was used to compare pre-test data between the control and intervention groups. The Mann-Whitney test was used to compare data from the post-test within the control and intervention groups. To determine the difference in Gait Speed (GS) values before and after the intervention, a Paired t-test was used. All data was processed on a PC using Stata® version 13.1. A p value <0.05 with a 95% confidence interval indicates the study's significance criteria was met.

RESULTS

The study was carried out in Salatiga City from April to May 2023. The total participant that had been analyzed was 36. All of participants that fulfill inclusion criteria and willing as a participant in this research have signed informed consent in the beginning.

Two people withdrew from the study: one was unable to participate in the exercise due to decline health, and the other already moving out of the city. Flow diagram of the study is available in Figure 1. In this study, the average age of the participants was 53.33 years for the control group and 52.28 years for the intervention group.

The participants' characteristics described in Table 1. The two groups did not differ statistically significantly (p value > 0.05). It indicated that both groups' research subjects had similar characteristics. There were also no significant differences at baseline measurement before intervention between them.

The mean results of 4-meter gait speed test at the beginning of the study were found in the control group (3.31 ± 0.83 s) which was longer than the

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intervention group (3.27 ± 0.55 s). However, the results of the independent t-test showed that there was no significant difference between the two groups (p=0.862). At the end of the sixth week of the trial, the mean average improvement results of the 4-meter gait speed test within the control group before and after treatment using the paired t-test indicated significant with p=0.000 with an increase of 0.87 ± 0.66 s. In intervention group, the mean average improvement results of the 4-meter gait speed test before and after intervention using the paired t-test also showed significant with p=0.000 with an increase of 0.86 ± 0.58 s at the end 6th week of research.

The comparison of mean average improvement results of the 4-meter gait speed between two groups using Mann-Whitney test showed there was no significant difference.

DISCUSSION

Participants demographic data showed no significant differences (Table 1). Participant characteristics were said to be homogeneous based on data of age, BMI, physical activity, education and occupation. The initial number of participants in this study was 214 Hajj Pilgrims who departed from Salatiga. Participants were excluded about 150 participants because they did not fulfill the inclusion criteria, so there were only 64 participants. The researchers carried out simple random sampling to get 38 participants according to the sample size obtained with the sampling formula. Participants who obtained from simple random sampling were divided into 2 groups with the same amount. They were the control group which only received aerobic walking exercise and the intervention group which received strengthening lower extremity exercise and aerobic walking exercise. In both groups, there was one participant of each who dropped out. In the control group, participants dropped out because of moving to another city and for the intervention group, one participant dropped out due to decline of the health problems. A total of 18 participants in each group underwent analysis (Figure 1).

There was a significant increase in gait speed results after adding strengthening lower extremity exercise in intervention group seen in this research is in line with changes demonstrated by Vafaeenasab et.al[16] and Hoffman et.al[13]. However, there was no significant difference between the control group and intervention group in the post-result. Maybe it was because the participants' baseline gait speed data is already well and this research was conducted only in healthy Hajj pilgrims.

The fifth pillar of Islam that is obligatory for every Muslim once in their life is the Hajj pilgrimage. Those must meet the requirements to be mature, intelligent, independent, and *istitha'ah* (capable). Hajj Pilgrims' health *istitha'ah* is defined as the Hajj Pilgrims' ability to carry out the Hajj pilgrimage in accordance with the guidance of the Islamic religion through aspects of physical and mental health which are measured through accountable examinations. [3,9,10]

The Hajj is a worship that is almost all harmonious and obligatory for the Hajj which is related to physical abilities, such as: spending the night in Muzdalifah, spending the night in Mina, throwing *jamarat*, and *tawaf wada* when leaving Mecca. Apart from these activities, the daily activities of Hajj pilgrims are also physical activities in the form of praying, leaving and returning from their accommodation to the mosque, as well as other pilgrimage activities. The Hajj pilgrimage is a physical worship which is included in the pillars of *fi'liyah*, meaning that it is mandatory to carry out physical worship activities and cannot be replaced by others, such as: *tawaf, sa'i* and *wukuf* activities on Arafah. Activities carried out by pilgrims at least three times for the Hajj pillars, plus activities outside the Hajj pillars, are estimated to be able to walk a minimum of 12 kilometers.[4,5]

The high physical activity of Hajj Pilgrims often causes side effects in the form of fatigue. Complaints of muscle soreness due to high levels of walking activity are caused by the inability of the muscle contractile elements to carry out their function. This inability is caused by depletion of energy reserves in the muscles, accumulation of lactic acid, cardiovascular and neuromuscular disorders. The body's physiological balance is disturbed due to excessive activity without good endurance preparation.[5]

High activity among Hajj pilgrims can reduce muscle and cardiorespiratory endurance levels. This will cause a decrease in the tissue response to a fixed stimulus or a larger stimulus is needed to produce a response. If this condition is not treated, it will

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become one of the factors causing increased morbidity and mortality of Hajj pilgrims.[3,4,6,11,12]

Assessment of physical function for clinical purposes and Hajj research can also be carried out by using a walk test. Several types of walking tests that are often used are walking tests on straight paths which assess walking ability based on a certain distance or time, including the 4-meter, 10-meter, 2-minute, 6-minute and 12-minute walk tests.[1]

Walking speed is influenced by physical conditions such as age, gender and height, the presence or absence of disease and physical fitness. In the other words, muscle strength and balance are factors that play a role. The normal or comfortable walking speed for elderly people without disabilities is 1 meter/second. If the walking speed is less than or equal to 0.8 meters/second, it is said to be not related to health problems and the risk of frailty. The existence of a difference between comfortable and maximum walking speed is a powerful indicator for assessing ambulation ability in the community.[1]

Mobility is an essential component of health at all ages, but it is especially important in older individuals to retain functional independence and autonomy.[14] Walking speed is the most typical indicator of mobility.[15]

Richardson et al. in showed that people with low walking speeds had reduced VO2 peaks and increased energy expenditure when walking. As a result, the effort associated with walking was higher in people who walked slowly than in people who walked quickly, and people who walked slowly experienced greater fatigue than people who walked quickly.

The mean preferred gait speeds of slow and fast walkers in the Richardson et al. study were consistent with this range; however, the researchers discovered that Cw (the energetic cost of walking) was higher among slow walkers than fast walkers, indicating that slow walkers expend more energy to cover a given distance. This has significant implications for daily mobility, as increased energy expenditures may limit the volume and extent of daily movement.[14]

Resistance exercise provides benefits such as improved bone and muscle mass, muscle strength, flexibility, and dynamic balance. Walking speed is another component of walking that can be influenced by age; beyond seven decades of life, walking speeds drop by approximately 12%-16% per decade. Muscle and functional strength can be improved by engaging in age-appropriate physical activity for 20 minutes three times per week. Vafaeenasab et al. demonstrated a 17% increase in walking speed following lower-body strength training. [16]

Strengthening exercises target the primary lower leg muscles, including the knee flexors, knee extensors, and hip abductors, which are critical for functional movement and walking. Hip muscular strength is required to correct mediolateral balance faults. The gluteus medius, the primary driving muscle of the hip abductor, plays a significant role (about 60%) in the stance phase of walking.[18] This muscle must provide adequate contraction force (eccentric contraction) to keep the pelvis from "falling" as a result of the left leg moving forward when swing phase. The hip abductor muscles must produce a large abduction torque during each single-limb support phase of walking. [19]

The ankle muscles are responsible for correcting small errors so as to strengthen the postural response of the ankle hip strategy. The quadriceps femoris muscle will produce knee extension which is the key to carrying out lifting and lowering movements of the body. Knee extensor strength also produces the extension momentum required when walking. The plantarflexor and dorsiflexor muscles of the ankle are important for maintaining balance.[20] Increasing balance and lower leg muscle strength will increase walking speed which can be seen through a significant increase in both the intervention and control groups.

This study is also consistent with the findings of Parvataneni et al., who found that increasing average strength measures in the affected side of stroke patients, particularly H1 (hip extensors including hamstring muscle) and A2 (ankle plantarflexors), accounted for approximately 75% of the variation in gait speed change following the training programme.[21]

In a prior study, Hoffman et al. discovered a very strong association between the percent change in the composite score for lower extremity leg strength and the percent change in 10 m fast-as-possible walking speed. This link indicated that children with cerebral palsy who improved their lower extremity strength improved their walking speed.[13]

Interventions that increase muscle strength, aerobic capacity or reduce energy costs when walking can prevent slowing walking speed and improve

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mobility. With a good walking speed, the time needed to complete the Hajj pilgrimage will be shorter so the energy expenditure will be smaller and the side effects in the form of fatigue will decrease.

Nevertheless, this study also has several limitations. Firstly, the researchers did not assess how long the effect of increasing gait speed would last because they only evaluated it once after the intervention was given. Besides, researchers also did not measure exercise intensity according to heart rate reserve because they did not use a heart rate monitor.

CONCLUSION

The results show that adding strengthening lower extremity exercise can significantly increasing the gait speed but not superior to walking aerobic exercise only.

Image 1. Flow Diagram of The Study

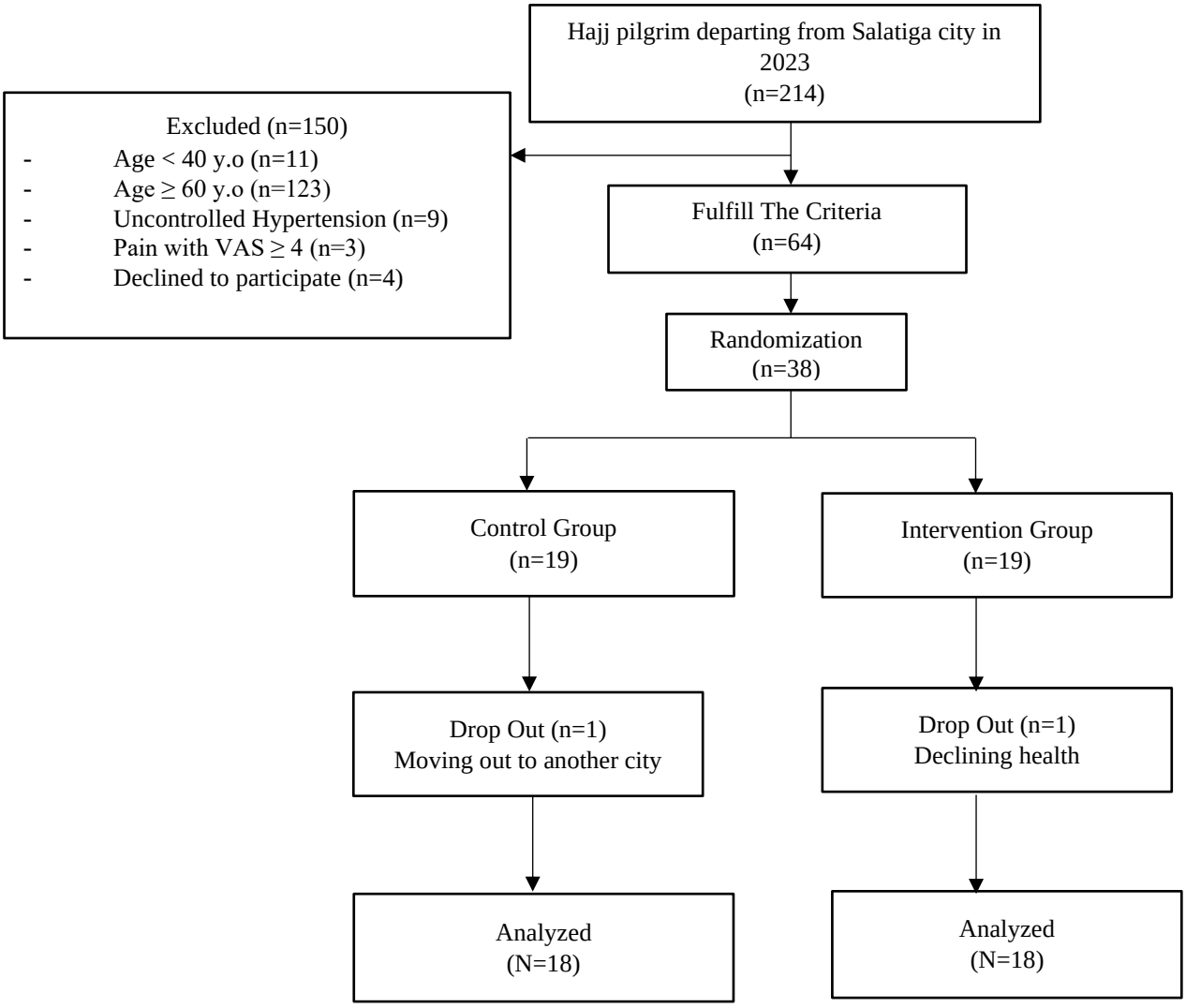

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Table 1. Baseline Characteristic

Variable	Group		P
	Control (n=18)	Intervention (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§
Body Weight (kg)	66,06 ± 8,29	68,61 ± 13,50	0,498§
Body Height (cm)	160,72 ± 7,66	162,28 ± 6,41	0,513§
BMI (kg/m^2)	25,50 ± 1,83	25,92 ± 4,06	0,692§
IPAQ			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%)	
Merchant	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%)	

Tabel 2. The Comparison Results of 4-Meter Gait Speed

GS	Group		P
	Control (n=18)	Intervention (n=18)	
Pre test	3,31± 0,83	3,27 ± 0,55	0,862§
Post test	2,44 ± 0,43	2,41 ± 0,35	0,937‡
P	0,000¶*	0,000¶*	
Difference	0,87 ± 0,66	0,86 ± 0,58	0,968§

Note: * Significant (p < 0,05); § Independent t; ‡ Mann whitney; ¶ Paired t

ETHICAL APPROVAL

The Research Ethics Committee at the Health and Medical Research Ethics Commission of Diponegoro University, Semarang, Indonesia granted ethical approval with the ethical clearance number No.102/EC/KEPK/FK-UNDIP/IV/2023.

CONFLICTS OF INTEREST

The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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