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Original Research

Effect of Agonist-Antagonist Paired Set and Traditional Set Strengthening Exercise Methods on Single-Leg Hop Performance

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ABSTRACT

Background: Functional activities mostly done in daily life such as jumping, walking, running, and stairs ascending-descending require dynamic stability of the knee. The knee joint dynamic stability is required to have effective and efficient functional activities and to avoid injury when performing them. It can be achieved by increasing muscle strength through strengthening exercises with the aim of balancing the agonist muscles (quadriceps femoris) and antagonist muscles (hamstring) using the agonist- antagonist paired set (APS) method.
Aim: The aim of this study is to find out the effect of strengthening exercise using APS method, compared to traditional set (TS) method, on single-leg hop performance.
Material and Methods: The subjects of this study were 14 untrained healthy men aged 18-40 years old divided into 2 intervention groups, APS group and TS group. The variable evaluated was the distance of single-leg hop (SLH).
Results: The results of this study showed a significant increase in SLH distance in APS group (p=0.005) and TS group (p<0.001) with no significant difference between the two groups (p = 0.933).
Conclusion: Quadriceps femoris and hamstring muscle strengthening exercises in both APS and TS methods increase SLH distance although there is no difference between them. The APS method has an advantage compared to the TS method in terms of a relatively shorter time with comparable results.

Keywords: *agonist-antagonist paired set, dynamic knee stability, functional performance, single-leg hop.*

Introduction

Functional activities in daily life, such as jumping, walking, running, and stairs ascending-descending require good dynamic knee stability. The dynamic knee stability is required to have effective and efficient functional activities and to avoid injury when carrying out these functional activities. In athletes, dynamic knee stability is needed to improve sports performance. One examination that can be used to assess dynamic knee stability is single-leg hop test. Single-leg hop test aims to assess the integration of neuromuscular control, lower limb muscle strength, ability to perform movements that challenge knee stability, and to evaluate progress in knee rehabilitation.[1,2] Single- leg hop test is one of the predictors, with a good correlation, of dynamic knee stability.[1] From several studies done before, the single- leg hop test showed hope as a tool to predict whether patients with anterior cruciate ligament injury can return to high-level physical activity without experiencing further episodes of knee instability after non-operative rehabilitation.

Dynamic knee stability is a result of the integrity of the articular geometry, soft tissue, weight bearing load received by joint, and muscle action.[3] One way that can increase the dynamic knee stability is by increasing muscle strength through strengthening exercises with the aim of balancing the agonist muscles (quadriceps femoris) and antagonist muscles (hamstring) of the knee joint.[4,5]

One strengthening exercise strategy actively investigated in recent years is the pre-activation of the antagonist muscles. Pre-activation is carried out through antagonist muscle contraction immediately followed by contraction of the agonist muscle. Previous studies have shown that individuals who adopt antagonist pre-activation have an acute positive effect in producing agonist muscle strength and improving performance. Other studies showed that after 8 weeks of resistance training in 1RM test, there were 21% increase in squat and vertical jump performance, and 2% increase in running performance.[6,7] These results suggest that the benefits of resistance training with antagonist pre-activation can produce positive effects associated with increased neuromuscular ability, which is required for functional activities. Antagonist pre-activation is considered to provide joint stability that is produced during the agonist muscle action and therefore supports increased functional performance.[8]

Studies examining chronic adaptation from strengthening exercise in the APS method are still limited. Robbins et al. reported that APS strengthening exercise were at least useful in increasing strength and power, and more efficient in terms of time compared to traditional strengthening exercise. However, the study only assessed 1 Repetition Maximum (1 RM) increase to assess the strength and did not assess the functional performance.[9] Other study assessing the long-term effect of strengthening exercise in APS method on the agonist-antagonist muscle co-activation is still lacking, although Maia et al reported an increase in agonist muscle activation that is thought to be through the effect of antagonist pre-activation.[10]

The aim of this study was to determine the single-leg hop performance difference between agonist-antagonist paired set and traditional set high-intensity strengthening exercise of the quadriceps femoris and hamstring muscle in untrained healthy subjects.

Materials and Method

This was an experimental study in untrained healthy male subjects with randomized pre-test and post-test group design.

Subjects

The study subjects consisted of 16 untrained healthy men who met the inclusion criteria. The inclusion criteria were untrained healthy men, aged 18-40 years old, body mass index (BMI) 18.5 - 24.9 kg/m^2, and willing to participate in this study. Exclusion criteria were men who had undergone thigh muscle strengthening exercise program within the past 6 months, history of injury, fracture, or previous surgery on non-dominant lower limb, proprioceptive disorders in non-dominant lower limb, hypertension, ischemic heart disease, and peripheral arterial disease in the lower limbs. The subjects were randomly divided into two groups, APS group (n = 8) and TS group (n = 8). Baseline data were collected before the training program and post intervention data were collected a week after the last training. The distance of single-leg hop in non-dominant lower limbs were measured before and after the training program as an outcome in this study. All participants were given instructions about the objectives and procedures of the study. This study was approved by the institutional ethics research committee of Dr. Soetomo Academic General Hospital with the ethic's number 1914/KEPK/III/2020.

Intervention

In the first visit, familiarization with all tests was carried out (50% 1-RM, 3 sets, 12 repetitions). One RM was determined using a quadriceps bench. The training program was initiated with warming up and ended with cooling down.

Training session for both groups (APS and TS) were characterized by isotonic quadriceps femoris and hamstring muscle exercise on the non-dominant lower limb using quadriceps bench, 70% 1 RM intensity, 3 sets of each muscle trained, 12 repetitions/set, twice a week with a minimum interval of 48 hours between each session, for 6 weeks, described as follows: 1) APS group, reciprocal exercise of agonist and antagonist knee muscles, initiated by flexion movement of the knee immediately followed by its extension at each repetition (rest interval between sets is 2 minutes; 1 set of antagonist muscle strengthening exercises performed in the middle of the agonist muscle rest interval and vice versa), 2) TS group, performed sequentially starting with 3 set of antagonist muscles and followed by 3 sets of agonist muscles, with a rest interval of 2 minutes between each set.

Statistical analysis

Data were analyzed using SPSS 23.0. Normality of the data was verified with Saphiro Wilk test, then, parametric tests were applied. The baseline characteristics between APS and TS groups were compared using independent sample t test. The differences between single-leg hop for distance before and after the training session of APS and TS group were compared using paired t test. Between-group differences (delta) of single-leg hop for distance were compared using independent sample t tests. The Cohen's d was applied to assess the effect size between single-leg hop for distance before and after training session. The differences were considered statistically significant at $p < 0.05$.

Results

Of all participants (16 subjects), 2 subjects were dropped out due to difficulties to continue study protocols. None of the subjects reported any adverse effects during the strengthening exercise program. The baseline characteristics of the subjects such as age, weight, height, BMI, and SLH value before training program did not show a significant difference between the two groups (Table 1). In both APS and TS groups, there was a statistically significant increase in SLH ($p<0.05$) after strengthening exercise (Table 2). Comparison of the SLH delta revealed that there was no difference between the two groups (p = 0.933) (Table 3). However, based on the measurement of effect size, the APS group showed a greater increase in SLH compared to the TS group, with Cohen's d value 1.56 and 0.6, respectively.

Table 1. Baseline characteristic of subjects

Variable	APS	TS	*p-value*
Age (year)	31.57 ± 3.95	34.71 ± 4.029	0.166
Weight (kg)	62.85 ± 9.88	65.0 ± 7.68	0.659
Height (m)	1.71 ± 0.06	1.69 ± 0.07	0.582
BMI (kg/m²)	21.49 ± 2.015	22.99 ± 2.15	0.205
SLH pre (cm)	83.52 ± 12.27	84.05 ± 33.26	0.969

*Significant if *p-value* < 0.05

Table 2 SLH value (cm) before and after strengthening exercise

	Before	After	*p-value*	Effect size
APS (n=7)	83.52±12.27	102.32±11.81	0.005*	1.56
TS (n=7)	84.05±33.26	102.66±31.07	<0.001*	0.6

*Significant if *p-value* < 0.05

Table 3 Comparison of delta SLH before and after strengthening exercise between two groups

	APS (n=7)	TS (n=7)	*p-value*
Δ SLH (cm)	18.8 ± 5.16	18.52 ± 6.98	0.933

*Significant if *p-value* < 0.05

Discussion

Hop tests are generally used as a representation of performance and are widely used for clinical assessment to measure dynamic balance.[1] Hop tests can provide qualitative data regarding quadriceps femoris and hamstring muscles strength.[11] However, there is no consensus in the literature about which muscle groups are more involved in functional activity. Li et al. reported a correlation between hamstring muscle during functional activities involving the knee joint[12], while Pasanen et al. found a correlation only with quadriceps femoris muscle.[13]

Muscle strength in the lower extremities can be a reflection and also influence the value of hop tests. The literature shows that there is a positive relationship between isokinetic muscle strength and muscle performance with single-leg hop and crossover hop.[14–17] Barber et al. found that 12 out of 18 participants with ACL deficiency who experienced quadriceps muscle weakness had abnormal scores for single-leg hop for distance.[14]

This study shows a significant increase in SLH after 6 weeks of strengthening exercise in both APS and TS group. The change in strength is considered to come from neurological and morphological adaptations, therefore the possibility of improving performance is mainly supported by changes in intra and inter- muscular coordination. In addition, the initial strength increase in untrained individuals is a consequence of neurological adaptation rather than structural changes. The training chosen in the strengthening exercise program has the potential to influence the magnitude of neuromuscular adaptation so that it affects the determinants of physiological performance.[18]

Strengthening exercise with APS method has an antagonist pre-fatigue mechanism by making the antagonist muscles tired and giving the effect on the agonist muscles. Induced fatigue in the antagonist muscles will facilitate greater activation in the agonist muscles (agonist pre-activation).[10,19,20] Based on this mechanism, it is expected that the APS group will experience a greater SLH increase than the TS group. However, in this study, only a larger effect size was obtained in the APS group without statistically significant differences. It might be because both TS and APS groups received the same quadriceps femoris and hamstring muscle strengthening exercises in the same exercise sequence (hamstring precedes quadriceps femoris), so the effects of antagonists pre-fatigue and agonist pre-activation that are suspected to occur in APS group were also found in TS group. In the absence of a control group given only agonist muscle strengthening exercises, we cannot conclude whether the increase in single-leg hop for distance in these two groups occurred due to the effects of the antagonist pre-fatigue and the agonist pre-activation.

Our results are similar to Cardoso et al. who reported strengthening exercise for 12 sessions in young healthy subjects with reciprocal training (3 sets, 10 reps, knee flexion followed immediately by knee extension) versus traditional training (3 sets, 10 reps, extensions knee) caused an increase in single-leg hop before and after exercise in both groups without differences in SLH increase between groups.[8] Study conducted by Robbins et al on 15 trained men, twice a week for 8 weeks, showed that the value of 1-RM bench pull and bench press increased significantly in the APS group, while the peak power of the bench press throw increased significantly in the TS group, but not in the APS group.[9] Quadriceps femoris and hamstring muscle strengthening exercises using APS methods may be more suitable for increasing muscle strength than power. Meanwhile, the dynamic joint stability examination only based on the measurement of single-leg hop is still lacking because the single-leg hop cannot distinguish whether the improvement from the hop distance is due to improved strength or power of the hamstring and quadriceps femoris muscles. Therefore, further research with strengthening and power training programs, and using other functional examinations such as drop vertical jumps is needed.

This study has several limitations. The training program is limited to quadriceps femoris and hamstring muscle strengthening exercises without a comparison group with other training program such as perturbation or neuromuscular training. The performance parameter is only single-leg hop without other functional performance parameters such as single-leg triple hop, single-leg crossover hop, or drop vertical jump. Participants' daily physical activity cannot be controlled. Both researchers and participants were not blinded with the intervention.

Conclusion

High intensity quadriceps femoris and hamstring muscle strengthening exercise using agonist-antagonist paired set and traditional set methods in untrained healthy subjects can increase single-leg hop for distance. There is no difference in the increase in single-leg hop for distance between agonist-antagonist paired set and traditional set.

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