2024, Retos, 59, 666-673

A combination of swissball hamstring curl and stiff-leg deadlift training on agility, hamstring asymmetry, and leg power in badminton athletes with hamstring asymmetry conditions
Una combinación de entrenamiento de flexión de isquiotibiales y peso muerto con piernas rígidas de Swissball sobre la agilidad, la asimetría de los isquiotibiales y la potencia de las piernas en atletas de bádminton con condiciones de asimetría de los isquiotibiales

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Abstract. Exercise-based physical therapy has become a crucial element of sports medicine, particularly in addressing conditions such as hamstring asymmetry in athletes. To find out the impact of 10 weeks of stiff-leg deadlift and Swiss ball hamstring curl training on the asymmetries of hamstrings, agility, and leg power in badminton athletes with asymetry conditions. The study design employed was a quasi-experimental pre-post design. The prepared programme gave the sample a combination of stiff-leg deadlift and Swiss ball hamstring curl training for 10 weeks. Data was collected twice during the pretest and posttest by measuring hamstring asymmetry using the Norboard, agility using the Illinois agility run test, and leg power using the Force Plate. Paired sample t tests and Wilcoxon tests were used to compare the initial test results obtained before and after hamstring muscle strengthening training for 10 weeks, which resulted in a p value of less than 0.05. The Wilcoxon test results for the hamstring asymmetry variable show a p-value of 0.000, and the agility variable shows a p-value of 0.001. Meanwhile, the leg power variable using a paired sample t test resulted in a p-value of 0.035. Engaging in a 10-week training program that combines stiff-leg deadlifts and Swiss ball hamstring curls can enhance the strength of the hamstring muscles and improve agility and leg power in athletes with a hamstring asymmetry ≥ 10%.
Keywords: Hamstring Asymmetry, Agility, Leg power, Badminton.

Resumen. La fisioterapia basada en ejercicios se ha convertido en un elemento crucial de la medicina deportiva, particularmente para abordar afecciones como la asimetría de los isquiotibiales en los atletas. Descubrir el impacto de 10 semanas de entrenamiento de peso muerto con piernas rígidas y curl de isquiotibiales con pelota suiza sobre las asimetrías de los isquiotibiales, la agilidad y la potencia de las piernas en atletas de bádminton con condiciones de asimetría. El diseño del estudio empleado fue un diseño pre-post cuasi experimental. El programa preparado le dio a la muestra una combinación de peso muerto con piernas rígidas y entrenamiento de curl de isquiotibiales con pelota suiza durante 10 semanas. Los datos se recopilaron dos veces durante la prueba previa y posterior, midiendo la asimetría de los isquiotibiales usando el Norboard, la agilidad usando la prueba de carrera de agilidad de Illinois y la potencia de las piernas usando la Force Plate. Se utilizaron pruebas t de muestras pareadas y pruebas de Wilcoxon para comparar los resultados de las pruebas iniciales obtenidos antes y después del entrenamiento de fortalecimiento de los músculos isquiotibiales durante 10 semanas, lo que resultó en un valor de p inferior a 0,05. Los resultados de la prueba de Wilcoxon para la variable de asimetría de los isquiotibiales muestran un valor de p de 0,000 y la variable de agilidad muestra un valor de p de 0,001. Mientras tanto, la variable de potencia de las piernas utilizando una prueba t de muestras pareadas resultó en un valor de p de 0,035. Participar en un programa de entrenamiento de 10 semanas que combine peso muerto con piernas rígidas y curls de isquiotibiales con pelota suiza puede mejorar la fuerza de los músculos isquiotibiales y mejorar la agilidad y la potencia de las piernas en atletas con una asimetría de los isquiotibiales ≥ 10%.
Palabras clave: Asimetría de isquiotibiales, Agilidad, Potencia de piernas, Bádminton.

Fecha recepción: 24-06-24. Fecha de aceptación: 29-07-24
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Introduction

Hamstring injuries are prevalent in sports that involve rapid running, such as badminton. The optimization of hamstring exercise selection is a crucial focus in preventing and rehabilitating hamstring injuries. This is because low eccentric strength is considered one of the most important but changeable elements that increase the risk of hamstring injury (Ekstrand et al. 2023; Hegyi et al. 2018; Opar et al. 2014; Orchard, Seward, and Orchard 2013). According to the literature, having weak hamstring muscles is one of the first factors that increases the risk of hamstring strain injury (Agre 1985). The clinical significance of strength tests in assessing the risk of sustaining a hamstring strain injury is somewhat contradictory (Van Dyk et al. 2017).

However, prospective cohort studies have demonstrated that athletes with inadequate hamstring eccentric strength are more prone to hamstring strain injury (Marchiori et al. 2022). The hamstring is a biarticular muscular complex that consists of four muscles: the long and short heads of the biceps femoris muscle, the semimembranosus muscle, and the semitendinosus muscle (ST). The muscle complex in question is accountable for both extending the hip and flexing the knee, and it has a significant function in physical activities such as walking, jogging, cycling, and jumping (Schoenfeld 2010). Therefore, achieving ideal performance in athletics may necessitate significant hamstring strength and power (Schoenfeld et al. 2015). The primary causes of hip, knee, and hamstring injuries are weakness or stiffness in the hamstring muscles, imbalanced activation within distinct muscle segments, neural inhibition, and a poor ratio of hamstring-to-quadriceps strength (Hegyi *et al.*, 2018; Guruhan *et al.*, 2020). Due to the unstable nature of badminton, which involves jumping, hitting the shuttlecock, and changing directions while pursuing the shuttlecock, it is important for training to simulate the specific demands of the sport (Behm et al. 2010; Behm and Anderson 2006; Hamlyn, Behm, and Young 2007). Moreover, engaging in training under unpredictable or imbalanced circumstances can mimic both training and everyday tasks, resulting in successful transfer of skills (Ignjatovic, Radovanovic, and Kocić 2019). Muscle imbalances, such as hamstring asymmetry, can lead to improper load distribution during high-intensity badminton movements, potentially contributing to decreased power output, reduced agility, and an increase in the risk of lower-body injuries. This is particularly concerning in the sport of badminton, where players must quickly transition between various movement patterns, often relying on their lower-body strength and flexibility to generate explosive power and maintain dynamic balance. Unstable training has been suggested as a method to enhance the specific effects of movement by increasing the activation of stabilisers and core muscles (Anderson and Behm 2005; Behm et al. 2010; Behm and Anderson 2006; Marquina et al. 2021).

Sports training is frequently prescribed as a therapeutic intervention to enhance an athlete's asymmetry, although the observed improvements are minimal and many outcomes are not statistically significant (Bettariga, Turner, *et al.*, 2022; Bishop, Turner and Read, 2018). Physical therapy with exercise has become an essential component of sports medicine since it offers players a variety of advantages that aid in injury prevention and management (Tenforde et al. 2017). Due to the increasing focus on physical fitness and athleticism, athletes frequently subject their bodies to extreme stress, thereby elevating the likelihood of sustaining injuries. Physical therapy can aid athletes in injury prevention, pain management, and expedited recovery, enabling them to optimise their performance. An important advantage of physical therapy for athletes is its ability to avoid injuries. Physical therapists can create exercise and training programmes to enhance athletes' strength, flexibility, and endurance by pinpointing areas of weakness or imbalance. These programmes are customised to meet the unique requirements of each athlete, considering factors such as their age, gender, sport, and fitness level. By improving their total physical function, athletes can mitigate their injury risk and maintain peak performance (Howard and Kaufman 2018).

Today, the use of various training methods to maintain athletes' stabilization capacity has become a common and frequent practice. The use of special devices to create unstable environments, such as balls on Swissball hamstring curl exercises and dumbels on stiff-leg deadlifts, has been widely used in sports centers and sports clubs (Jakubek 2007; Marquina et al. 2021). The reason for giving this training treatment is because Swiss ball exercises and stiff-leg deadlift exercises enhance the core stability for efficient conditioning and rehabilitation of the athlete (Kamatchi et al. 2020). The Swissball hamstring curl is a popular exercise that targets the hamstring muscles and can help improve strength, flexibility, and balance (Cuğ 2012). Similarly, the stiff-leg deadlift is a compound exercise that engages the posterior chain, including the hamstrings, and can enhance overall leg power and strength (Martín-Fuentes, Oliva-Lozano, and Muyor 2020a). When combined, these two exercises may have a synergistic effect on badminton athletes with hamstring asymmetry, potentially improving agility, reducing hamstring asymmetry, and increasing leg power. Previous studies have explored the individual benefits of these exercises, but they have not thoroughly examined their combined effects on badminton athletes with hamstring asymmetry conditions. This research paper aims to explore the impact of a training program that combines Swissball hamstring curl and stiff-leg deadlift exercises on the agility, hamstring asymmetry, and leg power of badminton athletes with hamstring asymmetry conditions.

Previous studies have investigated the relationship between foot posture and hamstring tightness, suggesting that there is an interconnectedness between these two factors. Weakness in proximal muscle stability, such as the hamstrings, can lead to reduced movement pattern efficiency and compensatory patterns, which may contribute to tissue overload. Additionally, research has explored the development of agility exercises for wheelchair badminton athletes, demonstrating the importance of targeted training to improve athletic performance in this population. The results of this study may provide valuable insights into the practical application of these exercises for improving athletic performance and injury prevention in badminton and other sports that require similar movement patterns.

Methods

Study Design

The study design employed was a quasi-experimental pre-post design, specifically a sort of experimental research in which observations were conducted twice: once before the treatment (pre-test) and once after the treatment (post-test) within a single group.

Subjects

We recruited 23 voluntaries, male Badminton athletes (age: 17.61±1.16 years, weight: 63.57±3.04 kg, height: 168.17±3.31 cm, and BMI: 22.48±0.89 kg/m^2), how meet the inclusion and exclusion criteria from three badminton clubs in East Java to participate in our study.

The research data was taken from three badminton clubs in East Java: Sony Badminton Training, PB Trisula, and Fifa Badminton Club. The sample used purposive sampling with the criteria of active badminton athletes with at least 5 years of experience in badminton, an age range of 16–20 years, and a hamstring asymmetry value above 10%. A total of 23 samples were tested twice, before the pretest and after the treatment (postest).

Treatment Procedure

The study familiarized the subjects with a two-week training program in hamstring muscle strengthening prior to treatment. This training consisted of a total of six exercises aimed at adapting the nerves and muscles and capitalizing on the "repeated bout effect". After familiarization was administered, research subjects were given rest time for one week to minimize the effects of adaptation training. After rest, the subjects were given 10-week hamstring muscle strengthening training with a frequency of three times a week (Petersen et al. 2011). The forms of hamstring muscle strengthening training carried out are stiff-leg deadlift and Swiss ball hamstring curl. Before the program is prepared, the maximum repetition (1-RM) is determined according to the individual's abilities, and the repetitions are organized in the form of a percentage of the maximal repetition of each individual. After 10 weeks of training, the sample did a post test. The training program was prepared by researchers who have been certified international badminton coaches (BWF Level 1).

The training program consist of a swissball hamstring curl and stiff-leg deadlift movements that are performed alternately right and left (Table 1). This is aimed at ensuring that the effect of the exercise is equal between the right and left legs so that there is no asymmetry (Wiriawan et al. 2024). In addition, the practice has applied the principle of progressive resistance training by increasing sets, repetitions, intensity and reducing rest times (Grgic et al. 2018; Paluch et al. 2024). The individual principle is also applied by making a percentage of the repetition according to the individual's ability at the time of the 1-RM measurement (Zhanneta et al. 2015).

Table 1.
10-Week Hamstring Muscle Strengthening Training Program

Exercise	Week	Set	Intensity	Rest/Sets	Rest/Exercise
Stiff –leg deadlift (right) Stiff –leg deadlift (left) Swiss ball hamstring curl (right) Swiss ball hamstring curl (left)	1-2	2	50% RM	1 minutes	5 minutes
	3-4	3	60% RM	1 minutes	5 minutes
	5-6	4	70% RM	1 minutes	5 minutes
	7-8	5	80% RM	1 minutes	5 minutes
	9-10	6	80% RM	1 minutes	4 minutes

%RM is repetition maximum

Instrument and Data collection

The data measured is agility, hamstring asymmetry, and leg power. Agility was measured by performing the illinois agility run test, asymmetry of the hamstring using the Norbord test, and leg power using the Force Plate (Bishop et al. 2022a; Murarka, Agrawal, and Murarka 2015; Samozino et al. 2008). The sample undergoes pre and post-tests to measure agility, hamstring assymetry, and leg power after 10 weeks of training. The *Illinois Agility Test* is a widely used assessment tool for evaluating multidirectional agility in many sports (Raya et al. 2013). To measure hamstring asymmetry, we used the Norbord test (Bishop et al. 2022b; Cuthbert et al. 2021). The Norbord test utilizes a sophisticated sensor that is tiny, wireless, and capable of measuring an athlete's hamstring strength in real-time. An athlete can undergo a Norbord test, which provides accurate and dependable findings, in just 30 seconds (Ercan, Kerem, and Kunduracioglu 2019; Opar et al. 2013).

Countermovement jumps were conducted using a force plate to assess leg power. The force plate is used as an instrument in this study because it is suitable for individuals with poor balance (Trivedi, Gilbert, and Dechman 2021). The instructions were to execute rapid and elevated jumps without any pauses between knee flexions, land with fluidity, assume an upright posture, and maintain immobility (Strotmeyer et al. 2018). Force was quantified via a Kistler force plate operating at a sampling frequency of 1500 Hz and employing a low-pass filter configured at 10 Hz. The measurements commenced prior to the participant's placement on the force plate and continued for a duration of 15 seconds. A digital marker was used to indicate the specific moment when the participants were instructed to perform a leap (Mentiplay et al. 2015).

Statistical analysis

The study analyzed agility, hamstring asymmetry, and leg power values before and after 10 weeks of training using a descriptive test. Leg power was analyzed using a paired sample T-test, while hamstring asymmetry and agility were tested using the Wilcoxon test. The initial test results before a 10-week hamstring muscle strengthening program were compared with the final results after the same training period, confirming a p-value of less than 0.05. Data analysis was conducted using Microsoft Excel 2013 and SPSS 23 software.

Ethics

All participants were verbally informed of the purpose, procedures, and risks associated with the study, their freedom to withdraw at any time without prejudice and if they agreed, they signed the consent form. The study was carried out according to the Declaration of Helsinki and the ethical approval for the study was granted by the Local Ethical Committee, the Universitas Negeri Semarang Health Research Ethics Committee, under the reference number 334/KEPK/EC/2022.

Results

The research results calculated the pre- and post-data using a paired sample t test and a Wilcoxon test with a p value of less than 0.05 to determine the difference in the effect of 10-week hamstring muscle strengthening training on hamstring asymmetry, agility, and leg power.

Table 2.
Effect of asymmetry hamstring, agility and leg power after 10-week hamstring muscle strengthening training

Variables	Pretest (n = 23)	Posttest (n = 23)	p-Value	Effect Size Cohen's d
Asymmetry hamstring, %	20.26±10.25	9.20±3.51	0.001*	1,153
Agility, s	11.46±1.25	10.86±1.07	0.001*	0,763
Leg power, watt	2886.26±786.65	3121.22±774.96	0.035**	0.468

*Significantly different using the Wilcoxon test ($p<0.05$); ** Significantly different using the paired sample t test ($p<0.05$)

Table 2 shows that there were changes in the posttest results after 10 weeks of hamstring muscle strengthening training. The agility and leg power variables classified the changes as moderate, while the hamstring asymmetry variable classified them as large (Cohen's d > 0.8). The percentage change between before and after training for the hamstring asymmetry variable was 54.59%, agility was 5.24%, and leg power was 8.14%.

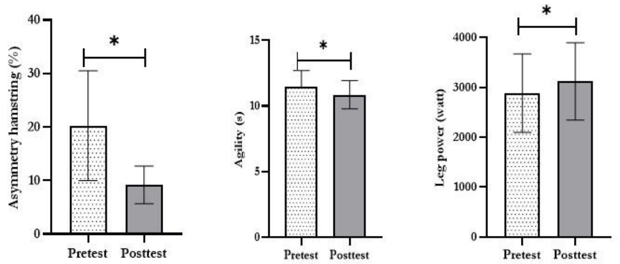

Figure 1. The changes in asymmetry hamstring, agility, and leg power after 10-Week Hamstring muscle strengthening training; (*) Significant difference ($p \leq 0.05$).

Figure 1 shows the changes in asymmetry in hamstring, agility, and leg power after the subjects were given 10-week hamstring muscle strengthening training. At the percentage asymmetry of the hamstring, there was a significant decrease, while agility did experience a significant reduction in time and leg power experienced a significant improvement.

Discussion

An asymmetry of more than 10% in hamstring conditions can significantly increase the risk of injury and skeletal muscle diseases, leading to a decrease in sports performance and limited mobility, resulting in reduced agility (Wiriawan *et al.*, 2024; Bishop, Turner and Read, 2018; Tucker and Hanley, 2017; Hoffman *et al.*, 2007). According to the research findings, 10-week hamstring muscle strengthening training has been shown to improve badminton athletes' hamstring asymmetry. This is justified by a statement by Howe et al.,(2014), which states that unilateral-based strength training can provide corrections against the asymmetry that an athlete may possess. According to the study conducted by Mrzygłód et al., (2021), using a 3-week body weight training program alongside one season of soccer training effectively decreased imbalances in the gluteal and hamstring muscles between the legs. Marchiori *et al.*, (2022) study also found that the stiff-leg deadlift exercise enhanced hamstring concentric strength and countermovement jump height in rugby athletes in a 5-week training program, and using the Nordic Hamstring exercise model, it improved eccentric hamstring strength and the fascicle of the long head of the biceps femoris. Providing a 10-week training programme using the stiff-leg deadlift (SLDL), unilateral stiff-leg deadlift (USLDL), Nordic hamstring exercise (NHE), and ball leg curl (BLC) exercises is a reliable way to train the hamstring muscles without causing any imbalances. These exercises activate the biceps femoris (BF), semitendinosus (ST), and semimembranosus (SM) muscles in a similar manner. Thus, during the initial stages of recovery after an injury, it is recommended to start with exercises such as SLDL (single-leg deadlift), USLDL (unilateral stiff-legged deadlift), and BLC (bilateral leg curl) that have lower activation levels before progressing to the NHE (Nordic hamstring exercise) (Guruhan et al. 2020).

Problems with mobility or stability around the weaker branch may often drive bilateral asymmetry, thereby reducing its capacity to develop strength. Both showed poor movement strategies during the exercise treatment in subjects with less wrist dorsophlexion (Mauntel et al. 2013). In another study, the subjects used increased medial knee displacement to compensate for hipomobility of the ankle, which led to a decrease in gluteal EMG activity relative to hip adductors (Padua, Bell, and Clark 2012). However, if an athlete has a unilateral deficiency in wrist dorsophlexion, then focusing on building strength through one-legged exercises without first addressing measures to improve wrist dorsiflexion may lead to suboptimal outcomes.

People widely recognize Swiss-ball exercises for their ability to improve strength, endurance, flexibility, coordination, and balance (Agina Widyaswara Suwaryo, Santoso, and Utoyo 2023). These exercises challenge the neuromuscular system by introducing an unstable surface, which requires increased muscle activation and proprioceptive demands (Ravichandran et al. 2020). This type of training can enhance overall physical function, making it particularly suitable for sports that involve rotational movements and require momentary strength and speed, such as baseball, badminton, golf, and hockey. A Swiss ball is a therapy tool that is utilized to enhance muscle tone, balance, control, structure, and coordination of movement, resulting in increased activation of the musculature (Kamatchi et al. 2020). The Swiss ball hamstring curl exercise engages the hamstring muscles, specifically the biceps femoris and semitendinosus, when the knees are extended (Monajati et al. 2017). Pietraszewski *et al.*, (2020) state that the glute muscles exhibit the most significant asymmetry between the right and left sides of the body, while the quadriceps muscles display the least amount of imbalance. These findings indicate a heightened requirement for engaging the gluteal and hamstring muscles. In SEnhancing the symmetry of hamstring strength can effectively improve agility and sprint performance by optimizing the effectiveness of alternating limb movements (Jiang et al. 2023).

The stiff-leg deadlift, on the other hand, is a compound exercise that primarily targets the posterior chain, including the hamstrings, gluteal muscles, and spinal erectors (Martín-Fuentes et al. 2020a). Studies have demonstrated the effectiveness of this exercise in enhancing eccentric hamstring strength, a vital component for preventing injuries and enhancing athletic performance. The stiff –leg deadlift is an exercise usually performed to enhance the lower limb muscles, notably the biceps femoris, semitendinosus (hamstrings), and gluteus maximus. Based on this systematic review of the sEMG activity in the stiff –leg deadlift exercise and its derivatives, it has been established that other muscles such as the erector spinae and quadriceps are more active than the hamstrings and gluteus maximus; however, some studies have found conflicting results. A deadlift workout incorporates a movement that might have a transference into daily life tasks; it is also known as one of the greatest compound lifts as it involves numerous muscle groups in coordination. A large spectrum of stiff –leg deadlift variants has been reported; thus, varied uses for these exercises could combine, including health, rehabilitation, and performance situations (Martín-Fuentes, Oliva-Lozano, and Muyor 2020b).

The stiff –leg deadlift exercise will elongate the hips and knees as it targets the hamstrings from a more extended position. This places the hamstrings in a rather unfavourable position when it comes to achieving full extension at the peak of the deadlift. The stiff-leg deadlift primarily targets hip extension and specifically activates the Biceps femoris long head, which is the knee flexor muscle most commonly prone to injury (Bourne et al. 2018; Opar, Williams, and Shield 2012). By combining the Swissball Hamstring Curl and Stiff-Leg Deadlift exercises, athletes may be able to address several key factors that contribute to athletic performance and injury risk. The unstable nature of the Swissball Hamstring Curl challenges the neuromuscular system, enhancing balance, coordination, and proprioception, which are essential for agility and change of direction (Gidu et al. 2022). The stiff-leg deadlift, with its emphasis on eccentric hamstring strength, can help mitigate hamstring asymmetry, a common issue that may lead to increased injury risk and compromised performance. Furthermore, the combination of these exercises may have a synergistic effect on leg power development. The Swissball Hamstring Curl requires the athlete to generate force in an unstable environment, which can translate to improved power output during dynamic movements (Marquina et al. 2021). Additionally, the stiff-leg deadlift targets the posterior chain, which is a critical contributor to overall leg power and athletic performance.

Conclusion

The strategic combination of Swissball Hamstring Curl and Stiff-Leg Deadlift training for 10 weeks can provide a comprehensive approach to enhancing agility, mitigating hamstring asymmetry, and developing leg power in athletes who experience hamstring asymmetry ≥10%. These exercises challenge the neuromuscular system, improve balance and coordination, and target key muscle groups responsible for athletic performance and injury prevention. The research results recommend combining stiff-leg deadlift and Swiss ball hamstring curl training, with a training dose based on a percentage of 1 RM, to minimize injury risk and enhance the strength, agility, and power of the athlete's legs.

Acknowledgements

I would like to thank Sony Badminton Training, PB Trisula, and Fifa Badminton Club for allowing their athletes to participate in this research. I would also like to thank Universitas Negeri Surabaya for funding this research.

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