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THE EFFECTS OF UNILATERAL AND BILATERAL PLYOMETRIC TRAINING ON UNTRAINED MALE UNIVERSITY STUDENTS

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Abstract

Introduction. In many sports the quality and efficacy of the movements performed are highly related to the athlete's power, strength, endurance, speed and coordination. A common example of a movement that puts a great demand on the athlete's physical abilities is jumping. There are many examples of sports in which jumping movements and exercises are highly utilized, and these sports typically require an athlete to have excellent explosive leg power (Adams et al., 1992; Chu, 1996).

The study objective was to determine the effects of unilateral and bilateral plyometric training on leg power, speed and back and leg strength in male university students.

Methodology. Twenty-four untrained but physically active male university students (age 19-24 years) were recruited and randomly assigned into 2 groups, the Unilateral Group (n=12) and Bilateral Group (n= 12). Height, weight and body mass index (BMI) of subjects along with leg power (vertical jump and broad jump), speed (30 m sprint) and back and leg strength (pull dynamometer) were done before and after the 6-week program for pre- and post-test. The unilateral and bilateral groups underwent plyometric training for the period of 6 weeks, with a frequency of 2 sessions per week. The unilateral group did only unilateral plyometric exercises (single leg) whereas bilateral group did only bilateral plyometric exercises (both legs simultaneously). Data was processed with SPSS software version 26.0 for paired and independent *t*-test.

Results. After 6 weeks of training the unilateral group had significant increases in vertical jump and back and leg strength ($p<0.05$), whereas the bilateral group had significant improvements in all tests ($p<0.05$). There were however no significant differences between the groups in the results of the unilateral group and bilateral group for all tested variables ($p>0.05$). The results suggest that both types of plyometric exercises were effective in improving vertical jump and strength of untrained individuals. However, there may be a slight benefit in bilateral plyometric exercises over unilateral exercises in untrained individuals. Overall, it is advised to incorporate both types of exercises in a jump training program.

***Keywords*:** untrained students; bilateral and unilateral plyometric training. INTRODUCTION

Plyometrics, also known as jump training, are exercises that train the muscles to produce maximal forces in the shortest amount of time. This training focuses on learning to move from a muscle extension to a contraction in a rapid or "explosive" manner, such as in specialized repeated jumping (Chu, 1998). Plyometric training is widely used in many different sports such as volleyball, basketball and track and field to improve an athlete’s power. The term plyometrics was first coined by Fred Wilt after watching Soviet athletes prepare for their track and field events. In the original version of plyometrics created by Yuri Verkhoshansky, the method was defined as shock method. The original plyometric training involved athletes dropping down from a height to absorb shock upon landing (eccentric contraction), followed by concentric contraction where the athlete immediately jumps upwards (Verkhoshansky, 1966).

Plyometrics could be done either unilaterally or bilaterally. Unilateral exercises or single-leg exercises are exercises that are done by alternating loads on right and left leg alternately or just repeating the movements with one leg. Bilateral exercises or double-leg exercises on the other hand are exercises that are done by using both legs simultaneously.

There are many exercises and movements that are introduced as plyometrics over the years. Though many studies have been done regarding the effects of plyometrics, few have been done by classifying the movements and the effects of the exercises on specific aspects of athletic performance. This study is proposed to provide an insight on the specific modality of plyometric exercises (Unilateral or Bilateral) in improving different aspects of exercise performance in untrained physically active students.

Jumping is an important movement that is present in many sports such as high jump, rebounding in basketball and spiking in volleyball. Therefore, many research has been done to identify parameters involved in vertical jump and proper training to develop it. Investigators have identified the importance of maximal rate of force production on maximal jumping performance (Rahimi and Behpur, 2005).

The ability to produce force in the form of speed-strength is known as power (Yessis, 2009). Power represents the amount of work done per unit of time. In the case of athletic performance, an increase in power allows an athlete to perform well in sports that require the ability to perform an action as quickly as possible.

It has been shown that resistance training improves measures of maximum strength, power and jumping ability (Arazi and Asadi, 2011). Weight training has been shown to improve vertical jump to a certain degree (Adams et al., 1992). However, it is found that doing weight training in a lighter and more explosive manner elicited better improvements in vertical jumping than heavier, slower lifts (Hakkinen et al., 1985). The quicker more explosive resistance exercises such as jump squats, power cleans or snatches are often used in sports to improve explosive power (Baker, 1996). These exercises require more rapid execution with lighter loads, allowing for general strength qualities to be converted into more specific strength qualities such as explosive power. However, it has been discovered that specific resistance training for maximal power elicited rather similar results on explosive movements (jumping, sprinting etc.) compared to that of a conventional resistance training program that is combined with plyometrics (Lyttle et al., 1996).

Jump training is often done by combining plyometrics and strength training for maximal performance improvements (Fatoruos et al., 2000) often showing better outcomes when combined (Adams et al., 1992). Applied separately, plyometric training group showed significant increase in maximal power production in countermovement jump and ballistic leg

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press which the resistance training group did not (Vissing et al., 2008). This suggests that plyometric training may have a significantly better effect on maximal power production as compared to conventional strength training.

Plyometrics are exercises that involve stretching an active muscle prior to its shortening have been shown to enhance performance during the concentric phase of muscle contraction. This effect has been attributed to the ability of muscles to release elastic energy stored in the muscles during the stretch. The ability of the muscle to store and utilize the elastic energy depends on the speed of stretch, length of stretch, force at the end of the stretch, and length of time the stretch is held (Bosco, 1981). Chu (1998) has classified jumping exercises into 6 types, namely jump in place, standing jumps, multiple hops and jumps, bounding, box drill and depth jumps. Plyometric exercises forms, also include counter- movement jumps (CMJ), drop jumps (DJ) and squat jumps.

The effects of plyometric training may differ depending on various subject's characteristics such as training level, age, gender, sport activity and familiarity with plyometric training. Other factors that may affect the results of the training include intensity level, duration, volume and intervention duration which may last from 4 to 12 weeks (Adams et al., 1992; Macaluso, 2012; de Villarreal et al., 2008; Makaruk et al., 2011).

The small number of studies regarding the effects of plyometrics on sprinting showed rather inconsistent results. There are studies showing no improvements in sprint times after a plyometric training intervention done by Fry (1998), Lytle (1996) and Wilson (1993). However, the plyometrics done in these researches were not specific to sprinting. On the other hand, improvements in 10 and 100m sprint timings were observed in research where more sprint specific plyometric exercises were used (Delecluse, 1995). Stretch shortening cycle in bounce drop jump and countermovement jumps were also found to be significantly related to sprint performance in female athletes (Henessy and Kilty (2001).

Training modalities wise, unilateral type resistance training has gained a little more popularity in strength and conditioning in the recent years (McCurdy et al., 2004). These unilateral exercises are typically used as assistance exercises after bilateral compound movements have been done. The effects of bilateral exercises such as back squats have been well established and widely used in strength and conditioning (Chelly et al., 2009; Speirs et al., 2016).

The back squat is performed with both legs, however, many sports movements such as sprinting or unilateral jumping are done by applying force unilaterally. It could be speculated that given the specificity; training unilaterally may be more effective for these movements. Specificity of training has always been an important aspect of a training program design (Stone and O'Bryant, 1987). Greater similarities between training exercises and physical performance variables have been considered to maximize training effect transfer (Behm,1993).

Researches have shown that there is a bilateral deficit where bilateral exertions are usually less than the sum of unilateral exertions done separately (Henry and Smith 1961; Howard and Enoka 1991). It is also found that bilateral deficit is reduced in bilateral strength training and increased in unilateral strength training (Taniguchi, 1997).

Stannard (1997) has indicated that single leg plyometrics brought greater improvements in unilateral jump tests whereas bilateral training led to similar improvements in both unilateral and bilateral jump tests. Delcore et al. (1998) had findings which suggested that unilateral plyometrics training are more effective in improving power abilities observed in bilateral tests. McCurdy et al. (2005) reported that in the unilateral jump tests, the unilateral group performed

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better than the bilateral group whereas in bilateral tests, both groups performed relatively the same. There are indeed inconsistencies among the studies conducted on this matter. The said it true for both trained and untrained individuals.

STUDY OBJECTIVE

The objective of the study was to determine the effects of Unilateral and Bilateral Plyometric Training on male untrained university students in terms of power, sprinting and strength performance.

METHODOLOGY

An experimental study design was adopted in this study. This study was a randomized trial and it was conducted in University Sains Malaysia Health campus (Kubang Kerian).

Population and sampling size

The intended population were healthy male university students from Universiti Sains Malaysia Health Campus. Purposive sampling method was used because the target population were male healthy university students only. The subjects were approached and asked personally or in groups at the sports complex. Social media was also used to promote participation in this study

Based on a previous similar study, the response within each subject group was normally distributed with standard deviation of 3.7 and a difference in mean of 5.0.

Using Statistical power of 0.80 and confidence level of 95%, the number of sample size obtained was 20 (10 per group). Adding 20% for potential dropout rate, the sample size was increased to 24. Therefore, a total of 12 subjects were recruited for each group.

Inclusion criteria were based on the following: healthy with no recent injuries' male physically active (but not involved in the structured sports training) University students aged between 18 and 25 years and BMI range of 18.5 to 25.0 kg/m^2

Exclusion criteria: candidates could be excluded if nursing chronic or recently suffered moderate to severe physical injuries, or having history of severe musculoskeletal injury.

Withdrawal could be initiated if participant missed more than 2 training sessions, has physical complications during the intervention period (injuries, sickness etc.) or personal reasons.

Data Collection

The data collection begun after getting ethical approval from Research Ethics Committee (Human) USM (protocol USM/JEPeM/18020149, dated 04/06/2018).

During the recruitment process, potential participants were explained regarding study purposes, nature of the study, benefits, risks and procedures. If they fulfil all the inclusion criteria, and were willing to take part in the study, they were asked to sign the informed consent form. Participation was voluntary and the participants were allowed to withdraw from the study at any time during the course of the study.

The participants were be randomly assigned into 2 groups: the bilateral group and the unilateral group**.** Randomization was done by using research randomizer on www.randomizer.org.

Training Intervention

Training was conducted for 6 weeks 2 times a week with 2-3 days rest in between the sessions. Each exercise was performed with 2-3 minutes of rest between sets (except for vertical jumps).

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For vertical jumps with 2 step approach, 20 - 45 seconds were given as rest after 1 set. Exercises were changed or alternated every 2 weeks (Table 1).

Table 1. Training intervention for Unilateral and Bilateral plyometrics groups

	Unilateral group*	**Bilateral group**
	Week 1-2	**Week 1- 2**
1	Side to side ankle hops (3 x 12 reps)	Side to side ankle hops (3 x 12 reps)
2	Step jumps (3 x 10 reps)	Squat Jumps on steps (3 x 10 reps)
3	Alternate leg bounding (4 x 6 reps)	Broad Jumps (4 x 6 reps)
4	Standing vertical jump off one leg (4 x 4 reps)	Standing vertical jump (4 x 4 reps)
5	Horizontal hops (3 x 15 reps)	Horizontal hops (3 x 15 reps)
	Week 3-4	**Week 3-4**
1	Horizontal hops (3 x 15 reps)	Horizontal hops (3 x 15 reps)
2	Alternate leg Lunge Jump (3 x 5 reps)	Half-Squat jumps (3 x 10 reps)
3	Single leg tuck jump (4 x 6 reps)	Tuck Jumps (4 x 6 reps)
4	Power skip for height (3 x 10 reps)	Step jump (3 x 10 reps)
5	Vertical jump with 2 stride approach (12 x 1 reps)	Vertical jump with 2 step approach (12 x 1 reps)
6	Drop jump off low platform (20 - 30 cm) (4 x 4 reps)	Drop jump off low platform (30- 45 cm) (4 x 4 reps)
	Week 5-6	**Week 5-6**
1	Alternate leg lunge jumps (3 x 6 reps)	Horizontal hops (3 x 18 reps)
2	Power skip for height (3 x 10 reps)	Broad Jumps (3 x 8 reps)
3	Single leg tuck jump (4 x 6 reps)	Tuck jumps (4 x 8 reps)
4	Alternate leg bounding (3 x 10reps)	Squat Jumps on steps (3 x10 reps)
5	Vertical jump with 2 stride approach (15 x 1 reps)	Vertical jump with 2 step approach (12 x 1 reps)
6	Drop jump off low platform (20-30cm) (4 x 5 reps)	Drop jump off low platform (30 - 45 cm) (4 x 5 reps)

***** For unilateral group, number of repetitions are for a single leg. A single set is counted only after exercises for both legs are completed. Rest was taken then.

Pre- and post- test

The pre-tests were conducted the week before the intervention program and the post-test were conducted on the week after the final training session. The tests were performed with 3 tries, with the best taken as the result. The participants were asked and guided to perform a dynamic warm up session for 5 minutes prior to conducting the tests. The tests performed were as follows: 30 m sprint test, standing vertical jump (jump and reach test), standing broad jump

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(standing long jump), back and leg strength test using pull dynamometer. Consort diagram is presented in Figure 1.

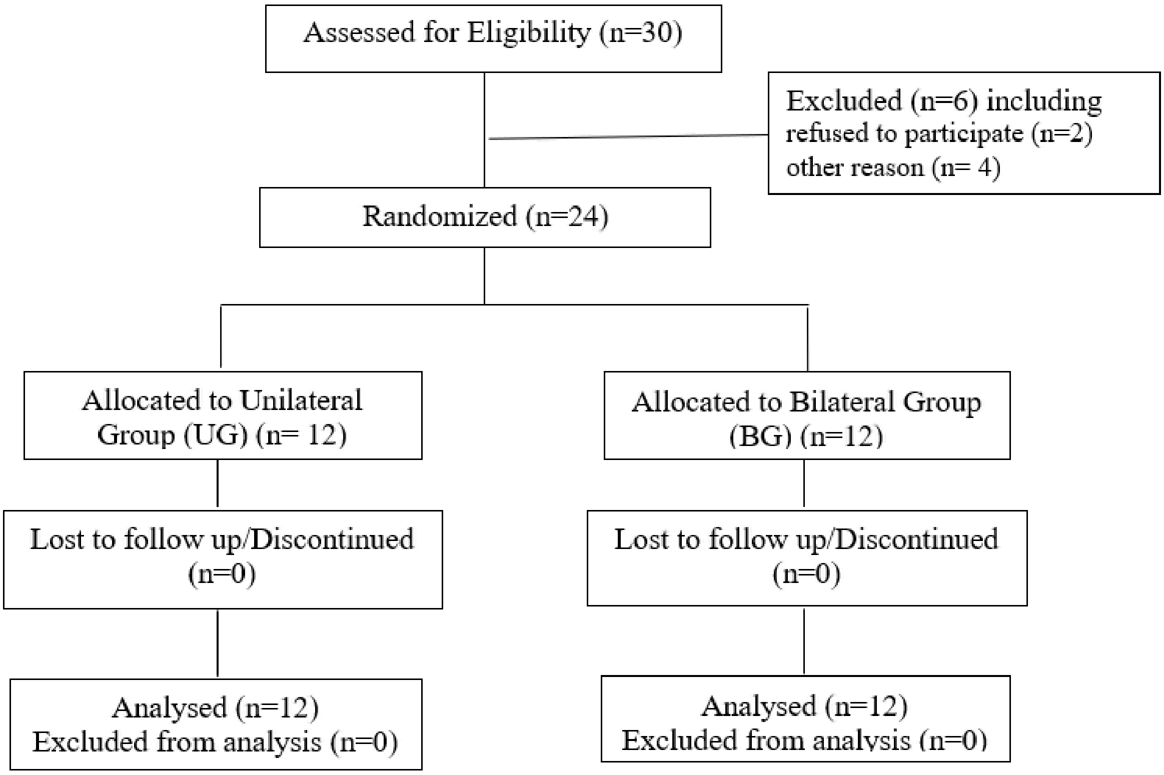

Figure 1: Consort Diagram showing flow of participants

Data Analysis

Data gathered was processed by using Statistical Package for Social Science (SPSS) software, version 26.0 for Windows. The data analysis will be conducted using mixed design ANOVA. Analysis for mean differences from pre to posttest were conducted using Paired *t*-test whereas independent *t*-test was used to determine any significant differences in mean difference between groups from pre- to post- test.

RESULTS

After a period of 6 weeks of plyometric training, a total of 24 subjects (Unilateral Group, n=12, Bilateral group, n=12) completed the study. There were no dropouts in the study.

Physical characteristics of participants

The demographic characteristics included age, body weight, height and body mass index (BMI). Data reflecting the participants' profile are presented in table 2.

Table 2: Demographic characteristics of the participants

Variable	Mean ± SD
Age (years)	21.9 ± 1.0

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Height (cm)	171.0 ± 8.2
Weight (kg)	67.04 ± 12.05
BMI (kg/m^2)	22.78 ± 3.08

Jumping performance

The results show there was a significant increase in vertical jump height for both groups from pre- to post- test (p<0.05) as shown by paired T-test. However, there were no significant differences in mean change for vertical jump between the groups (p>0.05) as shown by independent t-test. Results of vertical jump in subjects are presented in Table 3.

Table 3: Data analysis of jumping performance (cm)

Group	Pre-test	Post-test	Mean Difference	t value	p value
Standing Vertical Jump					
Unilateral	51.19 ± 8.58	53.84 ± 10.18	2.65	2.68	0.020
Bilateral	55.09 ± 14.30	58.59 ± 13.86	3.50	2.57	0.028
Standing Broad Jump					
Unilateral	2.11 ± 0.34	2.16 ± 0.34	0.05	1.56	0.146
Bilateral	2.15 ± 0.41	2.27 ± 0.43	0.12	4.24	0.020

For broad jump performance, the results showed that there was a significant increase in mean jumping distance for bilateral group in pre- to post-test (p<0.05), but no significant difference was found for unilateral group in pre- to post-test (p>0.05) shown by paired T-test. However, there were no significant differences in mean change for broad jump performance in between groups (p>0.05) shown by independent T-test. The mean results of broad jump of subjects are shown in Table 3.

Sprinting performance

The results show that there was a significant improvement (reduction) in 30 m sprinting time for bilateral group from pre to post test (p<0.05) as shown in paired T-test. However, no significant reduction in sprinting time was found for participants in the unilateral group from pre to post test (p>0.05) as shown in paired T-test. No significant differences were found in mean change of sprint times in between groups (p>0.05) as shown in independent T-test.
Mean results in 30m sprint is shown in table 4.

Table 4: Data analysis of 30 m sprint timing (s)

Group	Pre-test	Post-test	Mean Difference	t value	p value

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Unilateral	4.59 ± 0.28	4.54 ± 0.29	-0.05	-1.15	0.272
Bilateral	4.67 ± 0.45	4.52 ± 0.36	-0.16	- 2.25	0.048

Back and Leg Strength

The results showed a significant increase in back and leg strength (pull dynamometer) for both group from pre to post test (p<0.05) as shown in paired *T*-test. There were however, no significant differences in mean change of back and leg strength in between groups (p> 0.05) as shown in independent *T*-test.

Mean results in back and leg strength (pull dynamometer) is shown in table 5.

Table 5: Data analysis for mean back and leg strength with pull dynamometer (kg)

Group	Pre-test	Post-test	Mean Difference	*t* value	*p* value
Unilateral	125.46 ± 36.37	140.42 ± 33.97	14.96	2.63	0.022
Bilateral	103.64 ± 23.88	121.00 ± 30.00	17.36	2.57	0.028

DISCUSSION

Based on previous studies, it was discovered that unilateral plyometric training may induce better improvements in vertical jump performance and leg power after a short period (6 weeks) compared to bilateral plyometrics (Makaruk et al., 2011; Delcore et al., 1998; Stannard, 1997). It is speculated that in these studies, the better results from short term training in unilateral group may be due to more effective muscle recruitment in performing a movement unilaterally. Some sports physiologists believe that neuromuscular adaptations which contributes to power production may occur as early as the first 2-4 weeks of power training (Hakkinen, 1994). Van Soest et al. (1985) reported that the electromyographic activity of the gastrocnemius and vastus medialis during the concentric phase of a bilateral countermovement jump was 10- 20 % lower than that in a unilateral countermovement jump. In terms of force production and contact time, it is suggested that there is a difference between effect of unilateral and bilateral plyometric training due to difference in ground contact times. It is found that contact time in a unilateral jump is apparently longer than that in a bilateral jump which leads to leg extensors shortening at a higher rate in a unilateral jump and this suggests that lower force was produced based on the force velocity relationship (Bobbert et al. 2006; Islam et al., 2024). Since contact time and rate of force development are highly correlated, it may seem that unilateral plyometric training may be less efficient for training power as compared to bilateral. This effect may cause there to be a greater training effect for strength in unilateral plyometrics, whereas a bilateral plyometric program will supposedly have a better effect in terms of movement speed (Bogdanis et al., 2019). Although this speculation seems to correlate well with the results of sprinting speed for bilateral group (Drouzas et al, 2020), the same could not be said for strength improvements. Makaruk et al. (2006) also reported improvements in tasks specific to training groups, where unilateral group performed better in unilateral tasks, while bilateral groups tend to perform better in bilateral jumping tests. This ties in with concept of specificity of training. There are however, no unilateral specific tests in this study, therefore, that could be the reason for results that were slightly better in the bilateral group for bilateral tasks.

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Sprinting speed and agility appear to be highly correlated to ground contact time and can be trained by using plyometrics (Rimmer and Sleivert, 2000; Miller et al., 2006). Plyometrics appear to have greatest improvements on initial acceleration in a sprint. This is supported by the results from Delecluse et al. (1995), where sprint timings across the first 10m were improved to a greater extent compared to improvements in other phases of the sprint through concurrent plyometric and sprint training. In this case, neural and muscular adaptations occur to meet the specific needs of training (Behm & Sale, 1993; Mola et al., 2025). In relation to speed of movement, it is most likely that training effect occurring from plyometrics will have the most impact on the phase of a sprint that is similar in terms of velocity of contractions to the plyometric movements. Mero (1988) discovered that the ground contact times for the initial phase of a sprint is rather similar to that of bounding. This is supported by findings of Young (1992) who suggested that bounding could be a specific exercise used to develop acceleration in a sprint. This however, does not connect well with the results of this research, as unilateral group utilizing more sprint specific plyometric exercises (bounding and skipping) did not show significant difference in their sprinting performance. Rimmer and Sleivert (2000) however, did not discover significant difference between conventional sprint training and a rather sprint specific plyometric training on sprint times, despite utilizing both unilateral and bilateral exercises for the plyometric group.

Studies have reported that plyometric training can indeed improve measures of strength (Blakey and Southard, 1987; de Villareal et al., 2008; Singh et al., 2024). Markovic et al (2007), reported that more significant strength improvements were found in sprint exercises (unilateral) than that in bilateral plyometrics. As mentioned, this training effect was speculated be due to the slightly longer contact time in unilateral plyometric exercises, allowing for a slightly longer time under tension. This does not relate well to the results of this study as the bilateral group had a slightly higher mean change in strength results compared to unilateral group, although, no significant difference was found between the groups. Overall, in terms of strength gains, plyometrics are considered less optimal than conventional strength training or weightlifting. Wilson et al. (1996) reported that jumping with a barbell or conventional resistance training yielded significantly better strength improvements compared to plyometric training. Therefore, it can be speculated that plyometric training is less optimal to build strength as the ground contact time and time under tension of muscle when performing plyometric exercises are significantly lower than that in conventional resistance training. When compared to time under tension in a resistance exercise (a few seconds), the slight difference between unilateral and bilateral plyometric contact time (<1second) will most likely be insignificant. However, it is suggested that strength gains from plyometric training may come from the enhanced coordination and the ability to quickly increase muscle tension for a greater rate of force development (Clutch et al.,1983).

The results of this study may also have been affected by the subject's training level in all different areas tested. It is a well-known fact that untrained individuals may experience significantly greater effects of training in the first few weeks of training compared to trained individuals in all aspects of training (Blair and Connelly, 1996). A major part of the improvements in untrained individuals during the initial weeks of ballistic-type strength training is probably due to neural adaptations, such as increase in rate of motor neuron firing rates, improved synchronization in motor units, increased motor unit excitability, and increase in efferent motor drive. The reduced inhibition from antagonistic muscles as well as better co-activation of synergizing muscles may also explain this effect (Hakkinen, 1994; Reza et al., 2024). Since the participants of this study are mostly untrained (though rather active physically), it could be speculated that the significant improvements in almost all variables from pre- to

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post-test were mostly due to neural adaptations that occurs in untrained individuals in the first few weeks of training. The variable that may be impacted significantly by this effect may in fact be strength, since the training effect on strength was rather significant. It should also be noted that since the subjects were untrained, some of them may not be able to perform the exercises optimally even though familiarization was completed prior to testing/training. This could be especially true for unilateral group, since the higher ground forces on a single limb may pose as a challenge for them (especially in performing the exercises with optimal ground contact time).

CONCLUSIONS

This study was conducted to determine the effects of unilateral and bilateral plyometric training on male university students in Universiti Sains Malaysia Health Campus, Kelantan. The effects of unilateral and bilateral plyometric training were measured by assessing variables of power (vertical jump and broad jump), speed (30 m sprint) and strength (back and leg pull dynamometer). The major results of this study were that overall, unilateral plyometric training positively impacted vertical jump and lower body strength, whereas bilateral plyometric training positively impacted vertical jump, sprint speed, horizontal jump and lower body strength from a training period of 6 weeks with frequency of 2 sessions per week.

The results of this study suggest that plyometric training does indeed bring positive training effects on power and force production. Bilateral plyometrics appear to have a slightly better effect overall. However, it is important to note that plyometric exercises require a certain level of skill and coordination to properly execute. Ideally, a proper plyometric program should incorporate both unilateral and bilateral plyometrics for a wider variety of exercises. Utilization of proper equipment with good stability should also be used to prevent injuries from falling and allow for progression in terms of jumping height. Overall, plyometric exercises are considered to be effective and should be incorporated into sports training where power is a requirement.

RECOMMENDATIONS

The results of this study suggests that bilateral plyometrics may yield slightly better training results compared to unilateral plyometrics particularly in untrained individuals. Since this study was conducted on only physically active individuals, it can be suggested that studies can be done to determine the effects of plyometric training on strength in trained athletes vs untrained individuals. Studies may also be conducted to determine the differences between the types of plyometric exercises (hopping, bounding, standing jumps, drop jumps etc.). Plyometrics have been shown to produce greater results when paired with resistance training. This suggests that future studies can be conducted on specific plyometrics paired with specific resistance training.

Conflict of interests
Authors declare the absence of conflict of interests in relation to this research and publication.

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