COMPARISON OF THE EFFECTS OF LAND-BASED AND GRASS-BASED PLYOMETRIC TRAINING ON LEG POWER, MUSCLE ACTIVITY AND MUSCLE SORENESS AMONG ACTIVE YOUNG MALES

by

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Research Project Report Submitted For the Degree of Master of Science (Sports Science) For the Course Code GTS508

SCHOOL OF HEALTH SCIENCES

UNIVERSITI SAINS MALAYSIA

JULY 2018

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ACKOWLEDGEMENTS

I wish to thank my supervisor, Associate Professor Dr. Chen Chee Keong, for all of his guidance, time support in helping me to complete my Master Sports Science Programme. I am also grateful for his patience in reading and correcting this thesis for my research project. I also wish to thank my co-supervisor, Associate Professor Dr. Ooi Foong Kiew for all her guidance, time support in reading and correcting this thesis.

I wish to thank all my participants for their time, dedication and effort. Without them, this thesis would have been impossible. I would also like to take this opportunity to thank my fellow course mates and all the lecturers in Universiti Sains Malaysia for all the help that have been given to me throughout this programme.

ABSTRAK

PERBANDINGAN KESAN-KESAN LATIHAN PLIOMETRIK DI ATAS DARAT DAN RUMPUT TERHADAP KESAN-KESAN KUASA KAKI, AKTIVITI OTOT DAN KESAKITAN OTOT DALAM KALANGAN AKTIF LELAKI MUDA YANG AKTIF

Tujuan kajian ini adalah untuk membandingkan kesan latihan plyometric berasaskan rumput dan darat ke atas kuasa kaki, aktiviti otot dan kesakitan otot di kalangan lelaki muda aktif. Lapan belas lelaki muda telah terlibat dan mereka telah dibahagikan kepada dua kumpulan,iaitu kumpulan-kumpulan pliometrik berasaskan darat (Umur: 21.3 ± 1.6 tahun; ketinggian badan: 172,6 ± 3.7cm; badan berat: 65.8 ± 7.4kg; BMI: 22.1 ± 2.4 kg.m^{-2}; peratusan lemak badan: 16.6 ± 3.2%) dan rumput (Umur: 20.6 ± 1.9 tahun; ketinggian badan: 169,8 ± 2.3cm; badan berat: 64.4 ± 8.4 kg; BMI: 22.3 ± 2.9 kg.m^{-2}; peratusan lemak badan: 17.4 ± 2.6%). Peserta-peserta dalam dua kumpulan menjalani program latihan pliometrik yang sama selama 6 minggu (3 sesi seminggu). Pembolehubah-pembolehubah keputusan prestasi adalah kuasa puncak (lompatan menegak), kuasa purata (ujian isokinetik pada kelajuan sudut $180^{0}.s^{-1}$ dan $300^{0}.s^{-1}$), aktiviti EMG (lateralis vastus, medialis vastus, femoris rectus dan gastrocnemius sisi). Kesakitan otot anggota badan bawah ditentukan dengan menggunakan Visual Skala Analog (VAS). 'Paired t-test' digunakan untuk menganalisis semua parameter kecuali skala kesakitan otot yang dianalisis oleh 'repeated measures ANOVA'. Ketinggian lompatan menegak adalah lebih tinggi secara signifikan ($p<0.05$) pada pasca ujian dibandingkan dengan nilai pra ujian bagi kumpulan latihan berasaskan darat. Walaubagaimanapun, terdapat kecenderungan meningkat bagi parameter ini untuk kumpulan berasaskan rumput. Terdapat nilai-nilai kuasa purata 'knee extension' pada $180^{0}.s^{-1}$ and $300^{0}.s^{-1}$ yang lebih tinggi pada pasca ujian dibandingkan dengan pra ujian bagi kaki bukan dominan dalam kumpulan pliometrik berasaskan rumput. Dalam kumpulan pliometrik berasaskan darat, terdapat nilai-nilai kuasa

yang lebih tinggi bagi nilai purata ‘knee extension’ pada $180^0.s^{-1}$ bagi kaki dominan, $300^0.s^{-1}$ bagi kaki dominan dan bukan dominan, serta kuasa purata ‘knee flexion’ pada $180^0.s^{-1}$ bagi kaki bukan dominan. Kedua-dua kumpulan berasaskan rumput dan darat menunjukkan aktiviti EMG yang lebih tinggi secara signifikan bagi vastus medialis kaki bukan dominan pada pasca ujian dibandingkan dengan pra ujian. Tahap kesakitan otot adalah lebih rendah secara signifikan pada minggu kedua, kelima dan keenam dalam kumpulan latihan berasaskan rumput dibandingkan dengan kumpulan latihan berasaskan darat. Kesimpulannya, latihan berasaskan darat memberikan kesan baik latihan yang lebih nyata ke atas ketinggian lompatan menegak dan kuasa purata isokinetic ‘knee extension’ dan ‘fleksion’ dibanding dengan latihan berasaskan rumput. Walaubagaimanapun, latihan berasaskan rumput menyebabkan kesakitan otot yang lebih rendah. Maka, latihan pliometrik berasaskan rumput boleh menjadi alternative bagi individu-individu untuk meningkatkan kuasa kaki di samping mengurangkan tahap kesihatan kaki.

ABSTRACT

COMPARISON OF THE EFFECTS OF LAND-BASED AND GRASS-BASED PLYOMETRIC TRAINING ON LEG POWER, MUSCLE ACTIVITY AND MUSCLE SORENESS AMONG ACTIVE YOUNG MALES

The purpose of this study was to compare the effects of land-based and grass-based plyometric on leg power, muscle activity and muscle soreness among active young males. Eighteen young males were recruited and they were divided into two groups, i.e. land-based (Age:21.3±1.6 years old; body height: 172.6±3.7cm; body weight: 65.8±7.4kg; BMI: 22.1±2.4kg.m^{-2}; body fat percentage:16.6±3.2%) and grass-based (Age: 20.6±1.9 years old; body height: 169.8±2.3cm; body weight: 64.4±8.4kg; BMI: 22.3±2.9kg.m^{-2}; body fat percentage: 17.4±2.6%) plyometric training groups. Participants in both groups underwent 6 weeks (3 sessions per week) of same plyometric training programme. Performance outcome variables were peak power (vertical jump), average power (isokinetic testing at the angular velocities of $180^0.s^{-1}$ and $300^0.s^{-1}$), EMG activity (vastus lateralis, vastus medialis, rectus femoris and lateral gastrocnemius). Muscle soreness of the lower limb was determined by using Visual Analogue Scale (VAS). Paired t-test was used to analyse all the parameters except for scale of muscle soreness where repeated measures ANOVA was used. Vertical jump height was significantly higher ($p<0.05$) at pre-test compared to its p-test value in land-based training group. However, there was also trend of improvement in this parameter in grass-based group. There were significantly higher values of knee extension average power at $180^0.s^{-1}$ and $300^0.s^{-1}$ in post-test compared to pre-test values for non-dominant leg in grass-based plyometric group. In land-based plyometric group, there were significantly higher values of knee extension average power at $180^0.s^{-1}$ for dominant leg, $300^0.s^{-1}$ for dominant and non-dominant legs, and knee flexion average power at $180^0.s^{-1}$ for non-dominant leg. Both grass- and land-based groups exhibited significantly higher EMG activity of vastus medialis for non-dominant leg in post-test compared to pre-test. Degree of muscle soreness was significantly lower at second, fifth and sixth week in grass-based training group compared to land-based training group. In conclusion, land-based plyometric training provided more discernable beneficial training effects on vertical jump height and isokinetic knee extension and flexion average power compared to grass-based training. However, grass-based training induced lower muscle soreness. Therefore, grass-based plyometric training may be an alternative for individuals to improve leg power while reducing the degree of muscle soreness.

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CHAPTER 1

INTRODUCTION

Plyometric exercises that involve jumping, hoping and skipping are used primarily in increasing leg power and jumping ability (Leubbers et al., 2003, Markovic, 2007). There are also several studies that have investigated the effects of plyometric training on the anaerobic power of the leg muscles (Hubert and Tomasz, 2010; Poomsalood et al., 2015; Singh et al., 2015; Sozbir, 2016; Asadi, 2013). According to Albert (1991), plyometric exercises are defined as exercises involving eccentric muscular contractions and then followed by concentric muscular contraction performed rapidly, which has a greater muscle strength and power compared to a contraction without the eccentric phase.

Hubert and Tomasz (2010) have demonstrated that there were improvement in relative maximal output in counter movement jump and drop jump after subjects underwent a six weeks plyometric training. Poomsalood and Pakulanon (2015) were also demonstrated that there was significant improvement in speed, agility, and leg muscle power in the training group that have undergone four weeks of plyometric training programme. It was also shown that there was an increased in peak torque force of non-dominant and dominant legs of plyometric group as well as increased agility and vertical jump height from a study conducted by Singh et al. (2015).

The explanation behind this is the generation of absolute anaerobic power output depends on total muscle mass in especially the cross sectional for thigh muscle.

Another factor influencing maximal peak anaerobic power achieved by individuals rely on presence of the amount of type II muscle fibers (Hautier et al., 1996).Sozbir (2016) also showed that 6 weeks of plyometric programme was able to elicit improvement in vertical jump performance, electromyography activities of vastus lateralis, vastus medialis and gastrocnemius muscle during countermovement jump. Chmielewski et al. (2006) suggested that the rate and magnitude of loading modulates the stretch reflex output, with faster rates and higher magnitudes of loading contributing to an increased stretch reflex, and the stretch reflex can augment muscle activity in the loading phase of a plyometric exercise.

Plyometric training has an amortisation period to separate these two contractions. According to Komi (2000), stretch-shortening cycle (SSC) is a process that is related to the storage of elastic energy during muscle stretch (eccentric contraction) and its rapid release during the shortening movement (concentric contraction). Since plyometric training has been shown to induce some benefits to sports that require dynamic, and explosive type of movement, it is considered a useful training tool for the athletes (Arazi et al., 2012)., It has been demonstrated in a few studies that a minimum 6 to 10 weeks (more than 20 sessions) of plyometric training was able to enhance muscular strength and power (Fleck & Kraemer, 2004; Markovic, 2007; Soundara & Pushparajan, 2010). Besides that, according to Váczi et al. (2013), plyometric training, which involves jumping, hopping, skipping and bounding was able to improve dynamic muscular stabilisation. Unfortunately, this type of training that requires repetitive jumping and landing may lead to injury (Dufek and Bates, 1991).

Diallo et al. (2001) and Fatourous et al. (2000) suggested that there is a possibility of simultaneous development of maximal muscle power output and jumping ability through plyometric training. However there are some authors who stated otherwise (Aragon and Gross, 1997, Bartosiewicz and Wit, 1985). Maximal power output can be increased through performing the movement rapidly, while in regular jumping training the movement performance does not have to be that fast. In other words, exercise performance time is an individual parameter. Bartosiewicz and Wit (1985) stated that subjects achieved the maximum jump height with the widest range of counter movement, and their performance time was often longer than that when they generated the maximal power output. Variable such as training load (drop box height), number of rebounds, and length of intervals between sets of exercise are usually being focused in a plyometric training programme. However, they often lack precise instructions about the way the exercises should be performed. For example, speed and range of movement, body position during push off, etc. Precise performance instruction is important in preventing and avoid injury happens during plyometric training.

In an attempt to assess the effect of surface type on plyometric training, there are several studies using land based and aquatic based plyometric training on leg muscle power (Robinson et al., 2004; Stemm and Jacobson, 2007; Arazi and Asadi, 2011; Donoghue et al., 2011; Arazi et al., 2012). Several studies have indicated that aquatic plyometric training elicited the same degree of improvement in leg power compared to land-based plyometric training and can be an alternative for land-based plyometric training by having the same results (Robinson et al., 2004; Stemm et al., 2007; Arazi and Asadi, 2011; Arazi et al., 2012). Robinson et al. (2004) showed that aquatic plyometric training group provide the same training effects as land plyometrics with significantly less post-training muscle soreness. Stemm and Jacobson (2007) concluded that aquatic plyometric training was able to elicit same training effect as land-based plyometric training but with lower impact to the knees due to water buoyancy and resistance of the water upon landing. According to Arazi and Asadi (2011), there was a significant improvement in aquatic- and land-based plyometric group. Plyometric training performed on mini-trampoline may induce greater effect on stretch-shortening cycle mechanism compared to exercises performed on the ground (Ross, 1997). There is also a study on the effect or plyometric training on sand versus grass on muscle soreness (Singh et al., 2014). Their result showed that 4 weeks (3 sessions per week) of plyometric training on sand/non-rigid surface induces similar improvements in strength, endurance, balance and agility as on firm surface but induces significantly less muscle soreness.

To our knowledge, there are limited studies comparing land and grass based plyometric training on leg muscle activation and leg power. Therefore, this study was proposed to compare the effects of plyometric training on these two surfaces on muscle activation, leg power and muscle soreness.

1.1 OBJECTIVES OF THE STUDY

1. To compare the effect of land-based and grass-based plyometric training on anaerobic leg power.
2. To compare the effect of land-based and grass-based plyometric training on muscle activity.
3. To compare the effect of land-based and grass-based plyometric training on post-training muscle soreness.

1.2 RESEARCH HYPOTHESES

Ho_1 There is no significant difference in anaerobic leg power between land-based and grass-based plyometric training groups.

H_{A1} There is a significant difference in anaerobic leg power between land-based and grass-based plyometric training groups.

Ho_2 There is no significant difference in muscle activity between land-based and grass-based plyometric training groups.

H_{A2} There is a significant difference in muscle activity between land-based and grass-based plyometric training groups.

Ho_3 There is no significant difference in post-training muscle soreness between land-based and grass-based plyometric training groups.

H_{A3} There is a significant difference in post-training muscle soreness between land-based and grass-based plyometric training groups.

1.3 OPERATIONAL DEFINITIONS

1.3.1 Land-based plyometric training

It is a specialised, high-intensity training that allows athlete's muscles to deliver maximum strength in the shortest period of time so that development of power occur. (Radcliffe and Farentinos, 1999; Chimera et al., 2004). This plyometric training was implemented on a hard surface for 6 weeks (3 sessions per week).

1.3.2 Grass-based plyometric training

The same plyometric training as described for 'land-based' in section 1.3.1 was implemented on the grass field for 6 weeks (3 sessions per week).

1.3.3 Electromyography (EMG)

EMG was used to record muscle activation by attaching electrodes on the skin. Operationally, electrodes of the EMG were attached on quadriceps and hamstrings of the subjects and data for muscle activity was collected when performing the vertical jump at pre- and post-plyometric training.

1.3.4 Isokinetic power

Isokinetic power of the participants are the isokinetic average power of the knee flexion and extension of the dominant and non-dominant legs. The parameters were measured at angular velocities of $180^0.s^-1$ and $300^0.s^{-1}$ by using the isokinetic dynamometer (BIODEX, USA).

1.3.5 Muscle Soreness

Visual analogue scale (VAS) was used to determine muscle soreness. The participants were asked about the presence of localised pain in the quadriceps, hamstrings and gastrocnemius at the end of the plyometric training session.

1.3.6 Vertical Jump Test

Vertical jump height was used to determine the leg power. Participants attempted to touch the wall at the highest point of the jump. Participants made note of where they touched the wall by using a piece of chalk. The score is the distance between standing reach height and the maximum jump height.

1.3.7 Active individuals

Malaysian young males (physically active and aged between 19 to 25 years old were recruited as the participants in this study.

1.4 SIGNIFICANCE OF THE STUDY

It is hope that the findings of this study will provide scientific data on which type of plyometric training induces greater effect on leg power and muscle activity but less effect on muscle soreness. Therefore, these findings can be used for formulating guidelines in planning training programme for improving leg muscle power, leg muscle activity while reducing muscle soreness.

CHAPTER 2

LITERATURE REVIEW

2.1 PLYOMETRIC TRAINING

Plyometric training is normally used to improve explosive strength and prevent injury. The drills in plyometric training are derived from four basic skills that are common in training programmes. These basic plyometric drills are jumps, hops, bounds and shock drills (Radcliffe and Farentinos, 1985). It has been known that plyometric exercises have an amortisation period to separate eccentric muscular contractions followed by concentric muscular contraction. These muscular contractions are performed rapidly to generate great muscle strength and power compared to a contraction that only consists concentric muscular contraction. Stretch-shortening cycle is a process that is related to the storage of elastic energy during eccentric contraction and it is rapidly releases during the concentric contraction. Several studies have been carried out to determine the minimum duration for plyometric training and it was shown that a minimum of 6 weeks of plyometric training was required to enhance muscular strength and power (Fleck & Kraemer, 2004; Markovic, 2007; Soundara&Pushparajan, 2010). Although the exercises are not well established, the exercises have shown effectiveness in improving these variables (Villarreal et al., 2009).

According to (Chu, 1998), plyometric training has been described the combination of speed and strength to produce an explosive movement and an increase in power. Plyometric trainings have been widely used by every sport due to the combination of force and velocity development (Yessis, 1991). It has been shown that at least 6 to 10 weeks of plyometric training are sufficient to notice improvement in leg power (Potach and Chu, 2008). However, a study found that land-based plyometric may have greater risk in injury and muscle soreness compared to other surfaces such as aquatic plyometric training (Arazi et al., 2012). Many studies have reported the effects of plyometric training on improved sport specific skills such as agility (Miller et al., 2006) and vertical jump performance which is the common measurement of muscular power (Markovic, 2007).

Plyometric trainings were mainly used in conditioning activities during in-season and there must be specific to the skills needed for the activity being performed. Metabolic and neuromuscular specificity should be included in conditioning as stated in the Specific Adaptation to Imposed Demands (SAID) principle (Arnheim, 1985). Hence, coaches and strength specialists who incorporate this type of training to their training programme due to the clear benefits from plyometric training.

2.2 EFFECTS OF PLYOMETRIC TRAINING ON FITNESS COMPONENTS

Plyometric training is considered the most frequently used methods for the development of change of speed, type of locomotion, direction and power (Shiner et al., 2005). Plyometric training requires rapid stretching of muscle (eccentric) followed by a concentric movement of the same muscle and connective tissue. Thus, it is known as stretch-shortening cycle (Chu, 1998). Several studies have shown that plyometric training induces physiological changes such as increase in muscle strength and power (Fleck and Kraemer, 2004; Markovic, Jukić, Milanović, and Metikoš, 2007; Soundara and Pushparajan, 2010). According to Stemm et al. (2007), 6 weeks of plyometric training programme was able to increase vertical jump significantly. Besides that, plyometric training helps in improving the rate of generating maximal strength in the shortest time and this is a must when one is competing in high level of sport performance (Kilnzing, 1991). Dynamic muscular stabilisation can be improved by plyometric exercises such as jumping, hoping, skipping, and bounding (Váczi et al., 2013). Plyometric training should be considered the goal of training for competitions or combine with other training to improve fitness components. A minimum of 6 to 10 weeks plyometric training is needed to observe the improvement of muscular strength and power (Potach and Chu, 2008). However, Villarreal (2009) stated that 10 weeks or more (more than 20 sessions) plyometric training are recommended to maximise the chances of obtaining significant result.

Poomsalood and Pakulanon (2015) has conducted a pilot study on the effects 4 weeks of plyometric training on speed, agility, and leg muscle power in male university basketball players. Ten male basketball players (18-23 years old) were recruited for this study and it was found that there was significant improvement in leg muscle power, speed, and agility in the training group ($p<0.05$). The subjects went for 2 sessions of plyometric training a week for 4 weeks (each session lasted 35 minutes). The training volume ranged from 100 to 140 foot contacts. These investigators stated that the results may due to the quality of the modified training programme which was designed to match with basketball movement. Vertical jump test was used in this study to evaluate the leg power while T-test agility was used to evaluate the agility of the participants. However, there was no significant difference between control and experimental group due to the limited number of subjects. Nevertheless, this short-term training could be useful in preparatory phase of periodisation for basketball players. They concluded that, plyometric training was able to improve muscular, speed and agility.

Asadi (2013) conducted a 6 week in season plyometric training (2 days per week) on jumping and agility performance of basketball players. 20 healthy intermediate basketball players participated in the study. Vertec jump test was chosen when measuring vertical jump height. The test was performed twice and the best value was used for the analysis. The plyometric training group had increased vertical jump and standing long jump, 4X9 m shuttle run, agility T-test and Illinois agility test ($p<0.05$). According to Maffiuletti (2002), improvements in muscular performance after plyometric training was attributed to neural adaptation in the nervous system. High intense plyometric training able to maximise the use of stretch shortening cycle to improve jumping performance (vertical jump and standing long jump). Hence, during short term training such as pre-season, coaches might want to implement plyometric training to improve power and agility of the athletes.

Lehnert et al. (2013) conducted a study to investigate the effects of 6 weeks of plyometric training programme on explosive strength and agility in professional basketball players. 12 elite players were chosen to participate in this study. There were two training session a week from week 1 to week 4 whereas on the fifth and sixth week, the training session was increased to 4 sessions per week with the combination of resistance exercises for the upper body. According to the authors, there were no increase in Counter Movement Jump Free Arms (CMJFA) and Two Step Run Up Jump (TSRUJ) tests ($p>0.05$). Subject characteristics could affect the performance of CMJFA and the training effect may be varied depending on training level, sports activity, age, gender, familiarity with the exercises, level, programme design (Villarreal et al., 2009). Besides, the training duration may be too short for elite level of the subjects. Besides that, according to the authors, there was a low motivation and concentration on testing sessions during competition period that could lead insignificant of the study.

Váczi et al. (2013) investigated the effects of short-term high intensity plyometric training programme on strength, power, and agility in male soccer players. 24 male soccer players were assigned into 2 groups which was experimental group and control group. Experimental group performed plyometric training besides of regular soccer training sessions while control group attended only regular soccer training sessions. The programme included two training sessions per week at maximal intensity with unilateral and bilateral plyometric exercise (40-100 foot contacts per session). There were significant results ($p<0.05$) in both agility test, depth jump height and isometric torque. The author hypothesised that 6 weeks of plyometric training with maximal intensity which consists of unilateral and bilateral exercises, would produce improvements in power, strength, and agility in male soccer players. According to Sheffard and Young (2006), the factor that affect agility is development of muscle factors such as strength and power. Hence, increased in power performance is one of the factors that led to enhancement of agility.

2.3 EFFECTS OF PLYOMETRIC TRAINING ON MUSCLE ACTIVITY AND JUMP HEIGHT

Rezaimanesh et al. (2011) conducted a 4 weeks plyometric training programme on lower muscle electromyography (EMG) in futsal players. 14 subjects were recruited from futsal teams with an average age of 19.1- 22.6 years. The subjects participated in a 4 weeks (2 sessions per week) of plyometric training starting with light training on the first week and activities such as hurdle jump and depth jump were not performed. There was gradual increase of intensity starting from the second week onwards. Results showed that the plyometric training had a significant effect ($p<0.05$) on biceps femoris for the squat movement while insignificant ($p>0.05$) in the vertical jump. These results were different from other studies and the probable reasons were different participants, type of exercises uses, time of training and the type of muscles studied. Nevertheless, these authors concluded that plyometric training was able to increase in lower body muscle activity.

Sozbir (2016) stated that there were improvements in vertical jump performance and electromyography (EMG) activities of lower extremity muscles during counter movement jump after the subjects undergone 6 weeks of plyometric training. Flying times were measured using a jumping mat (Bosco Ergojump, FINDLAND) and the performance of vertical jump was determined by vertical take-off velocity. The muscle activations were traced by using electromyography by attaching electrodes on vastus lateralis, vastus medialis and gastrocnemius, of the dominant leg. The best out of three trials were recorded for analysis. There were 2 sessions of plyometric training and subjects were instructed to maintain daily activities and also avoid any other vigorous physical exercises. The author adopted the training programme from Miller et al. (2007) training volume ranging from 90 foot contacts to 140 foot contacts in a session. The result showed that there has significant improvement ($p<0.05$) of muscle activation in the experimental group. However, there were no significant increases ($p>0.05$) in vertical jump height. The authors have listed a few possibilities such as length of training programme (difference in training load and volumes used in the studies); lack of experience, the athletic ability and the specificity of the training; the speed of the movement during training that might affect such finding.

Ebben et al. (2016) conducted a study on the effect of low and high volume on jumping performance during plyometric training on 35 male experienced subjects. Subjects have to undergo a pre-test habituation session to ensure proper technique of each plyometric exercise in the programme. Then, they were randomly assigned to low volume or high volume plyometric training. The high volume group performed twice the foot contact as in low volume group. Both groups attended two sessions per week with 48-96 hours of recovery for 6 weeks. The authors reported that lower daily volume plyometric training was as effective as high volume training. Hence, low volume plyometric trainings were as effective in bringing positive effects. Besides that, performance will be enhanced when there is sufficient period of time for recovery after training. The authors stated that it was sufficient to prescribe low to medium volume of plyometric training since higher volume plyometric did not bring extra benefits.

Makaruk and Sacewicz (2010) conducted a study on effects of plyometric training on maximal power output and jumping ability. 44 non training students of physical education underwent 6 weeks of plyometric training (2 days of training per week). Results showed that maximal power output increased ($p<0.001$) in counter movement jump and depth jump.

However, there was no changes in the center of mass elevation and five-hop test distance length ($p>0.05$). The authors stated that plyometric training was able to improve maximal power output of the legs but not jumping height.

Aquatic plyometric training can be an alternative from land-based plyometric training and gaining attention in the literature due to buoyancy, resistance from fluid and hydrostatic pressure as key physical properties of water (Martel et al. 2005; Miller et al. 2007; Ploeg et al. 2010; Hasaloei et al. 2013) Athletes may encounter more resistance when performing plyometric training in water due to viscosity of water. There will be a different when subject performing a counter movement jump (CMJ) on water compare to on land due to kinetic specificity (Louder et al. 2016). According to Louder et al. (2016), jumping movement on land and in water have differences in flight time, mechanical power output for jumps. According to Donoghue et al. (2011), jumping movement on land and in water have differences in flight time, mechanical power output for jumps. Aquatic plyometric exercises able to reduce 62% in peak impact forces, impulse, and eccentric rate of force development.

Hasaloei et al. (2013) have conducted a study on the effects of 6 weeks aquatic plyometric training programme on vertical jumps in 10-14 years amateur children Taekwondo players. 26 subjects participated in the research and were divided into 2 groups which was aquatic plyometric group (APT) and control group. The APT group performed 6 weeks of plyometric exercise twice a week. There was a significant improvement ($p<0.05$) in vertical jump in APT group. Vertical jump was used as a measurement for leg power.

2.3 EFFECTS OF PLYOMETRIC TRAINING ON DIFFERENT SURFACES

Martel (2005) stated that the combination of aquatic plyometric training (APT) with volleyball training resulted in improvements in vertical jump. Due to the viscosity of water, aquatic plyometric may provide a different manner of stimulus compared to land-based plyometric training. These researchers recruited 19 female high school volleyball players (15 years old). The baseline of fitness was estimated by using submaximal cycle ergometry before the beginning of the study. Vertical jump was also used in this study to measure leg power. Leg strength was measured by using isokinetic peak torque. These subjects underwent 6 weeks (2 sessions per week) of APT which lasted about 45 minutes per session. The results showed that there were improvements in APT group compared to control group in vertical jump height while both groups showed improvements in concentric peak torque. However, APT group showed significant improvement ($p<0.05$) in concentric peak torque compare to the control group. The authors suggested that further investigations should assess on muscle soreness, muscle damage, skeletal muscle biochemistry, neuromuscular characteristics, and biomechanics that induced the adaptations observed.

A 4 week (3 sessions per week) study about plyometric training in comparing the muscle soreness on sand versus grass was carried out (Amrinder et al., 2014). The authors recruited 40 participants and they were divided into sand plyometric group and grass plyometric group. This study concluded that muscle soreness in sand based plyometric training group experienced less muscle soreness compared to grass group. There were no significant ($p>0.05$) differences in strength, endurance, balance and agility between the 2 groups. However, there was a significant ($p<0.05$) difference in muscle soreness for sand group.

Donoghue et al. (2011) conducted a crossover study in comparing the impact forces of plyometric exercises performed on land and in water. 18 subjects were recruited by the authors to participate in their study. Their results showed that there were significant reductions in peak impact forces (33%-54%), impulse (19%-54%), and rate of force development (33%-62%) in water compared with land for the majority of exercises in this study ($p<0.005$). These authors concluded that the level of force reduction varies with landing technique, water depth, and participants' height and body composition.

2.4 EFFECTS OF PHYSICAL TRAINING ON ISOKINETIC LEG POWER

Parrilla et al. (2011) conducted on a study comparing isokinetic strength in sports science students following 3 weeks of plyometric or isokinetic training. 24 participants were recruited by the authors and were divided into 3 groups (isokinetic exercises, plyometric group and control group). Variables such as knee extensor and flexor muscle peak torque, total work and average power of each leg were concentrically measured at the angular speed of $300^{o}\cdot s^{-1}$ using Biodex System 3 isokinetic dynamometer. These authors found that there were significant differences for peak torque ($p<0.05$), average power ($p<0.05$), knee extension of the right leg and peak torque knee extension of the left leg ($p<0.05$). The authors suggested that the current finding was due to the neural adaptations which predominate in short-term isokinetic training and the heavily implied the theory of training specificity.

A pilot study was conducted by Seynnes et al. (2014) to investigate the effects on low intensity training programme (posture-balancing mobility) on muscular function. The authors recruited 9 elderlies (74.3±6 years) to undergo posture-balancing mobility (PBM) training for 11 weeks (2 sessions per week) while another 9 elderlies performed aquatic exercises during the same period and with the same frequency. The mean power of the knee extension muscles increased slightly but significantly on the dominant ($p<0.05$) and non-dominant sides ($p<0.05$) in the PBM group with no significant fatigue index variation. The authors concluded that PBM group showed slightly enhanced strength production. However, the low statistical power does not conclude that this training causes significant improvements.

Zouita et al. (2018) conducted a study on comparing isokinetic trunk flexion and extension torques and power between athletes and non-athletes. 33 participants (18 high level male athletes, 15 male non-athletes) were recruited by these researchers. The tests included isokinetic trunk extension and flexion at the angular velocities of $60^{0}.s^{-1}$, $90^{0}.s^{-1}$ and $120^{0}.s^{-1}$.

Athletes group showed significantly higher trunk extension torque compare to non-athletes at $90^0.s^{-1}$ and $120^0.s^{-1}$ but not $60^0.s^{-1}$. There was no difference between the athlete and non-athlete groups in respect of trunk flexion torque or power at any angular velocity. However, the ratio of trunk flexion to extension strength was greater in non-athletes compare to athletes. The authors stated that these findings may due to the strength training exercises such as squats and deadlifts, or may be associated with greater athletic performance for higher level athletes.

According to Heiderscheit et al. (1996), 8 weeks (twice a week per session) of isokinetic training was able to enhance concentric/eccentric isokinetic power of the shoulder internal rotators. 78 female subjects were recruited by the authors and they were randomly assigned into 3 groups (control, isokinetic training and plyometric training). There were no significant ($p<0.05$) pre/postpower differences between the softball group and the three groups. While pre/postpower differences were significantly greater for the isokinetic group at $60^0.s^{-1}$ eccentric, $120^0.s^{-1}$ concentric and eccentric, and $240^0.s^{-1}$ concentric and eccentric. The authors suggested that these findings may be due to the physiological overflow within the concentric velocity spectrum. They concluded that isokinetic training was able to increase isokinetic power but not in functional testing such as softball throw.

According to above literature review, most of the studies have been carried out for a duration of 6 to 8 weeks to show improvements in leg power, agility, jumping height. Low to medium volume (40-100 foot contacts) of plyometric training should be given to the subjects. However, there is a concern on the effect plyometric training to muscle soreness and muscle damage. Nevertheless, there are not many studies have been done on investigating the effect of grass-based and land-based plyometric training on muscle activation, isokinetic power as well as muscle soreness. Thus, the present study was carried out.

2.5 EFFECTS ON PLYOMETRIC TRAINING ON MUSCLE SORENESS

Singh et al (2014) have reported that both sand and grass plyometric training induced similar degree of improvements in post-readings of strength, endurance, balance and agility. However, authors concluded that sand/non-rigid surface induces significantly less muscle soreness compared to grass/rigid surfaces. In another done by Robinson et al. (2004), land-based plyometric training carries an increased risk of muscle soreness due to the force generated during ground impact and intense plyometric contractions. In this study, the authors found that the results indicated a significantly higher perception of muscle soreness in land plyometric group when compared to the aquatic plyometric group for each muscle at 48 hours and 96 hours after a training bout.

Jamurtas et al. (2000) carried out a study to compare plyometric exercise on muscles soreness and plasma creatine kinase levels. The results of this study indicated that plyometric exercises produced a significantly higher perception of muscle soreness when compared with concentrically performed exercises but not difference when compared with eccentric exercises. According to the force–velocity relationship, each individual muscle fiber can exert a larger force while being stretched than it can while being shortened, fewer fibers are recruited to exert a given amount of force. Larger forces per muscle fiber developed during the eccentric contraction result in greater damage. It could be speculated that the eccentric phase of the plyometric exercises produces more microscopic damage to the muscle fibers, and hence propagating a higher degree of muscle soreness compared with concentric exercises. However, there were no significant difference in creatine kinase concentrations in plyometric exercises when compared with concentric and eccentric exercises.

Chapter 3

METHODOLOGY

3.1 PARTICIPANTS

In this study, eighteen young males, age between 19 to 25 years old were recruited. All the participants were fully informed by the researchers about the nature of the experiments, the purpose of the study, procedures, benefits, potential risks and discomforts that would be experienced in this study. All the participants were required to fill up the participants' information sheets and sign on the consent forms (Appendices A and B). The research design was approved by the Human Research Ethics Committee of Universiti Sains Malaysia (Appendix C).

The inclusion criteria for participation in this study were:

1. Participants must be aged between 19-25 years old
2. Participants should be exercising minimum twice a week

The participants were then randomly assigned to grass-based and land-based plyometric group using counterbalancing method by ranking the data obtained from pre-test (Figure 3.1).

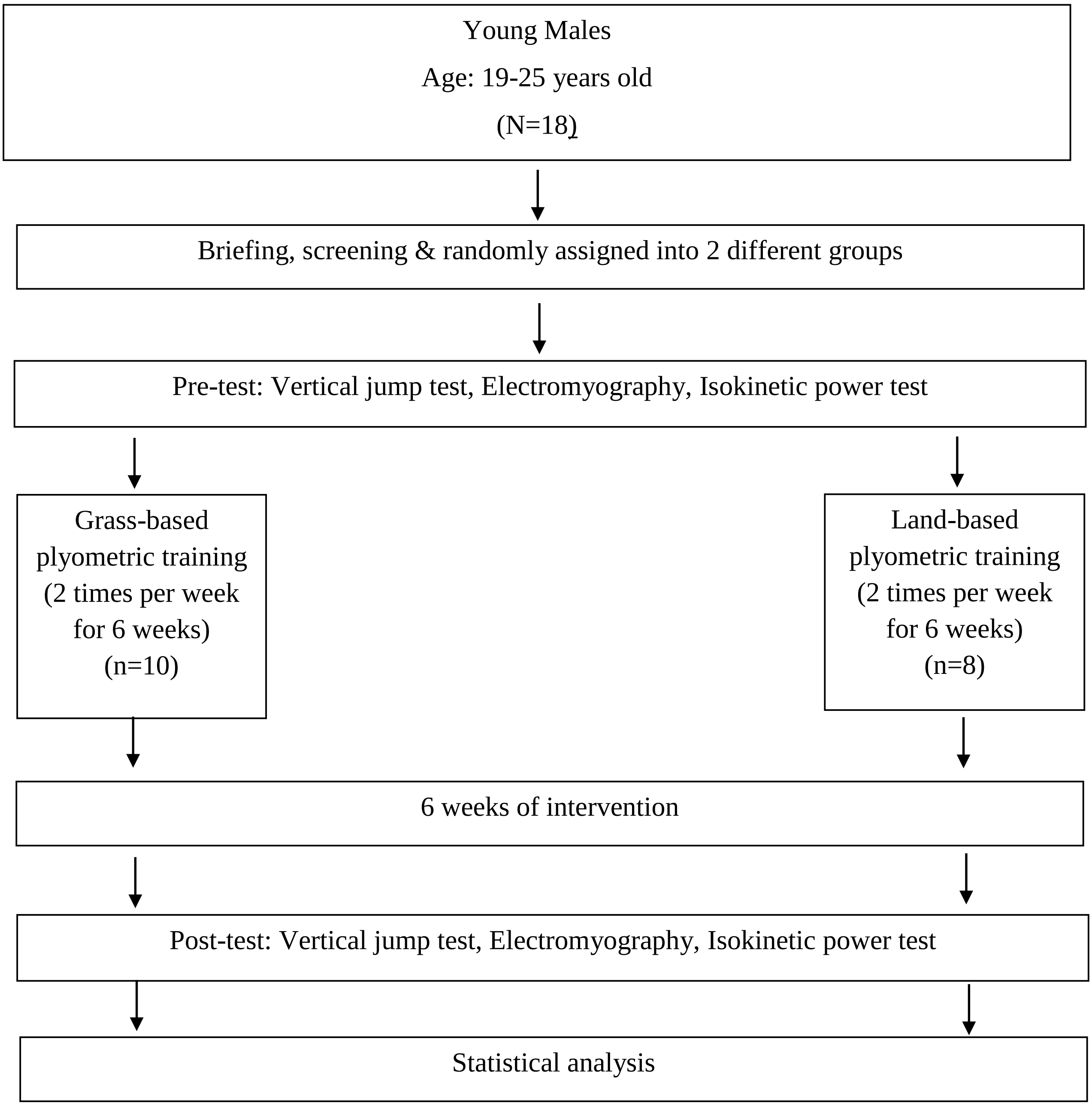

Figure 3.1: Experimental Design

3.2 SAMPLE SIZE CALCULATION

The sample size used in this study was calculated by using GPower software. The power of the study was set at 80% with 95% confidence interval, and the effect size was set at 0.30 with two study groups. The total number of participants calculated was 24 participants. Since two groups of participants were required to be recruited, therefore 12 participants would be recruited for each group.

3.3 TEST PROCEDURES

The pre- and post-tests involved 2 tests which were vertical jump and isokinetic power measurements for each participants. The participants were asked to perform a vertical jump with electrodes of EMG attached on their vastus lateralis, vastus medialis, rectus femoris and lateral gastrocnemius. Participants were then required to perform isokinetic test for knee flexion and extension for both legs (Appendix E).

3.3.1 Vertical Jump Test

Vertical jump height, defined as the difference between standing reach height and the maximal jump height, was measured in all participants at baseline and 6 weeks. Briefly, the initial reach height of each participant was determined by having them stand, with feet flat, in a designated area adjacent to the wall with their dominant arm raised as high as possible. Each participant was then given an opportunity to perform two to three submaximal practices countermovement jumps. After a 2–3-min recovery, each participant performed three separate maximal vertical jump attempts. Although participants were allowed to squat and swing their arms during each maximal attempt, they were required to maintain their feet within the designated area for all pre-jump movements. The highest of the three vertical jump attempts for each participant was recorded for data analysis. The intraclass correlation coefficient for the vertical jump test was 0.9293 ($p < 0.9633$) and the test-retest reliability was $r = 0.93$ ($P < 0.001$) (Appendix H).

3.3.2 Electromyography (EMG)

Electrodes of EMG (ME 6000 Biomonitor) were attached on the participants' vastus lateralis, vastus medialis, rectus femoris and lateral gastrocnemius (Appendix H). The peak of the muscle activity data for each muscle were recorded when performing the vertical jump. Thorough skin preparation for all recording electrodes included removal of body hair and dead epithelial cells with a razor and cleansing of the designated areas with alcohol swap. Bipolar surface electrodes were placed along the longitudinal axes and muscle belly of the selected muscle at an interelectrode distance of 20 mm for vastus lateralis, vastus medialis, rectus femoris and gastrocnemius. The EMG system bandwidth was between 10-600 Hz with an overall 1200 Hz in order to assure the capturing of the entire signal. After the signals have been recorded, 10-15 Hz high-pass filter was used to eliminate the movement artifacts. On the other end, low pass filter with cut-off of 600 Hz for surface EMG was used as an anti-aliasing filter.

3.3.3 Isokinetic Power Measurement

An isokinetic dynamometer (Biodex multi-joint system 3 pro, New York) was used to measure the participant's dominant and non-dominant knee extension and flexion muscular power at 2 angular velocities, i.e., $180^0.s^{-1}$and $300^0.s^{-1}$. The procedure was fully informed to all the participants before performing the test. They were required to do 10 repetitions for the

$180^0.s^{-1}$ angular velocity and $300^0.s^{-1}$ angular velocity, with 10 seconds to rest between each angular velocity. The isokinetic parameters of the participants are the isokinetic average power of the knee flexion and extension of both legs (Appendix H).

3.3.4 Muscle Soreness

The visual analogue scale (VAS) of muscle soreness was used to measure the perception of muscle soreness, the participants were asked about the presence of localised pain in the quadriceps, hamstrings and gastrocnemius at the end of the third plyometric training session on each week (Appendix F).

3.3.5 Plyometric Training Programme

The plyometric training programme was adapted from Miller et al. (2007) (Appendix G)(Table 3.1).

3.4 STATISTICAL ANALYSIS

Statistical analysis in this study was performed by using the Statistical Package for Social Science (SPSS) version 24.0. All values were presented as means ± standard deviations (SD). Paired t-test was used to analyse all the parameters except for scale of muscle soreness where repeated measures ANOVA was used. The statistical significance was accepted at $p<0.05$.

Table 3.1: Plyometric Training Programme

Training Week	Training Volume	Plyometric Drills	Sets x Repetitions	Training Intensity
1	90 jumps (2-3 min rest interval)	Side to side ankle hops Standing jump and reach Front cone hops	2 X 15 2 X 15 6 X 5	Low Low Low
2	120 jumps (2-3 min rest interval)	Side to side ankle hops Standing long jump Later jump over barrier Double leg hops	2 X 15 2 X 15 6 X 5 10 X 3	Low Low Medium Medium
3	120 jumps (2-3 min rest interval)	Side to side ankle hops Standing long jump Later jump over barrier Double leg hops Lateral cone hops	2 X12 2 X 12 6 X 4 8 X 3 2 X 12	Low Low Medium Medium Medium
4	140 jumps (2-3 min rest interval)	Sigle leg bounding Standing long jump Lateral jump over barrier Lateral cone hops Tuck jump with knees up	2 X 12 3 X 10 8 X 4 3 X 10 4X 6	High Low Medium Medium Medium
5	140 jumps (2-3 min rest interval)	Single leg bounding Jump to box Double leg hops Lateral cone hops Tuck jump with knees up Lateral jump over barrier	2 X 10 2 X 10 6 X 3 2 X 11 6 X 5 3X 10	High Low Medium Medium High High
6	120 jumps (2-3 min rest interval)	Jump to box Depth jump to prescribed height Double leg hops Lateral cone hops Tuck jump with knees up Lateral jump single leg	2 X 11 4 X 5 6 X 3 2 X 10 4 X 5 2 X 10	Low Medium Medium Medium High High