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THE EFFECT OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) VERSUS FOAM ROLLER AS RECOVERY MODALITIES ON MUSCULAR POWER OUTPUT



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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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FACULTY OF SPORT SCIENCE AND COACHING
UNIVERSITI PENDIDIKAN SULTAN IDRIS

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ABSTRACT

This research aimed to determine and compare the effect of Transcutaneous Electrical Nerve Stimulation (TENS) versus foam rolling on muscular power output. Sixteen kayak sprint ($n=16$) athletes were involved in this research. All the participants underwent both interventions (traditional and modern-technological based methods) on different days. All the participants were required to perform 10 repetitions of squat jump as a pre-test, then 1 minute of body weight squat as a training. After that, participants need to recover using the recovery methods in different session. Then, a post-test was done to compare and determine the results. Descriptive statistics were used to determine the mean and standard deviation and paired T-Test was used to compare the effect of both interventions. Pearson correlation and Intraclass Correlation Coefficient (ICC) were used to determine validity and reliability of squat jump test protocol on power development. There were significant differences found in the kinetics and kinematics performance in term of power produced during squat jump ($p < 0.05$) using foam roller. Both interventions reported high correlation between jump height and force and power produced during squat jump performance; foam roller ($p = 0.000, r = 1.00$) while TENS ($p = 0.000, r = 1.00$) but less reliable in foam roller compared to TENS; force (foam roller, ICC = 0.47; TENS, ICC = 0.80) and power (foam roller, ICC = 0.48; TENS, ICC = 0.88). This is probably due to the limitation of participants, the effectiveness of the foam roller and insufficient lack of rest intervals. As a conclusion, foam rollers revealed a significant effect on kinematics and kinetics performance during squat jump and researchers recommended and suggested that foam rollers are more practical due to being affordable and easy to carry. Future research is needed for reliable and accurate markers for performance and recovery.





KESAN TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) VERSUS FOAM ROLLER SEBAGAI MODALITI PEMULIHAN TERHADAP PENGHASILAN KUASA OTOT

ABSTRAK

Kajian ini dijalankan adalah untuk menentukan dan membandingkan kesan *Transcutaneous Electrical Nerve Stimulation* (TENS) dan *Foam Rolling* (FR) terhadap penghasilan kuasa otot. Seramai enam belas orang atlet kayak pecut ($n=16$) telah melibatkan diri dalam kajian ini. Kesemua peserta menerima kedua-dua intervensi (kaedah tradisional dan moden) pada hari yang berbeza. Peserta dikehendaki melakukan 10 ulangan *squat jump* sebagai ujian pra kemudian perlu melakukan 1 minit *squat* menggunakan berat badan sebagai latihan. Kemudian, mereka diminta untuk memulihkan otot mereka dengan menggunakan kaedah pemulihan. Ujian pasca telah dilakukan bagi menentukan dan membandingkan hasil kajian tersebut. Statistik diskriptif telah digunakan bagi menentukan nilai min dan sisihan piawai serta ujian T berpasangan juga telah digunakan bagi membandingkan kesan kedua-dua intervensi tersebut. Ujian *Pearson correlation* dan *Intraclass Correlation Coefficient (ICC)* telah digunakan untuk menentukan kesahan dan kebolehpercayaan protokol ujian *squat jump* terhadap penghasilan kuasa. Terdapat kesan yang signifikan terhadap prestasi kinetik dan kinematik serta terhadap penghasilan kuasa semasa aktiviti *squat jump* ($p > 0.05$) menggunakan *foam roller*. Kedua-dua intervensi menunjukkan korelasi yang tinggi antara penghasilan daya dan kuasa; *foam roller* ($p = 0.000$, $r = 1.00$) manakala *TENS* ($p = 0.000$, $r = 1.00$) tetapi kebolehpercayaan yang rendah menggunakan *foam roller* berbanding *TENS*; daya (*foam roller*, $ICC = 0.47$; *TENS*, $ICC = 0.80$) dan kuasa (*foam roller*, $ICC = 0.48$; *TENS*, $ICC = 0.88$). Perbezaan ini mungkin disebabkan oleh pengehadan peserta bagi kajian ini, keberkesanan *foam roller* dan tempoh rehat yang tidak mencukupi. Sebagai konklusi, *foam roller* menunjukkan kesan yang signifikan dan pengkaji berpendapat dan juga mencadangkan *foam roller* lebih praktikal kerana harga mampu milik dan mudah dibawa. Kajian masa hadapan diperlukan sebagai penanda yang boleh dipercayai dan tepat bagi tujuan prestasi dan pemulihan.





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LIST OF ABREVIATIONS

ATMMET	Applied Thai Massage Combined with Muscle Energy Technique
B-SES	Belt Electrode Skeletal Muscle Electrical Stimulation
COD	Change of Direction
DOMS	Delayed Onset Muscle Soreness
DYN	Dynamic Warm up
EMS	Electrical Muscle Stimulation
FR	Foam Roller
HL	High Load
Hz	Hertz
ICC	Inter Class Correlation
ICC	Intraclass correlation coefficient
LL	Light Load
LT	Linear Transducer
MBPP	Medicine Ball Push-Press
NRF	Non-failure
PSST	Passive Static Stretching Technique
RF	Training Failure
RM	Repetition maximum
ROM	Range of Motion
SEMG	Surface Electromyography



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XV

SMR Self-myofascial Release

TENS Transcutaneous Electrical Nerve Stimulation



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CHAPTER 1

INTRODUCTION



The main aim of strength related training is to produce stimulus mechanically and physiologically that will trigger responses which will lead to specific adaptation intended. Basically in preparing the training programs, coaches will used a periodized training method and focus on phases of their training to physical fitness components. Physical fitness is divided into two components, namely health related fitness and psychomotor related fitness (Harun & Salamuddin, 2007; Hashim, 2004; Baurmgartner et al., 2003; Corbin & Landsey, 1988; Falls, 1980). The components of health-related fitness are cardiovascular endurance, muscular endurance, muscular strength, flexibility and body composition, while the components of psychomotor related fitness were speed, agility, power, balance, coordination and reaction time. Out of all these components, it is the main focus of this study to explore more on responses produce by



strength related exercises, which normally be used to develop muscular strength, muscular endurance and other components derived from it such a power, speed and agility. National Strength and Conditioning Association (2009) stated that resistance training was a specialized method of physical conditioning that involves the progressive use of a wide range of resistive loads and a variety of training modalities – from medicine balls to high-intensity weightlifting that enhance or maintain muscular fitness (i.e., muscular strength and muscular power).

Strength training program designed depends on specific sports needs for example kayaking more focusing on upper body region and rugby for lower limb. (Gabbett, Kelly & Pezet, 2007; Sheppard, Cronin, Gabbett, McGuigan, Etxebarria & Newton, 2008; Stone, Sanborn, O'Byrant et al., 2003; Wisloff, Castagna, Helgerud, Jones & Hoff, 2004) reported that although the extent to which qualities such as strength and power were important to sport performance may vary depending on the activity.

According to (McBride, Triplet-McBride, Davie & Newton, 2002; Zaras, Spengos, Methenitis, Papadopoulos, Karampatos, Georgiadis et al., 2013) muscular power has been shown to be improved following either force (e.g. heavy loads) or velocity-oriented (e.g. plyometrics) training program. Moreover, muscular power is important to increase speed and to generate explosive power in short time. As stated by McGuigan, Wright and Fleck (2012), power output is an important attribute in determining athletic ability and predicting success in different sports. An example of this is squat exercise using loaded barbell for force oriented training, while a body weight squat jump exercise as velocity-oriented strength training.

Proven methods to enhance strength and power include the traditional approach using strength equipment of free weights and machines. Pearson et al., (2000) believed that resistance training has been identified as one factor of which plays an important role in development of muscular power. According to Eriksson and Häggmark (1979), integration of functional electrical stimulation with a traditional volitional isometric training program has been shown to be more effective at improving muscle function and preventing atrophy after five weeks compared to isometric training alone as utilized by individual during post-anterior cruciate ligament. However, the same electrical method and equipment, if adjusted voltage and frequency may able to also assist recovery process of the muscle (Cheing & Hui-Chan, 2004; Pietrosimone, Saliba, Hart, Hertel, Kerrigan & Ingersoll, 2011).



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Normally, athletes or individuals were using traditional method like massage to recover themselves after having a heavy exercise. So, they need to massage the muscle to ensure that they can recover the muscle quickly. (Ernst, 1998; Hausswirth & Le Meur, 2011; Weerapong, Hume & Kolt, 2005) reported that massage give benefits including increased blood circulation and venous return, greater lactate clearance, decreased pain sensation and well-being. Based on the benefits, massage becomes an alternative method to enhance the performance and recovery process.

Previous studies showed that massage with combination of other recovery interventions could be efficient to increase recovery and performance. Jakeman et al., (2010) stated that an improvement in jump performance 48 hours after plyometric exercise when athletes received a massage combined with lower leg compression compared to compression alone. At the same time, McKeag (2003) supported that

massage was more beneficial for recovery when combined with active recovery. However, the effect of massage still debating on recovery process and enhancing the performance of athletes. (Callaghan, 1993; Robertson, Watt & Galloway, 2004; Weerapong, Hume & Kolt, 2005) mentioned that although massage shows positive effect on perceived pain or well-being, there are contrasting results in the literature on other aspects such as physical performance. Therefore, Delextrat, Calleja-González, Hippocrate and Clarke (2013) also reported there was no significant effect of a 30-minute lower limb performed immediately after an official match on vertical jump and repeated sprint performance in men and women.

Another alternative for sport massage is using foam rolling which is self-myofascial release perform by participants, by rolling the focus muscle group or body part. Foam rolling has been more effective to improve range of motion (ROM), recovery, reduce muscle soreness and performance. Foam roller usually used after having an exercise to recover from muscle soreness or reducing an injury. It was important for individuals to ensure that they are free from fatigue that can affect their performance. Pescatello, Arena, Rieba and Thompson (2013) mentioned that a single exercise usually comprises four phases: warm-up, stretching, conditioning or sports-related exercise and cool-down.

Healey et al., (2014) stated that foam rolling has been adopted as a tool of self-myofascial release (SMR). Foam rolling has been widely used by individuals to recover themselves because it was quite similar to massage on reducing pain and increase the range of motion (ROM). However, the effect of foam rolling on recovery and performance still debated among the researchers. MacDonald et al., (2013) examined

the acute of foam rolling on quadriceps maximum voluntary contraction force and found no changes in muscle strength 2 and 10 minutes after foam rolling on quadriceps. Meanwhile Healey et al., (2014) examined the acute effect of foam rolling exercise on vertical jump height and power, isometric force and there were no significant differences between foam rolling and planking for all of the athlete tests.

Nowadays, a modern technological device which is electrical stimulation has been popular and widely used among athletes and practitioners to stimulate muscles and achieving proper recovery during training and competitions. An electrical stimulation has been used in specific part of muscle to stimulate and increase the muscle. According to (Brocherie et al., 2005; Maffiuletti et al., 2002; Pichon, Chatard, Martin & Cometti, 1995) electrotherapy has a specific effect on athlete's body and can be a means of stimulating recovery and increasing muscle strength. The electrical current flowed and stimulate the specific part of muscle by controlling the voltage of the device. As studied by (Enoka, 1988; Hainaut & Duchateau, 1992) reported the recruitment of motor units depends on the duration, amplitude and frequency of impulses and the ratio of stimulation-to-rest time in Electrical Myostimulation (EMS).

Despite of controlling the voltage current, it is still debating in previous studies either low or high intensity will be affected on athlete's performance. This is because it will be a guideline to coaches, athletes and other practitioners using the modern method to enhance the performance and recovery process. As found by Miyamoto et al., (2016), prolonged low intensity Belt Electrode Skeletal Muscle Electrical Stimulation (B-SES) showed significant increases in muscle strength and cardiorespiratory fitness in healthy subjects.

Inadequate recovery after having exercises can promote fatigue, affecting the performance and athletes tend to get injuries. So, an efficient recovery process will ensure that individuals or athletes can perform well in the competition and reducing the risk of the injuries but it is depending on the duration of recovery and type of exercise including the intensity. Bishop et al., (2008) stated that there are three type of recovery: (a) immediate, which is the recovery between the muscle contraction or movements; (b) short-term which is the recovery between bouts of exercise; and (c) training recovery which is the recovery period required between successive sessions. Requirement of high intensity and volume training in elite sports causes athletes needs to give their full commitment and effort during training and competition. So, optimizing recovery process should be done to avoid the impairment of muscle and tissues that affected their performance. However, recovery process still depends on duration, type of recovery and injuries.



However, several research found that massage was not effective to increase performance but it helps to increase the range of motion and flexibility. But, massage also beneficial to reduce muscle spasm and increase blood circulation. Other than that, it was significant to decrease pain and discomfort. Hemmings (2000) in his study stated that massage provide support for the benefits of psychological but some questions were raised towards the benefits of sports performance and physiological restoration.

Cold water immersion was one of the recovery modalities that helps to recover and reduce muscle pain. Many research findings stated that cold water immersion was effective as a recovery modality. Cold water immersion was one of the popular methods that has been used among athletes and active people to recover after having high



intensity exercise. Versey, Halson and Dawson (2013) mentioned that the best temperature within 10 - 15°C while 5 - 15 minutes of duration was effective during ice bath. High intensity exercise caused the muscle damage, fatigue and muscle soreness. Hence, cold water immersion or cold bath was one of the optional to diminish muscle pain and soreness. Stephens et al., (2017) reported that the result of cold-water immersion was influenced by time and temperature of immersion, water level and type of exercise also different in physique traits.

In term of exercise used for muscular power output test and measurement, velocity-oriented types of exercise have widely been used. An example of the exercises such as squat jump, standing broad jump, and counter movement jump (Keller & Engelhardt, 2019; Turner, Unholz, Potts & Coleman, 2012; Cormie, McCaulley, Triplett & McBride, 2007; Hughes, Warmenhoven, Haff, Chapman & Nimphius, 2022; Morin, Jimenez-Reyes, Brughelli & Samozino, 2019; Loturco, McGuigan, Freitas, Nakamura, Boulosa, Valenzuela & Pareja-Blanco, 2022). Schimidtbleicher (1992) characterized that explosive exercise as exercise that having maximum or near maximum rates of force development (RFD), in which this exercises do have this characteristic. According to (Moss, Refnes, Abilgaard, Nicolaysen & Jensen, 1997; Stone et al., 2003) maximum strength affects power over a much wider range than might be expected. This is because it was generally believed that maximum strength affects of power production by having a heavy load. Exercise utilizing body weight and minimal additional load (lighter load) reduce this negative effect (Lipecki & Rutowicz, 2015, Madam, Nuell, Cronin, Diewald, Rowley, Forster & Fosch, 2021; Madam, Nuell, Cronin, Uthoff, Nagahara, Neville & Tinwala, 2020).

At the same time, plyometrics training such as squat jump and clap push was able to increase muscular power. This training can help to develop muscular power depends on the specific sports need. Previous researchers found that squat jump was able to develop lower muscular power due to the jump height during squat jump activity. This is because the jump height was one of the key indicators to determine the power output produced as previous stated that the higher the jump height the higher the power output produced. (McBride, Triple-McBride, Davie & Newton, 2002; Zaras, Spengos, Methenitis, Papadopoulos, Karampatsos, Georgiadis et al., 2013) found that muscular has been shown to be improved following either the force (e.g. heavy loads) or velocity-oriented (e.g. plyometrics).

Other than that, body weight training can be used as a resistance training as an alternative to traditional strength training. Body weight training was effective to improve general physical fitness to promote health and wellness. For example, push up, pull up and dips exercise. The exercise uses the body weight as a resistance to improve physical fitness such as muscular endurance, muscular strength and power. Vossen, Kramer, Burke and Deborah (2000) found that plyometric push up was significantly greater than dynamic push up on medicine ball put. At the same time, body weight training activated the muscle during the exercise. This showed that body weight training was an alternative to traditional strength training and effective to increase general physical fitness performance. McKenzie, Crowley-McHattan, Meir, Whitting and Volschenk (2022) found that a higher peak of muscle activated in bar grip compared to bench grip. Body weight training also promoted a healthy lifestyle among people. High intensity of body weight training burned more calories and improved cardiovascular endurance. Previous research mentioned that there were many benefits of body weight

exercise towards health and can low the risk of disease. Bombelli, Facchetti, Fodri, Brambilla, Sega, Grassi and Mancia (2013) stated the abnormal of morphological fitness of body structure and composition lead to a higher risk of death and disease.

Nowadays, there are many software developed to assist data analysis process using only smartphones and/or tablets devices. Two most common for many strength and conditioning professional nowadays are Kinovea and MyJump application that can be used using smartphones and tablets. This allows for coaches to able to monitor and asses the effectiveness of their periodized training programs on the athletes more easily. Thus, the evolution of science and technologies in sports seems significantly improved the performance and recovery of an athlete indirectly. Previous research used the force plate platform to determine kinematics and kinetics performance of an athlete.

However, not all of coaches, sports scientist and sports practitioners were able to use the technology especially in developing region. This is because the force plate platform was highly expensive. Therefore, a higher budget and costs of maintenance were needed to spend to measure and determine the performance.

However, sports scientist developed a software on smartphones and tablets to help other sports practitioners and coaches to enhance their athlete's performance. But, there was a question was raised towards the validity and reliability of the software on smartphone and tablet in term of the data collection process and the findings from the study. Was the software reliable and valid to measure the performance? Balsalobre-Fernandez, Glaister and Lockey (2015) in their study revealed that there was almost a perfect agreement of countermovement jump height force plate and My Jump application. Therefore, the findings from the study showed that the countermovement

jump height was easily, accurately and reliable using the application that specially developed using iPhone 5s.

At the same time, the advances of science and technologies have changed our lives very much. The invention of science and technologies such as machines, computers and softwares have assisted the innovation and calculation in laboratories. For example, the sports scientist developed the softwares that can be used in data collection to quantify and measure the performance in sports. Therefore, coaches and sports practitioners may use the software to quantify the performance outside of the laboratories such as field and court. According to Balsalobre-Fernandez et al., (2019), there was a perfect correlation between timing gate and change of direction (COD) Timer application. The findings showed that the iPhone application was reliable and

valid to measure the change of direction (COD).

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Several studies showed that there many methods were used to quantify the performance such as one repetition maximum (1-RM) was used to determine the strength of an athlete. Buckner et al., (2017) supported that one repetition maximum (1-RM) was widely used in strength and conditioning. At the same time, the advances of science and technologies also helps our works can be done faster. The software developed helps the coaches and sports practitioners quantify the performance anytime and anywhere using their smartphones and tablets. Previous studies reported that these software that has been used was highly reliable and valid to quantify performance. A survey by Shaw, Satchell, Thompson, Harper, Balsalobre-Fernandez and Peart (2021) found that there was a significantly related found on the application used on sports performance. The findings revealed that many practitioners used a smartphone

and tablet applications towards the biomechanical data collection such as jumping and sprinting. In other words, the advancement in sports science to assist, monitor and improve the preparation of an athlete. Moreover, sports science helps an athlete maximize the potential of performance with the least of risk of injury.

There was a significant relationship between general fitness and performance. Many previous reported that physical fitness was able to improve the performance due to physical and physiological preparation. Thus, many mechanism or methods provided to determine the physical fitness such wingate anaerobic test was used to measure anaerobic capacity and anaerobic power output, multistage fitness (beep test) was used to quantify aerobic capacity and prediction of maximal oxygen uptake (VO_2 max) while sit and reach test was used to examine flexibility. Hence, the assessment of physical fitness was essential for talent identification or talent development in sports among young athletes (Baker et al., 2020; Lidor, Cote & Hackfort, 2009). According to Saal et al., (2022), the identified predictors for specific performance and testing batteries should be appraised age and sex for talent identification program for canoe sprint athletes.

Kayak athletes developed more muscular on upper limb compared to lower limb due to specific sports demands. Hence, high capacity of anaerobic and aerobic functions were needed to increase strength and endurance. As stated by Ackland et al., (2003), an elite kayak sprint have greater upper body, narrow hips and high of lean body mass compared to other adults athletes. This is because the athlete used the upper body during paddling. There were three events in kayak sprint whereby 200 m, 500 m and 1000 m. So, a specificity of training program was needed due to different distances. Thus, the

level of functional support for special endurance for paddlers were different between 200 m and 1000 m (Guo et al., 2022; Diachenko et al., 2021). At the same time, the morphology of physical characteristic among kayak athletes were different to other sports due to the sport demands. Canoeing and kayaking were classified as a sport that required mixed of anaerobic lactic energy production, aerobic capacity also endurance (Bishop, 2004; Van Someren & Howatson, 2008; Nekriosius et al., 2018).

Normally, time trials were used to determine the performance of kayak athlete based on specific distance. Time trials have been a gold standard assessment to measure the performance of an athlete so that the coaches will determine and create a training program to improve their current performance. However, there were many factors should be considered in time trials for kayak athletes such as forces, wind and the environment. Jackson (1995) in his study revealed that the changes of hydrodynamics and aerodynamics of water and air was toughly effected the forces that acting on boat. Then, the fitness test of kayak athletes also different compared to other sports, for example, one repetition maximum (1RM) of bench press was used to assess upper body muscular strength. Gabler et al., (2021) stated that the characteristics of physical fitness assessment should be similar to the biomechanical and metabolic demand of the sports among kayak athlete.

Many benefits of body weight training such as prevent dangerous disease, obesity and improve self-esteem. Normally, people who were involved in physical activity for social networking and try to compete at a high level of competition especially athletes. The enhancement of functional capacity, development of relationships and increasing the self-esteem have been manifested by the benefits of

physical activity (Wilhite & Shank, 2009; Pereira, Osborne & Pereira, 2013). The regular squat exercise was different to squat jump exercise and other modified squat exercises. This is because squat jump exercise was one of the plyometric training that maximize the force and power output of lower body parts such as hamstring, quadriceps and gluteus maximus. Squat jump can be used as a resistance training to generate muscular power that helps in sprinting, kicking and other sports demands. Resistance training has been purposed as an effective mechanism to improve the performance of an athlete that gained via maximal, explosive and reactive strength (Abernethy et al., 1994, Moir, 2015, Stone et al., 2007). Squat jump exercise has been proven to generate power output that can be used in warm up protocol and training methods. As indicated by Rossetti et al., (2017), ballistic jump squat may be beneficial to develop power output due to the high velocity and forces produced during the exercise.

At the same time, the load or intensity training of squat jump can be increased to produce more power output and forces. This is because the greater external load or intensity may resulted in production of greater forces and contraction compared to lower external load. Cormie, McCaulley, Triplett and McBride (2007) reported the external load, the velocity during each repetitions and selection of exercise effected the power output during strength training. However, the protocol should be monitored by coaches, strength and condition professionals and certified sports practitioners to avoid injury occurred during training session. Weber et al., (2008) concluded that the acute performance in average and peak jump height and ground reaction force (GRF) were improved during a heavy load of back squat before a set of consecutive of squat jump was performed.

Even though squat jump exercise was effective to generate explosive power for lower body sports such as martial arts, football and athletics, squat jump exercise also can be used to as a training mechanism to enhance general fitness for other sports. Ruffieux et al., (2020) and Kyrolainen et al., (2005) mentioned that squat jump exercise was essential to gain success in many sporting events and involved in many exercise methods for untrained and trained people that contributed to vertical jump performance. Hence, the coaches, strength and conditioning professionals and sports practitioners can used squat jump exercise in their strength training program to develop muscular strength and endurance on lower body muscles so that the risk of injury can be avoided due to the effectiveness of adaptation of lower body muscles. Squat jump exercise was one of the popular in high intensity interval training (HIIT) because the exercise burned more calories compared to regular squat that used body weight as a resistance.

Furthermore, squat jump exercise only generate the muscular power and force but also increased the dynamic balance. Normally, the squat jump exercise was used to examine an explosive lower body power such as speed and strength ability (Young, 1995; Markovic et al., 2004). Therefore, squat jump exercise seems to be practical, simple and reliable to determine lower body power. According to Markovic et al., (2004) reported that squat jump has been reliable and valid to assess lower body explosive power.

Even though squat jump improved the force and power output but is squat jump was reliable and valid to assess force and power output among athletes? Muscle strength and power can assessed by squat jump and countermovement jump (Forte & Pigozzi, 2008; Edwen et al., 2014). Squat jump test was widely used to determine the kinetic performance among the coaches and researchers. There were many field and laboratory

test to measure the performance of an athlete such as one repetition maximum (1RM) for muscular strength, Wingate test for anaerobic capacity and beep test for maximal oxygen uptake (VO₂ max). Previous findings reported that squat jump test has been proven to increase muscular power and force output. However, Acero et al., (2011) reported that the countermovement jump was highly reliable than squat jump to examine force and power output but both methods can be used to assess lower limb muscular output. Markovic et al., (2004) mentioned that squat jump was the second popular and reliable to measure the power output compared to the other jumping methods. The coaches can increased the loads of the squat jump to generate more explosive power and force output. Therefore, squat jump has been established and proven to improve the kinetic performance and highly reliable and valid in testing and measurement of lower body power output.

There many scientific based recovery provided to enhance recovery process and improve the performance among high level athletes. The variety of recovery modalities may gives optional to coaches, athletes and sports practitioners to choose a better recovery modality for recovery session. Currently, many researchers compared the combination of recovery modalities to determine the effectiveness of each recovery modalities on sports performance, physiological and psychological. Therefore, performance parameters such as Wingate anaerobic test, treadmill run, vertical jump and 20 m sprint were used to determine the efficacy of recovery mechanisms. However, the performance parameters were depends on sports skills and specific demands. Vaile et al., (2008) stated that cold water immersion and contrast water therapy increased the performance in five days trials among males cyclists compared to hot water immersion and passive recovery.

Various of recovery modalities have been identified and beneficial for individualize recovery strategies. Therefore, athletes especially elite athletes can focus purely in training and competition due to recovery foundation provided. High intensity training and repetitive competition may exposed to tiredness and fatigue among athletes and may effected their performance. Hence, the advantages of recovery strategies provided many benefits on performance and recovery. Mujika et al., (2008) mentioned that recovery was needed to maximize athletes performance in training and competition due to high training loads that may provided physiological fatigue. De Oliveira et al., (2023) found that foam roller was significantly effective in recovery perceptions compared to static stretching while Moore et al., (2023) in their study reported that cold water immersion was more benefits on recovery of muscular power and flexibility compared to active recovery, contrast water therapy and warm water immersion. The systemic review and meta-analysis were used in the study to determine the effective of cold water immersion and other recovery modalities that have been used in athletics recovery.

In summary, this study investigated two types of recovery modalities, in which one of it utilizes electrical based equipment (TENS), while another one utilizes a more traditional manually applied based (foam roller). In assessing this recovery methods, a strength training protocol using squat jump based was used to elicit strength training stimulus and responses for the purpose of recovery modality afterwards.

1.2 Problem Statement

For most practitioners that do understand the importance of well-planned periodized training program, two most important factors that can influence the effect of training were the types of training involved, and the types of recovery methods applied afterwards. Appropriate combinations of both ensure optimum effect and adaptation for maximum sporting performance. However, the problems normally faced by most practitioners were there were too many choices of training and recovery methods. Commercial industry seems to put more confusion with advertisement that sometimes elevate the actual effects higher than it actually was. With the advanced of technology, training using the electrical stimulation apparatus has become a norms among most physical fitness enthusiast and athletes. However, better biomechanical studies also indicating the effectiveness of TENS and self-applied recovery method using foam roller. Thus, this study has been proposed to be conducted because there were lack or nearly no studies on the effect of Transcutaneous Electrical Nerve Stimulation (TENS) versus foam rolling for power development. At the same time, this study also to explore the effect of both recovery modalities on recovery performance by using jump height as an indicator that correlated with force and power produced. Previous research reported that the higher the jump height recorded the more power produced. Hence, the correlation between jump height and power produced during squat jump was able to support the previous research that reported the squat jump can be used to determine general fitness level among healthy people.

1.3 Purpose of The Study

The purpose of the study was to determine and compare the effect of Transcutaneous Electrical Nerve Stimulation (TENS) versus foam rolling on power development. At the same time, this study also aimed towards establishing the recovery methods that will benefit exercise practitioners, coaches and athletes due to the novel findings and technical information on training and recovery. Other than that, this study also to determine the validity and reliability of squat jump as power based protocol, to be used in investigating the primary purpose of previously stated.

1.4 Research Objectives

The objective of the research were;

- 1.4.1 To profile of kinematics and kinetics during squat jump test protocol.
- 1.4.2 To investigate the effect of Transcutaneous Electrical Nerve Stimulation (TENS) on kinematics and kinetics of squat jump performance.
- 1.4.3 To investigate the effect of foam rolling (FR) on kinematics and kinetics of squat jump performance.
- 1.4.4 To compare the effect of TENS versus Foam Roller on kinematics and kinetics of squat jump performance.
- 1.4.5 To determine the reliability of squat jump as test protocol.
- 1.4.6 To determine the validity of squat jump as an assessment on kinematics and kinetics of squat jump performance.

1.5 Research Questions

This study has been answered the questions as below;

- 1.5.1 What was the amount of kinematics and kinetics produced during a squat jump test protocol?
- 1.5.2 What was the effect of Transcutaneous Electrical Nerve Stimulation (TENS) on kinematics and kinetics of squat jump performance?
- 1.5.3 What was the effect of Foam Roller (FR) on kinematics and kinetics of squat jump performance?
- 1.5.4 Was there showed a significant differences of TENS versus Foam Roller in term of kinematics and kinetics output during squat jump performance?
- 1.5.5 Was the squat jump reliable when used in a test protocol?
- 1.5.6 Was the squat jump valid as an assessment for muscular power capabilities?

1.6 Significance of Study

The goal of any coaches and athletes are to enhance performance and reduced risk of injuries. Getting the most appropriate combinations of training and recovery methods ensured by this goal was achievable. Thus, this study is significant in the sense that it provided the much sought after information on combination of strength training and recovery methods, both traditional ways or modern-technological based one. Findings of this study will benefit the coaches, athletes and exercise practitioners to select power-based training and recovery combination as described previously. In certain

long-term periodization, findings of this study assisted for the practitioners to use both combinations but at different time of periodization phases. Overall, this study was provided another novel findings and technical information on training and recovery.

1.7 Limitations of Study

The limitations of the study that may be exist in this study were;

1.7.1 The commitment of the participants. This is because all of the participants were actively training due to *Sukan Malaysia (SUKMA) 2022*. Hence, a permission from the coach was needed to involve the athletes in this study.

1.7.2 The effort of the participants. This refers to the efforts and honesty of the participants during the test and following the procedures given to avoid the data become error and need to do the test frequently. It also can effected the recovery period of the participants.

1.7.3 Participants in this study. This study was limited to the kayak sprint athletes. 16 of male athletes were involved in this study.

1.8 Delimitations of Study

This study was delimited to research participants with criteria as indicated in the methodology sections only. Loading prescribed for all methods of training and recovery also limited to one type of load.

1.9 Operational Definitions

For the purpose of this study, definition of terms as understood within the scope of this study are as below:

1.9.1 Body weight squat

Referring to the training that act as a stimulation to the muscle before recovering the muscle. The participants need to perform 1 minute of body weight squat.

1.9.2 Foam rolling

Self-myofascial release performed by participants, by rolling the focus muscle group or body part on a cylinder shape of roller equipment built of foam. In this study, the muscle targeted was hamstring.

1.9.3 Squat jump test protocol

Squat jump test protocol referred to the test that consist of two repetitions (pre-test and post-test) whereby all of participants needs to perform 10 repetitions of squat jump in each test (pre-test and post-test). The kinematics and kinetics performance was recorded using mobile software and application.

1.9.4 Transcutaneous Electrical Nerve Stimulation (TENS)

A transcutaneous electrical nerve stimulation (TENS) sends electrical pulses from the device stimulate the targeted muscles that act like pain killer. The electrical pulses can release endorphins and other substances to stop pain signals in the brain. TENS activates a complex neuronal network to result in a reduction in pain.

1.9.5 Kinematics performance

Referring to the motion of the squat jump test protocol and kinematics performance measured were; (i) jump height that referred as the height recorded by each of participants after 10 repetitions of squat jump was completed, (ii) flight time can be defined as the time taken of participants spend in the air without ground contact and (iii) velocity was referred to the speed of the participants after 10 repetitions of squat jump test protocol was completed.

1.9.6 Kinetics performance

Referring to forces resulting from the motion of the squat jump test protocol. Kinetics performance were determined by; (i) power output that referred to the rate of work whereby 10 repetitions of squat jump test protocol was done and the average was calculated and (ii) force that act the action of the squat jump test protocol when the participants started to take-off and landing phase after 10 repetitions was completed and the average was calculated.