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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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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.

Keywords: Transcutaneous Electrical Nerve Stimulation (TENS), foam rolling (FR), squat jump, power, recovery

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. 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).

According to (McBride, Triplet-McBride, Davie & Newton, 2002; Zaras, Spengos, Methenitis, Papadopoulos, Karampatsos, 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 be able to also assist recovery process of the muscle (Cheing & Hui-Chan, 2004; Pietrosimone, Saliba, Hart, Hertel, Kerrigan & Ingersoll, 2011).

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. 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).

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Plyometrics training such 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 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 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 to 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.

There many scientific based recoveries provided to enhance recovery process and improve the performance among high level athletes. The variety of recovery modalities may give 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 depending 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 on training and competition due to recovery foundation provided. High intensity training and repetitive competition may be exposed to tiredness and fatigue among athletes and may affected their performance. Hence, the advantages of recovery strategies provided many benefits on performance and recovery. Mujika et al., (2018) mentioned that recovery was needed to maximize athletes' performance in training and competition due to high training loads that may provide 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., (2022) 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.

MATERIALS AND METHOD

Participants

This research involved sixteen (n=16) Terengganu *Sukan Malaysia (SUKMA)* kayak athletes. All of participants were free from injury and in healthy physical condition during the time of the study. The total of participants was determined based on the effect size using G*Power version 3.1.9.4, Paired T-Test within a significant level at 0.05 was used to measure the effect size and power. The total of participants involved (n=16) showed the effect size was 0.5 meanwhile the power was 0.45.

All the participants for all sessions were males aged 16-21 years old based on their year of birth. The demographics and anthropometry data of all participants as shown in data analysis.

Research Design

The study conducted was utilized a within-group quantitative experimental with cross-over design method that aimed to determine and compare the effect of Transcutaneous Electrical Nerve Stimulation (TENS) for (Session 1) versus Foam Rolling (FR) which is for (Session 2) using the same participants for both assessment on kinematics and kinetics of squat jump performance.

This cross-over design that involved the same participants received different treatments during different time periods were conducted to compare the effects of the modern-technological based or traditional method approach.

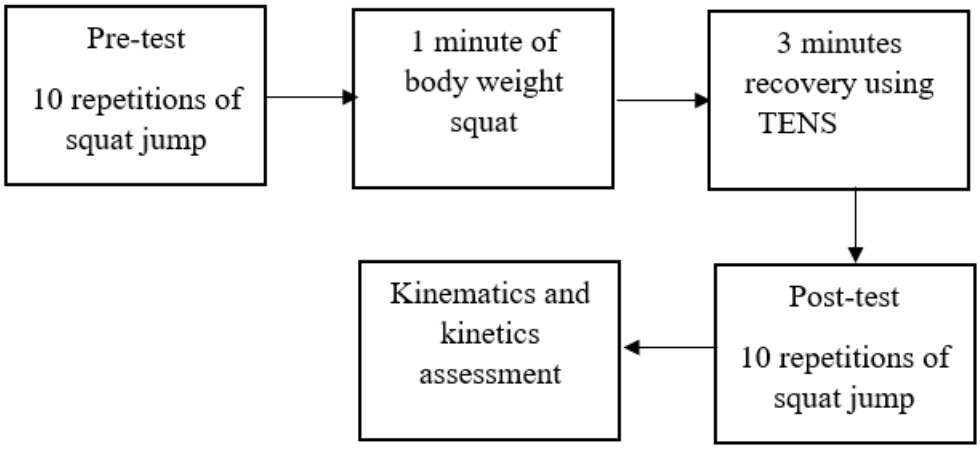

Figure 1: Session 1 Flow Chart

Figure 1 showed the flow chart for Session 1. Participants underwent modern-technological based as an intervention. A Myolito device (010E-105, EME Services Ltd, UK) which is the device combining 3 treatments; muscle stimulation, pain relief and incontinence therapy was used in this study. The self-adhesive electrodes were put on both hamstrings for 3 minutes; burst mode (100 Hz, 350 µS). The Transcutaneous Electrical Nerve Stimulation (TENS) aimed to detoxification and relaxation. At the same time, this mode also aimed to relief the pain after having the previous strengthening exercise as stated. After finished the intervention, the participant was ready underwent the post-test protocol.

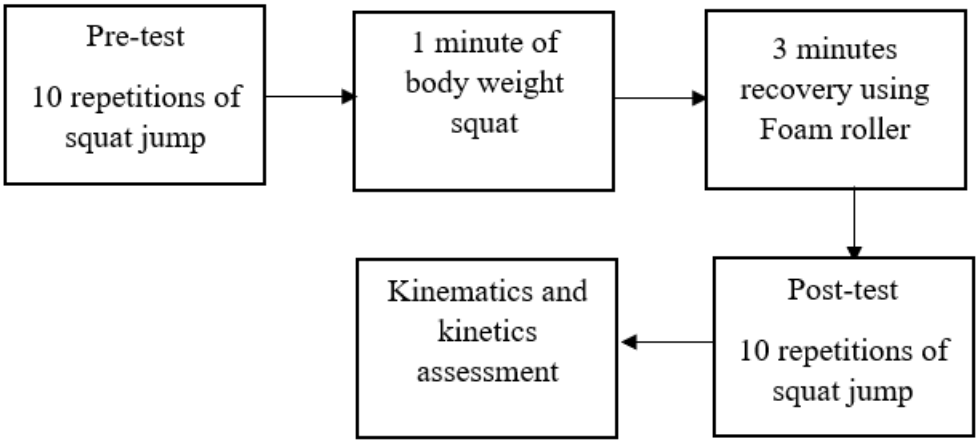

Figure 2: Session 2 Flow Chart

Figure 2 showed that the flow chart for Session 2 that is traditional method using foam roller. The protocols in this session also same as previous session except this session using a foam roller as a recovery method that required 3 minutes recover the muscle that was put underneath the hamstring. After that, the kinematics and kinetics performance were recorded and analyzed.

Research Equipment

For session 1, electrical device, MTR + Myolito device (010E-105, EME Services Ltd, UK) was used for Transcutaneous Nerve Electrical Stimulation (TENS) as a modern-technological based to recover and relief the muscle pain. Meanwhile foam roller (Decathlon, Malaysia) was used as an intervention in session 2 for recovery modality after all participants completed of 1 minute of body weight squat. They were asked to recover themselves by rolled the foam roller on the targeted muscles.

The video was recorded using iPhone camera (Apple 11 Pro, Apple Inc., USA) while the kinematics and kinetics performance were measured during squat jump using My Jump 2 application (Balsalobre-Fernandez, version 6.1.6, Spain). The application used in the study was highly reliable and valid for data collection (Balsalobre-Fernandez, Glaister & Lockey, 2015; Bishop, Jarvis, Turner & Balsalobre-Fernandez, 2022).

Procedure

Transcutaneous Electrical Nerve Stimulation (TENS)

Ten minutes given to all participants to perform warming up before underwent the test protocol. All of participants were briefed about the procedures and protocols of the test to avoid errors and miscommunication while they run the test. Then, each of the participants was given the device for some familiarization of the test.

First, all of participants need to perform 10 repetitions of squat jump as a pre-test and the motion was recorded using My Jump 2 application. After having of 10 repetitions of squat jump, they were asked to perform 1 minute of body weight squat as a stimulation to the muscle activity. Next, two self-adhesive electrodes of Transcutaneous Electrical Nerve Stimulation (TENS) were put on hamstring for 3 minutes as a recovery method. The electrical current from the device stimulated the muscles and reduce pain.

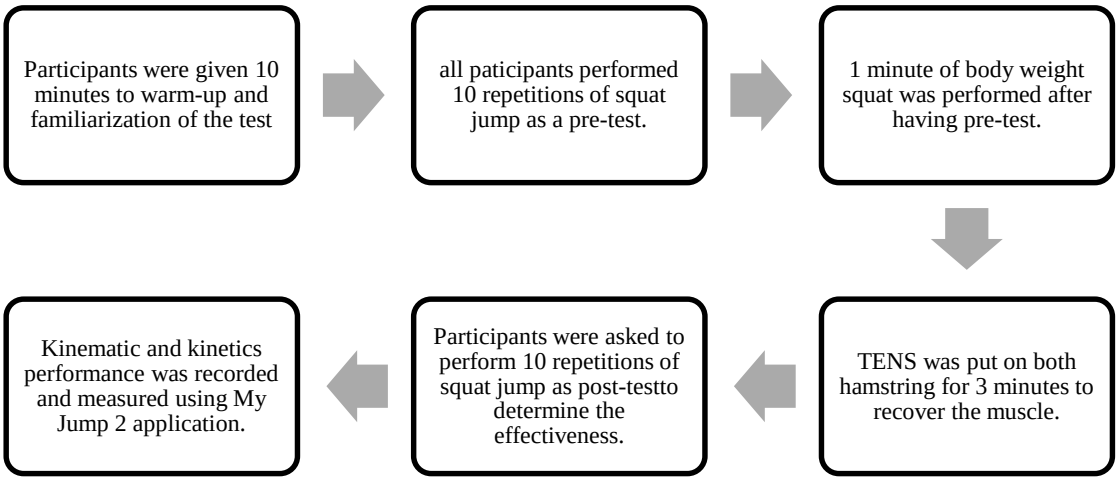

Figure 3: Transcutaneous Electrical Nerve Stimulation (TENS) for Squat Jump Test Protocol.

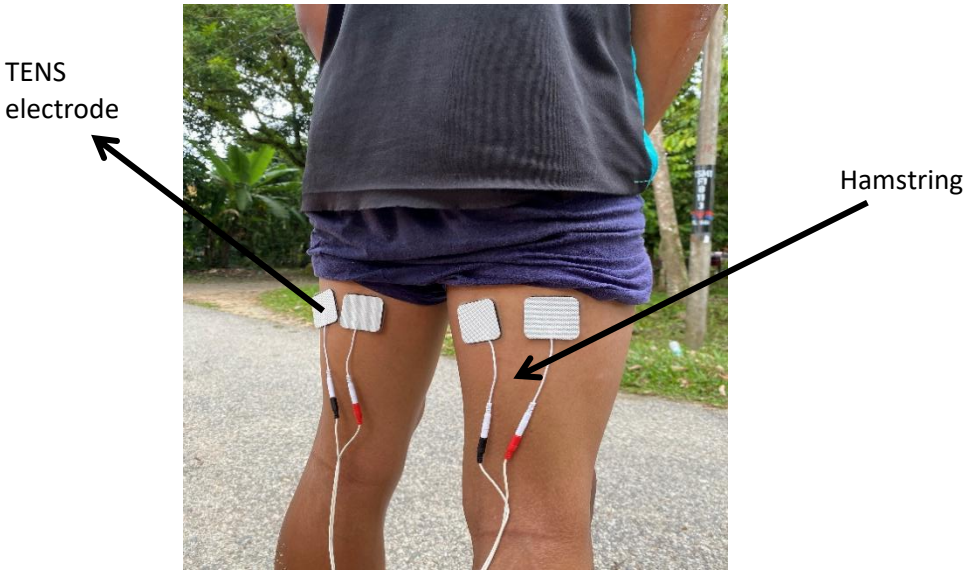

Figure 4: Placement of TENS Electrode on Hamstring Muscle During Recovery Protocol Using TENS

1-Minute Body Weight Squat

Figure 5 showed the one of participants performed the body weight squat activity in 1 minute. All of participants need to perform 1 minute of body weight squat after having 10 repetitions of squat jump that act as pre-test in this study. The aimed of 1 minute of body weight squat was to stimulate the muscle activity and as a training session to determine the effectiveness of recovery methods either modern-technological based (TENS) and traditional (foam roller).

After having the activity, they need to recover themselves using the recovery protocols as mentioned previous in 3 minutes to reduce muscle pain.

Figure 5: 1 Minute of Body Weight Squat Activity

Foam Roller

In this session 2, all of participants were given 10 minutes to perform warming up before underwent the test protocol. This is important to avoid and reduce the risk of injury. At the same time, it helps to increase the muscle and body temperature. After finished the warming up session, they were briefed about the session 2 to avoid errors during the session. All of participants were asked to perform 10 repetitions of squat jump activity as a pre-test. Then, 1 minute of body weight was performed before they recovered themselves using foam roller in order to relax and reduce the pain. After that, they were asked to re-test of 10 repetitions of squat jump to determine and compare the pre-test and post-test results. The activity was recorded and analyzed using My Jump 2 application.

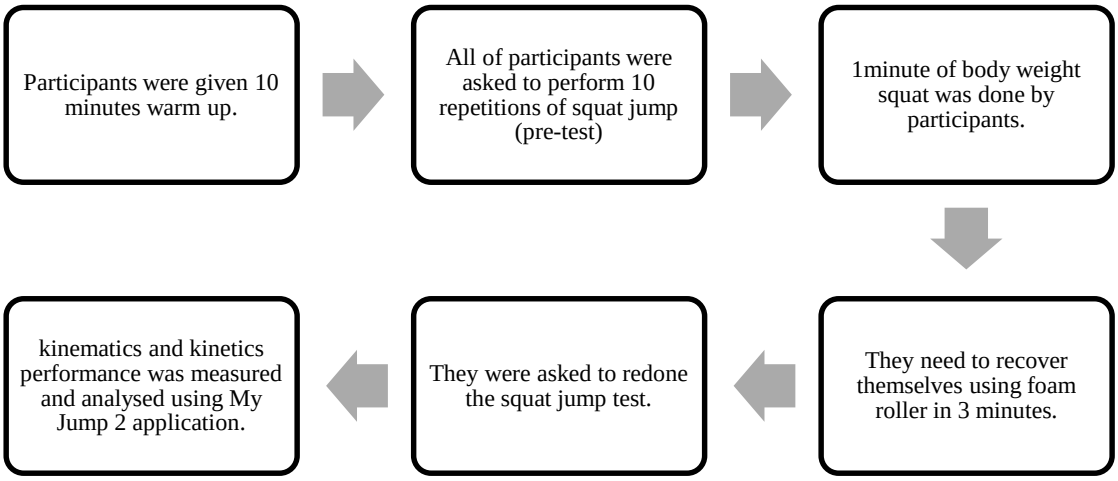

Figure 6: Foam Rolling (FR) for Squat Jump Test Protocol

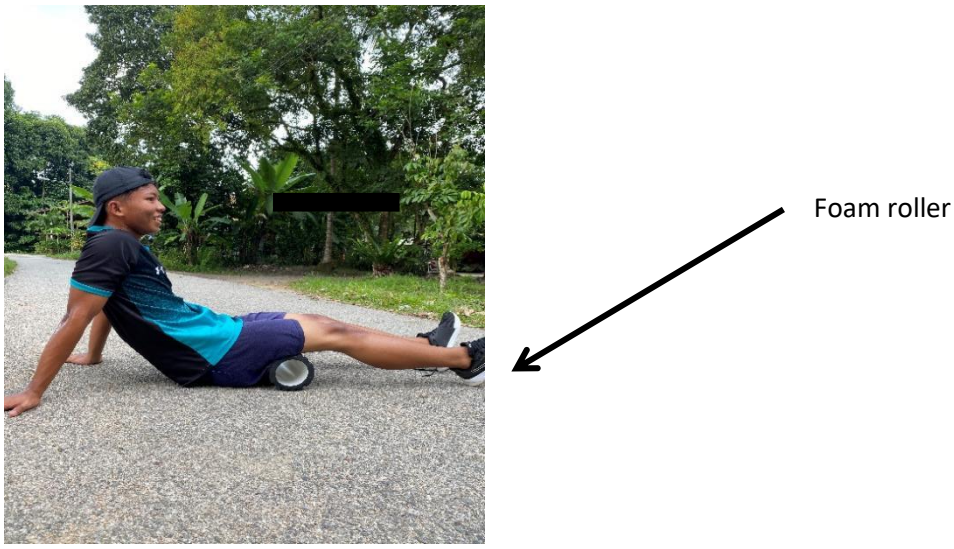

Figure 7: Participant Using Foam Roller Recovery Modality

Squat Jump Test Protocol

Before all of participant started to run the test, all of their physical characteristics were recorded such as body height (cm) and body mass (kg). At the same time, their leg length (cm) and height at 90° (cm) was measured and recorded into My Jump 2 application. Leg length (cm) was measured from anterior iliac spine to the tiptoe while the participant laying on his back while keeping a full ankle plantar flexion. To get an accurate measurement, the anterior iliac spine was marked. Then, height at 90° (cm), the vertical distance between anterior iliac spine and the ground in an optimal knee-flexed position in order to perform the highest jump at 90° of knee flexion. After all of the measurement was recorded, all of participants need to perform 10 repetitions of squat jump as a pre-test.

Then, 1 minute of body weight squat was performed as a training stimulation to the muscle activity. After 1 minute of body weight squat was done, they need to recover the muscle using the recovery method; modern-technological based and foam roller on different session. Next, they started to be performed of 10 repetitions of squat jump as a post-test. The motion of the squat jump was recorded, and the result of pre-test and post-test was compared to determine the effect of Transcutaneous Electrical Nerve Stimulation (TENS) and Foam Roller on kinematics and kinetics of squat jump test protocol.

Statistical Analysis

Descriptive statistics were used to measure the mean and standard deviation of each physical characteristics and the data scores. A Paired T-Test was used to compare both effects of session one and session two in terms of kinematics and kinetics output during squat jump performance. Then, a descriptive statistic was used to evaluate the amount of kinematics and kinetics during squat jump activity. Paired T-Test also was used to determine the effect of session 1 and session 2 on kinematics and kinetics of squat jump performance. Intraclass Correlation Coefficient (ICC) was used to determine the reliability of squat jump performance while Pearson Correlation for validity assessment of squat jump test protocol. Statistical significances were accepted at α-level of $p \leq 0.05$. All statistical analyses were conducted using SPSS version 26.0 (IBM, New York, USA). Normality test was used to determine either the data were normally distributed or not.

RESULTS

Table 1: Demographics Information

N	Age (years)	Body mass (kg)	Height (cm)
16	17.81 ± 1.17	62.66 ± 11.09	167.00 ± 5.18

Table 1 showed the demographics information of the participants whereby sixteen (n=16) of male kayak athletes that actively trained for *Sukan Malaysia (SUKMA)* 2022. The mean and standard deviation of the age of the participants in this study was (17.81 ± 1.17 years) meanwhile the body mass represents (62.66 ± 11.09 kg) and the height of the participants showed (167.00 ± 5.18 cm).

Table 2: The Effect of Kinematics and Kinetics Performance of Foam Roller and TENS

Variables	Recovery Modalities					
	Foam Roller			TENS		
	Mean ± Standard Deviation		*P*	Mean ± Standard Deviation		*P*
	Pre-test	Post-test	Value	Pre-test	Post-test	Value
Jump height (cm)	33.64 ± 4.9	37.10 ± 6.72	0.03*	35.47 ± 6.85	34.32 ± 7.60	0.22
Flight time (ms)	522.56 ± 37.86	547.94 ± 48.24	0.03*	535.75 ± 49.31	526.25 ± 56.45	0.19
Velocity (m/s)	1.28 ± 0.09	1.34 ± 0.12	0.03*	1.32 ± 0.12	1.29 ± 0.14	0.18
Force (N)	1227.75 ± 86.31	1288.87 ± 118.50	0.03*	3287.57 ± 1490.15	1239.85 ± 34.06	0.22
Power (W)	1580.66 ± 227.32	1745.59 ± 325.36	0.03*	9007.47 ± 5627.17	1617.47 ± 361.75	0.23

*Significant differences were accepted at level $p<0.05$

Table 3: The Differences of Kinematics and Kinetics Between Foam Roller and TENS

Recovery Modalities		
Foam Roller	TENS	*P* Value
Jump height (pre-test)	Jump height (pre-test)	0.18
Jump height (post-test)	Jump height (post-test)	0.00*
Flight time (pre-test)	Flight time (pre-test)	0.20
Flight time (post-test)	Flight time (post-test)	0.00*
Velocity (pre-test)	Velocity (pre-test)	0.20
Velocity (post-test)	Velocity (post-test)	0.00*
Force (pre-test)	Force (pre-test)	0.18
Force (post-test)	Force (post- test)	0.00*
Power (pre-test)	Power (pre-test)	0.17
Power (post-test)	Power (post-test)	0.00*

*Significant differences were accepted at level $p<0.05$

Based on the Table 2, the kinematics performance of both recovery modalities was analyzed. The height (cm) during squat jump was performed indicate the increasing of jump height from pre-test to post-test using foam roller. The mean and standard deviation in pre-test was 33.64 ± 4.90 cm then increased to 37.10 ± 6.72 cm in post-test. Both pre-test and post-test of squat jump showed significance differences due to *p* value was smaller ($p < 0.05$). Then, the flight time (ms) during squat jump was

increased. Pre-test showed 522.56 ± 37.86 ms then increased to 547.94 ± 48.24 ms. Based on the flight time (ms) recorded, the recovery modality using Foam Roller (FR) took a long-time during take-off and landing phase. However, there was a significance differences were found due to *p* value was smaller ($p < 0.05$). At the same time, the velocity (m/s) was slightly increased from both tests. Pre-test showed 1.28 ± 0.09 m/s then increased to 1.34 ± 0.12 m/s. A significant difference was found in velocity due to $p < 0.05$.

Meanwhile, recovery modality using TENS showed the jump height (cm) indicated 35.47 ± 6.85 cm in pre-test then decreased to 34.32 ± 7.60 cm in post-test. There were no significant differences were found due to $p > 0.05$. Based on the data recorded, the jump height (cm) using foam roller was higher compared to TENS modality. Next, the flight time (ms) during take-off to landing phase dropped from 535.75 ± 49.31 ms to 526.25 ± 56.45 ms. Even though the flight time (ms) taken using TENS was faster than foam roller but there was no significance differences were found due to *p* value = 0.22 ($p > 0.05$). Then, the velocity (m/s) taken decreased from 1.32 ± 0.12 m/s to 1.29 ± 0.14 m/s. The velocity using TENS modality was slower compared to foam roller during squat jump test and there were no significant differences were found ($p > 0.05$).

In short, kinematics performance showed a higher of jump height (cm) of squat jump in recovery modality using foam roller compared to TENS. However, the flight time (ms) taken during the activity was less in TENS compared to foam roller. At the same time, the amount of velocity (m/s) was recorded in modern-technological recovery modality was slower than foam roller. Overall, the kinematics performance using foam roller showed significant differences compared to TENS recovery modality.

As presented in Table 2, the amount of kinetics using foam roller recorded an increasing number in force and power production. The force (N) produced during squat jump rose from 1227.75 ± 86.31 N to 1288.87 ± 118.50 N and a significant difference was found due to *p* value = 0.03 ($p < 0.05$) meanwhile the power (W) generated from the activity was highly increased from 1580.66 ± 227.32 W to 1745.59 ± 325.36 W for both trials. Based on the data recorded, there was a significant effect on production of power and force in foam roller during squat jump test.

While the force (N) generated during squat jump in modern-technological recovery modality was negatively decreased from 1260.15 ± 120.86 N to 1239.85 ± 34.06 N. Then, the power (W) produced showed a decreasing value of pre-test and post-test; 1669.37 ± 331.24 N to 1617.47 ± 361.75 N. Both kinetics performance using TENS modality reported a reduction from pre-test to post-test and there was no significant effect during squat jump test protocol.

As a conclusion, the mean scored by foam roller revealed an improvement in kinematics and kinetics performance in pre-test and post-test compared to modern recovery modality. At the same time, the kinematics and kinetics performance using foam roller showed a significant effect on recovery process. Hence, foam roller was effective compared to TENS recovery modality.

Table 3 revealed the differences of kinematics and kinetics of both recovery modalities (foam roller and TENS). Kinematics value of jump height in pre-test scored 0.18 of *p* value while post-test indicate $p = 0.00$. Hence, there was a significance differences were found in both trials meanwhile flight time score a higher *p* value in pre-test ($p = 0.20$) and post-test revealed *p* value = 0.00. Thus, a significance differences were found in post-test ($p < 0.05$). The significant value (*p*) of velocity indicates $p = 0.20$ in pre-test while $p = 0.00$ for post-test. Therefore, there was significance differences were found due to $p < 0.05$. In short, the kinematics performance of both recovery modalities; foam roller and TENS reported significant effect in post-test protocol of squat jump test.

Then, the force generated during squat jump showed $p = 0.18$ of significant value in pre-test while $p = 0.00$ in post-test. Thus, the was a significance differences were found in force performance in post-test ($p < 0.05$). Lastly, the *p* value of power produced showed $p = 0.17$ in pre-test while $p = 0.00$ in post-test. Based on the *p* value scored, a significant effect was found due to p value of power performance in post-test ($p < 0.05$).

As a conclusion, both foam roller and modern method showed significance differences in kinematics and kinetics performance in post-test during squat jump activity. Even though the amount of kinematics and kinetics performance scored in TENS was higher than foam roller but both foam roller respectively indicated the increasing of performance in pre-test and post-test while TENS modality negatively dropped from pre-test to post-test protocol. Overall, both kinematics and kinetics

performance of squat jump test reported a significant effect in post-test during squat jump test activity. Then, foam roller seems more effective to reduce pain and improve recovery process after having a training session or exercise compared to TENS due to kinematics and kinetics performance recorded.

Table 4: The Reliability of Squat Jump Assessment Between Foam Roller and TENS

Variables	Recovery modalities	
	Foam roller	TENS
	Intraclass Correlation Coefficient (ICC) value	
Force	0.47	0.80
Power	0.48	0.88

Table 4 revealed the reliability of squat jump assessment between two recovery modalities whereby foam roller and TENS. Based on the table, the Intraclass Correlation Coefficient value for foam roller of force performance was (ICC = 0.47) meanwhile TENS was (ICC = 0.80). The Intraclass Correlation Coefficient of TENS showed a higher value compared to foam, but TENS recovery modality revealed a good reliability compared to foam roller that showed a less reliability due to the value of Intraclass Correlation Coefficient. The score of ICC reported the score from 0.8 to 0.9 considered as good meanwhile above 0.9 was high reliable (Vincent & Weir, 2012).

Meanwhile, Intraclass Correlation Coefficient (ICC) value of power output was high reliable in TENS compared to foam roller. The ICC value of foam roller was (ICC = 0.48) while TENS was (ICC = 0.88). However, squat jump test was positively significant to generate force and power output of lower limb muscle. Based on the data recorded, the squat jump test was reliable to assess and determine force and power output either for general fitness purpose or sport specific needs.

Table 5: The Validity of Squat Jump Performance Between Foam Roller and TENS

Variables	Recovery modalities			
	Foam roller		TENS	
	P value	Pearson correlation (*r*)	*P* value	Pearson correlation (*r*)
Jump height-force (pre-test)	0.00	1.00	0.00	1.00
Jump height-force (post-test)	0.00	1.00	0.00	1.00
Jump height-power (pre-test)	0.00	1.00	0.00	1.00
Jump height-power (post-test)	0.00	1.00	0.00	1.00

Based on the Table 5, the validity of squat jump performance in foam roller was (p = 0.000, r = 1.00) while TENS reported (p = 0.000, r = 1.00) whereby both recovery modalities; foam roller and TENS was highly valid and there was a correlation between jump height and force also power production in both recovery modalities during pre-test due to the score of validity from 0.8 to 0.9 considered as good validity while score above 0.9 (r > 0.9) was high validity (Vincent & Weir, 2012).

Then, during post-test of squat jump performance showed a high correlation for both recovery modalities. Foam roller and TENS reported (p = 0.000, r = 1.00) in post-test and highly valid for squat jump test protocol to develop muscular power output due to there was a correlation between jump height and force also power production.

DISCUSSION

The jump height (cm) of squat jump reported a significant effect in foam roller, this is showed that foam roller was able to generate the impact towards the recovery process of hamstrings. Overall, the jump

height of each participant was increased in pre-test and post-test. This study supported that squat jump can be utilized in training session especially sports that required lower body muscular power because the research findings showed that the power output during squat jump test protocol was increased in both tests (pre-test and post-test). As indicated by Keller and Engelhardt (2019), a greater of leg power of the athletes affected by the high of the jump. Hence, the squat jump exercise can be implemented in training session for kayak athletes to develop a stronger muscle in lower limb. According to (Hootman, Dick & Agel, 2007; Ekstrand, Hagglund & Walden, 2011; Fredericson & Misra, 2007), the muscle power can be increased to achieve certain goals such as improving physical condition, health, strength or achievement in a sport by weight training where itself is a systematic exercise.

Massage has been included rubbing and pressing the tendons and muscles. Massage gained more beneficial to reduce pain, increase relaxation and enhance blood circulation. There were many types of massage such as sports massage, traditional massage, Thai massage and self-myofascial release, foam roller. Previous research found that massage has been effective as other treatment to reduce chronic lower back pain. self-myofascial release has many variations such as foam roller, medicine ball, handheld roller and other devices. The application of foam roller (FR) can increase flexibility, muscle recovery and reducing the pain. Su, Chang, Wu, Guo and Chu (2017) found the effectiveness foam rolling was significance compared to static and dynamic stretching in increasing the flexibility of hamstrings and quadriceps and recommended to be used widely in health industry, training and recreation. As foam roller has been effective to reduce muscle pain and soreness but it must be used in proper technique and protocols as it is effective due to guidelines given. (Healy, Hatfield, Blanpied, Dorfman & Riebe, 2014; MacDonald, Penney, Mullaley et al., 2013; MacDonald, Button, Deinkwater & Behm, 2014; Curran, Fiore & Cricso, 2008) demonstrated that foam roller was effective in reducing soft tissue adhesions and muscle soreness. In spite of that, the effectiveness of foam roller to develop muscle strength and performance seems controversial among researchers.

Although the utilization of foam roller seems to be controversial, but it seems effective in this research whereby the mean of kinematics and kinetics performance showed an improvement during squat jump test protocol bit in spite of that the electrical recovery recorded a lower performance of kinematics and kinetics than foam roller in both trials. For example, electrical stimulation recorded 35.47 ± 6.85 cm to 34.32 ± 7.60 cm of jump height while foam roller indicates 33.64 ± 4.90 cm to 37.10 ± 6.72 cm. Then, the velocity (m/s) during squat jump in electrical stimulation was lower compared to foam roller; 1.32 ± 0.12 (m/s) to 1.29 ± 0.14 (m/s) while foam roller recorded 1.28 ± 0.09 (m/s) to 1.34 ± 0.12 m/s in post-test. In spite of the fact that electrical stimulation reported a lower amount of kinematics and kinetics performance than foam roller, there was a significance differences were found in foam roller compared to modern-technological based for power development during squat jump test protocol. Healy, Hatfield, Blanpied, Dorfman and Riebe (2014) reported there was no significance found in foam roller and planking for athletic test.

Both foam roller and modern-technological based recovery modalities have been established to enhance the performance, reducing muscle pain and soreness after training session. Although both modalities effectiveness has been argued but it was in a small group of findings. Much previous research found that foam roller and electrical stimulation showed a significant in recovery process and increase the performance in sports. (Healey, Hatfield, Blanpied, Dorfman & Reibe, 2014; MacDonald, Penney, Mullaley et al., 2013; MacDonald, Button, Drinkwater & Behmm 2014; Curran, Fiore & Crisco, 2008) supported that foam roller was effective in reducing soft tissue adhensions and muscle soreness while Cramp et al., (2000) stated that transcutaneous electrical nerve stimulation (TENS) was used to increase the cutaneous of the blood flow. Both recovery modalities have been widely used in rehabilitation, recreational and sports training but foam roller seems higher utilized in many practitioners, coaches and athletes because foam roller was economy in price and easy to handle. At the same time, the foam roller was practical to be used in reducing pain, improve performance and enhancing muscle recovery. MacDonald et al., (2014) recommended that foam roller was effective in reducing the sensation of delayed onset muscle soreness (DOMS) while MacDonald et al., (2013) stated foam roller preserved the strength and power while increasing the range of motion (ROM).

At the same time, the results reported that the power and force output produced during squat jump increased using foam roller and there a significant effect was found. This study supports that squat jump was able to improve the kinetic performance and can be used to determine the force and power

output among the athletes. The results of force and power output in the study was quite similar to previous study (Cappa & Behm, 2011; Koefoed et al., 2018). According to Markovic et al., (2004), the squat jump was the most popular and reliable to determine the power output compared to other jumps tests. As the study aimed to determine the effect of recovery modalities on kinematics and kinetics performance, the kinetics performance database was increased and the finding showed that foam roller modality revealed the high impact on recovery. Menezes et al., (2022) in their study revealed that electrical stimulation was not recommended to use in delayed onset muscle soreness (DOMS) and muscle recovery among athletes and untrained people due to the recovery modality was not effective for the population.

CONCLUSION

This research findings showed a significant effect in foam roller due the amount of kinematics and kinetics using foam roller was higher compared to electrical stimulation. Thus, a standardize protocols and a proper technique should be fixed and set to determine the effectiveness of both interventions for future research purpose. At the same time, modern-technological based and traditional approaches in enhancing the recovery process can be used in sports training and recreational with a proper technique and guidelines. Well-planned research can be improved for the next research purpose that gain benefits to all groups of people at the different ages. Then, squat jump seems to be practical and valid to develop lower body muscular power as well as by using a proper technique. Researcher also suggested to combine the modern method with traditional to explore another novel finding on training and recovery. An appropriate combination of training and recovery methods will ensure the training goal were achievable. The effect of electrical stimulation can be explored for further research due to the amount of kinematics and kinetics scored were lower than foam roller and these findings were benefits to enhance the sport performance, training and recovery. Lastly, researcher suggested that foam roller seems more practical to be used among athletes and practitioners because foam roller was not expensive, easy to carry at any places and simple in handling during recovery process compared to electrical stimulation. Future research was needed to reliable and accurate markers for performance and recovery.

REFERENCES

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of Sports Sciences*, *33*(15), 1574–1579.

Bishop, C., Jarvis, P., Turner, A., & Balsalobre-Fernandez, C. (2022). Validity and reliability of strategy metrics to assess countermovement jump performance using the newly developed *My Jump Lab* smartphone application. *Journal of Human Kinetics*, *83*(1), 185–195.

Bombelli, M., Facchetti, R., Fodri, D., Brambilla, G., Sega, R., Grassi, G., & Mancia, G. (2013). Impact of body mass index and waist circumference on the cardiovascular risk and all-cause death in a general population: Data from the PAMELA study. *Nutrition, Metabolism and Cardiovascular Diseases*, *23*(7), 650–656.

Brocherie, F., Babault, N., Cometti, G., Maffiuletti, N., & Chatard, J. (2005). Electrostimulation training effects on the physical performance of ice hockey players. *Medicine & Science In Sports & Exercise*, *37*(3), 455-460.

Cappa, D. F., & Behm, D. G. (2011). Training specificity of hurdle vs. countermovement jump training. *Journal of Strength and Conditioning Research*, *25*(10), 2715–2720.

Cheing, G. L., & Hui-Chan, C. W. (2004). Would the addition of TENS to exercise training produce better physical performance outcomes in people with knee osteoarthritis than either intervention alone? *Clinical Rehabilitation*, *18*(5), 487–497.

Cramp, Gilsenan, Lowe, Walsh, & Lowe, A. S. (2000). The effect of high- and low frequency transcutaneous electrical nerve stimulation upon cutaneous bloodflow and skin temperature in healthy subjects. *Clinical Physiology*, *20*(2), 150-157.

Curran, P. F., Fiore, R. D., & Crisco, J. J. (2008). A Comparison of the Pressure Exerted on Soft Tissue by 2 Myofascial Rollers. *Journal of Sport Rehabilitation*, *17*(4), 432– 442.

De Oliveira, F., Paz, G. A., Corrêa Neto, V. G., Alvarenga, R., Marques Neto, S. R., Willardson, J. M., & Miranda, H. (2023). Effects of different recovery modalities on delayed onset muscle soreness, recovery perceptions, and performance following a bout of high-intensity functional training. *International journal of environmental research and public health*, *20*(4), 3461.

Ekstrand, J., Hägglund, M., & Waldén, M. (2011). Epidemiology of muscle injuries in professional football (soccer). *The American Journal of Sports Medicine*, *39*(6), 1226–1232.

Enoka, R. M. (1988). Muscle strength and its development. New perspectives. *Sports Medicine*, *6*(3), 146–168.

Eriksson, E., & Haggmark, T. (1979). Comparison of isometric muscle training and electrical stimulation supplementing isometric muscle training in the recovery after major knee ligament surgery. *American Journal Of Sports Medicine*, *7*(3), 169-171.

Ernst, E. (1998). Does post-exercise massage treatment reduce delayed onset muscle soreness? A systematic review. *British Journal of Sports Medicine*, *32*(3), 212–214.

Fredericson, M., & Misra, A. K. (2007). Epidemiology and aetiology of marathon running injuries. *Sports Medicine*, *37*(4), 437–439.

Hainaut, K., & Duchateau, J. (1992). Neuromuscular electrical stimulation and voluntary exercise. *Sports Medicine*, *14*(2), 100–113.

Hausswirth, C., & Meur, Y. L. (2011). Physiological and nutritional aspects of post exercise recovery specific recommendations for female athletes. *Sports Medicine*, *41*(10), 861–882.

Healey, K. C., Hatfield, D. L., Blanpied, P., Dorfman, L. R., & Riebe, D. (2014). The effects of myofascial release with foam rolling on performance. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins)*, *28*(1), 61–68.

Hootman, J. M., Dick, R., & Agel, J. (2007). Epiomology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *Journal of Atheletic Training*.

Keller, K., & Engelhardt, M. (2019). Strength and muscle mass loss with aging process. Age and strength loss. *Muscle Ligaments and Tendons Journal*, *03*(04), 346.

Koefoed, N., Lerche, M., Jensen, B. K., Kjær, P., Dam, S., Horslev, R., & Hansen, E. A. (2018). Peak power output in loaded jump squat exercise is affected by set structure. *International journal of exercise science*, *11*(1), 776–784.

MacDonald, G. Z., Button, D. C., Drinkwater, E. J., & Behm, D. G. (2014). Foam rolling as a recovery tool after an intense bout of physical activity. *Medicine & Science in Sports & Exercise*, *46*(1), 131–142.

MacDonald, G., Penney, M., Mullaley, M., Cuconato, A., Drake, C., Behm, D., & Button, D. (2013). An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. *Journal Of Strength And Conditioning Research*, *27*(3), 812-821.

MacDonald, G., Penney, M., Mullaley, M., Cuconato, A., Drake, C., Behm, D., & Button, D. (2013). An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. *Journal Of Strength And Conditioning Research*, *27*(3), 812-821.

Maffiuletti, N., Pensini, M., & Martin, A. (2002). Activation of human plantar flexor muscles increases after electromyostimulation training. *Journal Of Applied Physiology*, *92*(4), 1383-1392.

Marković, G., Dizdar, D., Jukić, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *Journal of Strength and Conditioning Research*, *18*(3), 551.

McBride, J. M., Triplett-McBride, T., Davie, A. J., & Newton, R. U. (2002). The effect of heavy- vs. Light-load jump squats on the development of strength, power, and speed. *Journal of Strength and Conditioning Research*, *16*(1), 75.

McGuigan, M. R., Wright, G. A., & Fleck, S. J. (2012). Strength training for athletes: does it really help sports performance?. *International Journal Of Sports Physiology & Performance*, *7*(1), 2-5.

McKenzie, A., Crowley-McHattan, Z., Meir, R., Whitting, J., & Volschenk, W. (2022). Bench, bar, and ring dips: Do kinematics and muscle activity differ? *International Journal of Environmental Research and Public Health*, *19*(20), 13211.

Menezes, M. A., Menezes, D. A., Vasconcelos, L. L., & DeSantana, J. M. (2022). Is electrical stimulation effective in preventing or treating delayed-onset muscle soreness (doms) in athletes and untrained adults? A systematic review with meta-analysis. *The journal of pain*, *23*(12), 2013–2035.

Moore, E., Fuller, J. T., Buckley, J. D., Saunders, S., Halson, S. L., Broatch, J. R., & Bellenger, C. R. (2022). Impact of cold-water immersion compared with passive recovery following a single bout of strenuous exercise on athletic performance in physically active participants: A systematic review with meta-analysis and meta-regression. *Sports Medicine*, *52*(7), 1667–1688.

Mujika, I., Halson, S. L., Burke, L. M., Balague, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International Journal of Sports Physiology and Performance*, *13*(5), 538–561.

National Strength and Conditioning Association. (2009). Youth resistance training [updated position statement paper]. *Journal of Strength & Conditioning Research*, 23: S60–S79.

Pearson, D., Faigenbaum, A., Conley, M., & Kraemer, W. (2000). The National Strength and Conditioning Association's basic guidelines for the resistance training of athletes. *Strength & Conditioning Journal*, *22*(4), 14 27.

Pescatello, L. S., Arena, R., Riebe, D., & Thompson, P. D. (2013). Preview of ACSM's guidelines for exercise testing and prescription, ninth editon. *ACSM's Health & Fitness Journal*, *17*(2), 16–20.

Pichon, F., J.C. Chatard, A. Martin, and G. Cometti. (1995). Electrical stimulation and swimming performance. *Medicine & Science in Sports & Exercise.* 27:1671 1679.

Pietrosimone, B. G., Saliba, S. A., Hart, J. M., Hertel, J., Kerrigan, D. C., & Ingersoll, C. D. (2011). Effects of transcutaneous electrical nerve stimulation and therapeutic exercise on quadriceps activation in people with tibiofemoral osteoarthritis. *Journal of Orthopaedic & Sports Physical Therapy*, *41*(1), 4 12.

Su, H., Chang, N. J., Wu, W. L., Guo, L. Y., & Chu, I. H. (2017). Acute effects of foam rolling, static stretching, and dynamic stretching during warm-ups on muscular flexibility and strength in young adults. *Journal of Sport Rehabilitation*, *26*(6), 469–477.

Vaile, J., Halson, S. L., Gill, N., & Dawson, B. (2008). Effect of cold water immersion on repeat cycling performance and thermoregulation in the heat. *Journal of Sports Sciences*, *26*(5), 431–440.

Vincent, W, J., & Weir, J. P. (2012). Statistics in Kinesiology, 4th Edition. *Medicine and Science in Sports and Exercise*, *45*(6), 1221.

Vossen, J. F., Kramer, J., Burke, D., & Vossen, D. P. (2000). Comparison of dynamic push-up training and plyometric push-up training on upper-body power and strength. *Journal of Strength and Conditioning Research*.

Weerapong, P., Hume, P. A., & Kolt, G. S. (2005). The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sport Medicine*, *35*(3), 235–256.

Zaras, N., Spengos, K., Methenitis, S., Papadopoulos, C., Karampatsos, G.,Georgiadis, G., & ... Terzis, G. (2013). Effects of strength vs. Ballistic power training on throwing performance. *Journal Of Sports Science & Medicine*, *12*(1), 130-137.