THE EFFECTS OF THE WEARABLE RESISTANCE LOADING ON BIOMECHANIC OF AXE KICK IN TAEKWONDO

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THE EFFECTS OF WEARABLE RESISTANCE LOADING ON BIOMECHANICS OF AXE KICK IN TAEKWONDO

Abstract

Wearable resistance (WR) is used in sport training with the aim of increasing performance by enabling sport-specific movements to occur with additional loading. Despite of its potential of allowing athletes to move more specific, studies examining WR during kicking in Taekwondo is scarce. The purpose of this study is to determine the effects of WR loading on the biomechanics of axe kick. Thirty (N=30) university taekwondo athletes have been recruited as participants in this study. This study requires the participants to undergo the middle axe kick testing with WR loading worn at lower body (0%, 5%, 10%, and 15% of body mass) during the execution. High-speed motion capture system was used to analyse kinematic data (kicking velocity, kicking time, kicking height, hip angle and leg displacement). Force plate was used to measure ground reaction force (GRF) while electromyography was used to determine muscle activation (vastus lateralis, rectus abdominis, gastrocnemius medial, gluteus maximus and bicep femoris muscle) during the kick. Results showed there was a significant change in kicking kinematics (kicking time was longer, decrease in kicking velocity, the kicking became shorter, hip angle and leg displacement decrease) as the WR load increased. There was a significant increase of GRF on the supporting leg as WR loads attached increased. All muscle activation also increased with loading but no significant differences found. In conclusion, WR loadings of 5% body mass and higher at lower body affected the biomechanics of the middle axe kick. Although had mechanically affect the movement, future studies are suggested to investigate the chronic effects of these loadings. The implications of this study can be used as a guideline to choose proper WR loading to be used in training.
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KESAN BEBANAN PEMBERAT YANG BOLEH DIPAKAI KE ATAS BIOMEKANIK TENDANGAN KAPAK DALAM TAEKWONDO

Abstrak

Pemberat boleh pakai (WR) digunakan dalam latihan sukan bertujuan meningkatkan prestasi dengan membenarkan pergerakan spesifik sukan berlaku dengan tambahan beban. Walaupun dengan potensinya membolehkan atlet bergerak lebih spesifik, kajian ke atas tendangan dalam taekwondo adalah sangat sedikit. Tujuan kajian ini adalah untuk mengkaji kesan beban WR ke atas biomekanik tendangan kapak. Tiga puluh (N=30) atlet taekwondo universiti telah direkrut sebagai peserta kajian ini. Kajian ini memerlukan peserta untuk melakukan tendangan kapak dengan beban WR dipakai di bahagian bawah badan (0%, 5%, 10%, dan 15% jisim badan) semasa lakuan. Sistem rakaman pergerakan berkelajuan tinggi digunakan untuk menganalisis data kinematik (halaju tendangan, masa tendangan, tinggi tendangan, sudut pinggul dan sesaran kaki). Platform daya digunakan untuk mengukur daya (GRF) sementara elektromiografi digunakan untuk merekodkan pergerakan aktiviti otot (vastus lateralis, rectus abdominis, gastrocnemius medial, gluteas maximus and bicep femoris muscle) semasa tendangan. Keputusan menunjukkan terdapat perubahan signifikan pada kinematik tendangan (masa tendangan lebih lama, halaju tendangan menurun, sesaran tendangan lebih rendah, sudut pinggul dan sesaran kaki berkurang) apabila beban WR meningkat. Terdapat peningkatan signifikan pada GRF di kaki sokongan apabila beban WR meningkat. Pengaktifan otot pada kesemua otot meningkat dengan peningkatan beban, namun tiada perbezaan signifikan. Kesimpulannya, beban WR 5% jisim badan dan ke atas pada bahagian bawah tubuh memberi kesan kepada biomekanik tendangan kapak tengah. Walaupun memberi kesan secara mekanikal kepada pergerakan, kajian akan datang dicadangkan untuk menyiasat kesan kronik beban-beban ini. Implikasi kajian ini boleh digunakan sebagai panduan untuk memilih beban WR yang sesuai untuk digunakan dalam latihan.

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LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
ANOVA	Analysis of Variance
BF	Bicep Femoris
BM	Body Mass
CMJ	Counter Movement Jump
COG	Centre of Gravity
DL	Dominant Leg
EMG	Electromyography
GM	Gluteus Maximus
GMH	Gastrocnemius Medial Head
GRF	Ground Reaction Force
IOC	International Olympic Committee
MUAPs	Motor Unit Action Potential
MVC	Maximum Voluntary Isometric Contraction
NDL	Non-dominant Leg
NPL	Non-preferred Leg
PAP	Post-Activation Potentiation
PL	Preferred Leg
PAR-Q	Physical Activities Readiness Questionnaire
RA	Rectus Abdominis

SEMG	Surface Electromyography
SJ	Squat Jump
SLJ	Standing Long Jump
SPSS	Statistical Packages for The Social Science
SUKMA	Sukan Malaysia
UPSI	Sultan Idris Education University
VL	Vastus Lateralis
VO_2	Oxygen Volume
WR	Wearable Resistance
WRT	Wearable Resistance Training
WTF	World Taekwondo Federation

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The word “Taekwondo” brought down the meaning of “the art of kicking and punching” is one of the most popular martial art grouped as dynamic unarmed self-defence in which uses the entire body to produce a variety of kicking techniques. Different from other muscle art, taekwondo focuses more on kicking skills as the main technique that can produce greater force and power when performing these techniques. It was the unique characteristic of taekwondo to use the kicking as a main offensive weapon in the tournament, (Boyat, Singh, Sandhu, 2017; Hong, 1997). The taekwondo itself has many types of kicking that will then been widely known across all countries due to its powerful kicking techniques, (Daifeng et al, 2012; International Taekwondo Association, 1998-2012). A long time ago, taekwondo used for fighting and self-defence, recently now, taekwondo became one of the combat’s sports event organized

at the Olympic sports. Throughout the entire United States and not considering other countries alone, the people who participated in this martial art are about 2 million and we could say that taekwondo was very famous in this country, (Toskovic et al, 2002; David et al, 2017). In Malaysia, taekwondo was brought out in the 1960s and now became the main competition event in Sukan Malaysia (SUKMA), (Mohd Kassim, Suwarganda, & Mohd Nor, 2014).

As taekwondo now became part of the combat sport, coaches and researchers have selected the most offensive and effective kicking techniques that can be contributed to the match points during a tournament. The well-known kicking techniques of taekwondo are a front kick, turning kick (also known as roundhouse kick), and axe kick. Overall, of these kicks, the front kick was a popular technique that had been studied within the biomechanics area by the researchers, (Hwang, 1987; Park, 1989; Beraud 1995; Sorenson, 1996; Cular, 2010; Falco et al, 2011; Wasik, 2012; Daifeng et al, 2012). The potential of the front kick in terms of delivering a powerful kick strike with maximal kick foot velocity makes this technique so popular among the researchers to explore its biomechanical characteristics.

Besides, there is another powerful kick that rarely being studied within the biomechanics area that is axe kick, (Tsai, Lee & Huang, 2004) due to the limitation of measuring technology uses (i.e., only involves accelerometers rather than 3D motion capture). As the new taekwondo rule had been implemented in 2008, which striking to the head has become the vital component that capable to determine the winners and losers in a tournament (Changtao, 2017; Fei Ying & Song Hua, 2009), axe kick seem

to be the most suitable kicking technique due to its biomechanical characteristic and final strike output of these techniques result.

Originated from Korea in the 1940s, Taekwondo has been improved in terms of the technical and tactical features of many masters from the Korean army during the 1950s (Gillis, 2016). Taekwondo involves kicking and punches as the main strike techniques. 98% of scoring in Taekwondo is produced by kicking (Kazemi, De Ciantis, & Rahman, 2013). The athlete's ability to produce a good kicking is measured by the velocity and force of the kick. The ability to produce fast and powerful kick will result in opponents have less time to react and are more likely to concede points because of the forces produced. Looking back to these key advantages of axe kick and front kick, these two kicks matched the essential need during the taekwondo tournament. The powerful and fastest strikes when delivering accurately at a certain height during a taekwondo match would result in the highest point to the head (Topal et al, 2011; Koh & Watkinson, 2002; Shirley, 1992). Therefore, many researchers committed to explore and investigate the kicks within taekwondo kicking techniques which aim to find what kicks that can be focus more and be inserted in the training program.

During taekwondo or any other martial art match, the athletes want to finish the match as fast as possible. The question is, would it be possible if a single kick can reveal the winner during the match? The aim is to get the optimum kicking performance which includes, accuracy, fast and powerful strike with a single leg kick. The combat rules (knockdown) distinguished by World Taekwondo Federation (WTF) through their article 18 is; the declaration of the winner is based on the count of eight (Yeo-dul) if the fighters failed to rise and continue the match, (Preushl, Hassmann, and Baca, 2016;

World Taekwondo Federation, 2015, p. 39). The front kick is known as ‘Ap Chagi’ in Korean, which was the very basic kicking technique that will be learned in early the training for the new learner. In short meaning, a front kick is the foundation kick that needs to be learned before learning other kicks such as axe kick, spin kick (also known as roundhouse kick), and jump kick.

The axe kicks are commonly used by the athletes during the tournament either for defensive or for an offensive situation. It is also can be used to counter the attack from the opponent by striking the opponent's supporting thigh during the beginning stages of the kick. Nevertheless, the axe kick often used to launch an attack used to strike the head to get the points as it is the highest points in taekwondo competition rules; thus, it is becoming a popular kick used commonly by the fighters, (Changtao Zhou, 2017; Fei Ying, & Song Hua, 2009; Cheng Lei, 2005; Liu Baocheng, Zhao Qiurong, & Lu Fan, 1996). Unlike front kick, most of the axe kick strike is targeting the head of the opponent, while the front kick target can be changed based on its levels (front snap kick & front thrust kick). The execution of these kick needs the fighter/ athlete to pull out the leg up in a circular motion, and at the peak height, pull out the heel linear to the opponent’s shoulder or head. Similar to another kick technique within taekwondo, axe kick consists of four stages in common, (Daifeng et al, 2012). The first stage is just to faking the movement of legs so that the opponents become confused to predict which foot will be used, at the same time, created the opening for the target. The fighter then continues to rapidly change the stance to enter the second stage. The second stage was called power load where all the power output accumulated at the bold foot area (ankle and heel). At this stage, the fighter will pull up his/her kicking leg until reaching the peak height. The muscles at the legs area will stretch at the maximum level

and the joint extension will reach the maximum range of motion to develop the kicking power. On axe kick techniques, the height of the fighter's heel will decide the force output for the next stage. The third stage after the power load is 'drive', where the circular motion of the kicking leg (heel) reaching the peak height. The foot of the kicking leg is above the target area and the circular motion stops at one point where the force obtained from the power load transferred to the 'drive stage' moving down to the opponents (target). Finally, the last stage is the landing and stabilization to stable the fighter stance for the next axe kick performance.

Referring back to the mechanism, and characteristic of these axe kick, surely this kick is very important that make a mountain of the studies had been conducted by researchers due to the efficiency of these two kicks during a tournament. The biomechanical characteristic of kicking techniques defined how successful and effective the particular kick is. Therefore, the researcher and sport science expertise combined the recent advanced equipment (devices) in order to study the biomechanical of kicking techniques within taekwondo. The study on biomechanical characteristics usually highlighted the very important factor that could define how success and effectiveness of the execution of a certain kick. The factor that had been looking at on the axe kick by Daifeng Yu et al, (2012) are, the peak height target; the peak height attack of the fighter based on their anthropometry (i.e., body height and leg length of the fighter), the inertia of the kicking leg; to get the effective kicks, all kicking leg movement should be at the minimal execution time. Thus, at the time of the power load stage, minimizing the moment of the inertia on dynamic kicking kinematic is a must, and the last factor is the feet kicking speed; where the kicking speed of the feet will define the power output of the axe kick (when at the drive stage, the fighter executed

the kick downward towards the target). Besides that, a researcher is concerned about how a particular technique is accomplished (Kim, Kwon, Yenuga & Kwon, 2010; Falco & Estevan, 2015). As an example, certain kicking techniques within taekwondo are very efficient when used during the combat tournament and this what makes the researcher want to investigate and compare the different, (O'Sullivan et al, 2009; Estevan, Jandacka & Falco, 2013; Falco & Estevan, 2015) and what makes successful performance outcome can be reached, (Serina & Lieu, 1991; Falco & Estevan, 2015). Therefore, many aspects of Taekwondo have been scientifically investigated such as the speed of kicking foot and movement time (Estevan, Álvarez, & Castillo, 2016; Isaac Estevan, Álvarez, Falco, Molina-García, & Castillo, 2011) and the impact force of participants of the distinct level of expertise (O'Sullivan et al, 2009). Some authors have focused on the kinematics of the lower extremity and pelvis (Da Silva, Misuta, Silvatti, Mercadante, & Barros, 2011).

The exists of advances equipment and devices (i.e., Vicon three-dimensional motion analysis, high-speed camera, force platform, EMG, and many more) nowadays as a purpose for analysis makes it easy for the researcher to conducts research compared to a long time ago where the researcher has limited equipment for their research. Electromyography (EMG) is used to record any muscle activity by detecting the myoelectric signals, (Basmajian & De Luca, 1985; Falco & Estevan, 2015). In practical terms, the data obtained through EMG analysis can be split into two; static and dynamic conditions. The dynamic conditions are referred to as the movement of kicking, jumping, and punching during EMG analysis while the static condition is mostly used for obtaining the EMG activity of static movement (i.e., Bicep curl, bench press, etc.). With respect to the investigating of dynamic conditions, the muscle activated during

performing the kicks are based on the kicking phases, (Haddad, 2015; Sorensen, Zacho, Simonsen, Dyhre-Poulsen & Klausen, 1996). Another study regarding these conditions on lower limb axe kick reported that, although ten kicks rapidly executed, the EMG waveforms shows not very high, (Aggeloussis, Gourgoulis, Sertsou, Giannakou & Mavromatis, 2007). Furthermore, the study according to the expertise has been conducted and as the results, the muscle activity appears to be lower at the expert fighters while higher at the novice fighter. These results can be concluded that the experts recruited the suitable muscle group when performing the kick, (Machado, Osorio, Silva & Magini, 2010). For the study of static conditions, it is found to be a more reliable result of EMG measurement compared to the dynamic (movement) analysis throughout collective research. The analysis by the researcher on muscle activity mostly focused on the main muscle used during the execution of kicking techniques (i.e.hamstring, quadriceps, and gastrocnemius muscles). Muscle activated during the execution of the kicking techniques may give a very important result for the researcher because, through these, the researcher will have a knowledge on which muscle should be focusing more and recommended within the training program of athletes. Besides that, several studies (Youlian et al, 2000; Badilla et al, 2017; Estevan et al, 2015; Sutima & Orawan, 2014) also conducted a study regarding the muscle activity during kicking techniques. After all, the change in muscle activity during the kicking performance can be related to the force production (Haddad, 2015; Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2004). When coming to these matters (the study of force production during kicking), the uses of suitable devices such as force plate is recommended.

The force plate is the devices used to measure ground reaction force (GRF) and moments required within human body movement through the mechanical sensing system. The movements include kicking, jumping, walking, and all types of movement of the human body. Beyond the force data, the advance information data of human body movement such as velocity (m/s), power (W), and displacement (m) also can be measured. Therefore, because of the validity and reliability of it, many researchers have used it for the purpose to study the force production during kicking in taekwondo. In taekwondo, the force produced during executing the kick is very important to the researcher as it is very useful information to their knowledge. The force itself is split into two which is internal force and external force. Internal forces are the exert force produce by the system in the human body including muscle, tendons, etc. During kicking in taekwondo, muscle and tendons were acknowledged as the system that produces internal force and develops the kinematic state. The internal force then will initiate the movement of an extremity (lower and upper) but does not affect the motion of the center of gravity (COG). The external force is the force that produces happening from the outcome of the interaction between the human body and its environment. The external force is also divided into two; contact force and non-contact force and most of the study by researchers are interested in the contact forces (e.g., ground reaction force). Theoretically, the force is a vector quantity interpreted by its magnitude, direction, and point of application, (Robertson et al, 2004). The GRF is a similar magnitude but contrary in a direction towards the force that applied by the body on the supporting surface through the foot, (i.e. kicking performance in taekwondo, GRF occurs at supporting leg) while moments is the spinning effect of the force, (joint moments of the ankle, knee, and hip are responsible for the GRF on the stance leg). Through the force plate, we can see the GRF vector facing upwards from the supporting foot appears on

the computer screen in order to measure the GRF vectors 3D (represent by X, Y, and Z axes) orientation. Winter, (1984, p.51), has stated that the GRF vectors are the view of the amount (mass, time, and acceleration) outcomes of the full-body segments in which then described the amount of the entire net muscle and gravitational force delegated at each instance of time over the stance period. The study to measure the GRF and moments is very important within the biomechanics analysis of taekwondo kicks to determine joints kinetics (peak joint moments), which to figure out the scientific data for the improvement of the performance. Overall, the study of GRF and moments is important to improve the stability on the supporting leg during executing the taekwondo kicking. There are many studies regarding the GRF, moment and impact force proved according to the mounting of the study conducted by many researchers, (O'Sullivan et al, 2009) to analyze the difference between taekwondo athletes when executing the roundhouse kick, the study to analyze the effect of stance position during kicking (Estevan et al, 2013), the study of the relationship of the expertise level during 'dollyo chagui' kick, (Moreira, Franchini, Ervilna, & Goethel, 2018), the study by (Estevan et al, 2013; O'Sullivan et al, 2009) to compare the GRF within the vertical plane, and the study to analyze the GRF within a lateral plane (Estevan et al, 2013). In the study of impact force by (Pedzich, Mastalerz, & Urbanik, 2006), some researcher determined the impact force on three kicking distance to the head level (Estevan, Alvarez, Falco, Molina-Garcia & Castillo, 2011) and the same study of the impact force to the chest (Falco, Alvarez, Castillo, Estevan, Martos, et al, 2009).

In biomechanics of every kicking technique, there is also an important variable that contributed to the successful performance which is the standing position during execution of the kick and it is like the buildings need a strong and stable base to stay

on. The stance position has been known to be the factors that capable to influence the kick performance, (Avinash, Amrinder, & Jaspal, 2017; Estevan, Falco & Jandacka, 2011; Kim, Kwon, Yenuga & Kwon, 2010) and it is related to the joint moments and GRF. In taekwondo combats, the fighters maintain different stance positions in order to develop excellent performance. The fighters that can utilize the better applicable stance position perhaps the keys to the excellent performance. (Avinash et al, 2017; Estevan et al, 2011) conducted a pilot study focusing on the stance position has stated that, the execution and total response time of the lateral stance position (90^{o}) to be greater than the forward (0^{o}) and diagonal stance positions. They also stated the 45^{o} stance position as the better applicable position in combats.

The kicking techniques of the fighter are very important to further improve the optimum and successful results within the taekwondo tournament. As the consequence, the new and advanced equipment for motion analysis 2D and 3D imaging technology (i.e., high-speed video camera and Vicon) is being used by many researchers to study the kinematic of not only within taekwondo sports but across every sport. The 2D and 3D motion analysis is very useful and dependable in determining the kinematic of the performance of the entire technique (i.e., stance phase, swing phase, impact phase). In taekwondo front kick techniques, there are several kinematic characteristics that had been looking over which is a) hip, knee, and ankle muscle torque arrangement, b) the action of the dominant muscle groups order, c) types of muscle contraction and, d) the range of movement phases in regard to the efficient muscle torques applied, (Wasik, Czarny, Malolepszy & Teresa, 2015). In taekwondo, the fighter usually uses the lower extremity as the main method of kicking mechanism where all the extension and flexion of the knee, hip, and ankle occurs. Also, the peak height of the front kick is depending

on the starting movement at the lower extremity, (Wasik et al, 2015; Sorensen, Zacho & Simonsen, 1996). As mentioned before, foot velocity compliance the factor that leads to the excellent output performance of kicking during tournaments. The foot velocity is depending on two factors that must be a focus which is; a) the velocity of the upwards direction of the knee, and b) the total time of kick execution (consists of foot takeoff time and the duration of the time of bringing the foot up). Several researchers (Vagner, Malecek, Tomsovsky, Kubovy, Levitova & Stastny, 2019; Ramakrishnan et al, 2018; Vagner et al., 2018; Serina & Lieu, 1991) has mentioned that the main key elements related to the excellency of the front kick are including, the techniques, movement control, speed, velocity, force, energy, and power. All of the factors mentioned before are the result of the evaluation of the transferred momentum of energy (Vagner et al, 2019).

Apart from that, the axe kick showed the similarity of the high foot velocity as the result of the study by Jakubiak and Saunders, (2008) and Wasik et al, (2015), and most of the biomechanics studies regarding axe kick focus on kinematics. In taekwondo competition, the fighter who is able to deliver the kick towards the head perfectly will get the highest point and somehow possibly decides the winners. The study of the axe kick techniques by Changtao, (2017) utilizing the 3D imaging technology found that the change in the hip joint of the swing leg is relatively strong. During the knee flexion process, there is an increase in knee joint movement compared to the toe and ankle joint. During kicking, the toe and ankle joint are significantly important as the highest values are reached. Nevertheless, there is a decrease in hip, toe, and ankle joint displacements after performing the axe kick. Also, some researcher studies the axe kick technique towards another level whereby before this, they just focused on the normal

axe kick (the kick performed from the normal stance). In taekwondo, it is an advantage for the fighters if they can deliver the kick towards the target with a powerful kicking attack. The powerful attack of a certain kick like axe kicks can be easily produced with the addition of counter-jump movement before performing the kicks. Although this kick seems too cruel as the outcome perhaps could lead to serious injury, the kick is acceptable within both attacking and counter-attacking techniques in competition, (Preuschl et al, 2016). Preuschl et al, (2016) on their study proved that the jump front leg axe kick improves the impact velocity at the ankle. Another study on jumping axe kick was also conducted by Tsai, Gu, Lee, Huang, and Tsai, (2005) and Kloiber, Baca, Preuschl, and Horsak, (2009). Other aspects like target height, level of the fighter, and the target distance (short, medium, long) also have been studied by the researcher. Those aspects usually being tested on the movement of kicking leg, pivot hip, trunk, and pelvis as most of those appeared during kicking in taekwondo.

Throughout many types of research that had been conducted, it is obvious that kicking ability will affect the match outcomes, thus, the explosive kick should be a principal focus of Taekwondo training, and training with resistance is recommended to fulfill the demands of excellent performance. The intermittent sports required explosive power as the foundation of optimum output performance. Taekwondo also required those components in terms of the kicking limb flexors and extensors (ankle, hip, and knee) explosive strength and the results could lead to the successful kick execution. Also known as a triple extension (the combination of hip, knee, and ankle) are the main factors for the force production during kicking in taekwondo. For this reason, the fighters/athletes and coaches are advised to select the exercises that perhaps increase the explosive strength at the lower limb. Besides that, coaches or instructors should

comprehend the exercises that match those components of taekwondo kicking, (Vagner et al, 2019). The exercises then perhaps improve the maximum strength of internal stance limb, external rotators, and speed-strength of kicking limb hip flexors and extensors.

Resistance training is a kind of training that involves any kind of equipment/tools to become resistance. The traditional methods of resistance training involved individuals to go to the gym and lift weights. This is due to the mounting shreds of evidence that had shown the effectiveness of gym training to improve maximal strength through the increasing of muscle contraction velocity (da Silva, Valenzuela, & Franchini, 2015; Topal, Ramazanoglu, Yilmaz, Camliguney, & Kaya, 2011). The application of the resistance training not only affects the muscle size and strength but slowing the aging effects on the muscle (sacropenia) which leads to the decreasing of muscle size and function, (Algre & Csapo, 2015; Hakkinen et al, 1998; Reeves et al, 2004; Morse et al, 2005; Narici & Maganaris, 2007). Additionally, the resistance training also improves the effectiveness of the individual fundamental skills (FMS) such as (sprint, squat jump, standing long jump, throw, and vertical jump). The positive effect of FMS will be giving an advantage when the individual involves in a sport that requires specific skills because the athlete does not need to focus instead on the specific sport skills movement of that particular sport. In taekwondo, the uses of weight training are familiar and it is not the new things as through the previous study, there are many studies to determine the effects on kicking performance. The selection of what kinds of resistance training should be applied is the key's success to the performance in taekwondo or any other martial arts. If refer to the terms of triple extension (the combination of hip, knee, and ankle extension to complete kicking

movement), the taekwondo kick is more often to use a lower limb. Therefore, similar movement exercises with additional resistance (weight) should be implemented such as clean and jerk and power snatch. The power snatch and clean and jerk are known as the lower body exercises aim to improve the lower body maximum strength which leads to the level of explosive power, (Dietmar, 2010). Besides snatch, the application of the elastic rubber band in the resistance training is also has been implemented and combined with the free weight training (Shoepe, Ramirez, Rovetti, Kohler & Almstedt, 2011; Baker & Newton, 2005; Swinton et al, 2009). Another result of the combination of the elastic band and free weight has affected the strength improvement of the athletic groups within 7-12 weeks (Shoepe et al, 2011; Anderson et al, 2008; Ghigiarelli et al, 2009; Mccurdy et al, 2009; Rhea et al, 2009) and power (Shoepe et al, 2011; Rhea et al, 2009). Applying the elastic rubber bands on the taekwondo resistance training program perhaps enhancing the benefit since elastic band yield prominent resistance due to their elastic characteristic and their function as a variable component in training (Topal, Ramazanoglu, Yilmaz, Camliguney & Kaya, 2011; Shoepe, Ramirez, & Almstedt, 2010). The use of an elastic rubber band is to purposely improve the kicking performance and yet, there is no experimental evidence according to the statements by Jakubiak and Saunders, (2008), before the study to analyze the effect of a rubber band on taekwondo (strike force) has been conducted by Topal et al. (2011). In addition, the elastic band also improved the kicking velocity and impact force when measured by a three-axis accelerometer. The elastic bands seem very efficient if applies within the kicking training program for taekwondo as the evidence from the previous study reported, it can improve strike force. Apart from the resistance training, the plyometric training also giving a positive result on improving the maximum strength and explosive

power since the kicking performance in taekwondo generate explosive power to launch the powerful strikes attack.

However, until now, the issue of transferability of strength gains achieved from traditional resistance training methods to sport-specific performance is still debated among strength and conditioning's coaches, practitioners, and athletes (da Silva Santos et al., 2015; McGuigan, Wright, & Fleck, 2012; Pareja-Blanco, Rodríguez-Rosell, Sánchez-Medina, Gorostiaga, & González-Badillo, 2014). Despites the previous studies had confirmed that the other resistance training such as plyometric training, traditional gym training, elastic band training and machinery weight training, none of this training method could closely mimic the sport specific movement. The traditional resistance training is also preferrable to improve the muscle strength but the problem is, how we can train the sport most likely depend on the specific movement such as combat sport which mostly spent time on the specific skill movement. A few strengths and conditioning researchers have argued that a better training transfer can be achieved from exercises that display mechanical specificity to the movement performed in a competition (Haff & Triplett, 2015; Moir, Brimmer, Snyder, Connaboy, & Lamont, 2018) and specificity of the velocity of movement (Pareja-Blanco et al, 2014).

Currently, similar to most other sports, strength training protocols for combat sports utilize the normally available weight machines and free weight apart from the most widely used bodyweight strength training (Lenetsky, Harris, & Brughelli, 2013; Saraiva et al, 2014). It is thus proposed here that training should utilize loading methods that are more functional, and able to be loaded while performing the actual combat

sports movement. Therefore, loadings that permit performers to move freely according to sports movement are suggested.

The weighted vest is the one of the resistance training that has been applied by the military as part of their training routine. This weight vest involves the wearable tops with attachable weight. Those weight beg contains ceramic plate or sand which sewn separately into the small beg. Long before the weighted vest, the sand beg as a part of the wearable resistance has been used where the athletes will put it at the ankle and wrist. In military terms, this weighted vest is also known as a personal protective equipment (PPE) and wore during the real combat event. This type of resistance training now has been implemented into the sport area after a several innovation and improvement has been done to mimic the actual movement of the particular sport. The researcher has conducted the study regarding the weight vest wearable resistance to determine the effectiveness on the sport performance. The study conducted by, Vagner, Thiel and Tomsovsky et al, (2018) to determine the effects of ballistic and weighted vests on front kick kinetics where they had selected five male soldiers to performs the front kick. Cronin, Hansen and Kawamori et al, (2016) also has conducted the study in to compare the effectiveness between weighted vest and sled towing on 30 meters sprint kinematics on twenty athletes. Another researcher has conducted the study involved weighted vest during walking. Their study was to examine the effect of the vest on metabolic response (oxygen consumption), relative exercise intensity, vertical ground reaction force, and rate of loading by performing the walking movement on the treadmill. The resistance training with applying the mimic specific movement concepts has been use and included in the training routine since long time ago with variety of

characteristic in order to match the performer's comfort during wearing the wearable resistance (sand bag, and weighted vest).

After several improvements have been done since the weighted vest, the new wearable resistance with a comfortable concept has been created. Wearable resistance training involves an external load being attached to certain segments of the body during various sporting movements and is an example of the application of the concept of training specificity (Dolcetti, Cronin, Macadam, & Feser, 2018; Macadam, Simperingham, & Cronin, 2019). Wearable resistance is used in athletic training with the aim of increasing power output and performance by enabling specific movements to occur with additional loading without adversely affecting the technical execution of the action being performed (Macadam et al, 2017). It is in the form of weighted vests, shorts, arm, and leg sleeves increased the ability in terms of the movement specific action (i.e., external load is applied) and became the popular tool being examined among many sport teams and individual athlete. The new wearable resistance technologies (i.e., the Lila TM Exogen TM exoskeleton suit) enable much greater customization of load magnitudes, orientations, and locations around the body. This kind of wearable resistance enables sport-specific actions to be performed in an overloaded manner (Macadam, Cronin, & Simperingham, 2017). The study regarding wearable resistance previously involved researchers to select the loading in the range of 1-10 % of body mass (BM) for determining the effects on the physical performances and sports. Thus, through their studies regarding wearable resistance, they had provided the direction of a framework on loading position and particular % of BM. Those finding could be the guidance and references for the practitioner or coaches to adapt within their training program. The selected loading of wearable resistance is very important to

investigate the different effects of such weight on certain training or performance within the sport. The study by Macadam, Simperingham, and Cronin (2017), to test the acute effects of wearable resistance on vertical jump and sprint running with 3 % and 6 % BM loads. The loading of both 3 and 6 % recorded no significant difference between the loadings and the performance of vertical jump is decrease due to the reduction of peak velocity that at last affects the peak power output which also decreases. While, on sprint running performance, 3% of the wearable resistance loading at the lower limb reportedly, decrease the speed at 10- 20 meters running and no significant change occurred during the initial 10 meters of sprint running. Previously, the traditional method was implemented the sled pulling within their program training (14; 105), wearing parachutes (2;82), applying the loaded trunk loaded vest (Alcaraz, Palao, & Elvira et al, 2008; Cross, Brughelli & Cronin, 2014; Macadam, 2016), loading loads to the leg (Simperingham, & Cronin, 2014; Macadam, 2016), ankle (Ropret, Kukolj, & Matavujl et al, 1998; Macadam, 2016), and foot (Martin & Cavanagh, 1990; Macadam, 2016) to resist the sprint running of an individual. Reviewing from the all of this studies, the research attached the load more at the posterior rather than applying load on both side (anterior and posterior), therefore wearable resistance training could be the solution in which external loads can be attached on the anterior or posterior surface.

Feser, Bayne, Loubser, Bezodis, and Cronin, (2020); Macadam, Simperingham, et al (2017); Simperingham, Cronin, Pearson, and Ross, (2016), also study the acute effects of 3 % wearable resistance during the sprint acceleration. The performance involved professional male rugby athletes in which divided into the loaded and unloaded group. There are significantly different between groups where the group of 3% showed the change which is dominant in force due to the non-significant increase

in theoretical maximal horizontal force (5.08% -6.25%) and decreasing in theoretical maximal velocity (-3.57% to – 6.49%). From their results, the 3% loading of wearable resistance strained the velocity in the acute study. Another acute study by Couture, Simperingham, Cronin, and Lorimer et al, (2018), to investigate the effect of wearable resistance loading at the upper body (UB) and lower body (LB) on Spatio-temporal and kinetics parameters during running performance. The loading selected was 1/3/5% of BM for the lower body, 5% of BM for the upper body, and 5/10% of BM for the whole body. Also, the acute study by Simperingham, Cronin, Pearson, and Ross, (2016), with the selected load 3% and 5% of BM for the lower limb wearable resistance. There a 6% change in sprint acceleration biomechanics when loading with 5% of BM. This finding indicated that, the use of wearable resistance load of 5% affects the sprint acceleration of the participants due to the resisted from the wearable resistance external load.

Recently, the wearable resistance widely examined and studied by many researchers to investigate the effectiveness of this tool. Macadam, Mishra and Feser et al, (2020), stated that the arm mechanics function to minimize sprinting performance, however power-force-velocity profiling deliver as an effective method to measure athlete's individual power and acceleration capabilities. The forearm wearable resistance seems give impacted at the mid-late acceleration phase of a sprint. The study by (Feser, Bayne & Loubser et al, 2020) were focused on the longitudinal study among the rugby athletes with an intervention of 1% of wearable resistance attached to the left and right shank. Study found that the athletes that finished the wearable resistance training intervention did not significantly improve or slowest in the sprint running times or velocity. Based on this, we can see that the attachment of 1% load of wearable

resistance is not enough to resist any activity and recommended to increase the load percentage that perhaps stimulus the training of the athletes.

As through the previous acute studies evidence, it is clear that the wearable resistance training affected physical performance. The study by previous researchers selecting the lowest load from 1-10% of BM has clearly given a direction for the future study that the load between 3-5% has effects on physical performance. These findings then became the frameworks for other researchers to conduct the chronic or longitudinal study in order to fully understand the efficiency of this new training method on various sports. Previously before the evolution of the exogen suits wearable resistance, the longitudinal effects of the trunk loaded vest wearable resistance training on jumping performance with load range between 7-30% of BM with (3-10 weeks) training intervention was reportedly by Makovic, Mirkov, and Knezevic et al, (2013). The selected of 8-12% of BM attached to the trunk seems to improve the jumping height. Another 8 weeks study with load 30% on squat jump performance and countermovement jump by Makovic et al, (2013) where the results showed improvement on both movements. Macadam et al, (2016); Bosco, Rusko, and Hirvonen, (1986) also reported the study on trunk loading during sprint running performance with 7-8% of BM loading selected three weeks of the training intervention. Although trunk vest loading wearable resistance has similar concepts with the exogen suits, still the function and characteristic of the new exogen suits is more advance and the results from the previous study cannot represent the effectiveness of new exogen suit wearable resistance training. Therefore, the new longitudinal study on exogen suit is suggested to carry out the new knowledge about this suit. The study of wearable resistance widely conducted by many researchers as mention before which more

focusing on sprint, fundamental skill (i.e., vertical jump, standing broad jump, etc.) and a lot of the findings that pointed to the positive result and some suggested for conducting the longitudinal study to fully understand its efficiency. Several studies regarding the wearable resistance have been read, there are lacks of study on the kicking in taekwondo and only some study is conducted by Vecchio, Stanton, Macgregor, Humpries, and Borges, (2017) on mix martial art and kickboxing.

As to summarize, the application of the traditional method is still being used within the taekwondo training regime. As the new method currently appear which is wearable resistance, the selection of these new methods perhaps increases the advantage for the future athlete because of the ability to involve the specific movement within taekwondo while loaded with weight. With the addition of load within the training, able to move freely according to the specific movement as well as specific techniques and skills and perform at high velocities which usually cannot be found in traditional resistance equipment. This opportunity perhaps could be an effective new method with such advantages and become the reference sources for the coaches and researcher for the good of taekwondo sports future. Lacks of study focus on martial art has given the idea to conduct the study on kicking in taekwondo. Since the wearable resistance is newly developed, it may take a several time for the researcher to conduct the study on the various sports especially the combat sport. Besides, the lack of longitudinal studies on focusing the effects of wearable resistance in sports also initiates the idea to study the chronic effects of this training method. The selection of the amount of percentage used for the intervention suggested mostly more focus on light loading % of BM rather than heavy load. In several studies previously stated that, the low load percentage not significantly affective when used, so the addition of load should be

recommended for the new study. Through this proposed, it could be a great chance to determine the effect of the wearable resistance in the taekwondo kick. The taekwondo kick was widely examined and studied by many researchers in order to understand the biomechanical characteristic of certain kick, study the impact force, kick execution, ground reaction force and many more. The study also involving the intervention of the training to see the improvement in the kicking performance. However, the study of the taekwondo kick with the wearable resistance load is lack as to the several data base that have been reviewed. Apart from that, the study on the axe kick movement also rarely conducted by the researcher. In regards with this, it is considerable to conduct the study of the effects of wearable resistance on the biomechanics of axe kick in taekwondo. Therefore, the purpose of this study is to compare the acute effect of wearable resistance training loading in taekwondo middle axe kick.

1.2 Problem Statement

Kicking is the main way to collect points in Taekwondo. The ability to produce fast and powerful kicking will result in physical damage and score points, which later will increase the chance to win a match. Among the kick that has the potential to give maximum points is axe kick. Axe kick give chances to the Taekwondo athlete to hit the head of the opponent. Improving the ability to execute good axe kicks during a match is one of the main aims among Taekwondo athletes. Having good strength, speed, flexibility and power should be one of the main focus of athletes during the training sessions. Thus, training with resistance is suggested to be one of the methods of training. Previously, the resistance training required athletes attended the gym and

lifting the weight with the rapid movements in order to fulfil the training program instructed by the coaches and basically there is no problem within this traditional resistance training. However, the lack of the specific movement in traditional resistance training align with the sport specific skills could be the disadvantage to the sports. It was stated that the training that provided a movement specific action to performs with resistance assisted the athlete to adapts with specific movement of their sport. For examples in the middle axe kick of taekwondo, traditional resistance training improved the lower body strength via the squats, deadlift, and snatch exercises movement but none of these exercise mimics the specific movement in the middle axe kick and it could affect the kicking kinematic of the athletes.

Compared to traditional resistance training, wearable resistance allows the performer to train more specific to the main movements involved in the sport. Just like other training methods, it is necessary for the coaches and athletes to get to know the effects of loadings used during the training on the kicking biomechanics. Despite athletes can perform movement similar to the real movement in game, it is not truly understood on whether the kicking biomechanics changed significantly with increased loadings put on the wearable resistance. Since the wearable resistance training is the latest functional resistance training, and the study of wearable resistance conducted on the kicking biomechanics is very little, this study perhaps provides a new understanding information regarding the effects of wearable resistance on the kicking biomechanics.

Besides can be used in training session, wearable resistance could also be used during warm up. If the wearable resistance used during warming up session that consist of kicking drills, this could potentiate muscle excitation (the formation of the action

potential within the skeletal muscle fibers to the starting of the muscle tension) during the real skill that did not involve no loading.

It is the author's interest to find out the effects of different loadings used on wearable resistance during kicking execution. Currently, as to the authors' knowledge after articles searching through several databases, lack of studies had yet been conducted on determining the effects of new wearable resistance on taekwondo kicking biomechanics. Thus, a study in this area will provide new knowledge on wearable resistance training, with also considering the loading effects.

1.3 Objectives of the Study

1.3.1 To compare the effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on joint kinematics (kicking height, kicking velocity, kicking time, leg displacement and hip angles) during Taekwondo middle axe kick.

1.3.2 To compare the effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on kinetics (ground reaction force) of the supporting limb during Taekwondo middle axe kick.

1.3.3 To compare the effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on muscle activation (vastus lateralis, biceps femoris, gastrocnemius, gluteal, and rectus abdominis) during Taekwondo middle axe kick.

1.4 Research Questions

1.4.1 Are there any differences of effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on joint kinematics (kicking height, kicking velocity, kicking time, leg displacement and hip angles) during Taekwondo middle axe kick?

1.4.2 Are there any differences of effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on kinetics (ground reaction force) of the supporting limb during Taekwondo middle axe kick?

1.4.3 Are there any differences of effects between wearing WR with 5% of body mass, WR with 10% of body mass, WR with 15% of body mass, and control (0% of body mass) on muscle activation (vastus lateralis, biceps femoris, gastrocnemius, gluteal and rectus abdominis) during Taekwondo middle axe kick?

1.5 Significant of the study

It is the mission of the Ministry of Youth and Sports to ensure high-performance sports continue to emerge and developed, which later will improve the achievement of Malaysian athletes at the international level. In parallel to the government mission, it is important for the researchers in the sports science field to provide inputs in this area. To enhance performance in sports, one of the most important is physical ability. Athletes with more physical ability will have more advantages to adapt to the techniques and tactics provided by the coaches. Thus, it is the aim of this study to find out the effectiveness of the newly developed training tools (wearable resistance) on physical ability development. As the steps to achieve this, researchers need to understand how adopting the training tools will affect patterns of movement during execution and how will the body adapt to it in a longer duration. The importance of knowledge from the study will then pass on to the sport expertise such as instructor and coaches who is responsible for the athlete's training regimes.

Individuals involved in martial art sports such as Taekwondo usually subject their bodies to a lot of kicking movements during training and game. Developing the ability to execute fast and powerful kicks during a Taekwondo match is one of the main training aims among Taekwondo athletes. Wearable resistance provides an opportunity for freedom of movement during a training session, allowing resistance training to mimic actual sports such as martial art specific movement. Understanding the biomechanics and training adaptations of specific movements used in the sport while wearing wearable resistance will provide insight into the effectiveness of these more flexible methods of resistance training. Besides that, understanding how increment of

loading affects the mechanics of movement will provide valuable insight into the stimulus imposed on the physiological system during training, which can then influence the adaptive process. The different effects will provide information on the training specific responses, such as differences in muscle and performance variables. Overall, the findings of the present study will contribute to a richer understanding of the practice of resistance training particularly on the specificity of exercise selection for sports coaches, conditioning coaches, fitness coaches, athletes, exercise rehabilitation therapists, and strength training enthusiasts. It is also expected to enrich the existing body of knowledge and understanding from the perspective of physiological adaptations from differing exercise approaches which may influence the training methodology in the future.

1.6 Delimitations

This study consists of a number of delimitations by the researcher to test the research hypothesis:

1.6.1 This study only included male experienced taekwondo athletes who have at least two years of training in taekwondo.

1.6.2 This study involved only qualified male taekwondo athletes age 18-25 years old.

1.6.3 This study will only be conducted on healthy taekwondo athletes that have no injuries in the last 6 months.

1.6.4 The type of kicking only delimited to the Taekwondo middle axe kick.

1.6.5 Participants were asked to perform a maximal effort axe kick with an EMG sensor and reflective markers are placed at the selected muscle and area. The started and finished movement within the stationary position which the supporting legs were placed on the force plate surface.

1.7.6 All sessions will be conducted in the Biomechanics Laboratory of Faculty of Sport Science and Coaching, UPSI.

1.7 Limitations

This study consists of a number of limitations by the researcher to test the research hypothesis:

1.7.1 Age difference and the level of experience in taekwondo sport of participants may have influenced the way of performing the skill.

1.7.2 This study can only be generalized to train male amateur athletes where females are not included in the study.

1.7.3 Other variables included the motivation levels in the participants which were uncontrollable throughout the study carry out may influence their performance. However, despite the motivation and effort are uncontrollable, the researcher will still give the most effort in order to make sure participants perform the testing with best efforts.

1.8 Definition of terms

1.8.1 Wearable resistance

Wearable resistance Exogen Exoskeleton technology by Lila (Sport Boleh Sdh Bhd, Malaysia) is intended to permit additional weights on specific macula's of the athlete's body to incorporate progressive muscle overload while preserving the specificity of the sport (Macadam, Cronin, & Simperingham, 2017).

1.8.2 Electromyography (EMG)

Electromyography (EMG) is a diagnostic procedure usually used to evaluate the health condition of muscle activity and also the nerve cells that manage them throughout performing activities. These nerve cells area units are referred to as motor neurons. They transfer electrical indications that reason muscles to contract and relax. An EMG explains these indicators to diagrams or statistics, serving researchers to make an analysis. EMG consequences can expose nerve and muscle dysfunction or complications with the nerve-to-muscle signal transmission (Reaz, Hussain & Yasin, 2006).

1.8.3 Muscle Activation

In this study, the average muscle activation data were obtained from i) abdominis rectus, ii) gluteus maximus, iii) vastus lateralis, iv) bicep femoris and v) gastrocnemius medial head.

1.8.4 Kinetics

Kinetics refers to the study of forces that causing the motion. In this study, the kinetic method involves the use of a force platform to certify ground reaction force, (Ranavolo, Don, Cacchio, Serrao, & Paoloni et al, 2008; Blickhan, 1989; Cavagna, 1985). The kinetic in this study is refers to the ground reaction forces that will be collected from the supporting leg during the kick execution.

1.8.5 Ground Reaction Force (GRF)

The GRF data in this study were recorded from the supporting leg of the participants during the axe kick execution.

1.8.6 Kinematics

Kinematics refers to the study of what factors other than forces that affected the motion, (Hamill & Knutzen, 2006). The kinematic method involves the use of the three-dimensional motion capturing system (Vicon System) to acquire the lower limb joint kinematic such as kicking height, kicking velocity, kicking time, leg displacement and hip angle.

1.8.7 Kicking Height

Kicking height data in this study is taken from the peak height of the kick of participant during the axe kick execution. The marker at the toe as a reference point for calculating the kicking height data.

1.8.8 Kicking Velocity

The kicking velocity data in this study are obtained through the motion analysis software in the Biomechanics Labs. The kicking velocity is defined as time divided by toe displacement.

1.8.9 Kicking Time

Kicking time data is recorded from the starting position and to the peak height position of participant's leg during the axe kick execution.

1.8.10 Hip Angle

Hip angle is obtained through the relative angle of the joint segment of the knee, hip and ankle.

1.8.11 Displacement

The displacement data in this study are obtained from the start position and to the peak height of the participant's leg during the axe kick execution. The marker at the toe as a tracking point for the data.