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EFFECT OF SIX-WEEK TRAINING PROGRAM WITH WEARABLE RESISTANCE LOADING DISTRIBUTION ON JUMPING KICKS KINEMATICS AMONG PENCAK SILAT ATHLETES

Saidatul Nur Syuhadah Mohamed Sabadri [1,2*], Ali Md Nadzalan [1] Nur Ikhwan Mohamad[1] Mon Redee Sut Txi[1]

[1]Faculty of Sports Science and Coaching, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia

[2]Faculty of Sports Science and Recreation, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

***Corresponding Author:** syuhadahsabadri@uitm.edu.my

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Abstract

Pencak Silat is a martial art that requires explosive lower-limb movements, particularly during jumping kicks, where biomechanical efficiency plays a crucial role in performance. Wearable resistance (WR) training has been utilized to enhance athletic performance; however, the effects of different loading distributions on jumping kick biomechanics in Pencak Silat remain unclear. This study aims to determine and compare the chronic effects of WR with 3% of body mass placed at different limb segments (shank, thigh, combined shank and thigh) and without load (0% of body mass) on performance parameters, including kicking time and kicking velocity. The findings will provide insights into optimizing training strategies for Pencak Silat athletes. Forty (N=40) university Pencak Silat athletes have been recruited as participants in this study. Participants was randomly assigned into lower limbs group with 3% of BM (shank, thigh and combined shank and thigh) and control group. Kinovea software was used to analyse kinematic data, to investigate the effects of six weeks of wearable resistance (WR) loading distributions on performance. A pre-test was conducted, assessing jumping front kick and jumping back kick, with kinematic parameters such as kicking velocity and kicking time. Following a six-week intervention with WR loading distributions, a post-test was performed, measuring the same parameters to evaluate training-induced adaptations. There was a significant improvement in kicking time and kicking velocity following the six-week training program. Evidently, 3% of BM loading distributions placed at shank, thigh and combined shank and thigh is sufficient to observe the jumping kicks kinematics. Most importantly, the six-week training program with 3% body mass (BM) loading distributions using wearable resistance resulted in greater improvements in performance, including kicking velocity and kicking time during jumping kicks in Pencak Silat.

Keywords: Wearable Resistance, Loadings distributions, Resistance Training, jumping kicks, Pencak Silat athletes

INTRODUCTION

Pencak Silat is a sport that involves complex movements and demanding physical conditions. Athletes must develop fundamental components such as speed, endurance, strength, and flexibility. Additionally, a higher level of physical conditioning is required, including the combination of speed and strength, as well as endurance and speed, to optimize performance (Sepriadi, 2020; Sepriadi, Jannah, & Eldawaty, 2020). Pencak Silat involves various movements, including attacks, parries, and dodges. Among these, kicks are one of the most frequently used attack techniques in competitive matches. Research indicates that over 75% of attacks executed in Pencak Silat competitions involve kick techniques (Suwirman, Sepriadi, Ihsan, & Deswandi, 2021). Pencak Silat athletes dedicate significant time to training, both in physical conditioning and technical drills, to enhance their performance. Consequently, strength and conditioning professionals must implement resistance training methods that are time-efficient while ensuring optimal adaptations. Training methods that closely mimic the mechanical specificity of a movement are believed to result in the most significant performance improvements (Siff, 2003; Young, 2006; Zatsiorsky, 1995).

The implementation of a training program requires the systematic development of four essential aspects: technique, physical, tactical, and mental (Sulfa et al., 2024). As a full-contact combat sport, Pencak Silat demands athletes to maintain optimal physical condition to enhance their performance and increase their chances of winning matches (Wijaya et al., 2022). However, peak physical performance must be supported by other key components, including tactical and mental preparation (Wijaya et al., 2022). Pencak Silat athletes need to develop various physical attributes such as strength, endurance, speed, agility, flexibility, balance, power, accuracy, and reaction to excel in competitions (Rohman & Effendi, 2019). Power is a crucial physical component in Pencak Silat, playing a significant role in generating force during offensive movements (Munzir, 2022). Explosive power is the ability to produce maximum force in a short period, enabling athletes to deliver rapid and dynamic movements that optimize performance outcomes (Bafirman & Wahyuri, 2019). This physical attribute is fundamental in executing powerful kicks, punches, and other offensive techniques, contributing to competitive success in Pencak Silat.

Kicking techniques in Pencak Silat rely heavily on leg muscle power, which is essential for executing effective and rapid attacks. Athletes with greater leg muscle power are more capable of performing kicks with higher speed and force, reducing the opponent's ability to evade or block the attack. Consequently, Pencak Silat athletes require appropriate and targeted training methods to enhance leg muscle power, thereby improving overall performance in competition (Ahmad et al., 2024). Speed and power are largely derived from muscular strength, making strength and conditioning training essential for combat athletes. Enhancing muscle strength improves movement efficiency, contributing to overall performance enhancement (Barr et al., 2015; Carlos et al., 2019; Cobar & Madrigal, 2016; Vagner et al., 2020). Balanced muscle development between agonist and antagonist muscles, as well as posterior and anterior motion, is crucial for optimal movement. However, since most movements are primarily generated by posterior musculature, strength training often prioritizes these muscle groups to enhance performance and reduce injury risk (Turner, 2009).

In combat sports, strength training protocols typically rely on conventional weight machines, free weights, and bodyweight exercises (Chinnasee et al., 2018; Nasir et al., 2023a; Nasir et al., 2023b). However, it is proposed that training methods should incorporate loading approaches that are more functional and capable of simulating actual combat sports movements (Ibrahim et al., 2022). Thus, loadings that allow athletes to move freely while replicating specific sports movements are recommended (Nadzalan et al., 2021; Nadzalan et al., 2022). Previous research by McBride et al. (2002) demonstrated that eight-week training programs using light loads significantly enhance movement velocity performance compared to heavy loads. However, Schoenfeld et al. (2016) highlighted that a combination of heavy and light loads in resistance training provides superior muscular adaptations. Recent evidence by Cronin et al. (2018) and Marriner et al. (2017) indicates that wearable resistance (WR) ranging between 5% and 12% of body mass (BM) is an effective tool for enhancing power clean performance among recreationally trained males. WR offers a safer and more accessible alternative for recreational lifters, enabling them to maintain correct technique while undergoing eccentric loading. Unlike Olympic lifts, which target specific movement patterns, WR facilitates full-body dynamic movements with fast eccentric loading stimuli. Consequently, WR presents an alternative training modality to deliver an optimal overload stimulus for performance enhancement in future training programs (Bustos et al., 2020; Couture et al., 2020; Feser et al., 2018; Field et al., 2019; Hurst et al., 2018; Kravitz & McCormick, 2014).

Additionally, a study by Nadzalan et al. (2022) on wearable resistance (WR) has been increasingly utilized in sports training to enhance strength, endurance, and movement efficiency. The study investigated the acute effects of WR on the kinematics of the front kick among elite Taekwondo athletes. The findings indicated that WR did not significantly affect knee velocity or peak kick height but resulted in a reduction in foot velocity. This suggests that while WR does not impair the overall execution of the kick, it may negatively impact kicking speed, a crucial factor in Taekwondo performance. Therefore, while WR may offer potential benefits for strength and endurance development, its application in training should be carefully optimized to avoid unintended performance drawbacks.

Expanding on this, Nadzalan et al. (2021) examined the influence of WR on the axe kick kinematics among elite Taekwondo athletes. The study involved twenty-four state-level athletes who performed axe kicks under four resistance conditions: without WR (0WR) and with WR at 3% (3WR), 5% (5WR), and 8% (8WR) of their body mass. Kinematic variables such as maximum kick height, thigh angle, hip and knee range of motion, ankle speed, and movement duration were analyzed using motion capture technology. The results demonstrated that 3% WR did not significantly alter most kinematic parameters, except for a slight reduction in maximum kick height. However, higher resistance loads (5% and 8%) led to significant disruptions in movement kinematics, suggesting potential impairment in technique execution. Based on these findings, 3% WR appears to be an optimal load for training, as it maintains technical performance while providing additional resistance for adaptation.

The body's adaptive response to six weeks of training with different loading distributions for enhancing jumping kick performance remains unclear, creating uncertainty in selecting the most effective loading distribution for training implementation. Therefore, this study aims to determine and compare the chronic effects of wearing wearable resistance (WR) with 3% of body mass (BM) applied at different limb segments (shank, thigh, and combined shank and thigh) and without load (0% BM) on performance outcomes, including kicking time and kicking velocity of the kicking limb during jumping kicks in Silat.

METHODOLOGY

Participants

In this research, the purposive sampling method was strategically employed to select participants who would provide the most relevant and insightful contributions to the study. Forty (40) male Pencak Silat athletes University students recreationally active and free from injury (mean age = 22.95 ±0.78 years old) were recruited as study participants. Participants were screened prior to testing using PAR Q and had read and signed an informed consent for testing and training approved by the University Pendidikan Sultan Idris (UPSI).

Experimental Design

This experimental study employed a combination of quantitative and observational data collection methods. Pre- and post-test measurements were used to assess changes resulting from the intervention.

Table 1. Participants Characteristic

Participants Characteristic (N=40)	
Age (years)	22.95 ±0.78
Height (cm)	170.92±8.11
Weight (kg)	68.40±5.59

*Means ± Standard Deviations

Procedure

By adhering to these procedures, the research aims to yield results that are both reliable and highly relevant to the study's specific context. Prior to data collection, the researchers applied for ethical clearance from the Research Ethics Committee at the UPSI Management and Innovation Center (RMIC). Upon fulfilling all administrative requirements and obtaining the necessary certification for ethical compliance, the researchers proceeded to the next phase. Potential participants were contacted through an official invitation letter from Sultan Idris Education University, inviting them to participate in the study. Once participants provided informed consent, the researcher coordinated with them to schedule testing sessions at their convenience, ensuring the process was comfortable and conducted without any undue pressure. Before testing began, participants received detailed information regarding the study's aims, procedures, and potential risks to minimize any misunderstandings.

Testing sessions were conducted at baseline before the intervention and after six weeks of the training program. All sessions took place at the same time of day on the same outdoor track surface to maintain consistency. Participants wore identical clothing and footwear across all testing and training sessions. They were instructed to avoid strenuous physical activity within 12 hours before testing and to maintain their regular dietary habits throughout the study.

Each testing session began with a standardized 15-minute warm-up, including progressively intensified multidirectional running and dynamic lower limb stretching. Performance outcomes were measured through jumping kicks, including jumping front kicks and jumping back kicks. The jumping kick data were calculated as the average performance across three trial attempts for each kick type.

Jumping Kicks

During the jumping front kick execution, a quality of jumping front kick of the participants was determined according to the jumping forward while simultaneously executing a front kick with one leg. The key is to generate upward momentum while driving the kicking leg forward, extending it to deliver a forceful kick. The other leg is used for propulsion and balance. While for the jumping back kick, this kick involves jumping backward while executing a back kick with one leg. Jumping backward is combined with a rapid twist of the torso to deliver a back kick, often over the shoulder.

Training Program

Both the CON and WRT groups took part in the same training sessions comprising the same activities at the same relative intensities during six weeks of training program. The warm-up program consisted low to moderate dynamic warm up combined with active stretching. The intervention training program was conducted over six weeks, with three sessions per week, targeting agility, sprint performance, and technical skills. Day one focused on agility drills, including lateral lunges, lateral jumps, single-leg forward hops, and jump squats, performed in three sets. Day two emphasized sprint training, incorporating 100m, 50m, and 20m sprints, repeated in three sets. Day three was dedicated to technical training, where participants practiced kicking, catching, falling, sparring, attacking, and defensive techniques, ensuring sport-specific skill development.

Instrument

The equipment used for this study includes including Canon VIXIA HF R800 Full HD Camcorder, Kinovea Software and full suit Wearable Resistance. The details about the equipment had been reporting in this study.

Canon VIXIA HF R800 Full HD Camcorder

Canon VIXIA HF R800 Full HD Camcorder were used for this study. The camcorder was set up according to the data collection place which located in biomechanics laboratory and indoor training center. The camcorder used for video recording of movements during the executions of Pencak Silat jumping front kick and jumping back kick. As the function of the camcorder is to record the human movement, the uses of it within the sports would perhaps bring out new knowledge for the researcher, coaches, and athletes. The uses camcorder to record the movements in the biomechanics area is to study the specific movement that has contributed to the good or bad performance in particular sports and to improve the performances. The recorded movements will be analyzed using Kinovea software that measured kinematics data (kicking time and kicking velocity).

Kinovea software

Kinovea is an open-source video analysis software widely used in sports science, rehabilitation, and biomechanics for motion tracking and kinematic assessments. The software allows users to track movement patterns, measure angles, velocities, distances, and time intervals, making it a valuable tool for performance analysis and injury prevention (Puente-López et al., 2020). Kinovea software 2D analysis was used to retrieve all the outputs (images and videos) from the Canon VIXIA HF R800 Full HD Camcorder. All the recorded video (video files) was first play backed to check for any obvious error. Low quality captures were also discarded. For the accepted videos, Kinovea was used to locate and specify all the main markers according to the specific kinematics measurement. Kinovea kept track of the marker movement for the whole capture (jumping front kick and jumping back kick).

Statistical Analysis

Video recordings were recorded and obtained the results with Kinovea 2D Motion Analysis Software and further analyzed using Statistical Package for Social Science (SPSS) version 20.0 (IBM Corp., Armonk, New York, USA) to get mean and standard deviation. Repeated-measure one-way analysis of variance (ANOVA) test was used to analyze the kicking kinematics data significant exist between loading distributions. Statistical significance was accepted at an α-level of $p \leq 0.05$. All statistical analyses were conducted using SPSS version 29 (IBM, New York, USA).

RESULTS

Table 2 showed the physical characteristics of participants which indicates average age of the participants 22.95 ±0.78 years old, body mass (kg) 68.40±5.59 and Height (cm) of participants average 170.92±8.11.

Table 2: Descriptive Statistic

Participants Characteristic (N=40)	
Age (years)	22.95 ±0.78
Height (cm)	170.92±8.11
Weight (kg)	68.40±5.59

Table 3: Kicking Velocity (Jumping Front Kick)

Measure	Loading Distributions		Significant
Kicking Velocity (m/s)	Shank	Thigh	0.001*
		Shank+Thigh	0.001*
		Without load	0.001*
	Thigh	Shank	0.001*
		Shank+Thigh	1.000
		Without Load	0.001*

continued

	Shank +Thigh	Shank	0.001*
		Thigh	1.000
		Without Load	0.001*
	Without Load	Shank	0.001*
		Thigh	0.001*
		Shank +Thigh	0.001*

***Statistical significance between loading distributions and kicking velocity, p<.05**

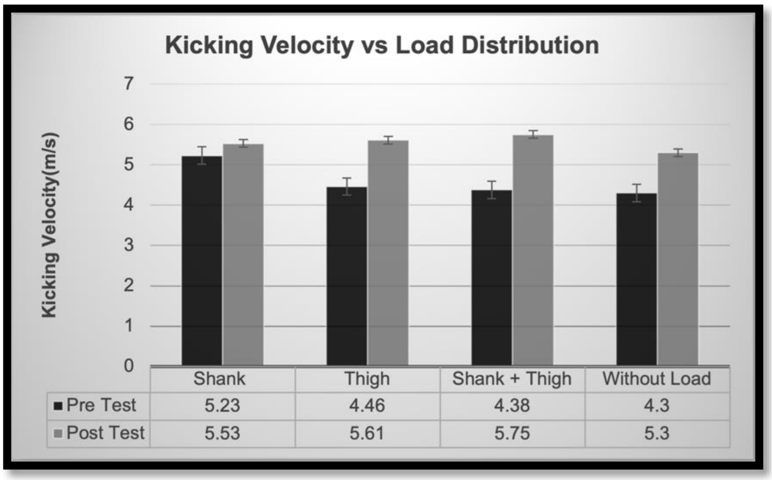

Figure 1: Graph of kicking velocity vs load distributions (Jumping Front Kick)

The results of the One- way repeated measure ANOVA showed that there was a significant main effect on loading distribution (shank, thigh, combined shank and thigh) with wearable resistance loads (WR 0% of BM and WR 3% of BM) on the kicking velocity, $F(3, 36) = 105.136$ $p < 0.001$, $\eta p^2 = 0.90$). The Bonferroni post hoc test revealed significant improvements in kicking velocity across different loading distributions after six weeks of training. The greatest improvement (36%) was observed when the wearable resistance was placed at both the shank and thigh, followed by the thigh (30%), without load (26%), and the shank alone (8%). Significant differences were found between shank and thigh, combined shank and thigh, and without load conditions ($p = 0.001$). However, no significant differences were observed between the thigh and combined shank and thigh conditions ($p = 1.000$).

Table 4: Kicking Velocity (Jumping Back kick)

Measure	Loading Distributions		Significant
Kicking Velocity (m/s)	Shank	Thigh	0.001*
		Shank+Thigh	0.001*
		Without load	1.000
	Thigh	Shank	0.001*
		Shank+Thigh	1.000
		Without Load	0.001*
	Shank +Thigh	Shank	0.001*
		Thigh	1.000
		Without Load	0.001*
	Without Load	Shank	1.000
		Thigh	0.001*
		Shank +Thigh	0.001*

*Statistical significance between loading distributions and kicking velocity, p<.05

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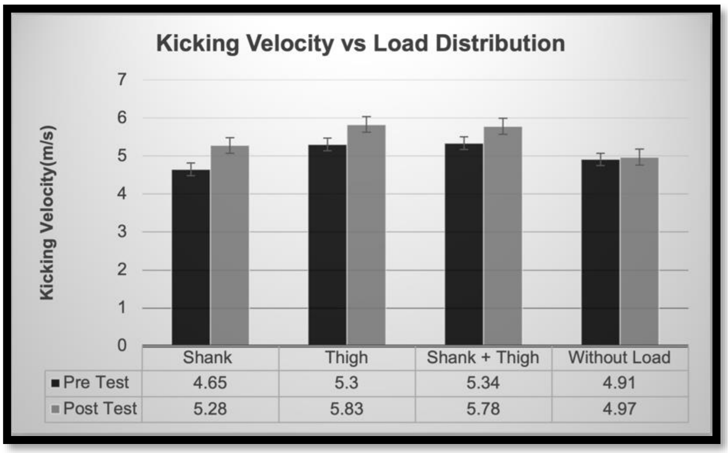

Figure 2: Graph of kicking velocity vs load distributions (Jumping Front Kick)

The results of the one-way repeated measures ANOVA showed that there was a significant main effect on loading distribution (shank, thigh, combined shank and thigh) with wearable resistance loads (WR 0% of BM and WR 3% of BM) on the kicking velocity, F (3, 36) = 21.078 p <0.001, $\eta p^2 = 0.637$). The Bonferroni post hoc test indicated a significant improvement in kicking velocity from pre-test to post-test when loading distributions were placed at the shank (M = 4.65 m/s, SD = 0.34 to M = 5.28 m/s, SD = 0.24, p = 0.001), thigh (M = 5.30 m/s, SD = 0.13 to M = 5.83 m/s, SD = 0.19, p = 0.001), and combined shank and thigh (M = 5.34 m/s, SD = 0.10 to M = 5.78 m/s, SD = 0.17, p = 0.001). However, no significant differences were found for the without load condition (M = 4.91 m/s, SD = 0.42 to M = 4.97 m/s, SD = 0.43, p = 1.000). Comparisons between loading placements showed that the thigh loading distribution significantly increased kicking velocity compared to the shank (p = 0.001) and without load (p = 0.001) conditions. No significant differences were found between the combined shank and thigh and thigh loading distributions (p = 1.000). In summary, the thigh loading distribution showed the greatest improvement in kicking velocity (38%) compared to the shank (32%), combined shank and thigh (26%), and without load (4%) conditions.

Table 5: Kicking Time (s) Jumping Front Kick

Measure	Loading Distributions		Significant
Kicking Time (s)	Shank	Thigh	0.001*
		Without load	0.001*
	Thigh	Shank	0.001*
		Shank+Thigh	1.000
		Without Load	0.073
	Shank +Thigh	Shank	0.001*
		Thigh	1.000
		Without Load	0.173
	Without Load	Shank	0.001*
		Thigh	0.073
		Shank +Thigh	0.173

*Statistical significance between loading distributions and kicking time, p<.05

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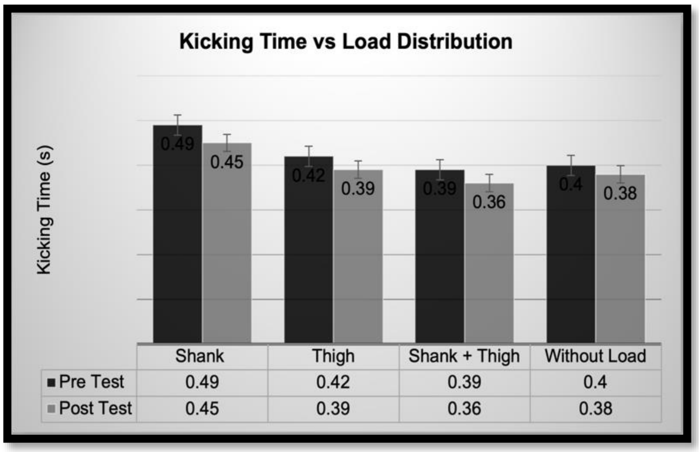

Figure 3: Graph of kicking time vs load distributions (Jumping Front Kick)

The results of the one-way repeated measures ANOVA showed that there was a significant main effect on loading distribution placed at (shank, thigh, combined shank and thigh) with wearable resistance loads (WR 0% of BM and WR 3% of BM) on the kicking time, $F (3, 36) = 33.372$, $p < 0.001$, $\eta p^2 = 0.736$). The Bonferroni post hoc test showed a significant reduction in kicking time from pre- to post-test when loading distributions were placed at the shank (M = 0.34s, SD = 0.02 to M = 0.32s, SD = 0.02, p = 0.001), thigh (M = 0.41s, SD = 0.01 to M = 0.39s, SD = 0.01, p = 0.001), and combined shank and thigh (M = 0.41s, SD = 0.01 to M = 0.39s, SD = 0.01, p = 0.001). No significant reduction was observed in the without load condition (M = 0.43s, SD = 0.02 to M = 0.42s, SD = 0.02, p = 0.073). The shank loading distribution showed a significantly faster kicking time compared to the thigh (p = 0.001), combined shank and thigh (p = 0.001), and without load (p = 0.001). However, no significant differences were found between the thigh and combined shank and thigh conditions (p = 1.000). Overall, the greatest reduction in kicking time was observed with thigh (29%) and combined shank and thigh (29%) loading distributions, followed by the shank (28%) and without load (14%) conditions.

Table 5: Kicking Time (s) Jumping Back Kick

Measure	Loading Distributions		Significant
Kicking Time (s)	Shank	Thigh	0.001*
		Shank+Thigh	0.001*
		Without load	0.001*
	Thigh	Shank	0.001*
		Shank+Thigh	0.138
		Without Load	1.000
	Shank +Thigh	Shank	0.001*
		Thigh	0.138
		Without Load	1.000
	Without Load	Shank	0.001*
		Thigh	1.000
		Shank +Thigh	1.000

*Statistical significance between loading distributions and kicking time, p<.05

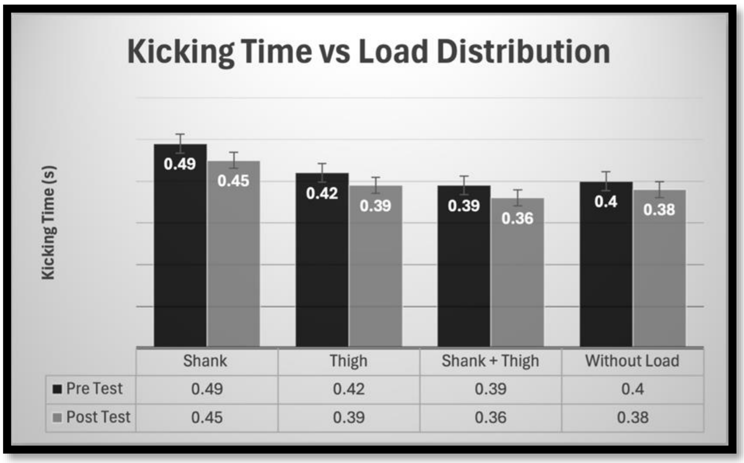

Figure 4: Graph of kicking time vs load distributions (Jumping Back Kick)

The results of the one-way repeated measures ANOVA showed that there was a significant main effect on loading distribution (shank, thigh, combined shank and thigh) with wearable resistance loads (WR 0% of BM and WR 3% of BM) on the kicking velocity, $F (3, 36) = 24.307$ $p < 0.001$, $\eta p^2 = 0.669$). The Bonferroni post hoc test revealed a significant reduction in kicking time from pre- to post-test when loading distributions were placed at the shank (M = 0.49s, SD = 0.02 to M = 0.42s, SD = 0.22, p = 0.001), thigh (M = 0.42s, SD = 0.22 to M = 0.39s, SD = 0.02, p = 0.001), and combined shank and thigh (M = 0.39s, SD = 0.02 to M = 0.36s, SD = 0.02, p = 0.001), while no significant differences were found in the without load condition (M = 0.40s, SD = 0.02 to M = 0.38s, SD = 0.02, p = 1.000). The shank loading placement significantly improved kicking time compared to thigh (p = 0.001), combined shank and thigh (p = 0.001), and without load (p = 0.001). However, no significant differences were observed between the thigh and combined shank and thigh (p = 0.138) or without load (p = 1.000) conditions. In summary, the greatest improvement in kicking time was observed with the shank (33%), followed by combined shank and thigh (25%), thigh (25%), and without load (17%) conditions.

Figure 5: Jumping Front Kick

Figure 6: Jumping Back Kick

Jumping front kick is to generate upward momentum while driving the kicking leg forward, extending it to deliver a forceful kick. The other leg is used for propulsion and balance. While jumping back kick involves jumping backward while executing a back kick with one leg. Jumping backward is combined with a rapid twist of the torso to deliver a back kick, often over the shoulder.

DISCUSSION

In Pencak Silat, achieving higher kicking velocity is essential, as faster kicks enhance impact force and increase the likelihood of scoring points effectively during competition. The findings of this study suggest that a six-week wearable resistance (WR) training program with 0% and 3% of body mass (BM) significantly impacts kicking performance by altering the biomechanics and energetics of the kicking motion. The results demonstrated that combined shank and thigh loading yielded the greatest improvement (36%) in kicking time compared to shank (8%), thigh (30%), and without load (26%) conditions. The superior performance observed with combined shank and thigh loading could be attributed to the greater distance from the body's center of mass, which influences stride length, stride frequency, and muscle activation patterns. This shift potentially enhances joint kinematics and energy transfer from the lower body to the striking limb, resulting in higher kicking velocities (Gavagan & Sayers, 2017). The whip-like snapping motion of the leg at the final phase of the kick further contributes to the increased acceleration and speed, aligning with previous research on the biomechanics of striking motions. Additionally, the variations in velocity and muscle activation patterns between loading distributions may be attributed to the specific muscle groups targeted. The combined shank and thigh loading appears to place greater emphasis on the calf muscles, ankle joints, quadriceps, and hip flexors, promoting muscle activation across multiple segments. This finding aligns with McBride et al. (2002), who demonstrated that heavier loads are more effective in improving strength gains, while lighter loads primarily enhance movement velocity.

Furthermore, the six-week WR training program significantly improved jumping back kick performance across all loading distributions. The results revealed that shank loading yielded the greatest improvement (38%), followed by thigh (32%), combined shank and thigh (26%), and without load (4%). These findings differ slightly from the jumping front kick, where combined shank and thigh loading produced the highest improvement. The superior performance in the shank loading group during the jumping back kick may be attributed to the greater involvement of the shank muscles in generating power. The gastrocnemius and soleus muscles, which contribute to ankle extension and push-off during the jump, play a crucial role in the back kick motion. This result is consistent with Vecchio et al. (2021), who suggested that the lower limbs' greater muscle mass and power potential enable higher velocities in kicking strikes compared to upper limb movements. The placement of WR at the shank region could enhance distal muscle activation, thereby increasing the velocity and power of the kick. These findings highlight the importance of segment-specific resistance training in improving explosive kicking performance, providing valuable insights for optimizing training protocols in Pencak Silat and other combat sports.

Faster kicking time is a critical performance factor, as it improves speed, reaction time, and the ability to outpace opponents during competition. The findings on kicking time in this study revealed significant differences between all loading distributions ($p < 0.001$), with shank loading showing the highest time reduction compared to thigh loading and combined shank and thigh loading. The combined shank and thigh loading produced the greatest improvement in kicking time (29%), followed closely by thigh loading (29%), while shank loading resulted in a 28% improvement, and without load only a 14% improvement. This outcome suggests that WR training with 3% BM does not negatively impact fast kicking performance. The positive effect of WR on kicking time could be due to neuromuscular adaptations resulting from the combination of resistance and dynamic movements. The engagement of both proximal and distal muscle groups in the combined loading distribution may contribute to faster muscle contractions and better coordination. This outcome supports the findings of McBride et al. (2002), which indicated that light-load training improves movement velocity without compromising performance.

Moreover, the current study indicates that WR training with 3% BM can be a valuable method for improving speed, strength, and power in Pencak Silat athletes. The placement of WR at the shank region produces greater improvements in jumping back kick velocity, while combined shank and thigh loading is more effective for jumping front kick performance. These results emphasize that load placement specificity plays a critical role in performance enhancement. The shank loading distribution exhibited the greatest reduction in kicking time (33%), compared to other WR distributions following six weeks of training. This finding aligns with previous studies by Feser et al. (2018) and Field (2019), which demonstrated that lower limb wearable resistance applied at the shank significantly influences velocity, kinematics, and metabolic responses during running and sprinting. The enhanced reduction in kicking time may be attributed to the greater distance from the body's center of mass, which increases the moment of inertia and forces the muscles to generate higher torque and power output. This significant improvement under shank-loaded and combined shank and thigh-loaded conditions can be explained by Newton's Second Law of Motion (Nie & Mohamad, 2021), which states that acceleration is directly proportional to applied force and inversely proportional to mass. Therefore, WR training likely improved the participants' force production capacity, resulting in faster kicking performance despite the external load.

In summary, these findings highlight the importance of specific loading distributions in enhancing speed, power, and neuromuscular adaptations in Pencak Silat athletes. Coaches and athletes may consider incorporating shank-based WR training protocols to optimize kicking velocity and explosive power without compromising technique. However, future studies should explore the long-term effects of WR training on different kinematic phases of Silat kicks, as well as the optimal loading percentages to maximize performance outcomes.

CONCLUSION

The findings of this study demonstrated a significant difference between all loading distributions ($p<0.001$) on jumping kick performance among Pencak Silat athletes. The effect of lower wearable resistance (WR) was larger on kicking time with shank loading compared to thigh loading, combined shank and thigh, and without load conditions. The results indicated that for the jumping back kick, load placement at the shank plays a crucial role in generating power and stability during the kick, while combined shank and thigh loading showed greater improvement for the jumping front kick. The distinction in these results highlights the biomechanical differences between the two kicking techniques, where the shank loading enhances propulsion and accuracy during the back kick, while combined loading improves velocity and speed in the front kick.

The greater improvement in kicking velocity with shank loading compared to other loading distributions suggests that the placement of WR at the shank targets the muscles responsible for explosive power and agility, particularly the gastrocnemius and soleus muscles. This placement allows for greater force production and faster kicking times following six weeks of WR training. Additionally, the natural aptitude of athletes for adapting to shank loading may have contributed to the faster improvements in jumping back kick performance.

In summary, the six-week training program with 3% of body mass (BM) WR significantly enhanced jumping kick performance, with shank loading and combined shank and thigh loading demonstrating the greatest improvements in kinematics. The results suggest that WR with 3% BM does not significantly disrupt the movement patterns associated with jumping kicks, making it a valuable tool for enhancing Silat athletes' explosive power and speed. However, continuous monitoring of individual responses and adjustments in WR placement are recommended to optimize performance outcomes. Future research should explore the long-term effects of WR training on Pencak Silat performance and identify the optimal WR loading percentages for different kicking techniques.

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