



EFFECT OF WEARABLE RESISTANCE LOADING DURING WARM-UP PROTOCOL ON FRONT KICK BIOMECHANICS IN TAEKWONDO

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Accepted for Publication: April 28, 2022

Published: June 25, 2022

DOI: 10.17309/tmfv.2022.2.11

Abstract

Research purpose. This study aims to examine and determine the effect of wearable resistance loading during warm-up protocol on front kick movement mechanics and muscle activation.

Materials and methods. Twenty-five ($N = 25$, height = 174.00 ± 4.76 cm, weight = 75.93 ± 13.64 kg, age = 22.57 ± 1.36 years) male university taekwondo athletes were recruited as participants of the study. Wearable resistance with loading of 0%, 5% and 10% of the athletes' body mass were attached to participants' thigh and shank. Kinematics, kinetics and muscle activation during front kick were assessed.

Results. Overall, the results showed that there were no significant differences found between different WR loading in kinematics, kinetics and muscle activation during front kick movement. The results reflected that there were no detrimental effects of wearing wearable resistance during warm-up sessions. The findings are somewhat surprising as it was hypothesized that WR loading would produce effects on the mechanics of kicking and muscle activation. Wearable resistance did not increase kicking performance which was reflected by kicking velocity. This might be due to percentage of loading used which are seen as not reducing the performance, which reflects that the wearable resistance can be used during warm-up in training sessions as an add-on to resistance training.

Conclusions. We suggest that future studies should examine the chronic effects of wearable resistance as specific tools to be used in enhancing the performance of taekwondo kicks.

Keywords: training, kinematic, kinetic, muscle activation, performance.

Introduction

Taekwondo is a martial art that focuses on empty-hand combat, concentrating on striking with the use of hand and leg techniques. Leg techniques such as roundhouse kicks, axe kicks, back kicks, and other advanced kick that involves leap action and rotation while executing kicks are commonly used in competition. Since the 1950s, the techniques have been modified and varied technically and strategically by old masters in the Korean army (Gillis, 2016). As a result, kicking techniques account for 98% of match points (Kazemi et al., 2013).

The athlete's ability to execute an excellent kick is measured by the velocity and kicking force. Meanwhile, the ability to execute powerful and fast kicks will give the opponent less time to counterattack and the need to admit the lost point scored.

Numerous studies had been conducted in Taekwondo such as kicking speed and time of movement (Estevan et al., 2016; Estevan et al., 2011), kinematic and kinetic (Mailapalli et al., 2015; Qian et al., 2010; Yu et al., 2012), tactical and technical (Casolino et al., 2012) and impact forces toward the participants whose has different background expertise (O'Sullivan et al., 2009). Therefore, based on the previous study, kicking capability can influence the match outcome. Thus, it becomes apparent that kicking variables need to be focused on during taekwondo training.

Warm-up is one of the most important routines that should be included in an athlete's training regime to achieve maximum potential during training. Warming up is a pre-

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workout practice that raises body temperature, improves blood circulation, and prepares the body for heavy load training (Erkut et al., 2017). In addition, a warm-up protocol can help athletes or individuals avoid injury and muscular soreness during training sessions (Çilli et al., 2014).

A dynamic warm-up is a warm-up method practiced by various types of sports. Previous findings showed dynamic stretching improves muscle locomotion, increases power generation, and effectively stimulates nerve-muscle communication (Burkett et al., 2005; Faigenbaum et al., 2006; Gelen, 2010; Thacker et al., 2004; Thompson et al., 2007). Besides, the dynamic warm-up also was shown to boost force, strength, response time, and flexibility (McMillian et al., 2006).

The use of wearable resistance devices during the Taekwondo pre-training program is thought to reduce the time needed to warm up for the next high-intensity training session or upcoming match in a specific protocol, as athletes can perform warm-up activities with load affixed to the targeted muscle location. Due to its contribution to the specific movement in sports, the load proportion on the targeted muscle is still within the research range (Bustos et al., 2020; Faigenbaum et al., 2006). Currently, little to no study has been done on determining and comparing the various load effects of wearable resistance intensities during warm-up protocol toward kicking biomechanics in Taekwondo. As a result, this research will add to the body of knowledge and literature about the influence of various wearable resistance intensities on taekwondo kicks during warm-up procedures.

The aims of this study are to examine, determine and compare the acute effect of wearable resistance loading (0% of body mass, 5% of body mass and 10% of body mass) applied during warm-up sessions on kinematics (maximum kick height, peak time, kicking velocity, kicking angle and displacement), kinetic (ground reaction force) and muscle activations (bicep femoris, gluteus maximus, gastrocnemius medial head, rectus abdominis and vastus lateralis) during front kick in Taekwondo. We hypothesized that there will be changes and significant differences of front kick movement mechanics and muscle activation as a result of different WR loading worn during warm-up protocols.

Materials and methods

Study participants

Twenty-five ($n = 25$) male taekwondo elite athletes voluntarily participated in this study. All of them hold a black belt in taekwondo and were currently competing in a national-level competition in taekwondo. All participants were screened to ensure that they are injury-free. Despite these requirements, it was discovered that the participants had no prior experience with WR thus familiarisation session is compulsory. All the participants were required to fill in the Physical Activity Readiness Questionnaire and informed consent. All the participants were told that they could withdraw from the study at any time. This study has been approved by the UPSI Human Research Ethics Committee [Code: UPSI/PPPI/PYK/ETIKA(M)/014(163)].

Study organization

Participants need to attend four sessions. Briefing and familiarisation were done during the first session. There was

a 72-hour gap between sessions. Taking into account the participants' preparation and the actual testing of the protocols, each session lasted around 30 minutes to an hour.

Participants were brief about the study, personal rights to withdraw and a pre-exercise questionnaire screening was also given. The session followed with an introduction of all testing apparatus that would be used. Participants are then asked to sign the consent letter. The equipment familiarisation session was crucial because none of the participants had previously used WR in their training.

During the second, third and fourth sessions, participants wore the WR with 0, 5 and 10% of their body mass during the warm-up session in a randomized order to avoid order effects. After performing kicking drills while wearing WR as a warm-up routine, the WR was removed from their body and their movements were recorded. The kicking drills included 10 minutes of various kicking movements. The loading was attached to the participants' lower limb at the targeted muscles which is the thigh and shank.

Data analysis

The kinematic data were recorded using multiple high-speed cameras (Vicon T10s). Reflective markers were placed on the participant's second metatarsals, lateral malleolus, calcaneus, lateral shank, lateral femoral epicondyle, lateral thigh, and anterior superior iliac spine on the right and left lateral side of the body using the plugin-gate marker set model. Vicon Nexus software then was used to analyse the kinematics data acquired. The kicking kinematic model includes the hip, thigh, shank, and ankle. Kicking height, peak time, kicking angle, displacement and kicking velocity were analyzed.

The electromyography (EMG) signals were converted from analog to digital, which was set at 1000Hz. The EMG data were analysed using EMG workstation software.

Raw data from the force platform was filtered using six channels of signal commercial conditioner (Gen5, AMTI, Watertown, USA) and the final data were processed by using netforce software (Netforce, AMTI, Watertown, USA) in Microsoft Excel file format (Microsoft Excel, Microsoft, Washington, USA) for further analysis.

Statistical analysis

Mean and standard deviations were used to represent the centrality and spread of the data for all biomechanical data measured. One-way repeated measure analysis of variances (ANOVA) was used to determine if significant differences existed across different load percentages. An alpha level of 0.05 was set to assess statistical significance for all tests.

Results

Table 1 showed the demographic background of participants involved in this study.

Table 1. Characteristics of subjects

Variables	Mean $\pm$ Age
Age (years old)	22.57 $\pm$ 1.36
Height (m)	1.72 $\pm$ 0.14
Body mass (kg)	75.93 $\pm$ 13.64

Table 2. Kinematics, kinetics and Muscle activation data for 0, 5 and 10 % WR

	Parameters	WR0	WR5	WR10	F value	Sig.
Kinematics	Maximum kicking height (m)	1.71 ± 0.15	1.69 ± 0.12	1.70 ± 0.13	0.25	0.78
	Kicking velocity (m/s)	5.13 ± 0.95	4.88 ± 1.03	5.18 ± 0.96	1.14	0.33
	Kicking angle (°)	112.84 ± 13.63	115.16 ± 13.41	114.16 ± 11.74	0.64	0.53
	Displacement (m)	2.17 ± 0.11	2.16 ± 0.09	2.17 ± 0.10	0.55	0.54
Kinetic	Ground reaction force (N)	955.10 ± 169.77	955.24 ± 169.68	950.91 ± 173.57	0.25	0.78
Muscle activations	Bicep femoris (% MVC)	13.48 ± 5.26	13.63 ± 6.85	13.74 ± 5.98	3.28	0.06
	Gluteus maximus (% MVC)	14.66 ± 8.50	13.55 ± 7.68	13.96 ± 7.84	2.19	0.15
	Gastrocnemius (% MVC)	17.74 ± 10.75	17.92 ± 9.13	18.55 ± 9.63	0.20	0.82
	Rectus abdominis (% MVC)	19.41 ± 6.49	19.84 ± 7.25	18.67 ± 7.67	0.69	0.47
	Vastus lateralis (% MVC)	21.05 ± 11.84	22.15 ± 11.70	20.68 ± 10.84	2.52	0.09

* Significant difference ($p < 0.05$)

The mean and standard deviation of kinematics, kinetics, and muscle activations data were shown in Table 2. No significant interaction was found for all the variables tested.

Discussion

The purpose of this study was to compare the acute effects of wearable resistance loading used during a warm-up session in taekwondo front kick where data of kinematic, kinetic, and muscle activities were compared between selected loads of WR (0%, 5%, and 10% of body mass) attached on the lower extremities. The analysis of kicking height, kicking velocity, kicking angle, displacement, ground reaction force (GRF), and muscle activities of BF, GM, G, RA, and VL were acquired from the data.

Looking at the kinematic data, no significant differences were found comparing all the loading conditions used during warm-up. Thus our hypothesis was rejected. We assume that there will be changes to the kinematic data, especially in the kicking velocity and maximum kicking height due to the warm-up protocols using loads. However, both these performance indicators were found not to be changed. Besides, kicking angle and displacement also were found not to be changed, thus demonstrating the wearable resistance can be used during warm-up as it did not change the movement mechanics related to performance. In terms of specific data during the kicks, we found that the kick velocity of the participants is less than what has been found by (Wąsik et al., 2018). The differences might be contributed by the factors of participants recruited. Wąsik et al. (2018) recruited elite level athletes while we in this study only recruit university level athletes.

Although there is no significant difference detected between all the WR tested, kinematics analysis demonstrated that kicking height is 1.16% lower when the front kick is executed with 5% load, and 0.58% lower with 10% load WR when compared to no WR implementation. Kicking velocity also showed that it is faster by 4.87% when executed with 0% load WR and 5.79% faster when executed with 10% load WR when compared to 5% load used. The kicking angle showed

that the angle is larger by 2.01% and 1.15% when executed with 5% load WR and 10% load WR respectively compared to 0% load WR. Displacement of kicking on the other hand showed an increase of 0.46% when executed with 0% load WR and 10% load WR when compared to 5% load WR.

WR application during the warm-up session will alter segment inertial properties and as such can be considered an organismic constraint (Field et al., 2019; Martin & Cavanagh, 1990). A prolonged adaptation toward the application of WR in training especially during the warm-up session would ultimately be a useful stimulus to develop and train an adapted movement behavior among athletes in preparation for changing real-life situations during match games which could be an advantage in terms of performance deliverance later on.

As found in the kinematic data, the ground reaction force that is the indicator of kinetic in this study was also found not to be changed. The ground reaction force in this study refers to the supporting legs that step on the force plate. The results, it shows that the supporting leg did not have any effects with the use of wearable resistance during warm-up. The supporting leg really does play role in determining kicking performance as what was found by (Chinnasee et al., 2018) who found the greater kick was produced by more force production by the supporting leg. Thus, the analysis of the supporting leg is also important in a study like this (Prajongjai et al., 2019).

Muscle activation data were collected to look at the muscle contraction during the kicks as the result of warming up with wearable resistance. The finding is somewhat surprising, that there were no significant changes occurred to the muscle activation even though they wore wearable resistance during warm-up. This showed that the muscles were able to overcome the loading used during the warm-up and not become tired to reduce muscle activation.

Muscle activation is a piece of vital information in determining which muscle contributes the most during kicking in taekwondo (Ervilha et al., 2020). The findings revealed a substantial difference between loads for the front kick. Although there is no significant difference to the muscle ac-

tivities when different WR load is applied during the warm-up session, there is a slight difference in terms of muscle activities when different WR load is applied. It can be seen that gluteus maximus activate the most when no WR load is applied compared to when there is WR load applied during warm-up session. This showed that when there is no load, there is less fatigue and typically the velocity of kicking would be faster and gluteus maximus is the muscle that are responsible to stabilize the whole movement of kicking which originated from the movement of quadriceps. Since the movement is light and faster, the gluteus maximus need to work more in order to stabilize the kicking movement.

Based on this finding, it can be noted that different WR load actually affect different type of leg muscles. The percentage involvement of muscle seems to be different when the WR load is getting heavier. As such, this could be a good indicator for coaches to determine which type of load effect different type of leg muscles independently.

The objective for development of WR technology has been to allow a relevant load to be applied directly to the body that will then directly stress specific movements under the specific demands of an actual sport and competitive environment, with little compromise to the speed of motion, range of motion and specific skill (Dolcetti et al., 2019). Nowhere is this more important than in the realm of speed and agility training where even slight modifications in these parameters greatly reduce improvement in actual competition. The application of WR in the movement of kicking like in this study is significantly important to deliver an optimum training mechanism which could then transfer to competition.

Coaches and athletes could benefit from a good warm-up session with the implementation of WR to optimize their warm-up session. This is generally important because warm-up is an important session before a workout session. This is to avoid injury during training sessions, especially in a burst activity like taekwondo. Further research could be done on the different percentages of WR implementation to add to the library of knowledge upon an optimum WR loading to be used in warm-up sessions. The physiological effect such as the heart rate, lactate level, and also any biomarkers that could indicate importance before starting an activity could be measured to see the effect of WR effectively as stimulation during warm-up.

Conclusions

The wearable resistance with 5% and 10% loads appear to be the suitable weight used during warm-up protocols without disrupting the whole movement of kicking and causing a significant decrease in all the kinematic and kinetic variables that is important during a kicking movement execution.

Future research should focus on long-term or chronic effects, as this will allow researchers to see how long the wearable resistance effect lasts on athletes. Furthermore, the study should take into account the 3D design because each WR placement will create a different outcome and more loading will be able to attach to the body segment as well to cover the important joint while exploring the biomechanical characteristics of the specific skills. Wearable resistance could be used by coaches and athletes as one of the choices

since it allows athletes to lift weights while performing movements that are unique to the tournament's skills without jeopardizing the mechanics of movement.

Acknowledgement

We want to express our gratitude to all authors and university institutions who have always supported all of these research activities.

Conflict of interest

The authors state no conflict of interest.

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ВПЛИВ НАВАНТАЖЕННЯ НАТІЛЬНИМИ ОБВАЖНЮВАЧАМИ ПІД ЧАС ВИКОНАННЯ ПРОТОКОЛУ РОЗМИНКИ НА БІОМЕХАНІКУ ПРЯМОГО УДАРУ НОГОЮ В ТХЕКВОНДО

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 2 табл., 1 рис., 25 джерел.

Мета дослідження. Це дослідження має на меті вивчення та визначення впливу навантаження натільними обважнювачами під час виконання протоколу розминки на механіку руху прямого удару ногою та активацію м'язів.

Матеріали та методи. У дослідженні брали участь двадцять п'ять університетських спортсменів чоловічої

статі (N = 25, зріст = 174,00 ± 4,76 см, маса = 75,93 ± 13,64 кг, вік = 22,57 ± 1,36 року), які займаються тхеквондо. До стегон і гомілок учасників були прикріплені натільні обважнювачі з навантаженням 0%, 5% та 10% маси тіла спортсменів. Оцінювали кінематику, кінетику та активацію м'язів під час виконання прямого удару ногою.

Результати. Загалом результати показали відсутність значних відмінностей між різними навантаженнями натільними обважнювачами в показниках кінематики, кінетики та активації м'язів під час виконання руху прямого удару ногою. Результати також показали відсутність шкідливого впливу внаслідок носіння натільних обважнювачів під час занять розминкою. Результати є дещо несподіваними, оскільки було висунуто гіпотезу, що застосування обважнювачів впливатиме на механіку удару ногою та активацію м'язів. Натільні обважнювачі не підвищили показник виконання удару ногою, якому відповідає швидкість удару ногою. Це, можливо, зумовлено використовуваними

відсотковими частками навантаження, які вважаються такими, що не знижують показник виконання, що показує, що ці натільні обважнювачі можна використовувати під час розминки на тренувальних заняттях як доповнення до тренувань з обтяженнями.

Висновки. Ми рекомендуємо в майбутніх дослідженнях вивчити хронічні ефекти натільних обважнювачів як спеціальних засобів, які використовуватимуть для покращення показників виконання ударів ногою в тхеквондо.

Ключові слова: тренування, кінематика, кінетика, активація м'язів, показники виконання.

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Cite this article as: Ibrahim, T. M. S. T., Tan, K., Malek, N. F. A., Jahizi, A. A. M., Mohamad, N. I., Ab Malik, Z., & Nadzalan, A. M. (2022). Effect of Wearable Resistance Loading during Warm-Up Protocol on Front Kick Biomechanics in Taekwondo. *Teoriâ ta Metodika Fizičnogo Vihovannâ*, 22(2), 223-228. <https://doi.org/10.17309/tmfv.2022.2.11>

Received: 03.02.2022. Accepted: 28.04.2022. Published: 25.06.2022

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