

# Effect of Post-Activation Potentiation according to Sequence of Velocity Using Isokinetic Device on Short-Term Performance of Lower Extremity: Taekwondo Athletes and Healthy Adults

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**Purpose:** The purpose of this study was to figure out how PAP (Post-Activation Potentiation) phenomenon affects short-term performance efficiently.

**Methods:** This study was conducted with 18 Taekwondo athletes and 16 healthy adults. By using isokinetic dynamometer, two different intervention, TDP (Top-down program) and BUP (Bottom-up program), were performed to measure isokinetic parameter; (peak torque: PT, total work: TW, average power: AP, and average torque: AT) of knee extensor for intragroup, intergroup comparison and two-way ANOVA.

**Results:** The Taekwondo athletes group showed statistically significant differences in all isokinetic parameters PT, TW, AP, and AT after TDP ( $p < 0.05$ ). However, in the healthy adult group, the difference in isokinetic parameters according to the exercise sequence was not statistically significant. ( $p > 0.05$ ). PT and TW at TDP were statistically significant ( $p < 0.05$ ) when the rate of change in TDP and BUP was compared and analyzed considering the difference in physical ability between the Taekwondo athlete group and the healthy adult group. However, AP and AT were not statistically significant. Finally, when examining the interaction between the two groups and two exercise sequence according to isokinetic parameters, only TW ( $p < 0.05$ ) showed a statistically significant interaction, while PT ( $P = 0.099$ ), AP ( $P = 0.103$ ), and AT ( $P = 0.096$ ) did not. This study suggests that short-term performance can be improved through the PAP phenomenon when TDP is applied to the Taekwondo group.

**Conclusion:** According to our result, for Taekwondo athletes, if the goal is to improve short-term performance just before the main game, we suggest a training program through TDP.

**Keywords:** Postactivation potentiation, Isokinetic dynamometer, Velocity, Taekwondo, Fatigue, Delorme training, Oxford training

## INTRODUCTION

Taekwondo, which is originated in eastern culture, is worldwide popular sports nowadays.<sup>1</sup> In Gyorugi, which refers to a match against an opponent, the use of both hands and feet is allowed, but the use of a kick with a relatively long range is preferred. Therefore, player focus to improve the speed and power of kick during training session.<sup>2,3</sup>

To make one's kick faster and powerful, a few factors such as hip, knee might be considered.<sup>3</sup> Among all these factors, we focused on structures which is related with knee extension. A typical muscle that affects knee

extension is the quadriceps femoris. Due to its quantification value, setting weight as a variable is widely known training method.<sup>4</sup>

In general, in the case of an exercise in which the variable is weight, intensity is set based on an individual's one repetition maximum (1RM). 80% or more of 1RM is classified as high-intensity exercise, 70-79% as moderate-high-intensity exercise, 60-69% as low-intensity-moderate exercise, and less than 60% as low-intensity exercise.<sup>5</sup> That is, the strength of the resistance can be customized according to an individual's ability. According to this concept, advanced methods which include pyramidal exercise and reverse pyramidal exercise with sequence and intensity as a

Received Nov 15, 2022 Revised Dec 19, 2022

Accepted Dec 19, 2022

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variable are commonly used to increase performance.

Pyramid exercise is a method that proceeds from low-intensity-high repetition to high-intensity-low repetition. In reverse pyramid type exercise, the exercise is performed until the muscles are tired, then lowered to 75% of the initial strength. Researchers figure out that both exercise methods showed significant results in improving performance, however pyramidal exercise was more effective in improving performance.<sup>6-11</sup>

On the other hand, recent studies refer that setting quantification value of speed as a variable by using isokinetic equipment showed significant improvement not only on strength but on agility.<sup>12,13</sup> In studies using the existing isokinetic equipment, the exercise speed was applied with a consistent value such as 60°/s, 180°/s, and 300°/s to all subjects. However, there was a limitation that the set speed (60°/s-300°/s) was faster than the person's maximum speed. Which leads some people might not be able to reach the set speed.<sup>14-16</sup> This indicates that even if the exercise is set at the same speed, a difference in exercise intensity may occur depending on the individual's ability.

To compensate this limitation, it is thought to be necessary to set the exercise speed according to individual ability. Therefore, this study intends to set the speed by measuring the maximum speed by isotonic contraction and converting the value to the ratio of 10%, 40%, and 100%. By combining these speed variables with a program that gradually increases or decreases of intensity, Top-Down program: TDP and Bottom-Up Program: BUP were set. TDP is performed in the order of 10% to 40%, and BUP is performed in the order of 40% to 10%, and then the final measurement is performed at 100% of their maximum velocity.

Previous studies argue that the slower movement velocity, the higher exercise intensity. Therefore, we assumed 10% of peak velocity as a slower velocity movement and higher intensity exercise than 40%.<sup>17</sup>

Many athletes proceed their own routines before the game. Among others, post activation potentiation: PAP is the representative strategies to maximize the effect of short-term performance.<sup>18-21</sup> PAP can be induced through resistance training prior to sports game, which leads to improved performance.<sup>22-25</sup> In general, performance degradation was observed due to temporary fatigue induction after preload exercise, but it was effectively observed to improve short-term performance as a PAP response afterward.<sup>18,26,27</sup>

Researchers have studied a few physiological mechanisms to explain this phenomenon. Among several mechanisms, the most recognized mechanism is that myosin and actin phosphorylation increase with conditioning training performed immediately before, which improves the

cross-bridge rate of muscle fibers and leads to improvement in performance.<sup>28-30</sup> Such short-term performance improvement is an important factor in martial sports such as Taekwondo.<sup>26</sup> Therefore, this study aims to find a more efficient way to induce the PAP phenomenon based on the hypothesis that "BUP will be better in improving short-term performance when TDP and BUP are combined with PAP."

## METHODS

### 1. Subjects

This study was conducted with 41 healthy adult men and women and college Taekwondo athletes from S University in Asan City, Chungcheongnam-do. The subjects of this study were those who had not undergone surgery within 6 months, those who had no previous lower extremity injuries, those who had no knee joint deformity, and those who had no abnormalities in their overall health.<sup>7</sup> participants were dropped due to our include and exclude criteria. This study was approved by Sunmoon University IRB (Institutional review Board SM-202203-004-2). All subjects were provided a sufficient explanation of purpose and method of the study and consents were gathered before the experiment was proceeded. The characteristics of the subjects are shown below (Table 1).

### 2. Experimental methods

The participants are divided into a group of taekwondo athletes and a group of healthy adults. Participants were set to single blind and did not know which group they belonged to. Our design, Factorial design, was set to observe the interaction between two different group after two types of interventions were equally applied. Height and weight of all participants were measured, and the sufficient resting term was provided to all participants between the measurement after TDP and BUP. All participants were measured with BUP, which is in the order of 40% to 10%, in the first measurement, and TDP, in the order of 10% to 40%, in the second measurement after sufficient rest.

**Table 1.** General characteristics of subjects (N = 34)

	TG	HG
Gender (M/F)	12/6	9/7
Age (yr)	20.2 ± 1.5	20.1 ± 2.4
Height (cm)	169.7 ± 6.4	170.8 ± 9.0
Weight (kg)	66.5 ± 10.7	70.4 ± 14.3
BMI (kg/m <sup>2</sup> )	23.0 ± 3.0	24.1 ± 4.4
Dominant (Rt/Lt)	17/1	15/1

All values are presented as mean ± standard deviation, Mean ± SD.

1) Measurement

Inbody (Inbody570 2013 KOREA) and Isokinetic Dynamometer (model HUMAC Norm: CSMI Solutions, Stoughton, Massachusetts) were used for the experiment. Inbody machine is a device that measures body weight and BMI. The isokinetic dynamometer is an instrument for measuring isokinetic parameters.

(1) Isokinetic dynamometer

All subjects were required to change their pants to prepared shorts and stay with bared feet before experiment. They were also informed to stop immediately if they felt any pain or fatigue before and during the experiment. Isokinetic dynamometer (model HUMAC Norm: CSMI Solutions, Stoughton, Massachusetts) was deployed for both exercise and measurement. Participants were positioned on the chair according to manual. A few belts were used to fasten the participants body such as upper limb, above knee of dominant leg and below knee of non-dominant leg. Participants were also required to grab handles to prevent their body floating from the chair. In short, every single part except below knee of dominant leg were fixated to make measurement of dominant leg efficiently. According to the studies which shown that high intensity and prolonged warming up might induce fatigue and degrade one's performance, we set 3 minutes of standing bike (DRAX, DX3U, 2019, Korea) with an intensity of 60 or higher RPM on grade 2.19 The isotonic mode of the isokinetic dynamometer was set to Torque 0, and the knee extension from 0° to 90° was measured 5 times after 3 times of practice. Assumed that the fastest value among 5 trial is one's peak velocity, we convert the intensity of exercise to 10% and 40% of peak velocity. On the first measurement, BUP exercise was performed in the order of 40%, 10%, and measured with 100%. After a sufficient resting term, on the second measurement, TDP exercise was performed in the order of 10%, 40%, and measured with 100%. After measurement, isokinetic parameters (PT: Peak torque, TW: Total work, AP: Average power, AT: Average torque) were compared. Between reps and sets, participants were provided 90 seconds of resting period.

(2) Isokinetic parameter

Four values of Isokinetic parameters; (peak torque: PT, total work: TW, average power: AP, and average torque: AT) were measured. Torque is mass X angular speed, and peak torque is the highest value of them. Work is force X displacement, and total work is the sum of all work. Power is work/time, average power is the average of all power values, and average torque is the average of all torque values.

3. Statistical analysis

In this study, descriptive statistics were used to calculate the mean and standard deviation (SD) of each variable. For all statistical analysis, SPSS/PC ver.25.0 for windows program (SPSS INC, Chicaco, IL) was used, and Shapiro-wilk was performed for normality test. Paired t-test was used to determine the difference according to the exercise sequence within the group, and the independent t-test was used to determine the rate of change of isokinetic parameters between groups.  $\{[(TDP-BUP)/BUP]*100\}$ . In addition, two-way ANOVA was used to determine whether there was an interaction between the group and the exercise sequence. The statistical significance level was set as  $p(\alpha) = 0.05$ .

RESULTS

The general characteristics of the subjects (age, height, weight, body mass index) are as follows (Table 1). The Taekwondo athletes group showed statistically significant differences in all isokinetic parameters PT, TW, AP, and AT after TDP ( $p < 0.05$ ) (Table 2, Figure 1). However, in the healthy adult group, the difference in isokinetic parameters according to the exercise sequence was not statistically significant ( $p > 0.05$ ). PT and TW at TDP were statistically significant ( $p < 0.05$ ) when the rate of change in TDP and BUP was compared and analyzed considering the difference in physical ability between the Taekwondo athlete group and the healthy adult group. However, AP and AT were not statistically significant (Table 3). Finally, when examining the interaction between the two groups and two exercise sequence according to isokinetic parameters, only TW ( $p <$

Table 2. Comparison of intragroup (N = 34)

	Sequence		t	p
	BUP=PE	TDP=RPE		
PT (Nm)				
TG	56.43±11.97	62.00±12.18	-2.49	0.02*
HG	43.50±12.13	39.94±7.73	1.36	0.19
TW (J)				
TG	63.43±13.71	75.44±14.15	-5.18	0.00*
HG	45.25±12.72	42.44±10.20	1.07	0.30
AP (W)				
TG	146.19±53.61	176.41±50.20	-2.79	0.01*
HG	91.33±35.65	86.65±26.08	0.51	0.61
AT (Nm)				
TG	31.59±7.06	35.46±6.49	-3.03	0.01*
HG	23.37±6.55	22.05±4.88	0.87	0.40

TG: Taekwondo group, HG: Healthy adult group, BUP: Bottom-up program, TDP: Top-down program, PT: Peak Torque, TW: Total Work, AP: Average Power, AT: Average torque, Mean±SD: Mean±Standard deviation. \* $p < 0.05$ .

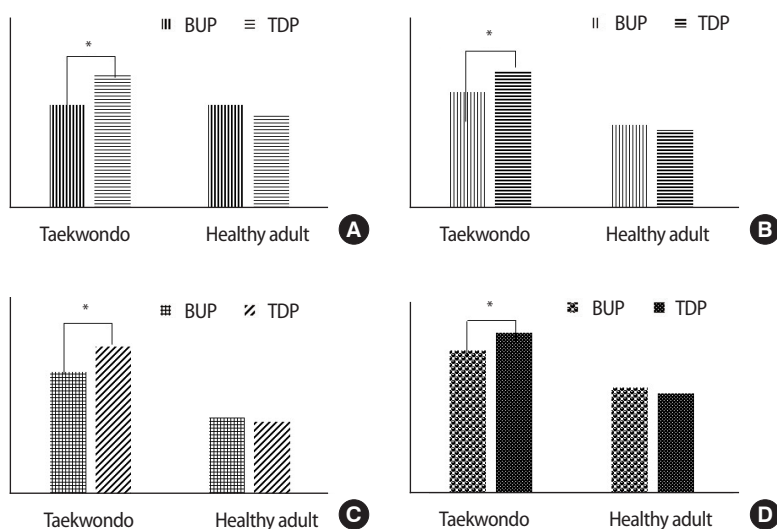


Figure 1. Comparison of intragroup. (A) Peak Torque, (B) Total Work, (C) Average Power, (D) Average Torque.

Table 3. Comparison of intergroup difference ratio (N=34)

	Group		t	p
	TG(N=18)	HG(N=16)		
PT (%)	11.99±18.32	-3.94±22.46	2.28	0.03*
TW (%)	20.99±17.28	-2.25±24.92	3.19	<0.001*
AP (%)	30.67±42.78	3.82±35.58	1.97	0.06
AT (%)	14.51±17.91	0.33±32.21	1.61	0.12

TG: Taekwondo group, HG: Healthy adult group, BUP: Bottom-up program, TDP: Top-down program, PT: Peak Torque, TW: Total Work, AP: Average Power, AT: average torque, Mean±SD: Mean±Standard deviation. \*p<0.05.

0.05) showed a statistically significant interaction, while PT (p=0.099), AP (p=0.103), AT (p=0.096) did not (Table 4).

## DISCUSSION

The purpose of this study is to examine how the exercise program which is combined PAP phenomenon with TDP and BUP affect taekwondo athletes and healthy adults. According to previous study, PAP was defined

Table 4. Comparison of sequence for each training program

(N=34)

Isokinetic parameter	Sequence		p value		
	BUP	TDP	Group	Sequence	Interaction
PT (Nm)					
TG	56.43±11.97	62.00±12.13	<0.001*	0.71	0.10
HG	44.22±12.16	41.20±9.11	F	41.186	0.136
TW (J)					
TG	66.43±13.17	75.44±14.15	<0.001*	0.15	0.02*
HG	45.25±12.72	42.44±10.20	F	67.08	2.17
AP (W)					
TG	146.19±53.61	176.41±50.20	<0.001*	0.23	0.10
HG	91.33±35.65	86.65±26.08	F	46.86	1.46
AT (Nm)					
TG	31.59±7.06	35.46±6.49	<0.001*	0.41	0.10
HG	23.37±6.55	22.05±4.88	F	49.42	0.69

TG: Taekwondo group, HG: Healthy adult group, BUP: Bottom-up program, TDP: Top-down program, PT: Peak Torque, TW: Total Work, AP: Average Power, AT: average torque, Mean±SD: Mean±Standard deviation. \*p<0.05.

as an acute enhancement of neuromuscular performance as a result of contractile history.<sup>19</sup>

BUP was performed in the order of 10% after 40% of the user's maximum velocity, and TDP was performed in the order of 40% after 10%. Wong et al.<sup>3</sup> argued that both the amount of fatigue generated according to the one's physical ability and required time to recover from fatigue should be considered to apply PAP phenomenon to maximizing the performance practically.<sup>31-34</sup>

Contrary to our hypothesis, Taekwondo athletes' intragroup comparison showed statistically significant difference in isokinetic parameters PT, TW, AP, and AT after TDP. These results are related to fatigue and recovery time.<sup>32-34</sup> Athletes accumulate greater amounts of fatigue at the expense of being able to perform exercise at a higher intensity than the healthy adult, who exercised as a hobby. Despite greater amounts of fatigue, athletes tend to possess larger potential capability: PC than healthy adults. A few researchers explain this phenomenon with adaptation and recovery ability of the athletes.<sup>31-34</sup> Fatigue, which takes a large part of functional weakness, is divided into peripheral fatigue: PF and Central Fatigue: CF. It was reported that, on average, PF which is caused by tiredness of muscle takes 4 minutes and CF which is caused by tiredness of nerves takes 2 minutes to be recovered from weakness. However, the occurrence of fatigue and recovery time may differ depending on individual's condition.<sup>35,36</sup> In the Taekwondo group, the TDP, which performed 10% speed in the first session, had a relatively sufficient time to recover from fatigue before measurement compared to the BUP which performed the exercise at 10% speed in the second session. To sum up, proceeding 10% intervention prior to 40% have sufficient given resting period to get recovered from weakness.

Our result indicates that all isokinetic parameters PT, TW, AP, and AT of healthy adults' intragroup comparison were not statistically significant. According to previous studies, the effect of the PAP phenomenon was not significant in the healthy adults because the resistance to fatigue, recovery ability, and performance were lower than that of athletes.<sup>32-36</sup> As a result, the values increased at PT: 3.56, TW: 2.81, AP: 4.69 AT: 1.32 after BUP compared to TDP, however this was not statistically significant.

According to a previous study, the rate of change of isokinetic parameters according to the isotonic E/R and I/R of baseball player's shoulder was statistically significant in PT and TW.<sup>37</sup> In this study, difference of physical ability between the Taekwondo athletes and healthy adults may cause bias. To supplement this bias, based on the above study, the amount of change was converted into a ratio for intergroup comparison.<sup>32-34,37</sup> According to another recent study, a significant difference in PT and TW

was reported for soccer players in positions who have relatively high frequency usage of lower extremity compared to soccer players in positions who did not.<sup>38</sup> Previous study argues that the difference in physical ability between athletes and the healthy adults is caused by the high frequency of use of the lower extremity muscles during daily training.<sup>32,33</sup> Therefore, the significant difference in the isokinetic parameter values of athletes depends on position is consistent with the results of this study.

Two-way ANOVA was applied to figure out interaction between each group and the exercise sequence. As a result, there was an interaction only with the TW, which was related to the physiologically generated additional movement. According to previous studies, the reverse pyramidal exercise emphasizes mobility rather than stability compared to the pyramidal exercise. While mobility-focused activity is conducting, additional movement is generated due to physiological mechanism to keep one's body stabilized.<sup>39,40</sup> Due to additional movement associated with TW, it seems that the interaction between the group and the sequence was statistically significant only with TW.

To summarize, despite all isokinetic parameter PT, TW, AP, and AT was statistically significant for Taekwondo group, only two isokinetic parameter PT and TW showed significant difference between Taekwondo and healthy adults' group. However only TW showed group and sequence interaction.

This study has two limitations. Firstly, due to lack of EMG and 3D motion analyze, fatigue depends on muscle fiber type and additional movement caused by physiological mechanism could not be analyzed. Secondly, there was a difference in basic physical ability between college athletes and healthy adults. Further research will be required to supplement the limitations of this study and to provide more effective training method to improve short-term performance.

This study suggests that short-term performance can be improved through the PAP phenomenon when TDP is applied to the Taekwondo group. Therefore, for Taekwondo athletes, if their goal is to improve short-term performance just before the main game, we suggest a training program through TDP.

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