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REVIEW ARTICLE

Investigation of Successful Performance Training for Taekwondo Athletes: Literature Review

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ABSTRACT

Background. Different factors are essential for taekwondo athletes to win competitions. The physiological, technical, tactical, and strength demands of Taekwondo have been investigated, and several studies have been conducted to train them effectively. **Objectives.** The purpose of this study is to categorize the methods for practical taekwondo training according to physiological, technical, strength, and tactical aspects so that taekwondo players can train effectively using the characteristics required during taekwondo training. **Methods.** The studies between 2000 and 2024 were selected, and 283 papers were collected and referred to in this study. Keywords were "Taekwondo performance," "Taekwondo athletes," and "Taekwondo training." **Results.** Taekwondo requires the aerobic system as an essential component. It should be used for practical training to be more effective in training those who require cardiorespiratory endurance training. The flexibility of the hip and knee joints is also an essential factor in winning a game. To perform taekwondo kicks for a more extended period and in a quicker motion, muscular endurance is essential, and training muscular endurance of hamstrings and quadriceps falls under an effective method. **Conclusion.** It is vital to perform aerobic training with intermittent training and minimize rest periods for practical training. Static stretches and proprioceptive neuromuscular facilitation stretches are effective for hip and knee flexibility, and visual training with red and blue lights is recommended for tactical components. It is essential to work on the muscular endurance of the hamstrings and quadriceps to extend the duration of the kick.

KEYWORDS: ***Taekwondo, Training, Aerobic System, Muscular Endurance, Flexibility.***

INTRODUCTION

Taekwondo is a Korean martial art and can be classified into three categories depending on the game's rules and operation method. In particular, Gyeorugi, a combat sport in which one player competes against an opponent, was adopted as an official event at the 2000 Sydney Olympics (1, 2). Under the current World Taekwondo Federation rules, different scores are given depending on a body part that is kicked or punched, and it is strictly restricted that the kicks and punches target permitted body parts (3, 4). Taekwondo is a sport that requires intense and full contact sparring, mobile stances, agility, speed, flexibility, and endurance, so when playing Taekwondo, athletes get easily injured (5). According to a previous study concerning the 2008 Olympic Games, most

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injuries occur during training and preparation for a competition (6). For male athletes one-third of male athletes' injuries were to the head and neck, while almost half, 44.5%, were to the lower limbs.

On the other hand, of female athletes, 15.2% of the female of them got injured in their necks and faces, but a high percentage, 53.1%, had injuries to the lower extremities. For these results, it can be said that most of the injuries were to the lower extremity (7). Most types of taekwondo injuries are contusions, strains, sprains, fractures, and concussions, which shows that there are many contact injuries as it is a combat sport.

During taekwondo training and competition, most injuries last less than 4 weeks, and in some cases, recovery can take more than 3 months, so minimizing damage can help improve performance (8). In martial arts, most injuries occur due to unexpected accidents, so preventing unnecessary injuries should be considered. Accordingly, injury prevention is an essential factor for taekwondo players. In particular, the prevention of musculoskeletal injuries is vital for athletes. In most cases, it occurs when the musculoskeletal structure is overloaded without sufficient regeneration or adaptation, so it is crucial to train athletes effectively to prevent injuries (9). Therefore, sports professionals and coaches need to use muscle strengthening, nutritional advice, and guidance as injury prevention strategies. In particular, it is more important for athletes to increase physical performance through scientific training (10). For practical training and injury prevention, training must be conducted to meet the requirements of many skills. Taekwondo is a three-round combat sport that consists of high-intensity movement with intermittent periods of inactivity (11). During attacks, anaerobic metabolism is essential, but in the intervals between attacks, the aerobic system uses most of the energy (12). Also, scoring techniques for each round can determine the winner. In Round 1, male winners scored less than non-winners and only 19% of the total in Round 1 among female winners, but in Round 2, female winners scored more points with 53% of the total points. This is because, in Round 1, the technique is meant to conserve energy against opponent moves (13).

Also, winners receive many warnings per match due to their aggressiveness and lack of fear. A high standard deviation characterizes Taekwondo because the physical elements of weight and height are essential depending on the weight category (14). In addition to these physical requirements, taekwondo performance must be emphasized in various areas, as swift kicks and dynamic footwork are the main components of Taekwondo (15). For this reason, studies have shown that medalists with proven performance are faster than non-medalists in speed tests using field test methods, allowing athletes with excellent speed and leg power to distinguish between different competition levels (16). While many studies have examined the physical elements and strategic methods for successful taekwondo performance, there has been little research on the practical training methods for coaches and professionals in taekwondo training. This study aims to organize the physiological, technical, tactical, and strength characteristics of taekwondo players to improve their performance, minimize injuries, and train athletes scientifically. As a result of this study, practical and scientific taekwondo training could be researched in the future.

MATERIALS AND METHODS

The databases of this study are Web of Science and Google Scholar, and the keywords were "Taekwondo performance," "Taekwondo athletes," and "Taekwondo training." The studies between 2000 and 2024 were selected, and 283 papers were collected and referred to in this study. This study mainly collected papers on physiological demands, technical and tactical characteristics, and strength demands of taekwondo competition (Figure 1).

RESULTS

Physiological characteristics. A previous study found that the aerobic system used 66±6% of total energy consumption when training 10 taekwondo players under the same conditions as taekwondo competitions (17). The reason for this is that in the first round, the opponent is attacked relatively quickly, so the anaerobic system is used a lot, but as the second round continues until the third round without full

recovery, the total energy can be said to use a lot of the aerobic system. In another study, when taekwondo training was performed on 8 athletes with 3 rounds of 2 minutes and 30 seconds recovery time, heart rate (HR), HR max, and rate of perceived exertion (RPE) were measured to see if there were any changes as each round was performed (18). HR, HR max, blood lactate, and RPE increased significantly because the physiological impact on the body and perceived by the individual increased. A study was conducted on eight abilities for successful taekwondo performance of specific strength, flexibility, specific endurance, speed, balance, coordination, agility, and accuracy taught to 242 coaches and national team managers, targeting 730 athletes from 69 countries on 6 continents (19). As a result of the survey, most coaches stated that speed and endurance skills influence successful taekwondo performance (Table 1).

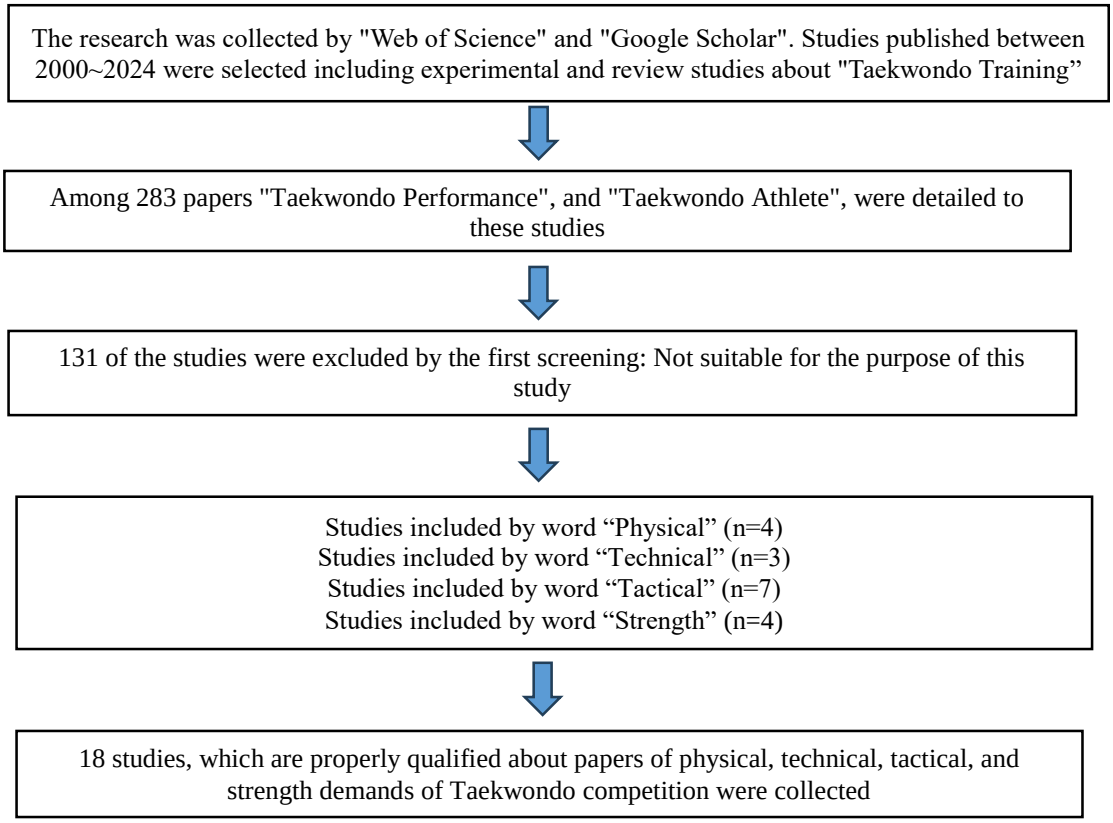

Figure 1. Progress of this study.

Technical Characteristics. Flexibility is defined as the range of motion of a joint without pain, and optimal flexibility increases muscle injury resistance (20). Muscle flexibility is vital for human function and is one of the most critical factors in improving physical performance (21). In a Dollyochagi, which is mainly used in taekwondo competitions, 32 people, when the standing board jump test, sit and reach test was performed, leg muscle explosive power and joint flexibility were used in 49% of the abilities, and when only flexibility was considered in Dollyochagi, 32% of the abilities were used (22). A literature review of several studies on flexibility training and taekwondo performance between 1970 and 2020 found that players cannot perform robust target strikes unless sufficient flexibility is ensured in the appropriate body, shoulder, and leg joints (23). For this type of performance, flexibility must be increased through static or proprioceptive neuromuscular facilitation stretching to increase flexibility to a level that does not affect performance (Table 2).

Table 1. Physiological characteristics

Year	Title	Participants	Methods	Effect
2005	Energy demands in Taekwondo athletes during combat simulation.	10 male athletes (age: 21±6 years, height: 176.2±5.3cm, body mass: 67.2±8.9 kg)	Three rounds of 2 min each, 1 min break between and combat: heart rate, blood lactate concentration, VO2.	The aerobic system is dominant in Taekwondo combat, accounting for 66±6% of the total energy cost of combat.
2007	Physiological responses and perceived exertion during international Taekwondo competition.	Eight male Taekwondo black belts (age 22±4, body mass 69.4±13.4 kg, height 182±0.1 cm, competition experience 9±5y)	Three 2-minute rounds with 30 s of recovery between each round. HR was recorded at 5s intervals during each combat. Capillary blood lactate samples were taken from the fingertip 1min before the competition, directly after each round, and 1min after the competition. RPE was recorded for each round using Borg's 6-to-20 scale.	HR (round 1: 175±15 to round 3: 187±8 beats·min−1; P<0.05), percentage of HR maximum (round 1: 89±8 to round 3: 96±5% HRmax; P <0.05), blood lactate (round 1: 7.5±1.6 to round 3: 11.9±2.1 mmol·L-1; P<0.05) and RPE (round 1: 11±2 to round 3: 14±2; P <0.05; mean±SD) increased significantly across rounds.
2011	Physiological and physical profile of Taekwondo athletes of different age categories during simulated combat.	The sample consisted of children (10.9±1.6y), cadets (14.7±1.3y) and adults (23.4±3.1y) male athletes	The match consisted of three 2-min rounds with 1-min rest interval, reproducing the characteristics of a real Taekwondo competition	Blood lactate, displacement, maximum speed, and HR peak differed among age groups, with no difference in acceleration and number of impacts. HR-peak and HR-mean differed among rounds. The time spent during the match simulated they differed among HR-peak zones.
2012	Predictors of fitness status on success in Taekwondo	730 subjects from 69 countries and 6 continents, 242 coaches, and national team managers with varying levels of education and competitive success.	Coaches were asked to rate the importance of eight predictor variables: Taekwondo-specific strength, flexibility, specific endurance, speed, balance, coordination, agility, and accuracy.	Elite sparring coaches from both competition systems assigned the highest percentage of their impact on success to speed and endurance variables.

VO2: maximal oxygen uptake, HR: Heart Rate, RPE: Rating of perceived exertion, P: P-value, SD: Standard Deviation.

Tactical Characteristics. It is one of the essential elements in taekwondo competition. In this study, tactical characteristics were divided into reaction time and tactics. In an experimental study with 7 athletes, reaction time, response time, performance time, and kick impact were measured before and after the after-exhaustion test. There was no change in reaction time and performance time, but kick impact decreased and reaction time increased (24). In an experiment with 30 people, reaction time was measured using auditory and visual stimulation. The experimenters were instructed to hold down the switch with both hands and release it with the dominant hand's index finger when stimulated. Taekwondo players responded faster to auditory high and low-frequency tones and faster to blue and red light stimuli (25). Reaction time to muscle activation has also been studied. According to a previous study, the premotor reaction time, total reaction time, and electromechanical delay of the rectus femoris and flexor pollicis brevis of 40 taekwondo players were compared with audiovisual stimulation (26). Professional taekwondo practitioners had better neuromotor performance in large and small muscles, which

enabled them to respond faster to sport-specific stimuli. In addition, they were slower to respond to non-sport-specific stimuli, which may be due to reduced sensitivity to irrelevant sensory input after intensive taekwondo training. Of the 356 fights of 204 collegiate taekwondo players, 178 were selected, and seven tactical parameters were defined as tactical actions (27). Attacks and counterattacks were compared, and then within attacking actions, direct and indirect actions. The victors used more counterattacks, direct attacks, indirect attacks, subsequent counterattacks, and anticipatory and simultaneous counterattacking tactical actions (Table 3).

Table 2. Technical characteristics

Year	Title	Participants	Methods	Effect
2006	Explosiveness and flexibility of leg muscles contribute to Padang Taekwondo hopscotch ability	32 people (16: male, 16: female) consisting of 16 males and 16 females.	Compared to the dolly kick ability of a Taekwondo player, the explosive power of the leg muscles and joint flexibility	The explosive power of the leg muscles and joint flexibility are 49% higher. Stone kick contributes 45% to the leg muscle explosive power of Taekwondo players' kicking ability. Contributes 32% to the flexibility of dolly kicking ability.
2009	The effect of different flexibility studies on the performance of Taekwondo. Turkish Journal of Sport and Exercise	Flexibility exercises on the performance of Taekwondo players spread over a broad period covering the years 1970~2020, mainly in the 2000s.	The microanalysis method, compiled from literature research covering information and interpretation of results, was used by comparison.	Taekwondo athletes cannot perform powerful, targeted strokes without properly developing flexibility in their body, shoulder, and leg joints. Short-term static and PNF stretching exercises have been found to positively contribute to flexibility without compromising performance.
2011	Acute Effects of Vibration Foam Rolling Warm-Up on Jump and Flexibility Asymmetry, Agility, and Frequency Speed of Kick Test Performance in Taekwondo Athletes	Fifteen healthy elite male Taekwondo athletes.	GW, GW combined with VR (GW+VR), and GW combined with double VR for the weaker leg (GW+double VR). Participants were required to perform a single-leg CMJ. Quadriceps hamstring flexibility test, CMJ, hexagon test, 505 agility test, and multiple frequency speed of kick tests.	Flexibility, CMJ, and VR and GW+double VR protocols for the weak leg were not significantly different from the GW protocol, and the superior effect of GW+VR was confirmed in the hexagonal test. The GW+VR and GW+ double VR protocols strengthened Taekwondo kicking fatigue resistance and improved Taekwondo kicking performance compared to the GW protocol.

PNF: Proprioceptive Neuromuscular Facilitation, GW: General Taekwondo warm-up, VR: Vibratory foal rolling, CMJ: Countermovement jump.

Strength Characteristics. During taekwondo competitions, kicks are the most common method of attacking an opponent. Therefore, the muscles in the knee and hip joints are crucial for powerful kicks. In the study of the strength demands of taekwondo competitions (28), hamstring, quadriceps, and Calf muscle strength was measured in slow movement at 60°/second and fast movement measured at 240°/second, targeting taekwondo players aged 14 to 19 years who joined 20 local taekwondo associations. Taekwondo training was correlated with hamstring and quadriceps, but only at 240°/second. There was no correlation between taekwondo training and calf muscle at a slow speed of 60°/second. In another study (29), an experiment was conducted on 31 adolescents divided according to the length of participation in Taekwondo: long-term, short-term, and non-practitioners. Participants were assessed for knee joint position sense, isokinetic quadriceps and hamstring strength, and sway during prolonged single-legged standing. The results showed that taekwondo training improves balance in one-legged standing and that long-term taekwondo practitioners have better postural stability due to

better knee joint position sense rather than muscle strength. Not only strength training but also functional training has positive results in competition. In a previous study, essential physical examination, maximal grade exercise test, and anaerobic exercise test were observed and measured by performing functional training for 3 hours per week, 1 hour per day for 6 days. Introducing the eight U.S. national team athletes participating in the 2017 Muju Taekwondo World Taekwondo Championships (30). After the functional test, there were significant changes in back strength, sit-up, repeated jump, and side step, and there were significant differences in the Wingate test and anaerobic exercise ability before and after (Table 4).

Table 3. Tactical characteristics

Year	Title	Participants	Methods	Effect
2000	Effect of fatigue on reaction time, response time, performance time, and kick impact in Taekwondo roundhouse kick	Seven male competitive athletes (24.5±3.9 y; 176.4±3.4 cm; 73.7±5.9 kg, and 11.7±1.4% body fat)	Determining reaction time, response time, performance time, and kick impact before and after the specific progressive Taekwondo test.	Kick impact decreased while reaction time increased. A moderate correlation was observed between kick impact and response time ($r=0.565$; $p<0.01$) and kick impact and performance time ($r=0.494$; $p<0.05$).
2004	Technical and tactical analysis of youth Taekwondo performance	Fifty-nine youth Taekwondo athletes	Comparison of game results of 37	Kicks performed with the rear leg occurred more frequently than those performed with the front leg; these findings might indicate not-yet complete attainment of fundamental coordinative capabilities in 10 to 12-year-old athletes, independently of match outcome.
2008	Auditory and Visual Reaction Time in Taekwondo Players	30 Taekwondo from the Martial Arts Training Center were recruited. Reaction time was measured with the Response Analyzer. It provides two types of stimuli: Auditory - Low and High-frequency sounds and visual - Blue and Red Lights.		Mean ART and Mean VRT of the non-athletes were more remarkable than that of the players, the difference between the two groups being statistically significant ($p<0.05$).
2008	Tactical Analysis of the Winners' and Non-winners Performances in a Taekwondo University Championship	A total of 356 performances corresponded to 178 matches from a Spanish University Championship.	A total of seven tactical parameters were defined into the tactical actions.	Winners perform fewer indirect attacks but more anticipatory counterattacks. There is a need to plan the tactical training to increase the tactical behavior of the Taekwondo athletes when a direct or an indirect attack is performed since it seems that the key to winning is based on applying the most adequate tactical skills in each tactical situation.
2011	Taekwondo training improves the neuromotor excitability and reaction of large and small muscles.	Neuromotor excitability, premotor reaction time, total reaction time, and electromechanical delay of rectus femoris and flexor pollicis brevis in response to audio and visual stimuli were measured.		React slower to non-sport specific stimuli, which suggested a decreased sensitivity to irrelevant sensory inputs after intensive Taekwondo training.
2015	Neuromuscular performance of half-moon chagwi: comparison between semi-elite and elite Taekwondo athletes.	Fourteen black belt competitors were divided into two groups, as follows: 7 elite athletes.	GRF was evaluated by a force platform, and surface electromyographic signals were evaluated in kicking leg muscles.	Timing parameters, except kinetic reaction time, were faster in elite athletes. Furthermore, angular velocity during knee extension, foot and knee linear velocity, and horizontal GRF were significantly higher in elite than in sub-elite athletes.
2016	Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo	A sample of 31 Taekwondo players	examine impact force and execution time in a Bandal Chagui or roundhouse kick, and explore the effect of execution distance in these two variables.	Significant differences were found in competitive experience and execution time for the three different distances of kicking considered in the study. Standing at a certain distance from the opponent should be an advantage for competitors who are used to kicking from a further distance in their training.

GRF: Ground reaction forces.

Table 4. Strength characteristics

Year	Title	Participants	Methods	Effect
2000	Relationship between Taekwondo training time and lower extremity strength in adolescents	20 Taekwondo practitioners aged 14-19 (13 men, 7 women)	Cybex Norm isokinetic dynamometer was used to test knee flexor (hamstrings), knee extensor (quadriceps), and ankle plantar flexor (calf) muscle strength at both slow (60°/second) and fast (240°/second) speeds	Significantly correlated with the peak torque of the knee extensors and flexors, but only at 240°/second No significant correlation between Taekwondo training duration and peak torque of the knee flexors and extensors at the slower speed (60°/second), nor was there a significant correlation between duration and peak torque of the ankle plantar flexors at any speed.
2004	Lower limb joint sense, muscle strength and postural stability in adolescent Taekwondo practitioners: original research article	31 adolescents, including long-term (n=11), short-term (n=10), and non-practitioners (n=10) of Taekwondo participated in the study.	The knee joint position sense, isokinetic strength of the quadriceps and hamstrings, and sway in prolonged single-leg standing were measured.	Taekwondo training can improve single-leg standing balance. The better postural stability demonstrated by long-term practitioners may be associated with better knee joint position sense rather than knee muscle strength.
2008	The influence of strength training on Taekwondo athletes' reaction speed	The control groups were Groups A1, B1, and C1. Confirmation of Taekwondo core strength training program, methods, and methods through survey. Confirm the effect of Taekwondo core strength training on strengthening strength through a 6-month experiment using rapid strength training methods, methods, and evaluation indicators on research subjects.		The analysis of experimental data shows that core strength training significantly improves the reaction speed of Taekwondo athletes.
2008	The Effect of Functional Training on the Physical Strength Factor of Elite Taekwondo Athletes	South American national players participated in Muju WTF World Taekwondo Championships in 2017 for 6 weeks, 3 times a week, 1 hour a day (N=8)	Body composition, Basic physical examination, Maximal graded exercise test, and Anaerobic exercise test were measured. The functional exercise program was performed three times a week for a week, and the one-hour daily	functional exercise program effect was Back strength, sit-ups, repeated jumps, and side steps were found to be effective in essential physical fitness items. In addition, there was a statistically significant difference ($p<0.05$) in all the measurement items because of the Wingate test, an anaerobic exercise ability item, before and after applying the functional exercise program. The maximal graded exercise test using a treadmill showed a significant improvement ($p<0.05$) in maximum oxygen uptake, exercise duration, and blood lactate concentration.

DISCUSSION

This study was conducted to summarize and analyze the technical, tactical, and strength characteristics and the physiological demands required in taekwondo competitions for use in practical and scientific taekwondo training. According to Campos, 2012 (17), Taekwondo uses the aerobic system for 66±6% of the total energy system, and HR, HRmax, and RPE increase over time, so training to increase aerobic capacity is essential. Furthermore, in a survey of 242 coaches on the factors necessary for successful taekwondo performance, most coaches stated that speed and endurance skills were

critical (19). This suggests that training should focus on endurance and speed. Another study found that adding technical training to recovery sessions is vital for practical training to build cardiovascular intensity. Therefore, intermittent exercise and recovery during training are essential for achieving physiological effects (31).

Taekwondo players, in particular, have done much research into flexibility because most attacks consist of kicks, so without measuring flexibility in multiple joints, it is impossible to hit the opponent on the practical side. According to studies on flexibility training and taekwondo performance from 1970 to 2020 (23), if body, shoulder, and leg joint flexibility is insufficient, it is difficult to hit the effective target. It cannot provide strong force, so flexibility is essential. Short-term static stretching or proprioceptive neuromuscular facilitation stretching are effective methods to improve performance without affecting performance.

The tactical nature of Taekwondo is also an essential factor. This study compared and analyzed studies on reaction time to quickly react to the opponent's movements and tactics to defeat the opponent. When the reaction time was measured by auditory and visual stimulation in 30 people (25), taekwondo players responded faster to auditory high and low-frequency sounds and faster to blue and red visual stimuli. In addition, when measuring the electromechanical delay of premotor and total reaction times of the rectus femoris, a large muscle used in kicking, and the flexor pollicis brevis, a small muscle used in kicking, in 40 taekwondo players, professional athletes responded faster to sport-specific stimuli of large and small muscles (26). According to the results of these previous studies, taekwondo players' reaction speed and fast movements are essential factors for successful performance. Training with high and low-frequency auditory stimuli and blue and red visual stimuli is necessary to improve athletes' reaction speed.

Taekwondo players mainly use kicks, so their strength is fundamental. In particular, the knee flexors, knee extensors, and ankle plantar flexors are muscles that are frequently used in kicking. When the strength of these muscles was measured using the slow and fast methods, there was a correlation between the knee flexors and the knee extensors in fast situations for taekwondo players. Hence, the strength of taekwondo players was that exercise methods that improve muscular endurance can be considered more effective than training that increases muscular strength.

CONCLUSION

In this study, physiological demands, technical and tactical characteristics, and strength demands of taekwondo competition were collected and examined as an effective method for the successful performance of taekwondo players. Taekwondo players use the aerobic system a lot due to their physiological characteristics, and as it is a sport that requires a lot of endurance and speed, it is adequate to focus on aerobic training. Flexibility is also one of the most essential elements in Taekwondo. If the flexibility of the hip and knee joints is not fully developed, delivering powerful force to the correct target would not be possible, so training in the specific joints is essential. In addition, it is vital for players who perform well in tactical situations to do a lot of auditory and visual training, as their reaction time to auditory and visual stimuli is relatively reduced. In the case of kicking, the most commonly used attack in Taekwondo, strength training to increase muscular endurance can be effective because it is used more at high speed than at low speed.

APPLICABLE REMARKS

- It can be compared with previous studies related to training methods in terms of physiological, technical, muscular strength, and tactical aspects, which are physical factors that affect the performance of taekwondo players.
- Research on extending the kick duration, an essential technique in Taekwondo, and research on technique performance ability related to the strength of the quadriceps femoris and hamstrings were referred to.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Je-Hun Lee, Seung-Ho Han. Acquisition of data: Soo-Won Uh. Analysis and interpretation of data: Soo-Won Uh, Na-Young Yoon, Su-Gyeong Jung, Je-Hun Lee, Seung-Ho Han. Drafting the manuscript: Na-Young Yoon. Critical

revision of the manuscript for important intellectual content: Je-Hun Lee, Seung-Ho Han.

CONFLICT OF INTEREST

The authors mention no conflict of interest in this study.

ETHICAL CONSIDERATION

This study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

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This study has no funding or support for the paper.

ROLE OF THE SPONSOR

The funding organizations are public institutions and had no role in the design and conduct of the study.

FINANCIAL DISCLOSURE

This study has no financial interests related to the material in the manuscript.

ARTIFICIAL INTELLIGENCE (AI) USE

This study agrees with the journal's policy in this section.

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