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Effect of a 10-week Training Program on Muscle Power, Endurance, and Jump Kick Performance in Young Male Taekwondo Athletes Using the 4D PRO® Bungee Trainer and Battle Ropes Exercises

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Abstract Taekwondo, which mainly involves kicking and flexibility exercises, demands physical fitness of strength, endurance, and power. Aims: The purpose of this study was to assess the effects on muscle strength, endurance, and jump kick performance of using 4D PRO® Bungee Trainer and Battle Rope for training in Taekwondo. Methods: The study included 40 male Taekwondo players aged 16-18, and the participants were divided into two comparable groups: the first group of subjects (experimental group) underwent training with 4D Pro and Battle Ropes (n = 20, mean ± SD, age 16. 95 ± 0.96 years, height 168.95 ± 1.28 cm, weight 67.55 ± 1.54 kg, training experience 3.30 ± 0.47 years). The second set of subjects (control group) included subjects who underwent traditional training without 4D Pro and Battle Rope (n = 20, mean ± SD, age 17.00 ± 0.73 years, height 168.90 ± 1.52 cm, weight 67.50 ± 0.95 kg, and training experience 3.35 ± 0.49 years). It was carried out using pre- and post-measurements, with ten weeks of training. In the EG, the program was designed to enhance muscle strength, endurance, and jump kick performance, with sessions conducted three times a week. Each training session was between 60-90 minutes and the training repetition duration was 50 to 90 seconds. The tool requires 30-60 minutes for a session and the load intensity level is between 60-85% maximum heart rate. The training program for the CG matched the program without 4D PRO® Bungee Trainer and Battle Rope exercises. Results: This study revealed that there was a significant difference between the pre and post-tests of the EG. This meant that the Cohen's d values for the EG were above 0.8 thus implying a very large effect size. The EG had a higher mean score than the CG in the measurements being used in this study. Conclusion: This study highlights the importance of using 4DPro and Battle Rope in providing quality training programs to develop muscle strength, endurance, and jump kick performance in Taekwondo.

Keywords 4D PRO Bungee, Battle Ropes, Speed Kicks, Taekwondo

1. Introduction

Taekwondo is characterized by flexibility and use of kicks, necessitating the participants to be fully fit and trained [1]. Research indicates that endurance, particularly measured through VO_2Max, is a key determinant of success in Taekwondo competitions, with athletes exhibiting higher VO_2Max levels correlating with better performance outcomes [2]. Additionally, muscle strength and flexibility are essential for executing complex techniques and maintaining balance during matches [3]. A study comparing these two training types found significant improvements in various biomotor capacities, including muscle power and endurance, in elite female Taekwondo athletes [4]. Another investigation highlighted that a 12-week high-intensity training program led to notable enhancements in strength and endurance among high-level Taekwondo athletes [5]. Traditional training methods in taekwondo have primarily concentrated on technical skills and sparring, often neglecting strength, stamina, and power. However, the introduction of new training techniques such as 4D Pro and Battle Ropes Training has the potential to transform athletic conditioning in the sport [6].

4D Pro and Battle rope training are effective exercise techniques that come with various benefits in enhancing one's physical fitness. Battle Ropes utilize heavy ropes aimed at increasing performance in terms of the shoulder, proprioception, lower limb strength as well as trunk muscle strength [7]. 4D Pro training is a plyometric exercise method that enhances sport-related physical fitness results such as cardiorespiratory endurance, strength, ROM, and sprinting performance [8].

The Battle rope has been developed to help improve motor performance and physical strength. The use of resistance ropes and other forms of exercises that incorporate body weight can help in attaining fast, muscle strength, and exertion without any need for additional equipment [7]. These ropes and 4D Pro assist in boosting the sports performance of the athletes' specialized gross motor skills. For instance, incorporating an athlete's body weight as resistance during exercises using equipment such as the 4D pro and Battle rope offers a significant boost to movement and performance; this applies to athletes across a multitude of sports activities [9]. Integration of resistance ropes such as the 4D pro and Battle rope into training schedules makes it possible for athletes to attain efficient workouts that improve general physical performance and propel their competitive levels upward [10].

Several scholarly articles [1,6,11,12] have estimated the feasibility of training martial arts athletes by applying elastic ropes. It has also been suggested that training programs incorporating the resistance rope exercise can enhance the strength and speed parameters of kicks in Kumite in novice karate performers [13]. In addition, the strength assessment system that utilizes resistance bands during training is an effective tool for determining the precise load required for performing specific strength tasks during taekwondo kicks. It also contributes to measuring athletes' performance during training sessions. Moreover, progressive elastic-band exercises could be advantageous for training in martial arts [14].

Studies have shown that battle rope training can improve cardiopulmonary fitness, muscle power and therefore should be incorporated into the exercise schedules for athletes like karate, taekwondo, and kung fu fighters [15]. In addition, the EMG analysis of muscle activity during battle rope training revealed that wave movement with ropes on the right and left side in both unilateral and bilateral manner may offer moderate to high levels of muscle activation for most of the major muscle groups and can give practitioners more options as to which specific muscles they want to train [16].

Bungee Rope Training (4D Pro) and Battle Ropes Training have emerged as innovative methods to enhance muscle power, endurance, and jump-kicking performance in Taekwondo athletes [17]. While Bungee Rope Training focuses on dynamic movements and resistance, Battle Ropes Training offers a challenging workout for strength and agility [1,18]. These training techniques cater specifically to the unique requirements of Taekwondo athletes, providing a dynamic and engaging approach to physical conditioning [19].

Research has shown that explosive strength training on lower limbs significantly improves physical fitness in Taekwondo athletes, highlighting the importance of incorporating innovative training methods to enhance athletic performance [20]. Additionally, the effects of repeated high-intensity technique training on combat-related performance in Taekwondo athletes emphasize the importance of specific training approaches for optimal skill development and combat readiness [21]. For augmentation in athletic movement in general and Taekwondo in particular, Taekwondo Sport needs quick fluctuations of velocity and direction, the rhythm pattern of which should be switched between fast actions and jumps [22]. This has raised the demand for the development of newer and better strategies for enhancing overall physical fitness and its attributes of muscle strength and endurance [23].

Thus, it is crucial to address the method of training muscle strength and endurance components in the skill path and athletic efficiency to achieve the outlined goals. In general, we have seen a reduction in athletes' performance in certain aspects of fitness, which includes muscle strength and endurance, as well as a reduction in the actual performance skills associated with some forms of jumping [24]. This issue can be attributed to inadequate preparation for training muscle strength and endurance within training systems designed to prepare athletes for physical demands. Consequently, researchers are focused on exploring modern training methods and effective tools that can enhance an individual's technical performance. Among these efforts are resistance exercises utilizing ropes, such as 4D Pro and Battle Rope. As noted, these

exercises can be implemented as a training regimen to improve athletes' physical performance. However, there is a notable lack of research that examines the simultaneous use of these tools in a single study. This gap has prompted the adoption of contemporary training methods like Battle Rope and 4D Pro, which are among the latest techniques aimed at boosting an athlete's physical capabilities, including their jumping ability in taekwondo. It can also introduce fun, reduce monotony among the athletes, and make them push for the best outcomes since it is safer, secure, and can be placed anywhere due to its small size. Hence, it was postulated that muscular strength, endurance and performance jumping kicks in Taekwondo differ between pre- and post-measurements of the experimental and control groups, with the experimental group being higher than the control group.

2. Materials and Methods

2.1. Study Design and Sample Characteristics

This is a test-retest cross-sectional study with a sample of 40 participants and the data was collected at the Matay Sports Club in Minya Governorate, Arab Republic of Egypt. This work was done following the guideline by Lundby et al. [25]. The sample size (n = 40) was determined using the calculation of sample size power analysis based on G-power software version (3. 1. 9. 7). The participants were divided into two comparable groups: the first group of subjects (experimental group) underwent training with 4D Pro and Battle Ropes (n = 20, mean ± SD, age 16. 95 ± 0.96 years, height 168.95 ± 1.28 cm, weight 67.55 ± 1.54 kg, training experience 3.30 ± 0.47 years). The second set of subjects (Control group) includes subjects who underwent traditional training without 4D Pro and Battle Rope (n = 20, mean ± SD, age 17.00 ± 0.73 years, height 168.90 ± 1.52 cm, weight 67.50 ± 0.95 kg, and training experience 3.35 ± 0.49 years). Before the experiment, we described the aim of the study, and all the procedures, including measurement processes, to the participants. They were also enlightened on the various risks encountered while participating in the study. Full informed consent was explained to all participants coming to the research and each completed an informed consent form based on the principles of the Helsinki Declaration [25,26]. The research protocol was approved by the locals. This study was carried out between January and March 2024, and the following activities were implemented; pre-measurements which took place on January 2-3, were a training program where the groups took a ten-week training from January 4 to March 17, 2024, and each training session was conducted three times a week. The post-measurements were taken immediately after the program's implementation by March 18 -19, 2024.

2.2. Measurements

2.2.1. Measurement of Height and Body Weight

The participant's height was measured by using a stadiometer (Seca 220, UK) whose precision was checked up to the nearest 0.5 cm. The tester needs to stand upright with legs joined together and he must fold his arms across his chest. The heels, buttocks, and upper back lay on a single line at one point. The test participant remains focused on the fixed point while taking deep breaths. Height was measured using a stadiometer as the distance between the standing platform and the vertex. The height of students was measured in centimeters. Body weight in kilograms was recorded using the electronic weighing machine (Seca Alpha 770, UK) with an accuracy of 50 gm. The tester was instructed to remove his upper clothes and shoes and put on shorts of known weight and then the bare weight of the tester was recorded 12 hours after the last intake of meal. He was standing at the weighing machine in the middle, and he was just keeping his eyes straight. The weight of the body was expressed in kilograms [27].

2.2.2. Measurement of Muscle Power, Endurance

Standing Long Jump Test (SLJT): This test aims to evaluate the muscle power of the lower legs over a given time. To complete this test, you will need: 30-metre tapes, a long jump pit, and an assistant. In this action, the athlete swings their legs outward in front of the sand pit. To execute this, the athlete must jump into the sand pit with both feet bent forward while swinging their arms backward, then forward, and again forward, all while leaning forward. This measurement should be recorded by the coach from the edge of the sand pit to the farthest contact point. The jump must begin from the state in which there is no movement. The athlete is allowed two attempts, and the better of the two is selected [28,29] (Figure 1).

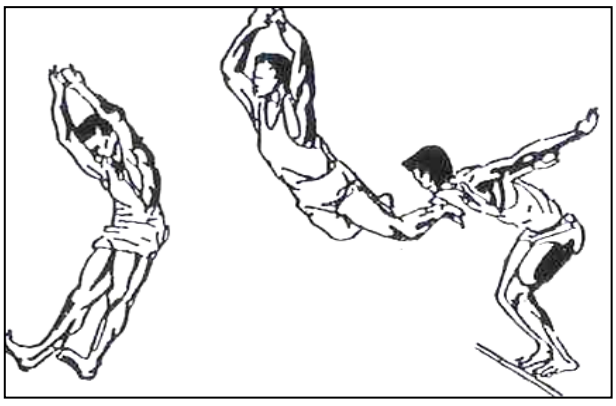

Figure 1. Sergeant Jump Test

Sergeant Jump Test (SJT): This test aims to record the athlete’s progress in improving elastic leg strength. To complete this test, you will need to perform the test using a wall, a one-meter stick, chalk, and an assistant. The first

maneuver is described as follows: applying chalk on fingers, standing sideways with feet firmly set to the ground, and reaching wall height with one hand while using fingertips to mark the wall (M1); the second is characterized as follows: standing, jumping to reach maximum possible height; and applying chalk on the tips of fingers to mark the wall (M2). The coach: then determines the distance between M1 and M2. The athlete is allowed two attempts, and the better of the two is selected [30] *(Figure 2)*.

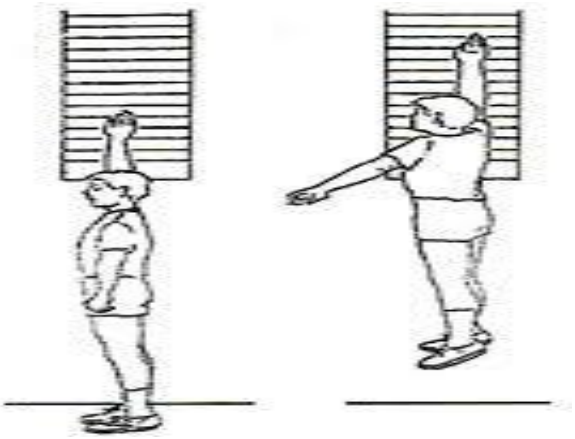

Figure 2. Sergeant Jump Test

Core Muscle Strength and Stability Test (CMSST): The development of the athlete's core strength might be monitored with the help of the Core Muscle Strength Test. For this test, the back, neck, and head should be positioned in the manner, when administering the test. The following is how the core muscle strength test is carried out: S1: The athlete begins with a 10-minute warm-up. They then assume the Start Position, using the mat to support their elbows and arms. Once properly positioned, the assistant starts the stopwatch, and the athlete holds this position for 60 seconds. S2: The athlete lifts their right arm off the ground and extends it forward, parallel to the ground, holding this position for 15 seconds. S3: The athlete returns to the Start Position, lifts their left arm off the ground, and extends it forward parallel to the ground, holding for 15 seconds. Stage 4: The athlete returns to the Start Position, lifts their right leg off the ground, and extends it backward parallel to the ground, holding for 15 seconds. S5: The athlete returns to the Start Position, lifts their left leg off the ground, and extends it backward parallel to the ground, holding for 15 seconds. S6: The athlete returns to the Start Position, lifts their left leg and right arm off the ground, extending them parallel to the ground, and holds for 15 seconds. S7: The athlete returns to the Start Position, lifts their right leg and left arm off the ground, extending them parallel to the ground, and holds for 15 seconds. S8: The athlete returns to the Start Position and holds this position for 30 seconds. S9: The test concludes. The test was stopped when (1) the participant became fatigued or voluntarily stopped the test, (2) the participant refused to hold the correct posture, or (3) the participant indicated adverse effects from the test (e.g., headache, dizziness, pain not associated with fatigue). The number of attempts at the test is recorded once, and the duration for which the athlete maintains the correct position is measured [29,30] *(Figure 3)*.

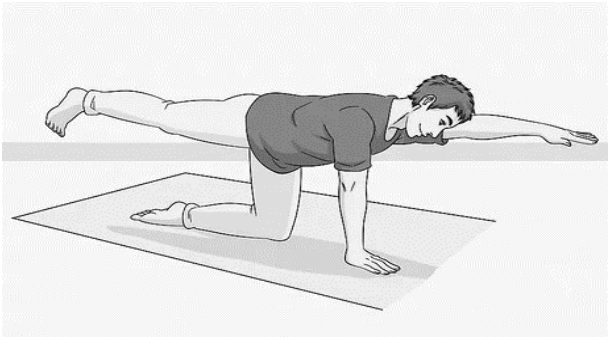

Figure 3. CMSST

Sit Up Test (SUT) (abdominal 30 sec): The aim is to evaluate muscle endurance. The participant starts by sitting upright with their knees bent, feet flat on the floor, and the arms across the chest. Start in the up position, with the back in a vertical position. When the timing starts, lower the back so the shoulder blades touch the floor, then return to the up position. Repeat for 30 sec. The total number of correct sit-ups in 30 sec is recorded as the score. Two attempts are allowed, with the best result being recorded [30] *(Figure 4)*.

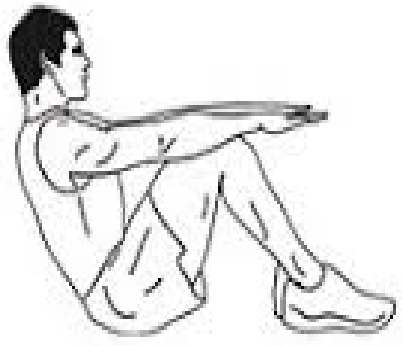

Figure 4. Sit Up Test

2.3. Speed Kicking Test (SKT)

The primary purpose of the test is to assess the performance of jump kicks in Taekwondo, specifically measuring the number of kicks the tester can execute each time. To conduct this test properly, a kicking bag, a counter, and an assistant are required. The tester assumes an attack stance facing the assistant, who holds the target at waist level. The tester's dominant leg is positioned backward, and the counter signals the tester to begin jump kicking with their back leg for 15 seconds, ensuring that each kick makes complete contact. A countdown timer (auditory

signal) is used, starting from 15 seconds down to 0 seconds. Participants are allowed to perform one kick during the first 15 seconds, followed by another kick in the next 15 seconds. One point is a jump-kicking worded for a perfect jump kick, while 0 points are given for kicks that do not contact the target or are deemed imperfect by the assistant. Participants are allowed to practice their kicking and pacing before the actual test to help them understand the expected rate and improve the consistency of their performance. Each participant is permitted one attempt for each kick. In terms of test-retest, the kick has been proven to have high reliability with a score of 0.84 [31, 32] (Figure 5).

Figure 5. Taekwondo kicking test

2.4. Experimental Design

The training procedures for the experimental group were conducted over a period of 10 weeks, with three training sessions held each week at the training center, resulting in a total of 30 sessions for the program. The inclusion criteria were as follows: a) Participants were Taekwondo athletes from Matai Sports Club in Minya Governorate, Arab Republic of Egypt. b). The study focused on athletes aged 16 and 18 years. To exclude athletes from the study, a) sustain an injury or illness that could impede their training, or b) be using any medications that might affect the outcomes of the investigation.

All the participants in the study and their parents were informed about these exercises and the type of study to be conducted and were asked to give written approval by the study participants as well as their parents, which was approved by the ethics committee for scientific research (protocol Ref. No. KFU-REC-2023-OCT-ETHICS 2108).

2.5. Training Program Protocol

2.5.1. Experimental Group

The program was systematically executed by using 4DPro& Battle Rope exercises to enhance muscular Power, endurance, and competence in performing jumping skills in Taekwondo within 10 weeks. The experimental group exercised with the 4DPro& Battle Rope during the three training sessions conducted each week. The duration of each training session was between (60-90) minutes and the training repetition duration was between 50-90 seconds. The tool requires (30-60 minutes) for a session and the load intensity level is between 65-85% maximum heart rate (See Table 1, 2). They are trained in phases.

Session Organization:

Warm-Up:

The preparation phase initially took 10-15 minutes and contained the following: Dynamic Stretching contains dynamic stretches focusing on the legs, hips, and shoulders to prepare the muscles for activity. Examples include leg swings, arm circles, and torso twists. Light Cardio contains light cardio exercises such as jogging or skipping to increase heart rate and blood flow to the muscles. Specific Drills include taekwondo-specific movements like high knees, butt kicks, and side shuffles to activate the muscles used in kicking and jumping.

Main phase:

Followed by 40-70 minutes which involved physical preparation with 4DPro & Battle Rope training and the demonstration of Taekwondo skills that included the execution of the double round kick with jumping (Dubal Dang Seong Chagi) and back round kick with jumping (Yop Ayo Dwi Chagi) and Integrate drills that mimic taekwondo movements, such as jumping kicks or explosive lunges, are done to improve performance in actual techniques. Consequently, the heart rates all the participants had during each training session were recorded.

Recovery:

The final phase of the training session takes 5 minutes. They include Cool Down: Gradually lower the heart rate with light walking and relaxation vibrations. Static Stretching: Focus on static stretches for the major muscle groups used during the session, holding each stretch for 20-30 seconds to promote flexibility and recovery. Breathing Exercises contains breathing exercises to help relax the body and mind.

2.5.2. Control Group

The traditional program was implemented for the control group over a period of 10 weeks. This program included a variety of exercises aimed at developing muscular strength, muscular power, and endurance. Additionally, it featured a set of drills focused on enhancing kicking techniques through jumping exercises. The main phase lasted between 40 to 70 minutes and did not incorporate the 4DPRO and Battle Rope training methods. However, the warm-up and recovery components were standardized across both the experimental and control groups.

Table 1. The 10-week muscle power, endurance and Taekwondo jump-related skills training program using exercises based on the 4DPro ® Bungee Trainer & Battle Rope exercise program

Week	***Session***	***Exercise 4DPro & Battle Rope***	***Intensity %***	***Groups***	***Rest***	
					BE	***BG***
1	*1*	*5,7,12,19,45*	*70%*	*3*	*60 s*	*40 s*
	2	*1,3,20,22,49*	*75%*	*4*	*60 s*	*50 s*
	3	*2,4,8,29,44*	*60%*	*3*	*60 s*	*45 s*
2	*4*	*10,11,14,21,48,61*	*75%*	*3*	*60 s*	*40 s*
	5	*6,9,17, 55,62,67*	*75%*	*3*	*60 s*	*45 s*
	6	*11,13,17,24, 44,61*	*60%*	*3*	*60 s*	*45 s*
3	*7*	*15,33,35,37, 42,65*	*75%*	*4*	*60 s*	*70 s*
	8	*16,39,40, 41,44,66*	*80%*	*4*	*60 s*	*65 s*
	9	*22,36,35, 44,70*	*60%*	*3*	*60 s*	*55 s*
4	*10*	*17,22,18,25,44,69*	*75%*	*3*	*55 s*	*45 s*
	11	*19,33,17,24,42,63*	*75%*	*3*	*60 s*	*45 s*
	12	*35,12,38,44,61,72*	*60%*	*4*	*65 s*	*45 s*
5	*13*	*10,12,44,50,65*	*80%*	*3*	*65 s*	*50 s*
	14	*20,32,46,55,63*	*70%*	*3*	*60 s*	*50 s*
	15	*40,13,18,51,65*	*60%*	*3*	*60 s*	*60 s*
6	*16*	*9,15,21,59,70*	*75%*	*3*	*60 s*	*60 s*
	17	*22,31,22,41,66*	*75%*	*3*	*65 s*	*50 s*
	18	*10,13,23,58,72*	*60%*	*4*	*60 s*	*45 s*
7	*19*	*24,30,46,57,66*	*75%*	*4*	*65 s*	*40 s*
	20	*8,15,25,42,45,63*	*85%*	*4*	*60 s*	*40 s*
	21	*7,12,15,47,56,67*	*60%*	*3*	*65 s*	*40 s*
8	*22*	*26,28,29,43,61*	*75%*	*3*	*60 s*	*45 s*
	23	*17,18,27,19,53,64*	*65%*	*3*	*60 s*	*45 s*
	24	*23,24,28,44,48,62*	*60%*	*3*	*60 s*	*55 s*
9	*25*	*20,49,50,55,68*	*75%*	*3*	*65 s*	*50 s*
	26	*21,16,51,54,60,70*	*85%*	*4*	*60 s*	*45 s*
	27	*22,52,25,60,68*	*60%*	*3*	*60 s*	*45 s*
10	*28*	*26,28,34,39,40,64*	*80%*	*3*	*65 s*	*45 s*
	29	*22,55,53,59,60,66*	*70%*	*3*	*65 s*	*50 s*
	30	*20,50,54,57,63,71*	*60%*	*3*	*60 s*	*60 s*

BE: Between exercises; BG: Between groups.

Table 2. Examples of 4DPro& Battle Rope exercises session

4DPro& Battle Rope number exercises (6/9/17/55/62/67)	
Execution method	Athletes are divided into two groups and placed in different stations each focusing on specific exercises and including jumping kicks in Taekwondo. In each group, athletes rotate through a series of game stations, working on specific tasks at each station and then moving on to the next station.
The exercises	
 6 A B C	
 9 A B	
 17 A B	
 55 A B	

62 A B

67 A B

Exercises	6,17	9,55	62	67
Performance shaping Individually / couple				
Skills / without Skill				

2.6. Statistical Analysis

In this study, the statistics were concluded through IBM SPSS Statistics 26 software which is in Chicago, IL, USA. The statistical analysis included two-way ANOVA with repeated measures with group (Control, Experimental) as the fixed factor and measures (PRE, POST) as the within-subjects factor with post hoc comparisons with the Holm-Bonferroni correction. Influence measures were determined preoperatively using the partial eta-square (ηp2) technique, the t-test (t), 95% confidence interval bounds, and the effect size (d). Cohen's d effect size interpretation was as follows: 0.1–0.2 meaning they were of a small impact, 0.3 – 0.5 a moderate effect, 0.5 –0.8 strong, and more than 0.8 a very large effect. Pre-established targets of statistical significance of the results in this study were set at $P < 0.05$. Results are presented in mean +/- standard deviation.

3. Results

Table 3 shows the outcome measures (mean ± Std) for the experimental (Exp) and control (Con) groups before (PRE) and after (POST) the 10-week period of the training program.

The results consisted of the F-statistic from analysis of variance (ANOVA) of the main effects: measurement and group, as well as ηp2 for the Interaction (measurement group). Bonferroni's post hoc test revealed that the experimental group had a higher incremental increase in all variables than the control group. The ANOVA details are given in Table 4. To sum up, the results of the investigation were as follows: Since $p < 0.05$, there were significant effects obtained relative to all the study variables.

Table 4 illustrates the differences in measurements ($P < 0.001$) for repeated measures of the main effects (measurement and group) as well as the interaction between measurement and group. The F values for the main effects (measurement) ranged from 286.074 to 1237.808, while the effect size (ηp^2) ranged from 0.883 to 0.970. The F values for the main effects (group) ranged from 20.464 to 183.932, with effect size (ηp^2) values ranging from 0.350 to 0.829 ($P < 0.05$). The interaction results show that the effect of measurement varies depending on the group. The statistically significant F values (ranging from 25.956 to 88.410) indicate that the differences in performance are not consistent across all

groups. The ηp² values (from 0.406 to 0.699) suggest a moderate to large effect size for the interaction, indicating that the relationship between measurement and performance is influenced by group membership.

Table 5 illustrates the differences in post - measurements ($P < 0.001$) for independent test for the Outcome measures.

Table 3. Descriptive Statistics

Outcome measures		Groups	PRE	POST	Imp. %
SLJT (cm)		Exp	180.90 ±2.12	195.37 ±3.40	8.00%
		Con	180.65 ±2.23	188.38 ±4.67	4.28%
SJT (cm)		Exp	30.67 ±0.58	37.19 ±1.01	21.26%
		Con	30.55 ±0.60	33.75 ±0.79	10.47%
CMSST (min)		Exp	1.73 ±0.05	1.94 ±0.05	12.14%
		Con	1.72 ±0.04	1.78 ±0.03	3.49%
SUT (CM)		Exp	17.40 ±0.94	21.85 ±0.88	25.57%
		Con	17.35 ±0.81	19.40 ±0.75	11.82%
SKT	DRKJ (score)	Exp	5.30 ±0.57	9.25 ±0.55	74.53%
		Con	5.20 ±0.70	7.00 ±0.73	34.62%
	BRKJ (score)	Exp	4.25 ±0.64	7.50 ±0.51	76.47%
		Con	4.00 ±0.56	5.10 ±0.55	27.50%

Exp= Experimental; Con= Control; DRKJ= double round kick with jumping (Dubal Dang seong Chagi); BRKJ= back round kick with jumping (Yop Ayo Dwi Chagi).

Table 4. The results included analysis of variance (ANOVA) and the ηp2 values for the main effects (measurement and group) as well as for the Interaction (measurement group)

Outcome measures	Measurement			Group			Group ×Time Interaction		
	f	p	ηp^2	f	p	ηp^2	f	p	ηp^2
SLJT (cm)	286.074	0.001	0.883	20.464	0.001	0.350	26.354	0.001	0.410
SJT (cm)	1040.577	0.001	0.965	121.568	0.001	0.762	88.410	0.001	0.699
CMSST (min)	458.400	0.001	0.923	125.645	0.001	0.768	38.942	0.001	0.506
SUT (sc)	896.927	0.001	0.960	122.279	0.001	0.763	25.956	0.001	0.406
DRKJ (sc)	1237.808	0.001	0.970	173.059	0.001	0.820	40.241	0.001	0.514
DRKJ (sc)	752.937	0.001	0.952	183.932	0.001	0.829	67.473	0.001	0.640

DRKJ= double round kick with jumping (Dubal Dangseong Chagi); BRKJ= back round kick with jumping (Yop Ayo Dwi Chagi); sec=second; sc=score; $p < 0.05$

Table 5. Independent test for the Outcome measures

Outcome measures		EX	Con	t	Sig. (2-tailed)	Cohens d.	D. imp. %
SLJT (cm)		195.37 ±3.40	188.38 ±4.67	5.41	0.001	0.86	3.72%
SJT (cm)		37.19 ±1.01	33.75 ±0.79	12.04	0.001	1.90	10.79%
CMSST (min)		1.94 ±0.05	1.78 ±0.03	10.58	0.001	1.67	8.65%
SUT (cm)		21.85 ±0.88	19.40 ±0.75	9.49	0.001	1.50	13.75%
SKT	DRKJ (score)	9.25 ±0.55	7.00 ±0.73	11.05	0.001	1.75	39.91%
	BRKJ (score)	7.50 ±0.51	5.10 ±0.55	14.24	0.001	2.25	48.97%

$p < 0.05$; D. Imp. — Differences in improvement percent.

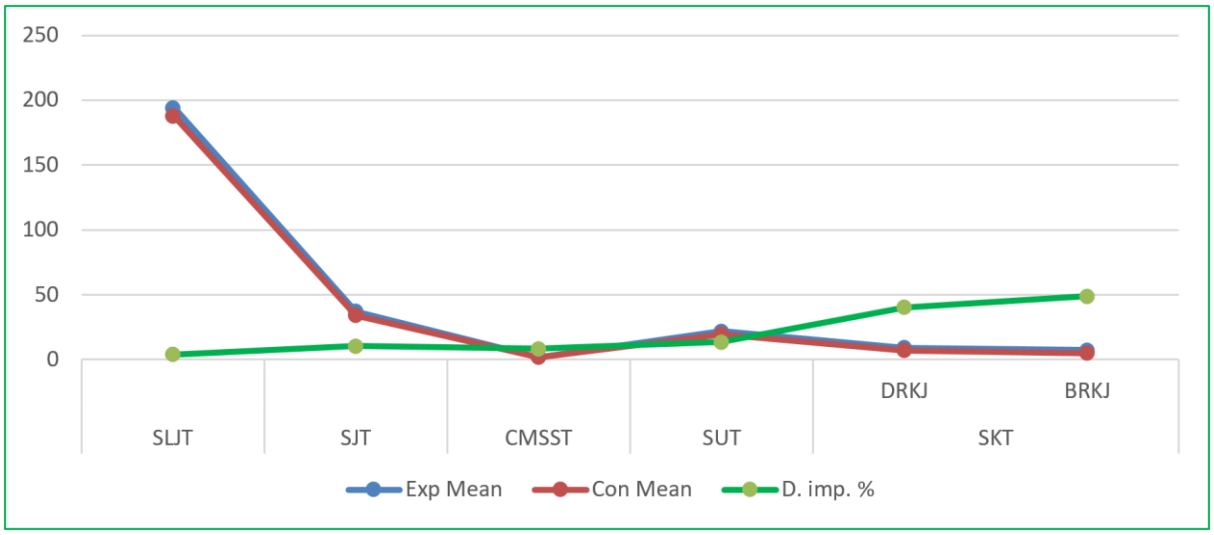

Figure 6. Post-measurements of the study variables

The table presents a statistical analysis of the differences in various measurements between the experimental and control groups of Taekwondo athletes in the study. The results indicate that the experimental group demonstrated significant improvements in performance compared to the control group across several variables. SLJT Performance: The experimental group showed a performance increase of 3.72% compared to the control group, achieving a moderate effect size of 0.86 (Cohen's d). SJT Performance: The experimental group exhibited a recovery improvement of 10.79% in physically demanding tests compared to the control group, with a large treatment effect reflected in a Cohen's d value of 1.90. CMSST Performance: The experimental group's results indicated an increase of approximately 8.65% compared to the control group, accompanied by a large effect size of 1.67. SUT Performance: The experimental group improved by 13.75% relative to the control group, which is categorized as a large effect size with a Cohen's d of 1.50. SKT Performance (DRKJ, BRKJ): The experimental group showed remarkable improvements of 39.91% and 48.97% in DRKJ and BRKJ, respectively, compared to the control group. These results indicate significant performance enhancements in SKT, with large effect sizes of 1.75 and 2.25 (See Figure 6.).

4. Discussion

This study aims at determining the differences in the muscular strength, endurance and jump kick performance of Taekwondo in the ten weeks of 4DPro and Battle Rope training. Comparing Tables 3, 4, and 5, it is quite clear that the experimental group is significantly superior to the control group in all muscular strength tests (SLJT, SJT, SUT), endurance test (CMSST) and jump kicks with p-value < 0.05. Based on the findings of the assessment, it was clearly seen that the benefits reported by the experimental group which utilized the 4DPro and Battle rope training were higher than those reported by the control group that followed conventional training styles ($p < 0.05$). These notable improvements emphasize the effectiveness of innovative training approaches in enhancing both the physical and skill performance of athletes.

The study conducted by Ouergui I. et al. [19] examined the impact of conditioning activities on physical performance in Taekwondo. The authors found that plyometric training significantly enhanced performance, as did repeated high-intensity techniques; however, plyometrics required shorter rest periods for optimal potentiation compared to the latter. Additionally, Aloui A, et al. [22] compared the effects of repeated sprint training (RST) and repeated high-intensity technique training (RTT) on Taekwondo athletes, concluding that RTT effectively facilitated perceptual responses and improved combat performance, highlighting the importance of training specificity for combat transfer. Furthermore, Wang P. [33] utilized optimization algorithms to assess the efficiency of Taekwondo training, considering the differences among learners and their feedback, which can enhance training quality. According to a meta-analysis by Jeong et al. [21], Taekwondo practice positively influences the growth factor levels in children and adolescents, suggesting that Taekwondo should be recommended to support normal growth in this demographic. Ojeda-Aravena A. et al. [34] conducted a systematic review demonstrating that plyometric jump training can enhance athletic performance in combat sport athletes, including those in Taekwondo. Integrating these findings, it can be hypothesized that incorporating 4DPro and Battle Rope training into a Taekwondo regimen could lead to improvements in strength, endurance, and jump kick performance, aligning with the documented enhancements in physical performance and growth factors associated with Taekwondo training.

Several researchers [35,36] have noted that specific rope exercises brought out high-impact improvements in physical fitness and the overall performance among martial arts athletes such as karate, taekwondo among others. Leaping movements have been identified to enhance agility and jumping performance, while rubber resistance rope exercises contributed to increasing the percentage of changes in strength and speed of kicks [37]. Moreover, battle rope training offers enhancement of energy and coordinated movements when compared to those that include ground exercises in their program; this has a potential of boosting performers who engage in combat-related activities such as martial arts especially the taekwondo [38]. All these findings give a cumulative emphasis on the assertion that incorporating rope exercises like Rubber ropes (4DPro) and combat ropes (Battle Rope) should be adopted in martial arts training to enhance physical capacity and skill level improvement.

The development of muscle capacity, endurance, and jumping ability in taekwondo kicks can be attributed to the proper application of specific exercise tools like rubber rope exercises (4DPro) and Battle Rope. All the above tools have proved to have a positive impact on the performance of taekwondo performers. These exercises basically mimic the movement patterns of taekwondo and enhance physical characteristics, as well as fine motor skills, thus tend to enhance the performance of a Taekwondo athlete. Moreover, other cross-sectional studies [39-41] suggest that there is a strong relationship between kicking power and the anthropometric measures which support the significance of the physical and anthropometric indices in kicking and agility among taekwondo athletes. Consequently, incorporating exercises that enhance muscle capacity, endurance, and jumping ability is essential for optimizing the physical and technical skills necessary for successful taekwondo performance.

5. Conclusions

The investigators concluded that with 4DPro and Battle Rope training for 10 weeks, there is an enhancement of muscle strength and endurance, and jumping kick performance of the subjects in the experimental group. The scores on muscle strength, endurance and jumping kick Taekwondo exercises of the experimental group who practiced using 4DPro and Battle Rope were significantly higher than that of the control group with no 4DPro and Battle Rope exercises. Therefore, the level of support for the proposition that 4DPro and Battle Rope exercises are useful in improving muscle strength, endurance and jumping kick performance for Taekwondo athletes is apparent. As a result, it is suggested to include these exercises as a part of the training program to obtain improved outcomes and to exercise the physical abilities in a comprehensive way.

5.1. Study Limitations and Future Studies

Limitations include a) using the specific exercises as recommended by the 4DPro and Battle Rope training program -this is the most serious limitation, b) using only male athletes, c) there was no control over the athletes' diet and sleeping patterns.

Informed Consent Statement

Consent was obtained from all study participants.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Additional Information

No additional information is available for this paper.

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