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The Effects of 8-week Plyometrics Training on Fitness and Soccer-specific Performance in Female Middle School Soccer Players

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The purpose of this study was to investigate the effects of 8-week plyometrics training on fitness and soccer-specific performance in female middle school soccer players. Twelve female soccer players participated in this study. These subjects were randomly divided into 2 groups: the control group, which performed interval training for 8 weeks, and the experimental group, which performed plyometrics training for 8 weeks. The training programs consisted of one-hour exercise sessions, 5 days per week. Tests were performed in two time periods: the first was done prior to the initial training (pre-test) and the second was done following the training program (post-test). The tests for fitness included muscle strength, endurance, speed (37m run), Wingate anaerobic power tests, and the tests for soccer-specific performance included agility running, dribbling speed, passing accuracy, and shooting abilities (shooting accuracy, shooting ball velocity, and shooting quality). The results were analyzed with independent samples T-test ($P<0.05$) using an SPSS 21 program. Our results showed that 8-week plyometrics training significantly increased the peak power of the Wingate power test ($P<0.05$) in female middle school soccer players. 8-week plyometrics training significantly increased the shooting ball velocity in female middle school soccer players ($P<0.05$). It was concluded that 8-week plyometrics training increased anaerobic muscle peak power and this increase may contribute to the increased shooting ball velocity in the female middle school soccer players in this study. It is suggested that plyometrics training may increase the shooting performance by increasing shooting ball velocity.

Keywords: plyometrics training, soccer, fitness test, soccer-specific performance test, Wingate anaerobic power test

I. INTRODUCTION

Soccer is a sport that requires various movements like many other sports. Soccer repeats various movements and plays the game through physical strength, skill, and tactics. The performance that determines the victory or defeat of a football game can be classified into tactical, technical, mental, and physical fitness factors (Shin et al., 1992). Tactical factors are dependent on formations which are divided into offense and defense through the placement and activity of players. Winning or losing the match depends on the individual's position in the field. In particular, the defense is largely divided into two types: interpersonal defense and regional defense. The game of interpersonal defense requires individual responsibility and aggressiveness, and there is a danger that the use of offside traps and pressure is limited, and the individual's strength is required. The regional defense-style game is easy to maintain stability, creativity, and turn around, and it has a numerical advantage around the ball when defensing, and it is easy to find a solution when pressing the opponent. However, adaptability and instant response are required when marking an opponent. Depending on the position of the soccer player, the defense and offense methods will be freely implemented. Depending on the capabilities of a soccer players, various systems such as 4-4-2, 4-3-3 and 4-2-3-1 will be created, and the role of the striker and defender can also be changed. For example, if you are relatively weaker than the opponent team, you can increase the number of defenders to focus on overall defense and gain a chance to score by counterattack.

Other than tactical factors, technical and mental factors are important, but fitness factors are the most important factors in winning or losing. Among the fitness factors related to soccer, there is a demand for endurance which can act continuously, and muscular power with instantaneous response, and agility and quickness with which to change directions quickly and accurately, which can be the basis of soccer skills (Vanderford et al., 2014). It requires 90 minutes of non-stop endurance, instantaneous power such as passing or shooting, ability to assess the situation of the opponent to read the flow of the game, the sense of balance and rotation for ball control, and various fitness factors such as coordination, agility, and power (Kim, 2000).

As the fitness factors of a soccer game cannot be omitted, leaders have been trying to improve their performance through training. In the 1970s, a training method called plyometrics was developed in Eastern Europe. Plyometrics training performed well in track and field events on the track, and leaders and athletes in many events began to build training programs by applying these training exercises to their sport (Ahn, 1995). Plyometrics training is very effective for sport or motor events that require rapid muscle contractions after a short stretch, and increase power, speed and agility by reducing the time required for these changes and enabling faster turnovers in motion (Choi, 2008). It is said that by using plyometrics training properly, it can help not only the efficiency of muscular activity, but also the skill improvement and physical fitness in the field. Plyometrics training is easy to learn and easy to teach, so it can also be taught to elementary school children as it can be done with a variety of strengths and may

compensate for the disadvantages of weight training that have little transfer to functional physical abilities (Kim, 2009).

Since plyometrics training is known for its effective training in many ways and has been studied on adult players, it is not well known whether plyometrics training is effective in improving physical fitness and performance for youth players. In particular, female middle school soccer players are in the process of growth, development, and maturation of the human systems, including the nervous system, skeletal system, muscle system, respiratory system, and metabolic system and may differ in response compared to adults, and may also show poor response to various training such as resistance training or aerobic training.

It has been questioned whether or not plyometrics training will cause a considerable or slight effect in female middle school soccer players. Specifically, it raises questions about what fitness factors plyometrics training can contribute to the fitness and performance of youth female soccer players. This study was conducted to investigate whether plyometrics training for youth female soccer players can improve physical fitness as well as performance.

II. METHODOLOGY

Subjects

Female soccer players from middle schools belonging to the Korea Football Association (KFA) and the Women's Football Confederation (KFA) were tested by dividing each of the 12 players who had been trained professionally for more than three years into an experimental group and a comparative group.

Experimental Design

The physical fitness and soccer performance indices were measured by the pre- and post-training sessions of female middle school soccer players. In addition to basic team training, the comparison group, which is the control group, conducted eight weeks of interactive training, while the experimental group, which is the plyometrics group, applied an eight-week plyometrics training program in addition to basic team training.

Experimental Methods

1. Body composition measurement

The height, weight, percent body fat, and fat mass of all subjects were measured using a bioelectrical impedance analyzer (Inbody 720, Biospace, Korea). This bioelectrical impedance analysis method can obtain the ratio and amount of body fat and fat-free mass by giving a high energy alternating current wave around both soles of the feet by using the difference of the electric resistance between body fat and fat-free tissue.

2. Training intensity

The intensity was controlled using a wireless heart rate system with a moderate intensity (HRmax 50-60%). The exercise intensity was set to 60 ~ 80% based on the individual's maximum heart rate, and then the target heart rate was substituted into the Karvonen formula. The Karvonen formula is as follows.

- ([HRmax-HRrest] × percent intensity) + HRrest.
- HRmax: maximal heart rate, HRmax=(220-age)
- HRrest: resting heart rate
- percent intensity: percentage of intensity

3. Plyometrics training methods

After the end of the afternoon training, the experimental group performed additional plyometric training 5 times a week for 40 minutes including a warm-up and cool-down. Training was conducted starting with 10 repetitions per set in the first 2 weeks, increasing the number of repetitions to 12 times over the next 3 weeks and the number of repetitions, again, to 15 over the last 3 weeks. The components and methods of plyometrics training are described in Figure 1. The comparative group conducted the interval training 5 times a week for 40 minutes, including a warm-up and cool-down, and the intensity of the exercise was like that of the experimental group. As shown in Figure 2, the interval training was initiated by starting at the corner of the soccer field and sprinting diagonally across the field, then jogging (rest) straight across to the other corner. The first 2 weeks of training consisted of 5 repetitions per set, 6 repetitions per set in weeks three and four, and 7 repetitions over the remaining four weeks.

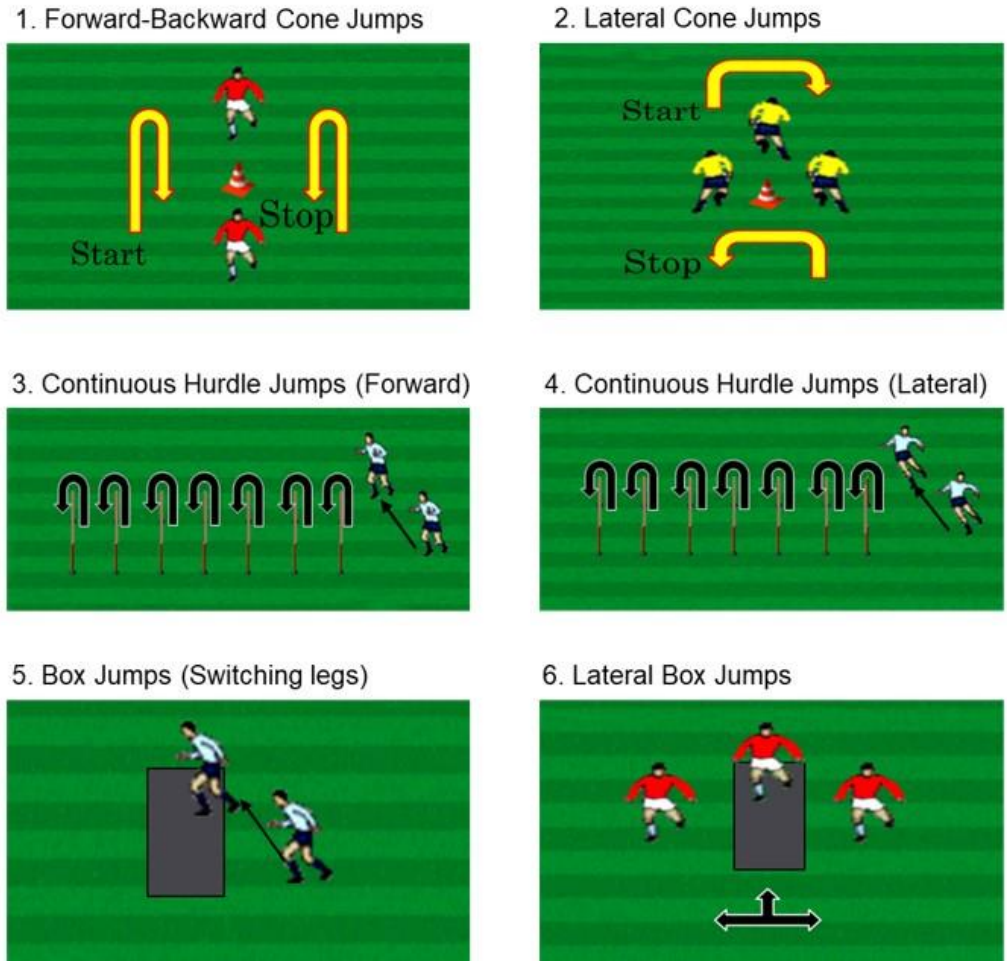


Figure 1. Plyometrics training program

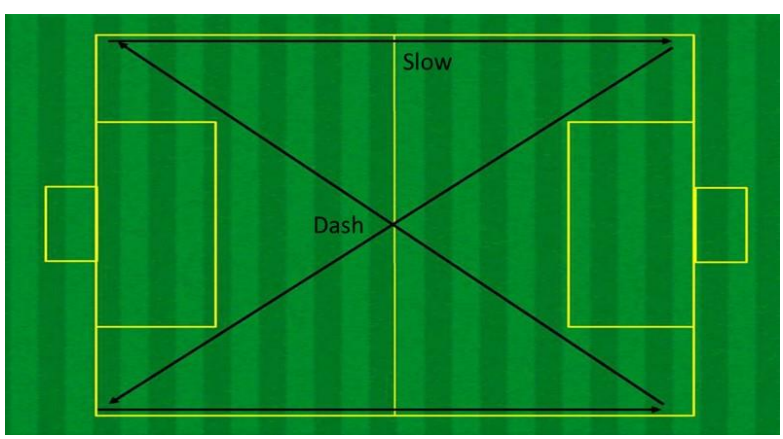


Figure 2. Interval training program

4. Muscular fitness indices

1) Strength test

Muscle strength was measured using an isometric instrument (BACK-D, TAKEI, Japan).

2) Endurance test

Using a 30 cm high bench, the stopwatch begins with a "pre-start" sign and the player jumps on the bench with two feet and then returns to the floor. The number of times a person performed a one-minute jump on two feet and down to the floor was measured.

3) Speed test

The speed was measured through a 37 m running (shuttle run). This test, called round-trip running, performed like a game situation, using sprint and break time like those analyzed during soccer games. As the players got tired, they could sprint more and more quickly until they could no longer meet the target speed while having a break between sprints. The speed decision used the running speed of the last session.

4) Anaerobic power test

Muscle power was measured by the Wingate power test. Wingate test is a test to measure anaerobic power using an electric resistance bicycle ergometer (Excaliber, USA).

Bike pedaling is carried out at 50 rpm for 1 minute in the preparation phase to warm up and the individual load is multiplied by 0.7 per body weight to determine the torque. Then a 5-second count is carried out and the bike is peddled as fast as possible for 30 seconds at the "start" signal. The maximum peak power, mean power, total work, and fatigue index are calculated. The maximum peak power, mean power, total work, and fatigue index were calculated.

5. Soccer performance tests

1) Agility test

Agility was measured through agility run tests. This test measured the soccer-specific agility running test using a method developed by Vantinen et al. (2010). Agility was determined by measuring the elapsed running time of five flags as shown in Figure 3.

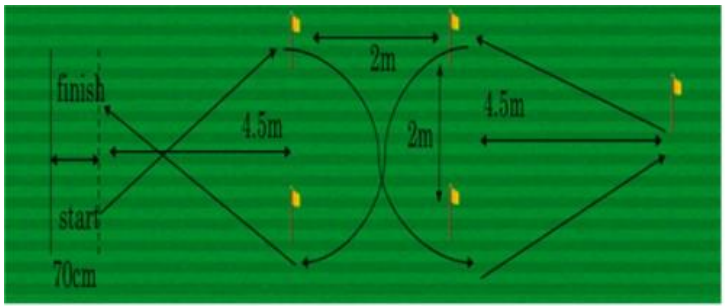


Figure 3. A diagram of soccer-specific agility test

2) Zig-zag dribbling test

As shown in Figure 4, the dribble technique was measured by the dribbling test method used by Vanttinen et al. (2010). This test includes four dribbling procedures.

1. Straight running with the ball - Touch the ball at least three times before turning on the last flag.
2. Turn around at the last flag and dribble to the starting line.
3. Dribble again to move to the last flag - Touch at least 3 balls until the last flag.
4. Take turns dribbling the flags and reach the arrival line. The performance of the dribbling test is evaluated through the elapsed time during the entire dribble.

3) Pass accuracy test

Pass accuracy was measured using the Loughborough Soccer Passing Test (LSPT) method (Figure 5). LPT is a test that can measure various aspects of soccer skills such as pass, dribble, control, and decisive power (Ali A. et al. 2007). This test was conducted using a method measured by BenOunis et al. (2013). Subjects were practiced four times to familiarize themselves with the LSPT test for one week. The subjects started with a soccer ball in the center, and the first tester uses a stopwatch to start measuring the time as soon as the ball comes out of the inner square box. The second tester orders the sequence of passes and shouts "special color" before the current pass is over. The result of the pass is determined by one of eight attempts. Each attempt consists of eight long (4m; green and blue) passes and eight short (3.5m; white and red) passes. The subject may only pass within the passing area between marked lines. The subject may only pass within the passing area between marked lines.

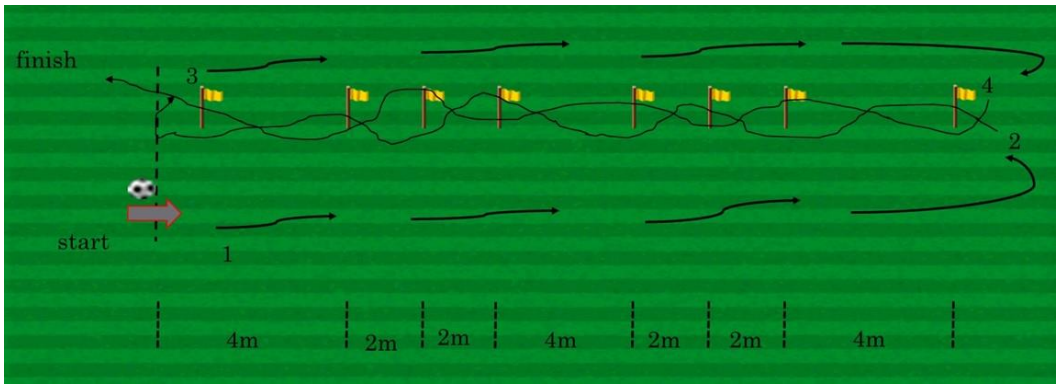


Figure 4. A diagram of soccer-specific zig-zag dribbling test

The subject may only pass within the passing area between marked lines. Upon receiving the ball from the previous pass, the subject must cross a line marked inside the two balls before attempting the next pass. Subjects should pass as quickly as possible with the least number of errors to achieve the best LSPT performance. The second tester should stop the stopwatch at the end of the last pass. The second tester records penalty time points that occur during the trial. The penalty time is obtained by:
5 seconds: When a bench is completely missed or passed (a pass is made) to the wrong target,
3 seconds: when the target area (0.6×0.3 m) is missed,
3 seconds: when the ball is handled,
2 seconds: when passing the ball outside the specified area,
2 seconds: When touching the ball in any cone,
1 second: every time the test is over one second from the allotted time of 43 seconds,
1 second (Bonus): When the 10cm line in the center of the target is hit with a ball, the entire time is reduced by 1 second.

The performance of the LSPT is calculated using 3 indices.
① Time required to complete 16 passes (LSPT time: LPT T)
② Penalties calculated by participants as mistakes during the trial (LSPT penalty: LPT P)
③ LSPT total performance (LSPT TP)

The participant makes two attempts and obtains the average and records it as a performance score.

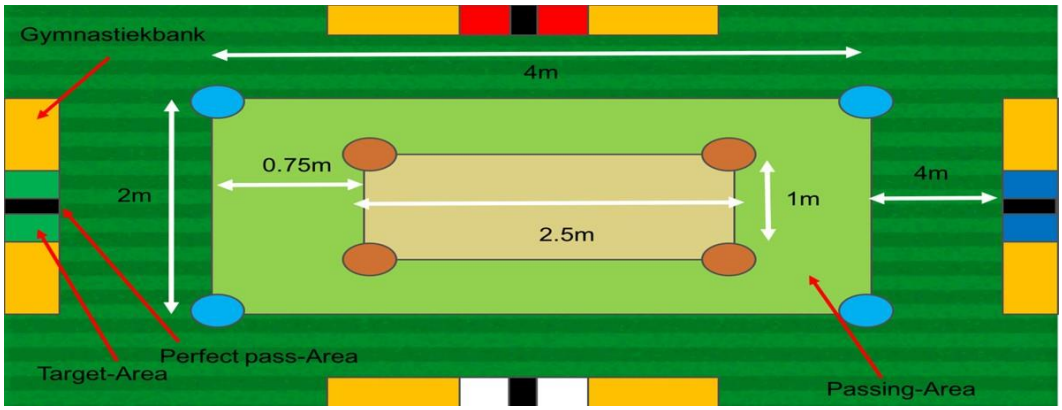


Figure 5. A diagram of Loughborough soccer passing test (LSPT)

4) Shooting test

The soccer shooting test consists of shooting accuracy (SA), ball velocity (BV), and shooting quality (SQ) tests. To test these three performance tests, we used the method of measurement of soccer kick performance developed recently by Radman et al. (2016). As shown in Figure 6, the subjects shoot in the box 16.6 m away from the goal line. The right footers shoot to the left goal area and left footers shoot to the right side of the goal. A grid-shaped net is installed at the front of the goal post, and the score of the goal-in point is described in Figure 6. This score is calculated by a score that is high for points that are difficult to defend by the goalkeeper in the center and low for those that are easy to defend. This score is recorded in meters. Each box is 48.8cm × 48.8cm in size and consists of 30 boxes in total. With 10 attempts, the average of the 7 best shooting scores is calculated. A speed gun is placed behind the goalpost and the ball speed (m/s) of each shot is recorded. The SQ test is calculated from the score of SA and the score of BV. SQ = SA / t, where t is the trajectory distance at which the ball is flying and is the time at which the ball flies. Theoretically, the trajectory distance the ball travels is obtained by the following equation (Radman et al., 2016).

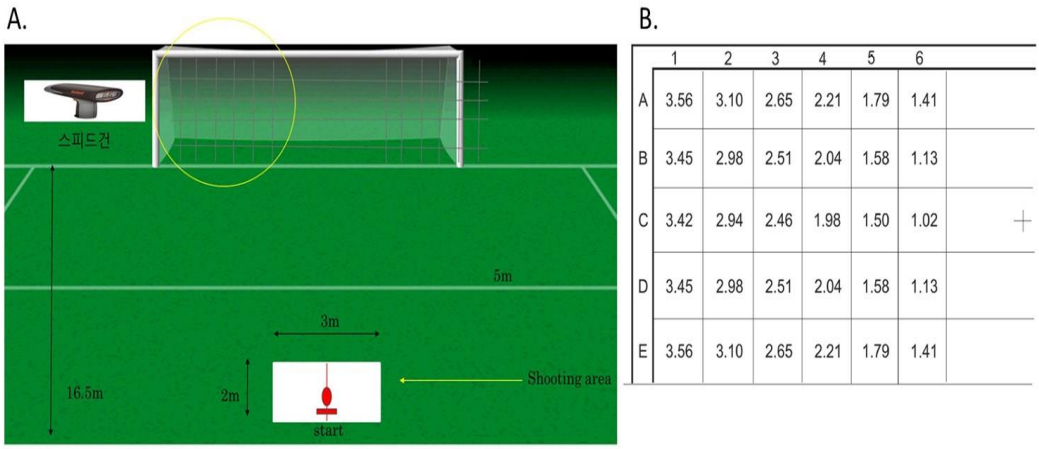
$$D = \sqrt{(SA + 0.75)^2 + 273.74}$$

$$t\ (s) = D\ (m) / \text{ball velocity}\ (m/s)$$

The obtained t is inserted into the SQ = SA / t formula and the SQ value is calculated. The SQ is equivalent to the value given by the SA divided by the time it takes for the ball to reach the goal. The velocity of the ball was measured during shooting using the speed gun on the back of the goalpost. The accuracy of the shot is determined by the point at which the ball passes through the grid of the goalpost, and the average score of seven times is the value.

6. Data analysis

All data measured in this study were calculated using the IBM SPSS win 22.0 statistical program to calculate the mean and standard deviation, and the dependent variables of the experimental group and comparison group were analyzed through the independent samples t-test.



	1	2	3	4	5	6
A	3.56	3.10	2.65	2.21	1.79	1.41
B	3.45	2.98	2.51	2.04	1.58	1.13
C	3.42	2.94	2.46	1.98	1.50	1.02
D	3.45	2.98	2.51	2.04	1.58	1.13
E	3.56	3.10	2.65	2.21	1.79	1.41

Figure 5. A diagram of shooting tests (A)
Shooting scores from the center of the goal poster (B)

III. RESULTS

Physical Characteristics of the Subjects

The physical characteristics of female middle school soccer players (n=12) who participated in the study are as shown in Table 1. The physical characteristics between the comparison group and the experimental group did not show statistically significant difference in all variables. The mean values of the variables of the two groups were 163cm in height, 55.6kg in body weight, 20.6% in percent body fat, and 24.4kg in skeletal muscle mass.

Table 1. Physical characteristics of the subjects

Group	Age (yr)	Height (cm)	Weight (kg)	% body fat (%)	Skeletal muscle weight (kg)
Control	15.4±2.1	162.8±4.8	54.3±3.7	19.4±2.5	24.4±1.7
Plyometrics	15.5±4.3	163.2±5.9	56.9±2.5	21.8±4.5	24.4±2.0

Muscular Fitness

1) Muscular Strength, Endurance, and Speed

The results of comparing the muscular strength, endurance, and speed of female middle school soccer players are shown in Table 2. The back muscular strength of the comparison group was 93.9 kg and the experimental group was 89.6 kg. There was no statistically significant difference in muscle strength between the two groups for the 8-week plyometrics training (P>0.05). The muscle endurance of the comparison group was 74.3 times and the experimental group was 72.8 times. There was no statistically significant difference in muscle endurance between the two groups for the 8-week plyometrics training (P>0.05). The muscle endurance of the comparison group was 5.7 seconds and the experimental group was 5.6 seconds. There was no statistically significant difference in speed between the two groups for the 8-week plyometrics training (P>0.05).

Table 2. Effects of 8-week plyometrics training on muscle strength, muscle endurance, and speed

Group	Strength	Endurance	Speed
	Back strength (kg)	Box jumps (reps/min)	37m dash (sec)
Control	93.9±14.3	74.3±5.5	5.7±0.17
Plyometrics	89.6±9.4	72.8±2.3	5.6±0.25

2) Anaerobic power

The maximum anaerobic power was 747.2W in the experimental group and 647.6W in the comparative group, showing a statistically significant difference ($p < 0.05$), and the experimental group showed an increase of 15% over that of the comparative group. On the other hand, mean power, fatigue index and total workload did not show statistically significant differences between the two groups ($p > 0.05$).

Table 3. Effects of 8-week plyometrics training on Wingate anaerobic power

Group	Peak power (W)	Average power (W)	Fatigue index (%)	Total work (J)
Control	647.6±41.5	398.1±20.3	65.2±9.6	11849±599
Plyometrics	747.2±49.3*	420.9±30.2	73.7±8.9	12251±678

Soccer Performance Tests

The results of comparing the agility, the dribbling, and the passing accuracy of female middle school soccer players are shown in Table 4. The agility of the comparison group was 7.94 seconds and the experimental group was 7.64 seconds. There was

no statistically significant difference in agility between the two groups for the 8-week plyometrics training (P>0.05). The dribbling of the comparison group was 29.2 seconds and the experimental group was 28.1 seconds. There was no statistically significant difference in dribbling between the two groups for the 8-week plyometrics training (P>0.05). The passing accuracy of the comparison group was 50.7 seconds and the experimental group was 47 seconds. There was no statistically significant difference in passing accuracy between the two groups for the 8-week plyometrics training (P>0.05).

Table 4. Effects of 8-week plyometrics training on soccer-specific performance tests

Group	Agility	Dribbling	Pass accuracy
	Agility run (sec)	Dribble test (sec)	LSPT (sec)
Control	7.94±0.3	29.2±2.9	50.7±12
Plyometrics	7.63±0.2	28.1±1.9	47.0±5

The results of comparing the shooting performance of female middle school soccer players are as shown in Table 5. The shooting ball speed was 20.6 m/s in the experimental group and 21.4 m/s in the comparative group, showing a statistically significant difference (p <0.05), and the experimental group showed an increase of 4% over that of the comparative group. On the other hand, shooting accuracy and shooting quality did not show a statistically significant difference between the two groups (p> 0.05).

Table 5. Effects of 8-week plyometrics training on shooting performance tests

Group	Shooting accuracy (m)	Ball speed (m/s)	Shooting quality (m/s)
Control	2.8±0.7	21.4±1.6	3.5±0.8
Plyometrics	2.7±0.7	20.6±1.5*	3.9±0.9

IV. DISCUSSION

In the present study, we investigated the effect of plyometrics training on physical fitness and performance of female middle school soccer players. Twelve middle school female soccer players were trained 5 times a week for 8 weeks to determine muscular fitness, which is muscle strength, muscle endurance, speed, muscle power and specific soccer performance abilities. Soccer performance ability, consisting of agility, dribbling, passing accuracy, and shooting abilities,

were measured by dividing players into two groups: experimental group (plyometrics training) and comparison group (interval training). The 8-week plyometrics training did not show any significant difference in muscle strength (back muscle strength), muscle endurance (box jump, Wingate fatigue index), and speed (37 m running), which are indicators of muscular fitness of middle school female soccer players. In contrast to the results of this study, 12-week plyometrics training in adult men in their late 20s led to a significant increase in muscle strength by about 20% as measured by back muscle strength measurement (Park, 2003). The reason for these conflicting results may be attributed to differences in gender (male and female) and age. In addition, in the study of Park (2003), 12-week plyometrics training showed no significant difference in a pre- and post-training 30-second sit-up (muscle endurance) test. These results are consistent with the results of the box jump test conducted in this study. In this study, the number of 1-minute box jumps and the fatigue index (power endurance) of the Wingate test did not show any significant change when compared to the experimental group and the comparison group. Park (2003) evaluated the muscle endurance by measuring sit-ups. However, in this study, the plyometrics was a repetition of jumping-based lower body movements, measured by a box jump measuring lower extremity endurance rather than a sit-up measurement measuring upper extremity endurance. However, it may be more desirable for plyometrics to measure the endurance of the lower body rather than a sit-up measure, which measures the endurance of the upper lower body since plyometrics is a training that repeats jump-based lower body motion. This test is a reasonable method of measuring the effect of plyometrics training on muscle endurance by measuring the number of repetitions of the lower body.

In this study, there was no significant difference in the 37-meter speed running record of 8-week plyometrics training. A study on elementary school students reported by Jeong (2005), which reveal similar findings as our study, showed that the 8-week box jump training twice a week did not change the 50-meter running record. In this study, the only significant change in the 8-week plyometrics training was the peak power of the Wingate anaerobic power test variables, as shown in Table 3. Park (2003) showed that the 12-week plyometrics training of 20-year-old adult males increased muscle power by 13% (7.1 cm) (Sargent jumps) and significantly increased the Sargent jump record of the elementary school volleyball players of 10 weeks by 18% (Lee, 2003), and the results of these studies are consistent with ours. Therefore, it is believed that the plyometrics training is an important method of training to improve muscle power. And speed is also expected to increase when players' muscle power improves. This is because increasing power and power endurance based on improvement of muscle strength will improve speed. In this study, however, the plyometrics training increased muscle power but did not improve speed. The exact reason is unclear, but it may be due to the lack of muscle maturity or development of female middle school soccer players or short duration of the study.

In this study, 8-week plyometrics training did not show a significant difference between pre- and post-training and the comparison group in the soccer sport-

specific agility run test. According to Park (2003), the 12-week plyometrics training of 20-year-old adult male was increased by 4.4 repetitions for 20 seconds compared to the pre- and post-training session during a side step measurement for 20 seconds. In addition, in a study by Kwon (2001), 8-week plyometrics training on basketball players increased the whole-body reaction time by 86m/sec/ml, and this increase was caused by shortening of the muscle nerve reflex time. The shortening of muscle nerve reflex time seems to be a very effective way to improve agility. However, this study did not measure the response time of plyometrics training, so the change of reaction time did not show the relationship with agility and the 8-week plyometrics training did not seem to improve the agility of female middle school soccer players.

As a result of examining the effect of the 8-week plyometrics training on the soccer performance of female middle school soccer players, the dribbling test developed by Vanttinen et al. (2010) reported that there was no difference in dribbling time between the comparison group and the experimental group. Using the Loughborough Soccer Passing Test (LSPT) method developed by BenOunis et al. (2013), the results of measuring the accuracy of passes including soccer skills such as dribbling, control, and decision power also showed no significant difference between the two groups. Among the soccer sport-specific competence tests, the shooting test measures the shooting accuracy and the shooting ball speed, and through these two variables, the qualitative value of the shooting can be determined. The 8-week plyometrics training did not affect the shooting accuracy of female middle school soccer players but showed a significant difference in shooting ball speed (m/s). If both the accuracy of shooting and the speed of shooting balls increases, the chances of the goalie stopping the ball are reduced, which increases the quality of shooting. However, in this study, the shooting accuracy was not different between the two groups and only the shooting ball speed was improved. This may also increase the quality of the shooting sufficiently, but the improvement in shooting ball speed by the 8-week plyometrics training did not result in improvement in shooting quality. This showed that the change in specific football abilities in relation to the plyometrics training conducted in this study increased the speed of the ball when it was kicked and flown into the air. The ability to increase the kick speed of the ball is likely to occur because of the increased power (force/speed) of the kicked leg muscles. Yoon (1984) said, "kicking is a ball-impacting motion using the foot, and generally, the more experienced the player, the more the ankle is stretched by the forward movement of the waist, the greater the impact on the ball by the kicker. It is important to speed up the foot and fix the kicking foot without moving it at the moment of kicking. It is most effective when the energy consumption is low, the ball speed is high, and the kick accuracy is high.

V. CONCLUSION

In this study, the plyometrics training significantly increased the Wingate maximum anaerobic power. The increased muscle power is thought to have significantly improved the shooting ball speed of female middle school soccer players. These results suggest that continuous training of plyometrics will be a good training method to improve ball kick speed and shooting quality. In addition, if the coach's teaching and the players' efforts to improve the ball's accurate passing or accurate kicking ability are combined, the plyometrics training can be a very useful way to improve the shooting quality of a young female soccer player.

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