The Effect of Six-Week Plyometric Training on Enhancing Sports Performance of Adolescent Students

by Shidqi Hamdi Pratama

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THE EFFECT OF SIX-WEEK PLYOMETRIC TRAINING ON ENHANCING SPORTS PERFORMANCE OF ADOLESCENT STUDENTS

Shidqi Hamdi Pratama Putera[1ABCD], Hari Setijono[1ABCD], Oce Wiriawan[1ABCD], Heryanto Nur Muhammad[1ABCD] and Agus Hariyanto[1ABCD]

[1]Universitas Negeri Surabaya

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Shidqi Hamdi Pratama Putera, E-mail: shidqi.20002@mhs.unesa.ac.id
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Abstract

Numerous studies have documented that plyometric training is an effective method to improve sports performance. **The purpose of this study** was to compare the effects of six weeks of plyomeytric training on strength, speed, and power.

Materials and methods. An experimental study using a pretest-posttest control group design was conducted on 30 Perisai Diri athletes. They were randomly divided into three groups: the plyometric jumping jack (JJ) group, the countermovement jump (CMJ) group, and the tuck jump (TJ) group. The respondents in the TJ and CMJ groups were then assigned to six weeks of exercise consisting of three sets each session (18 sessions in total), with intensities ranging from 60% to 80%. Pretest and posttest were conducted to obtain data on strength and explosive power. Data were analyzed using SPSS 21 and presented in mean and standard deviation. Paired sample t-test was performed to compare the differences between the groups before and after the training they were given. One-way ANOVA was used to examine multiple comparison in the gains of strength and power between the groups.

Results. The results showed that the students' strength and power in all groups increased significantly ($p<0.05$) after six weeks. Differences between the groups were found in strength ($p = 0.000$), which was the case between TJ-CMJ pair ($p = 0.001$) and TJ-C pair ($p = 0.000$). Between-group differences were also found in power ($p = 0.017$), which was the case between TJ-CMJ and TJ-C pairs ($p<0.05$).

Conclusions. Based on these findings, it was concluded that plyometric training was able to improve strength and leg muscle power of non-trained individuals.

Keywords: countermovement jump (CMJ), plyometric training, power, tuck jump (TJ), strength, stretch-shortening cycle (SSC), student.

Introduction

Plyometric training (PT) is one of the most frequently used method in all sport activities (Benzidane et al., 2015) especially among people playing dynamic sports (Váczi et al., 2013). There are many factors contributed to the rising popularity of PT in the last decades, one of them due to its flexibility that can be done by individuals at any intensity levels, ranging from low-intensity exercise to high intensity unilateral drills (de Villareal et al., 2010). Plyometric training has been extensively used to improve explosive sport performance and considered as one of the effective training methods for its comprehensive motor and neuromuscular control benefits (Buckthorpe & Della Villa, 2021). Furthermore, besides PT can produce fast and explosive movements (Anwer & Nuhmani, 2015), several studies have confirmed that PT is considered an essential part of a health-promoting lifestyle in young individuals (Peitz et al., 2018) making PT becomes one of the most effective training methods that is not only used by athletes and professionals, but also people of all ages to improve both physical (Sole et al., 2021) and muscular fitness (Peitz et al., 2018).

Plyometric training consists of wide range of movements such as jumping, running, kicking, hopping, bounding, (Davies et al., 2015), tackling (Slimani et al., 2016) and throwing (de Villareal et al., 2010). These explosive movements are produced by a sequence of rapid eccentric muscle contraction (lengthening movement or deceleration) followed immediately by a quick concentric contraction (shortening movement or acceleration) in the shortest possible time (Bedoya et al., 2015; Makaruk et al., 2014). This process is referred as stretch–shortening cycle (SSC) and is one of the underlying mechanisms of plyometric training (Aloui et al., 2021; Vetrovsky et al., 2019; Wang & Zhang, 2016). SSC works by utilizing the elastic properties of connective tissue and muscle fibres, facilitating them to gather elastic energy through the deceleration phase and launch it immediately during acceleration phase to produce greater muscle's mechanical works (Radnor et al., 2018; Sole et al., 2021) and maximal force (Idrizovic et al., 2018).

For the last decades, studies about the benefits of plyometric training have been observed so often, with most studies agreed that PT is a great type of exercise to improve balance (Ramachandran et al., 2021), agility (Asadi, 2012), and speed (Michailidis et al., 2013). Recent studies have found that plyometric training when combined with a periodized strength training program, is able to improve vertical jump performance, muscular power, acceleration, and proprioception in general (Mazurek et al., 2018; Slimani et al., 2016). Aloui et al. (2021) in their experiment on soccer player reported that eight-weeks of plyometric training improved jump performance, balance, sprinting, and change-of-direction (CoD). Another study employing eight weeks of PT in athletes found that PT when combined with balance training program gave better effect on shuttle run and sprint performance (Chaouachi et al., 2014). In addition to that, a systematic plyometric training for lower limb has been found to be an effective method to improve strength and power of muscle legs (Shafeeq et al., 2013). Strength and power are one of the most important skills in sports, where individuals qualified of these factors would highly contributes to their performance in the field (Váczi et al., 2013). Thus, plyometric training is often used by athletes playing in sports that required explosive movements such as volleyball (Ben Ayed et al., 2020), soccer (Sedano et al., 2011), and basketball (Ivanović et al., 2022).

Despite many benefits of plyometric training on increasing performance in athletes, little is known whether this training can give similar results on non-athlete or non-trained individuals. Moreover, little information is available to determine whether short term PT can actually enhance physical performances. Previous studies related to plyometric training were mostly done in long-term duration (8 weeks) (Hariyanto et al., 2022). Therefore, this study was conducted to analyse the effects of six-weeks plyometric trainings on sport-spesific performance of high school students, especially strength and power of muscle legs.

Materials and methods

Study participants

It was a quasi-experimental study with pretest-posttest control group design. A total of 30 non-trained high school students were randomly selected using simple random sampling. The inclusion criteria of this study were: (1) male students; (2) age 16-19 years old; (3) had no chronic conditions that would affect their ability to perform the exercise; and (4) had no injuries of the lower limbs. All participants were informed the details of experimental procedure and instructed to avoid consuming alcohol and heavy activity at least 24 hours prior to testing. Afterward, each participant was assigned to one of three groups: tuck jump (TJ), countermovement jump (CMJ), and control group (C), with each group consisted of 11 subjects. An individual written informed consent was acquired before the experimental began.

Study organization

All participants were assigned to respective plyometric training (TJ and CMJ) and standard training program (C) according to the group they belonged. Participants in TJ completed a repetitive tuck jump, started in standing position with both feet hip-width apart. Then they jumped with knees raised toward the chest, then landed on both legs. After landing, they needed to complete the next tuck jump as quick as possible. Participants in CMJ were instructed to stand in upright position with hands rest on the hips. They were then instructed to perform downward movement followed by a maximal effort of vertical jump as high as possible. After that, they should land in an upright position and to bend the knees following landing. While participants in C were assigned to regular training program.

The training was individualized for each subject or participant based on the results of maximal strength and power test. The training programs were conducted three times a week over six weeks on non-consecutive days as recommended by previous studies to provide time for regeneration, made it a total of 18 sessions. Each training session was preceded with 10 minutes of standardized warm up, then followed by the actual training performed in three sets. All trainings were performed in the same order with two minutes of resting period between each set. The intensity of each training was gradually increased every two weeks, starting from 60% to 80%. All sessions were thoroughly monitored and exercise logbook was recorded for each subject. The detail of training program was illustrated in Table 1.

Performance measurements were obtained before the first week (pretest) and after training period (posttest). Each participant was required to wear the same shirt and shoes during each performance measurement. Prior 24 hours before the training was performed, all participants did not engage in any heavy activity with respect to jumping. A baseline anthropometric measurement was taken following their arrival at the training site during the week 0 before first session. Standing height was measured at the nearest 0.1 cm using portable stadiometer (Seca 213, Seca Ltd.), and bodyweight were measured using digital bathroom scale at the nearest 0.1 kg.

Strength was assessed using Back Leg Dynamometer that has been calibrated. Participants were asked to lift the handle vertically by providing continuous isometric contraction of the lower back, hips, and knee extensors while holding the handle. They were asked to rise the pull gradually and reach maximum strength in three seconds, while maintaining this pull for two seconds. Each participant was given three attempts, with a 30 seconds rest period between attempts. The highest value (in kg) between three measurements was used for further analysis.

Table 1. The Details of Training Program for TJ, CMJ, and C Group

Week	Session	Day	Intensity	Repetition	Rest
	1	Sunday	60%	3	2 min
1st	2	Wednesday	60%	3	2 min
	3	Friday	60%	3	2 min
	4	Sunday	60%	3	2 min
2nd	5	Wednesday	60%	3	2 min
	6	Friday	60%	3	2 min
	7	Sunday	70%	3	2 min
3rd	8	Wednesday	70%	3	2 min
	9	Friday	70%	3	2 min
	10	Sunday	70%	3	2 min
4th	11	Wednesday	70%	3	2 min
	12	Friday	70%	3	2 min
	13	Sunday	80%	3	2 min
5th	14	Wednesday	80%	3	2 min
	15	Friday	80%	3	2 min
	16	Sunday	80%	3	2 min
6th	17	Wednesday	80%	3	2 min
	18	Friday	80%	3	2 min

Vertical jump test was done using Jump Mat MD with belt to measure power of muscle leg. Participants were asked to stand in upright position on jump mat with feet shoulder width apart and hand placed on the hips to minimize the contribution of the arms during the jump. Afterward, they needed to move downward followed immediately by explosive upward vertical jump, then landed with both feet completely on the jump mat for the jump to count. Each participant was also provided with three attempts with 30 seconds of break was provided between jumps. The reading of the highest value (in joule) was used for analysis.

Statistical analysis

Means and standard deviations as descriptive statistic were calculated and presented for the measured variables. All variables were tested for normality using Saphiro-Wilk test. Further analysed using paired t-test to compare the difference before and after plyometric training completed. One-way Anova was used to evaluate potential group differences between TJ, CMJ, and C. Confirmatory analysis was conducted using Least Significant Different (LSD) to find out which pairs were different. In all instance, p-value less than 0.05 was set to establish statistical significance. Data analysis and all statistical evaluations were performed using SPSS 21 for Windows.

Results

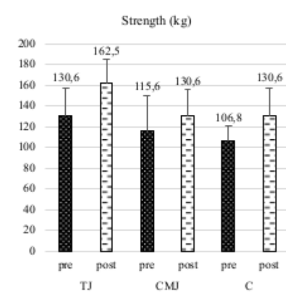
All participants have completed their respective training programs. There were no significant muscle soreness or any injury of the spine or lower limb, and no drop outs reported during the six weeks of experimental period. Participants were very enthusiastic and actively followed every instruction in the exercise program that has been scheduled.

Table 2. Baseline Characteristic of Participants (n = 30)

Characteristic	Groups			sig.
	TJ	CMJ	C	
Age (year)	14.80 ± 0.64	14.30 ± 0.88	15.30 ± 0.41	0.060
Weight (kg)	46.5 ± 2.04	45.40 ± 5.86	47.30 ± 3.36	0.053
Height (cm)	151.40 ± 3.23	154.40 ± 8.43	154.80 ± 5.45	0.218
Body mass index (kg/m²)	19.40 ± 0.85	19.10 ± 0.55	19.08 ± 0.70	0.195

TJ = tuck jump; CMJ = countermovement jump; C = Control group. Data were presented as mean ± SD

Table 2 shows the descriptive values of participants' characteristics in each group. Participants in CMJ had the lowest average of age and weight, which were 14.30 ± 0.88 years and 45.40 ± 5.86 kg, respectively. Control group had the highest average of height (154.80 ± 5.45 cm). The overall body mass index between group was ranging from 19.08 ± 0.70 to 19.40 ± 0.85 kg/m², which was categorized as normal according to cut-off of growth reference for 5-19 years (WHO, 2007). We found no statistical difference between groups with regard to baseline characteristics (p>0.05), so we learnt that the baseline data of all groups were equally homogeneous.



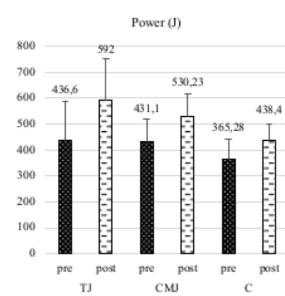


Fig. 1. The changes in strength (left) and power (right) before and after 6-weeks of plyometric training

Table 3 revealed the comparison results in strength and power before and after training programs were performed for six weeks. Significant improvement in strength were found in all groups, with p=0.000, p=0.005, and p=0.001

Table 3. Paired Sample Analysis of Change in Strength and Power of Muscle Leg over Six Weeks of Plyometric Training (Mean ± SD)

Group		Strength (kg)		sig.	Power (J)		sig.
		T score	Mean ± SD		T score	Mean ± SD	
TJ	pre	10.55	130.60 ± 26.59	0.000*	10.03	436.6 ± 152.1	0.000*
	post		162.50 ± 22.49			592.0 ± 160.0	
CMJ	pre	3.63	115.60 ± 34.25	0.005*	7.51	431.1 ± 90.32	0.000*
	post		130.60 ± 25.53			530.23 ± 87.94	
C	pre	5.22	106.80 ± 13.64	0.001*	5.18	365.28 ± 75.49	0.001*
	post		130.60 ± 26.59			438,4 ± 64,26	

TJ = tuck jump; CMJ = countermovement jump; C = Control group. *significant at α = 0.05*

Table 4. Between Group Differences in Delta Strength and Power

Group	Δ Strength (kg)	%	Sig.	Δ Power (J)	%	sig.
TJ	31.90 ± 10.55	24.4		155.37 ± 10.03	35.6	
CMJ	15.00 ± 3.63	13.0	0.000*	99.13 ± 7.51	23.0	0.017*
C	10.20 ± 5.22	22.8		73.18 ± 5.18	20.0	

TJ = tuck jump; CMJ = countermovement jump; C = Control group. Data were presented as mean ± SD. *significant at α = 0.05

Table 5. Post-hoc Analysis of Significant Different in Strength

Pairwise Group		sig.	
		Strength	Power
TJ	CMJ	0.001*	0.010*
	C	0.000*	0.000*
CMJ	C	0.293	0.210

TJ = tuck jump; CMJ = countermovement jump; C = Control
*significant at α = 0.05

respectively. Significant differences were also observed in explosive power where training programs that were performed for six weeks increase the power in both PT group or control group. The highest improvement in strength was found in TJ, which increased from 130.60 ± 26.59 to 162.50 ± 22.49 kg (Δ = 24.4%). Similar result was also showed in another variable, where TJ group exhibited the greatest increase in power from 436.6 ± 152.1 to 592.0 ± 160.0 joule (Δ = 35.6%). Meanwhile, CMJ had the lowest increase of strength among all groups, which was 13.0%, and control group had the lowest increase of power, which was 20.0%. Overall, one-way Anova revealed that the significant differences were found in Δ strength and Δ power, with p = 0.000 and p = 0.0017, respectively (Table 4).

Post-hoc test using LSD was performed for further analysis to examine pairwise differences. The results of the test disclosed that strength was found to be significantly different between TJ and CMJ (p=0.001), as well as between TJ and C group (p=0.000). Regarding power, it was revealed that TJ and CMJ group were significantly different (p=0.010), as well as between TJ and C group (p=0.000). Meanwhile, the significant differents were not found in strength and power between CMJ and C pairwise (Table 5).

Discussion

Present study demonstrated that plyometric training was effective to increase the measured variables, particularly strength and power of muscle legs. We also hypothesized that higher gains would occur in PT group compared to C group was clearly supported, as the given plyometric trainings (TJ) resulted in a significantly larger improvement in strength by the sixth week. The greatest increase was found in TJ group, where a change of 24.4% indicated that significant adaptation in strength was occurred.

Plyometric training relies on SSC mechanism, which consists of a quick eccentric and concentric phase of the muscle (Davies et al., 2015). Because of this continuous mechanism, it has been clarified that PT is able to induce greater performance improvement in fatigue-free state (Kobal et al., 2017). Hirayama et al. (2012) in their research showed that one session of plyometric exercise was able to change muscle-tendon characteristics by modulating neuromuscular activity with the lengthening and shortening of tendon occurred more frequently than fascicles. Unlike the acute effects of other exercises, plyometric training will enhance the performance of SSC exercises differently, with muscle tendon unit (MTU) behavior changes in a favorable way, adjusting to the altered muscle strength and tendon stiffness (Fouré et al., 2010; Hirayama et al., 2017; Wu et al., 2010). Tuck jump and countermovement jump that were assigned to experimental groups were able to shorten the change of eccentric phase to concentric phase, where this condition will also improves the ability to jump, supported by muscle ability to perform explosive moves which lead to the gain of strength and power in leg muscle (Louder et al., 2015).

In the context of physical fitness, countermovement jump (CMJ), squat jump (SJ), tuck jump (TJ), and depth jump (DJ) are one of vertical jump (VJ) tests widely used to measure strength and power of lower muscle limb (Hirayama et al., 2017; Mirzaei et al., 2014; Petrigna et al., 2019; Ruffieux et al., 2020). However, the present study found that countermovement jump appeared to be less effective in improving strength and power compared to tuck jump. It was contradictory with other finding which revealed that countermovement jumps was found to be more effective than other vertical jump test used, ie. drop jump (Ruffieux et al., 2020). But, the findings of present study confirm previous randomized control trial study conducted by Muthukumar and Sokkanathan (2014) where significant difference in muscle strength was found between control group and plyometric training group. Elnaggar et. al. (2019) also observed similar results where subjects in plyometric training group had significant improvement in quadriceps and hamstring muscle strength compared to their peers in non-plyometric group. Some possible explanations beside SSC that can elucidate how PT can produce strength is that PT requires an adequate level of joint coordination as well as muscle strength, which later it augments the contraction of inter- and intra-muscle capacity, which finally produces force (de Villareal et al., 2010). However, higher increase in strength performance may be gained when plyometric is combined by various exercise to maximize the utilization of SSC. This may be explained by the fact that the combination of exercise will facilitate mechanical and neural mechanisms that increase performance in activity of maximal force (de Villareal et al., 2010).

Significant improvement in power was also found in all groups. In this study, high school students were trained at 60% to 80% 1 RM throughout six weeks, which is considered as high intensity training. Previous study reported that muscle power capacity could be transiently improved after high intensity training regimes (Kobal et al., 2017). For example, Smilios et al. (2005) reported an acute increase in CMJ height following 1 and 2 sets of half-squat exercise with intensity set at 60% 1 RM. Several studies have mentioned the effectiveness of PT in increasing strength and vertical jump performance, with one study suggested that the increase muscular power of lower limb, was again, might be due to the force variable in CMJ (SSC mechanism), coupled with the production of high velocity during vertical jump take off (Ben Ayed et al., 2020). In addition to that, plyometric training is able to enhance coordination (de Villarreal et al., 2009), therefore it induces a neuromuscular adaptation that improve power production (Chelly et al., 2010).

Some studies have demonstrated that the improvement in maximum strength would be accompanied by the improvement in power and vertical jump ability (Loturco et al., 2013, 2015). The finding of present study revealed that explosive power increased after six weeks of plyometric training. Three times a week over six weeks of exercise that were used in this study appeared to have good impact on increasing power in high school students. This finding supported previous study that used PT with similar duration where small but significant improvement (5.8%) was observed in vertical jump among collegiate female athletes (Chimera et al., 2004). Another study revealed the significant increase in vertical jump (Rubley et al., 2011), supported the notion that plyometric training increase vertical jump ability, thus increasing the power of lower limb.

Conclusion

Plyometric training has been becoming a popular training method that is extensively used by sport professionals and strength-conditioning specialists in improving sport-specific performance. Based on this research, it can be concluded that six-week plyometrics significantly increases the strength and power of muscle leg in high school students. A limitation of this study is the specific sample in which students may limit the applicability of these findings to a more diverse population. Longer training duration (>6 weeks) might show different results. Additionally, further studies must also consider the intensity, form or type of plyometrics exercise that is carried out, and whether PT will be combined with other training, as a combination of various exercises leads to greater improvement in physical performance.

Conflict of interest

The authors declare no conflict of interest.

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ВПЛИВ ШЕСТИТИЖНЕВИХ ПЛІОМЕТРИЧНИХ ТРЕНУВАНЬ НА ПОКРАЩЕННЯ СПОРТИВНИХ ПОКАЗНИКІВ УЧНІВ ПІДЛІТКОВОГО ТА ЮНАЦЬКОГО ВІКУ

Шідкі Хамді Пратама Путера[1ABCD], Харі Сетіхоно[1ABCD], Оце Віріаван[1ABCD], Геріанто Нур Мухаммад[1ABCD], Агус Харіянто[1ABCD]

[1]Сурабайський державний університет

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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Численними дослідженнями документально зафіксовано, що пліометричні тренування є ефективним методом покращення спортивних показників.

Метою цього дослідження було порівняння впливів шеститижневих пліометричних тренувань на показники міцності, швидкості та сили.

Матеріали та методи. Було проведено експериментальне дослідження за планом попереднього та підсумкового тестування з використанням контрольної групи на 30 спортсменах школи бойових мистецтв «Перісай Дірі» (Індонезія). Методом випадкового відбору учасників розподілили на три групи: група, яка виконувала пліометричні вертикальні стрибки «ноги разом – ноги нарізно» з положення стоячи (JJ), група, яка виконувала вертикальні стрибки з початковим присіданням (CMJ), і група, яка виконувала вертикальні стрибки з групуванням у повітрі (TJ). Потім учасникам груп TJ та CMJ був призначений шеститижневий курс вправ, які складалися з трьох комплексів вправ на кожне тренувальне заняття (загалом 18 тренувальних занять), під час виконання яких рівень інтенсивності коливався в межах від 60% до 80%. Для одержання даних про показники міцності та вибухової сили були проведені попереднє та підсумкове тестування. Дані були проаналізовані з використанням ПЗ SPSS версії 21 та представлені у формі середнього та стандартного відхилення. Для порівняння відмінностей між групами до та після пройдених тренувань використовували t-критерій Стьюдента для парних вибірок. Для аналізу множинних порівнянь збільшення показників міцності та вибухової сили між групами використовували однофакторний дисперсійний аналіз.

Результати. Результати показали, що за шість тижнів показники міцності та вибухової сили учнів в усіх групах статистично значуще ($p<0,05$) зросли. Відмінності між групами були виявлені в показниках міцності ($p = 0,000$), що було встановлено між парою TJ-CMJ ($p = 0,001$) та парою TJ-C (контрольна) ($p = 0,000$). Міжгрупові відмінності також були виявлені в показниках сили ($p = 0,017$), що було встановлено між парами TJ-CMJ та TJ-C (контрольна) ($p<0,05$).

Висновки. На підставі одержаних результатів було зроблено висновок, що пліометричні тренування змогли покращити показники міцності та сили м’язів ніг нетренованих осіб.

Ключові слова: вертикальний стрибок із початковим присіданням (CMJ), пліометричні тренування, сила, вертикальний стрибок із групуванням у повітрі (TJ), міцність, цикл розтягання-скорочення (SSC) м’язів, учень.

Information about the authors:

Putera, Shidqi Hamdi Pratama: shidqi.20002@mhs.unesa.ac.id; https://orcid.org/0000-0001-6811-3130; Doctoral Program of Sport Science, Postgraduate Program, Universitas Negeri Surabaya, Jalan Unesa Kampus Lidah Wetan, Surabaya 60213, Indonesia.

Setijono, Hari: harisetijono@unesa.ac.id; https://orcid.org/0000-0001-8305-4933; Department of Sport Coaching Education, Universitas Negeri Surabaya, Jalan Unesa Kampus Lidah Wetan, Surabaya 60213, Indonesia.

Wiriawan, Oce: ocewiriawan@unesa.ac.id; https://orcid.org/0000-0003-1830-9519; Department of Sport Coaching Education, Universitas Negeri Surabaya, Jalan Unesa Kampus Lidah Wetan, Surabaya 60213, Indonesia.

Muhammad, Heryanto Nur: heryantomuhammad@unesa.ac.id; https://orcid.org/0000-0001-8878-3991; Department of Sport Education, Universitas Negeri Surabaya, Jalan Unesa Kampus Lidah Wetan, Surabaya 60213, Indonesia.

Hariyanto, Agus: agushariyanto@unesa.ac.id; https://orcid.org/0000-0002-7927-8827; Department of Sport Coaching Education, Universitas Negeri Surabaya, Jalan Unesa Kampus Lidah Wetan, Surabaya 60213, Indonesia.

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