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*Research article*

# The Effect of Maxex Training on Leg Power Moderated by Vertical Jump Time : An Experimental Study on Adolescent Volleyball Players

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**Abstract:** This study aimed to test the maxex (maximal exercise) training method: (1) the difference in the effect of maxex and control on leg muscle power, (2) the difference between vertical jump times (quick and slow) on leg muscle power, (3) the interaction between the method and quick and slow vertical jump times on leg muscle power. The research method used was a 2x2 factorial experiment. The sample consisted of 40 volleyball players aged 17 years and divided into 20 control groups and 20 experimental groups, with heights ranging from 169 to 179 cm and weights ranging from 60 to 70 kg. The research instrument was a vertical jump with the Harman formula to calculate power, and a Canon 1200D camera was entered into the Kinovea 0.8.1.5 application to determine vertical jump time. The data analysis technique was Two-Way Anova assisted by SPSS version 23. (1) There is a significant difference in the effect of maxex training and the control group on leg muscular power (F 51.495, sig 0.000 <0.05) (hypothesis accepted). (2) There is a significant difference between quick and slow vertical jump times on leg muscle power (F 40.480, sig 0.000 < 0.05) (hypothesis accepted). (3) There is no interaction between the two groups and vertical jump times (quick and slow) on leg muscle power (F 3.662, sig 0.064 > 0.05) (hypothesis rejected). Maxex training improves leg muscle power in adolescent volleyball players. The absence of this significant interaction shows that the effect of maxex does not differ between athletes with quick and slow jump times..

**Keywords:** Maxex training, vertical jump time, teenage volleyball players, leg muscle power

## 1. Introduction

Volleyball requires a high level of physical fitness [1,2]. To win a match, young volleyball players must have coherence between offense and defense, in addition to teamwork. Each attack and defense phase needs jumping motions as well as smashes and blocks; therefore, leg muscle power is essential. Previous research has demonstrated that leg muscle power is an important physical component in all volleyball matches [3,4]

Power refers to the ability to generate maximum force in a very short amount of time, explosively and constantly [5,6]. Consistent with this definition, power is a key determinant of volleyball victory [7]. Furthermore, increasing leg muscle power specifically requires mastery of fundamental techniques such as blocking, smashing, and serving.

According to studies, power and jumping ability are associated with aerobic and anaerobic performance [8]. Power requires speed and force, whereas force requires mass and acceleration [8]. Several specific training methods, which combine jumping and non-jumping approaches, are uniquely capable of boosting power and jump-

ing ability [8]. As a result, programs that include a diverse range of loading can specifically boost power [8]. In response, identifying methods of training that focus on boosting power is vital for improving competitive performance.

In this context, maximal exercise training (maxex) is a power-related training method. This method is a novel approach that produces maximum power results [9]. The study describes that this exercise is performed at 60-80% of maximal load for 6-8 repetitions, 1-3 sets, and 2-4 minutes of recovery [10]. However, this exercise must be carried out cautiously in the form of free weight training, where the eccentric contraction is done slowly, followed by a rapid concentric contraction [10]. Sometimes this exercise is also combined with plyometric movements such as drop jumps and bounding after performing free weight movements [11]. Physiologically, maxex training manipulates recruitment for high motor skills, such as stimulation with heavy loads, then converting it into maximum speed and explosive power [11].

While Maxex training does enhance power, boosting leg muscle power is more than just jumping as high as possible; it can also be influenced by jump phase timing. Countermovement, push-off, fight, and landing are all complicated movements required for an effective vertical jump. Push-off occurs when the leg pushes upward from the floor.

Biomechanically, the takeoff phase represents an athlete's ability to generate more effort in a shorter amount of time. Furthermore, in volleyball, jumps are sudden and need quick reactions, such as when blocking or spiking. As a result, lowering takeoff time is critical to reaching the same leap height with minimal effort and a quick contact time. Players with a more accurate takeoff phase are more explosive and have superior timing accuracy in fast-paced games. Furthermore, athletes with a slower takeoff time, despite having more power, are less effective in fast-paced games.

In this context, various studies have shown that maxex training increases power, including those by Syukur et al and Auditya et al [12,13]. However, these studies tend to look at the effects only partially, not taking into account the factors that influence the adaptive response to training.

Furthermore, numerous past studies stated that vertical jump height is a result of power [3,14], despite the fact that power is measured in watts, leading to a theoretical misconception [15]. More research is required to establish a correct understanding that the unit of power is watts. Furthermore, some of these have not considered jump height as a moderating variable.

This study aims to test the Maxex training method on leg muscle power, moderated by vertical jump time in adolescent volleyball players. The research questions are as follows:

1. How do the Maxex and control groups influence leg muscle power?
2. How do fast and slow jump times influence leg muscle power?
3. How does the interaction between the groups (Maxex and control) and vertical jump times (fast and slow) affect leg muscle power?

## 4. Materials and Methods

*Study participants*

The research method was an experiment with a 2x2 design. This design expressly included moderating variables that could potentially influence the independent and dependent variables [16]. The jump time phase in quick and slow seconds acted as a moderating variable, with maxex training and control as independent variables and leg muscle power as the dependent. The sampling technique used in this study was purposive because certain criteria had to be met, including: (1) volleyball players aged 17 years, (2) male gender, (3) attending the same training center, (4) having a history of strength training, and being able to lift a barbell squat weighing 1.5 times their body weight.

The research instrument was a vertical jump test with analysis using the harman formula and then the use of a Canon 1200D camera integrated with the Kinovea 0.8.1.5 application to determine the jump. The reliability of the measuring instrument and video analysis was tested through a pilot study of 10 subjects. The test-retest reliability results showed high consistency with the Interclass correlation coefficient (ICC) value being 0.92 for jump height, 0.89 for jump time.

This analysis resulted in a sample of 40 people. All of them were then tested for vertical jumps, with video recordings of the movement captured with a Canon 1200D camera and imported into the Kinovea 0.8.1.5 application to assess the vertical jump time phase. During the initial testing, the vertical jump time phase was determined and graded from quickest to slowest. Match Ordinal Pairing (MSOP) was then used with an ABBA pattern to achieve equitable group allocation [17]. Using this application, 20 groups were identified with quick jump times and 20 groups with slow jump phases. Next, each group of 20 athletes was divided into two groups, each consisting of 10 athletes with high and slow push-off phases. Justification for sample size using G*Power software, so that for Anova test with effect size (f) 0,40, alpha level 0.05 and power 0.80, at least 34 people are needed to anticipate any shrinkage, thus this study involved 40 athletes. For clarity, the 2x2 factorial design is explained in Table 1 as follows:

Table 1. 2x2 Factorial Design

| Method (A) | Maxex (A1) | Control (A2) |
|---|---|---|
| Time Jump (B) | | |
| Quick (B1) | A1B1 | A2B1 |
| Slow (B2) | A1B2 | A2B2 |

Description:
A1B1: Maxex with quick jump time moderation
A1B2: Maxex with slow jump time moderation
A2B1: Control with quick jump time moderation
A2B2: Control with slow jump time moderation

*Study organization*

Following the division of groups between Maxex and control with moderation of quick and slow jump phase times, the next step was to conduct a vertical leap test as a preliminary test. After obtaining the initial test results, the formula for jump height was subtracted from the hand reach height to obtain the jump height result in centimeters, and the overall body weight was measured to convert the jump height and body weight into Harman's formula to find leg muscle power in watts. The same procedure was used to collect data after the treatment was completed for 18 meetings to assess post-test improvement. The next stage was to apply the Maxex training program three times each week. Stretching and core exercises are always recommended before beginning the exercise program. The control group carried out technique training only with a training duration of 60 minutes focusing on game patterns. To maintain rigor, several steps are implemented, namely (1) all sessions are supervised by a trainer to ensure adherence to the exercises, (2) participants are prohibited from participating in additional training programs outside, (3) data collection during the post-test does not require information regarding group division to avoid subjective bias.Table 2 presents the Maxex training program as follows:

Table 2. Maxex Training Exercise Program

| Week | Meeting | Material |
|---|---|---|
| 1-6 | 1-18 | Material<br>a. Barbell squats<br>b. Barbell squat to jump<br>c. Drop jump with barbell squat to jump up once<br>d. The exercise dose settings are described below. |

Description: The first step is for the athlete to be guided through a warm-up and stretch that focuses on the leg muscles for approximately 5 minutes, followed by the training procedure in which the athlete performs the barbell squat movement slowly during the eccentric phase and quickly during the concentric phase. This training model is carried out for 5-6 repetitions, 3-4 sets, and the interval between sets is 1 minute, with an intensity of 60-70%. Then, a full rest is carried out after 3-4 sets, which is 3 minutes, followed by the second model. The second model involves a slow eccentric phase of barbell squats. This is followed by a concentric phase of jumping upwards as quickly as possible, which is done for 5-6 repetitions, 3-4 sets, with a 2-minute rest period in between, and at 40-50% intensity. Following 3-4 sets, there is a 3-minute rest period. This stage is followed by a third model in which drop jumps are done while carrying a barbell. In the initial step, athletes stand on the box while carrying the barbell, then drop down and jump upwards while holding the barbell on their shoulders. This model is carried out for 5-6 repetitions, 3-4 sets, with a 1-minute rest between sets and a 30% intensity. As a result, this program is implemented consecutively across 1-18 sessions, with the same intensity, sets, and recuperation in each. After finishing the exercise, athletes are instructed to cool down.

*Statistical analysis*

The data analysis technique employed was descriptive analysis, followed by preliminary tests with normality and homogeneity tests, and finally a two-way ANOVA hypothesis test with a significance level of $p<0.05$ [16,18]. SPSS version 23 was used to aid in this analysis [19]

## 2. Results

Table 3. Results of the description of the pretest-posttest data for all groups

| Group | Pretest (Mean ± SD) | Postest (Mean ± SD) | Improvement | 95% CI Lower |
|---|---|---|---|---|
| A1B1 | 3070.33 ± 53,39 | 3313.67 ± 58.90 | 243,34 | 211.23, 275.45 |
| A1B2 | 3088.40 ± 61.02 | 3238.68 ± 61.02 | 150.28 | 122.15, 178.41 |
| A2B1 | 3116.12 ± 36.10 | 3224.97 ± 49.21 | 108.85 | 85.12, 132.58 |
| A2B2 | 3024.08 ± 32.00 | 3085.47 ± 41.83 | 61.39 | 41.20, 81.58 |

For ease of understanding, the increase in power in the pretest-posttest group is depicted in diagram 1 below, as follows:

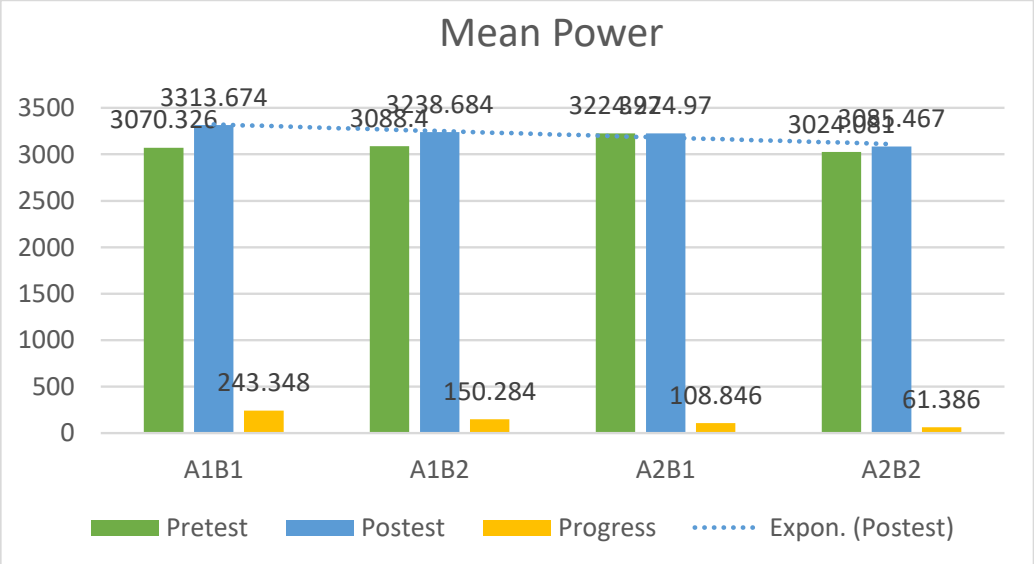


Figure 1. Pretest-posttest diagram of the entire group

According to Table 3 and Figure 1, the results of the leg muscle power pretest show that the posttest group is better than the pretest, such as group A1B1: pretest 3070.326 - posttest 3313.674 with an increase of 243.348, group A1B2: pretest 3088.4 - posttest 3238.684 with an increase of 150.284, group A2B1: pretest 3224.97 - posttest 3224.970 with an increase of 108.846, and group A2B2: pretest 3024.081 - posttest 3085.467 with an increase of 61.386. By looking at the data, the blue line above reveals that groups A1B1 and A1B2 are better than groups A2B1 and A2B2, indicating that the group receiving treatment is superior to the control group.

Table 4. Results of the Kolmogorov-Smirnov Normality Test

| Group | | Significance | Decision |
|---|---|---|---|
| **Pre-test** | A1B1 | 0.200 | Normal |
| | A1B2 | 0.200 | Normal |
| | A2B1 | 0.200 | Normal |
| | A2B2 | 0.200 | Normal |
| **Post-test** | A1B1 | 0.200 | Normal |
| | A1B2 | 0.200 | Normal |
| | A2B1 | 0.200 | Normal |
| | A2B2 | 0.200 | Normal |

Based on the Kolmogorov-Smirnov normality test, the significant value of the entire group between pretest and posttest varies from 0.052 to 0.200 >0.05, implying that the entire group is normally distributed and can proceed to the next stage of testing.

Table 5. Results of Levene's Homogeneity Test

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| **0.457** | 3 | 36 | 0.714 |

Based on the findings of Levene's homogeneity test, the significance value is 0.516>0.05, indicating that the entire group has homogeneous variance. In other words, the overall prerequisite test has been met.

Table 6. Two-way ANOVA Test of Hypothesis 1

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig | Partial Eta Squared |
|---|---|---|---|---|---|---|
| **Maxex - Kontrol** | 146314.426 | 1 | 146314.426 | 51.495 | 0.000 | 0.589 |

According to the results of Levene's homogeneity test, the significance value is 0.516>0.05, suggesting that the entire group has homogeneous variance. In other words, all of the required tests have been met.

Table 7. Two-way ANOVA Test of Hypothesis 2

| Source | Type III Sum of Squares | df | Mean Square | F | Sig | Partial Eta Squared |
|---|---|---|---|---|---|---|
| **Vertical jump time (quick and slow)** | 115018.118 | 1 | 115018.118 | 40.480 | 0.000 | 0.529 |

Table 7 shows an F value of 40.480 and a significance of 0.000<0.05, implying a significant difference. Thus, the second hypothesis, which states "there is a difference between high and slow vertical jump times in relation to leg muscle power," has been proven, namely that the group with a quick vertical jump time is better than the slow group.

Table 8. Two-way ANOVA Test for Hypothesis 3

| Source | Type III Sum of Squares | df | Mean Square | F | Sig | Partial Eta Squared |
|---|---|---|---|---|---|---|
| **Group (maxex – control)* vertical (high – low)** | 10404.818 | 1 | 10404.818 | 3.662 | 0.064 | 0.092 |

Table 8 shows a F value of 3.662 and a significance of 0.061>0.05, indicating that there is no significant difference, implying that the third hypothesis, "there is an interaction between groups (maxex and control) and jump time (quick and slow) on leg muscle power," is not supported by adequate evidence.

## 3. Discussion

This study aims to evaluate the effectiveness of maxex training on leg muscle power moderated by vertical jump time (fast and slow) in adolescent volleyball players. The findings show that Hypothesis 1 and Hypothesis 2 are accepted; namely there is a significant difference in the effect of maxex training compared to the control group on increasing power, and there is a significant difference between the group of athletes with fast vertical jump times compared to slow jumps. However, hypothesis three is rejected; no significant interaction was found between the method (maxex vs control) and jump time (fast vs slow) on leg muscle power. According to studies, 6 weeks of Maxex training treatment has a significant effect on leg muscle power in basketball players [10], while another study found that twelve weeks of Maxex training treatment resulted in a significant increase in step frequency compared to the control group in a sample of student athletes [20].

Sudirman's study supports the finding that Maxex training has a significant effect on kicking skills in the sport of pencak silat when compared to circuit training [21], but it also has a positive effect on the speed of the pencak silat sickle kick [22,23]. Interestingly, Kusuma et al. created a model for under-the-ring shooting training utilizing the Maxex training method. After testing it out, it outperformed shooting without the Maxex model in basketball players [24]. In soccer, the Maxex method assists in developing explosive powers as well as a variety of attacking skills [25]

As a result, the Maxex training group outperformed the control group in terms of both quick and slow jump times. Maxex training is defined as weight training at an intensity of 60%-80% of the maximum repetition (RM). For example, when performing a barbell squat, the eccentric phase is done slowly, followed by the concentric phase, which has the potential to create optimum strength. In line with previous studies, eccentric phase training generates significant force, estimated to be 20%-60% more than that produced by concentric motions [26]. This training is specifically capable of increasing motor unit and force output before high-speed power training such as plyometrics [11]. As a result, maxex training is one of the training methods capable of optimizing leg muscle power because of its unique characteristics, which involve using external loads and performing slow eccentric movements followed by quick concentric movements to produce a more optimal jump during the vertical test.

A quick jump phase allows for greater power gains. Other studies indicate a correlation between jump height and speed [27]. Another study found that peak power is unrelated to ground reaction forces, but is related to jump height and speed at peak power [9]. According to relevant studies, jump height is a more cost-effective way to measure jump height and power than other tests [28]. Based on the findings of the preceding studies, the group with a quicker jump time is more likely to have stronger tendons and muscles, allowing for a more effective transfer of energy from eccentric contractions to concentric contractions. As a result, any training stimulus,

including maxex training, will produce more optimal power in samples that are already inherently efficient in jumping mechanics.

This lack of interaction needs to be analyzed within the context of training adaptability and biomechanical individualism. These findings indicate that the effects of maxex training are relatively similar for all athletes, regardless of jump time. This is likely because fast jump profiles are already closer to the physiological threshold. Therefore, the training stimulus does not provide additional synergistic effects beyond those of the slow-paced group. Furthermore, adaptations to explosive power are not solely driven by jump time indicators, but are regulated by genetic factors such as the individual's neuromuscular system. Maxex training tends to act as a general adaptation stimulus that leverages the power base without discriminating specifically about the jump phase. Furthermore, appropriate programming adjustments are needed to achieve better results. [29]

This study adds to and restricts the discussion regarding the use of personalized power training. The results show that maxex training is generally successful for adolescent volleyball players, regardless of launch timing or individual differences, with the rejection of interactions. However, we simplify the training recommendation so that maxex can be included in training regimens without requiring extensive biomechanical testing to forecast power. Furthermore, the athlete's power training phase, whether established or not, must be considered. Since maxex training is quick and explosive in nature, athletes must first pass maximal power testing to ensure that they achieve optimal power results and avoid injury.

**Limitations**

The study involved only 17-year-old males, limiting the generalizability of the findings. The six-week treatment period was insufficient to induce structural muscle adaptations. The training dosage applied was flat, without considering a linear or linear training program. The study focused solely on moderating jump time, while other biomechanical factors potentially influencing power, such as neuromuscular efficiency or muscle fiber composition ratio, were not analyzed.

**Future Research Directions**.

Further research needs to replicate the design with a larger sample size. Implementing a training program management model is recommended. Further research is encouraged to examine the interaction effect with more complex moderating variables to help clarify the reasons for the interaction. A longer duration, such as 12–16 weeks, is needed to more optimally track the effects of power increases.

## 5. Conclusions

It was discovered that (1) the maxex training group was significantly better at increasing power; (2) athletes with quick vertical jump times were better at increasing leg muscle power; and (3) there was no significant interaction, indicating that the maxex effect did not differ between athletes with quick and slow jumps. This result is one of the recommendations for coaches who seek to improve power using the maxex method, but it requires special attention, such as building power training first before power training. Other limitations include the flat training dose, the training's generality, and the need to investigate other moderating variables. Furthermore, it is necessary to consider using a linear or nonlinear training dose arrangement model, a more specific model for volleyball movements, and moderating variables such as gender or tendon stiffness, rather than just jump time, as there may be a significant interaction effect.

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