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# Effect of plyometric training on back and leg muscle strength: A meta-analysis study

**Idris Kayantaş[1]* and Mehmet Söyler[2]**

[1]Physical Education and Sports Academy, Bingöl University, Turkey.
[2]Yapraklı Vocational High School, Çankırı Karatekin University, Çankırı, Turkey.

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**ABSTRACT**

This study combines the results of studies on the effect of plyometric training on back and leg muscle strength in different places and times to reveal the overall effect sizes of these results. For this purpose, between 2000-2020 years of plyometric training method in Turkey, back and legs taken the subject of the effect on muscle strength parameters of the Council of Higher Education of the National Thesis Archive, Google and academic journals park websites postgraduate published in theses and research papers by the inclusion of studies appropriate studies are discussed. Studies that do not meet the specified criteria are excluded from this study. For the studies whose heterogeneity value is above normal, moderator analysis of training duration, sports branch and broadcast type variables were done. Comprehensive Meta-Analysis (CMA) program was used for experimental meta-analysis. According to the results of the meta-analysis data of this study, the effect of plyometric training on the back muscle strength was 0.404 in the fixed effects model; in the random effects model, it was found to be moderate with an effect size of 0.408. In the fixed effects model for leg muscle strength, 0.478; in the random effects model, it was determined that it has a moderate effect size with a moderate effect size with an effect size of 0.525. Considering the results of this study; for the development of back and leg muscle strength, plyometric training can be said to be moderately effective.

**Keywords:** Training, plyometric, plyometric training, meta-analysis.

*Corresponding author. E-mail: idris_kayantas@hotmail.com. Tel: 0546 625 9223.

## INTRODUCTION

Plyometric is a compound word formed from the Greek words "pleion" meaning "more", and "metric" meaning "measure" Bompa, (2001). Plyometric training is generally seen as one of the most successful techniques to provide speed and strength in order to increase the muscle strength of the legs and to improve the development of the leg muscles by increasing the bounce feature, to make the athlete higher jumps during the game and to react instantly when needed in the game. If the space between speed and strength can be filled with plyometric studies, weight training performed in plyometric training is seen as one of the most useful techniques for the development of this feature (Rannou et al., 2001, Göllü, 2006). Training programs made with plyometric exercises make positive contributions to motor features such as speed and power. Strength training with plyometric training causes hypertrophy in muscles. This increase in muscle strength is directly proportional to the increase in performance improvement (Paul et al., 2003).

Plyometric training is a training method that positively affects the explosive power, maximal force and speed performance of the athlete. In other words, the plyometric training method is a resistance training involving rapid stretching of the muscle in a short period of time, from the eccentric contraction to the concentric contraction to produce a strong movement (Şimşek, 2002). Plyometric training is preferred by athletes to develop strength and explosive strength in all sports branches. It is a training technique (Baechle, 1994). Completed studies have shown that plyometric exercises have a positive effect on improvement in vertical jump performance, speed, leg muscle strength, muscle strength, joint sensitivity and body reaction when working with periodic strength training (Adams et al., 1992).

The term meta-analysis was first introduced by Glass (1976). Meta-analysis emerges as a statistical method that reveals the general effect on the subject of the research and has been a quick shot in use recently, using the summary statistics included in the findings of studies conducted in a more specific area. Some researchers define “meta-analysis” as a research method, while others define “meta-analysis” as an analysis technique used in research synthesis (Shelby and Vaske, 2008). Glass, who is considered to be the name father of the term "meta-analysis", mentioned as follows; In order to combine the previously studied findings, meta-analysis was used as a re-analysis of many analysis results from individual studies (Glass, 1976).

The purpose of this study is combining the studies examining the effect of plyometric training method on back and leg muscle strength between 2000 and 2020, to determine the overall effect size of plyometric training method on back and leg muscle strength by meta-analysis method. By determining this effect size with meta-analysis method, it is thought that plyometric training will guide athletes and trainers about how effective the back and leg muscle strength is.

## MATERIALS AND METHODS

In this study, meta-analysis method was used. Meta-analysis, according to Durlak (1995), is a method of reinterpretation by analyzing the findings obtained from a previously determined, independent of each other and using the results of many studies. In this method, quantitative data is presented to the researchers by considering the experimental research results; combining the results of all the researches, it is possible to reach a more definitive statement about the results by increasing the level of statistical significance of the research (Dinçer, 2014; Sağlam and Yüksel, 2007). Meta-analysis also reveals whether there is a difference between the effectiveness of plyometric training in the studies conducted. It can be mentioned as the most important feature of meta-analysis researches that the results of multiple studies conducted in a field by combining the results, increasing the validity of other researches reaching similar results (Abramson and Abramson, 2001; Sağlam and Yüksel, 2007).

### Collection of data

For this research, in the Turkish council of higher education National Thesis Archive, which focuses on the effect of plyometric training method on speed parameters, a total of 11 studies were included for the back muscle strength, which includes survey method from postgraduate theses and research articles published on Google academic and journal park websites, i.e. 1 doctorate, 8 master's theses, 2 research articles. In addition, a total of 18 studies for leg muscle strength; 2 doctoral theses, 3 research articles and 13 master theses met the inclusion criteria and were realized for the study. The total number of samples within the scope of the studies is 362 for back muscle strength and 523 for leg muscle strength. The studies were obtained by scanning the keywords "training, plyometric training, plyometric". These resulting studies are included in the meta-analysis method if they contain data suitable for the analysis.

The selection criteria of the researches used in this meta-analysis research are as follows:

- The effects of plyometric training on back and leg muscle strength.
- Being a postgraduate thesis published in The Council of Higher Education national thesis center,
- Being a published research article.
- The existence of experimental and control groups of researches, plyometric training applications in the experimental group, traditional applications in the control group.
- Sample sizes, standard deviation and arithmetic means.

Researches that do not meet the selection criteria have been eliminated. The remaining 43 studies were recorded in Microsoft Excel using a coding form.

### Analysis of data

Experimental meta-analysis method was applied in the research. Comprehensive Meta-Analysis (CMA) program was used in experimental meta-analysis. In this analysis, where the effect size is calculated depending on the experimental and control groups, the effect size means the standardized average difference between the groups (Malofeeva, 2005; Çelik, 2013).

As a result of meta-analysis, interpretations of the effect sizes obtained were made by using Cohen's (1988) classification as shown in Table 1.

## RESULTS

### Effect of plyometric training on back muscle strength

The publication bias, heterogeneity test and the fixed effects and the random effects model findings of the 11 studies included in the meta-analysis are presented in Table 2.

#### *Publication bias findings*

In meta-analysis studies, it is necessary to determine whether there is bias before publishing the effect sizes. In

**Table 1.** Cohen's effect size classification scale (Cohen, 1988).

| | | | |
|---|---|---|---|
| -0.15 ≤ d < 0.15 | Insignificant level | 0.75 ≤ d < 1.10 | Large level |
| 0.15 ≤ d < 0.40 | Low level | 1.10 ≤ d < 1.45 | Larger level |
| 0.40 ≤ d < 0.75 | Moderate level | 1.45 ≤ d | Perfect level |

**Table 2.** Descriptive information of studies included in the research for leg muscle strength.

| Writer, Publication year | Female | Male | Publication Type | Branch | Age | Training time |
|---|---|---|---|---|---|---|
| Uzun, 2018 | | 30 | Master Thesis | Judo | 21 | 10 |
| Ciğerci, 2017 | | 22 | Doctoral Thesis | Basketball | 15-17 | 9 |
| Nacaroğlu, 2018 | 12 | 12 | Master Thesis | Volleyball | 17-19 | 8 |
| Kıratlı, 2014 | 40 | | Master Thesis | Handball | 12-16 | 8 |
| Yarayan, 2019 | | 40 | Master Thesis | Football | 13-14 | 8 |
| Kılıç, 2008 | | 30 | Master Thesis | Football | 13-15 | 10 |
| Ateş and Ateşoğlu, 2007 | | 24 | Research Article | Football | 16-18 | 10 |
| Güzel, 2020 | 50 | | Master Thesis | Volleyball | 14 | 8 |
| Arı, 2012 | 35 | | Master Thesis | Football | 14-16 | 12 |
| Demirci, 2016 | 30 | | Master Thesis | Volleyball | 14-16 | 8 |
| Kaya, 2015 | | 37 | Research Article | Wrestling | 21 | 8 |

this study, publication bias was tested using funnel scatter plot and Orwin's Fail Safe N. It is expected that there is no publication bias in the study and the studies included in the study will be spread symmetrically on both sides of the vertical line showing the combined effect sizes (Borenstein et al., 2011). The funnel scatter plot is presented in Figure 1.

If there were bias in publication in these 11 studies included in the study; a large part of the study would have been concentrated at the bottom of the funnel shape or only part of the vertical line. When Figure 1 is examined, almost all of the studies are in the funnel and it is seen that there is a symmetrical distribution around the average effect size. According to this result, it can be said that there is no publication bias. The results of Orwin's Fail Safe N (1983) test, another method of evaluating publication bias, are shown in Table 2.

When Table 2 is examined, the number of studies will decrease the average effect size value of the 11 studies included in the meta-analysis to almost insignificant levels and it appears to be 434 studies. Except for these 11 studies on this subject in Turkey, it is thought that it is unlikely to reach out to 434 more studies. Therefore, according to this result, it can be said that there is no publication bias in the study.

When Table 3 is examined, it is seen that the Q statistical value of the studies is 10.853 according to the fixed effects model. This value is less than 10 degrees of freedom chi-square ($\chi^2$) value (18.307) and the effect sizes show a homogeneous distribution under the fixed effects model. Therefore, no moderator analysis is needed for back muscle strength.

According to the fixed effects model, the average effect size (95% confidence interval) of the 11 studies included in the meta-analysis shows that the upper limit is 0.614 and the lower limit is 0.194 and the average effect size value is 0.404 (z = 3.775; p = 0.000). This value is in the 'moderate' effect size range according to the Cohen's classification (1988) (Table 4).

The average effect size (95% confidence interval) of these 11 studies included in the meta-analysis according to the random effects model shows that the upper limit is 0.628 and the lower limit is 0.189 and the average effect size value is 0.408 (z = 3.647; p = 0.000). According to the Cohen classification (1988), this value is in the 'moderate' effect size range.

The average effect size value of the studies, which were combined according to both the fixed effects and random effects model, was found to be "moderate" according to the Cohen classification (1988). This result shows that plyometric training moderately affects athletes' back muscle strength compared to traditional methods. Figure 2 shows the forest plot of the effect sizes of the studies according to the random effects model. The black squares seen in the forest graph show the effect size of the study, and the horizontal lines on both sides of the square show the 95% confidence interval of the effect size of that study. Here, the length of the horizontal lines indicates the width of the confidence interval. The quadrangle at the bottom of all frames reveals the overall effect size of all studies (Ayaz and Söylemez, 2015). In Figure 2, the broadest confidence interval of the study of Ciğerci (2017) is 1.329; it shows that the study of Nacaroğlu (2018) has the smallest confidence interval with 0.003. On the other hand, the effect sizes of the 11 studies included in the study are

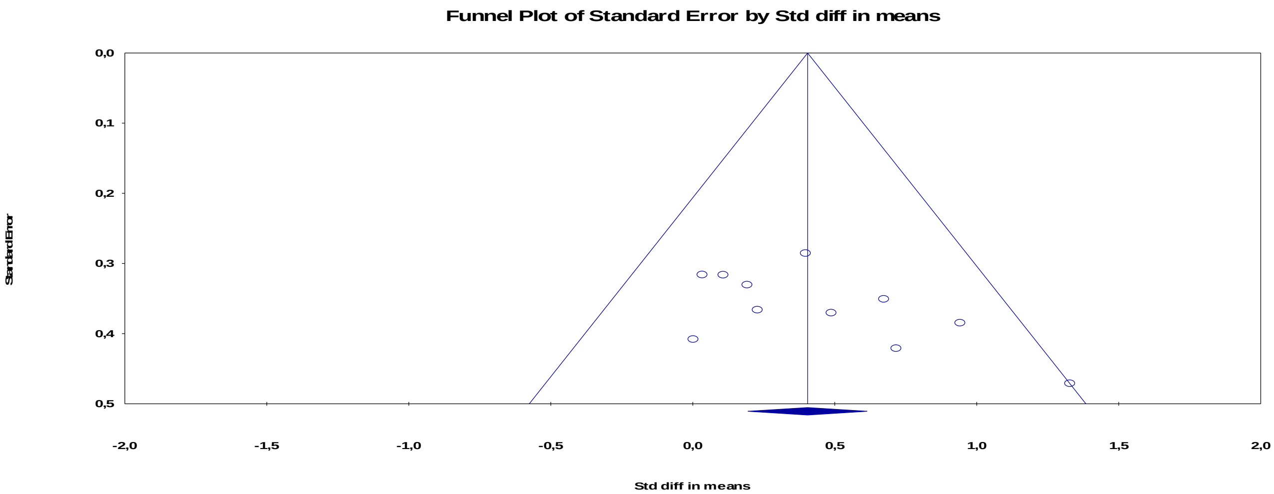


**Figure 1.** Funnel scatter graph of studies containing the effect size data related to the back muscle strength performance of the plyometric training method.

**Table 3.** Heterogeneity test.

| *Q-Value* | *χ2* | *P- Value* | *$I^2$* |
|---|---|---|---|
| 10.853 | 10.000 | 0.369 | 7.855 |

**Table 4.** Combined findings and homogeneity test of the effect size meta-analysis on the effect of plyometric training on back muscle strength according to the fixed and random effects model.

| | N | Effect size | Standard error | Variance | Low limit | Upper limit | Z-value | P-value |
|---|---|---|---|---|---|---|---|---|
| Fixed effects | 11 | 0.404 | 0.107 | 0.011 | 0.194 | 0.614 | 3.775 | 0.000 |
| Random effects | 11 | 0.408 | 0.112 | 0.013 | 0.189 | 0.628 | 3.647 | 0.000 |

| Study name | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
|---|---|---|---|---|---|---|---|
| uzun, 2018 | 0,489 | 0,371 | 0,137 | -0,237 | 1,215 | 1,320 | 0,187 |
| cigerci, 2017 | 1,329 | 0,471 | 0,222 | 0,406 | 2,253 | 2,822 | 0,005 |
| nacaroglu, 2018 | 0,003 | 0,408 | 0,167 | -0,797 | 0,803 | 0,007 | 0,994 |
| kiratli, 2014 | 0,035 | 0,316 | 0,100 | -0,585 | 0,655 | 0,110 | 0,913 |
| yarayan, 2019 | 0,108 | 0,316 | 0,100 | -0,512 | 0,729 | 0,342 | 0,732 |
| kilic, 2008 | 0,943 | 0,385 | 0,148 | 0,188 | 1,697 | 2,449 | 0,014 |
| ates vd., 2007 | 0,718 | 0,421 | 0,177 | -0,108 | 1,543 | 1,704 | 0,088 |
| güzel, 2020 | 0,399 | 0,286 | 0,082 | -0,161 | 0,958 | 1,395 | 0,163 |
| ari, 2012 | 0,674 | 0,351 | 0,123 | -0,014 | 1,362 | 1,921 | 0,055 |
| demirci, 2016 | 0,229 | 0,366 | 0,134 | -0,489 | 0,947 | 0,625 | 0,532 |
| kaya, 2015 | 0,193 | 0,331 | 0,109 | -0,455 | 0,841 | 0,583 | 0,560 |
| | 0,408 | 0,112 | 0,013 | 0,189 | 0,628 | 3,647 | 0,000 |

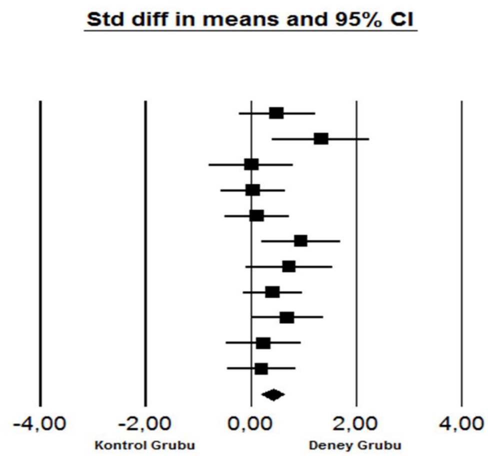


**Figure 2.** Forest graph belong to studies' random effects model.

positive. The lower limit of the effect sizes of these studies ranged from -0.797 to 0.406 and the upper limit ranged from 0.628 to 2.253.

## Effect of plyometric training on leg muscle strength

The publication bias heterogeneity test of 17 studies included in the meta-analysis and the findings of the fixed effects and random effects model are given in Table 5.

### *Publication bias findings*

In this study, publication bias was tested according to funnel scatter plot and another method, Orwin's Fail Safe N results. One of the indicators that there is not any publication bias is that the studies included in the research are expected to spread symmetrically around the vertical line showing the combined effect sizes (Borenstein et al., 2009).

For these 17 studies included in the study, in order to have publication bias, it would be in question that most of the studies would be collected at the bottom of the funnel shape or only part of the vertical line and taken out of the funnel graph. When Figure 3 is examined, almost all of the studies are in the funnel and it can be said that they show an almost symmetrical distribution around the average effect size. Depending on this situation, it can be said that there is no publication bias. The results of Orwin's Fail Safe N test, another method of evaluating publication bias, are given in the Table 6.

When Table 6 is examined, the average effect size value of 17 studies included in the meta-analysis; it is seen that the number of studies that will decrease to almost insignificant level is 796. Except that 17 studies were carried out in Turkey on this subject are not expected to mention the 796 studies more accessible.
According to this result, we can say that there is no publication bias in this study.

### *General effect size findings*

When Table 7 is analyzed, it is seen that the Q statistical value of the studies is 34.615 according to the fixed effects model. This value indicates that it is greater than the 16 degree of freedom chi-square (262) value (26.296) and the effect sizes have a moderate heterogeneous distribution under the fixed effects model. Therefore, the results of the moderator analysis of the type of broadcasting, training period and sports branch are calculated and shown below. Developed as another complement of Q statistics, $I^2$ gives us more reliable results for heterogeneity (Petticrew and Roberts, 2006; Yıldırım, 2014). In contrast to the Q statistics, the $I^2$ statistics are not affected by the number of studies included in the study. In the interpretation of the heterogeneity level for $I^2$, it results in 25% low heterogeneity, 50% medium level heterogeneity and 75% high level heterogeneity (Cooper et al., 2009). As a result of the homogeneity tests (Q and $I^2$) performed for the velocity property variable, the model was turned into a random model for joining because there was a moderate level of heterogeneity between the studies. The results of the age group and publication type moderator analysis performed to reveal the causes of this heterogeneity are presented in Table 8.

According to the fixed effects model, it was concluded that the average effect size (95% confidence interval) of these 17 studies included in the meta-analysis was upper limit 0.651 and lower limit 0.306 and the average effect size value was 0.478 (z = 5.433; p = 0.000). According to the Cohen (1988) classification; this value indicates the moderate effect size range.

According to the random effects model, for the 17 studies included in the meta-analysis, the average effect size (95% confidence interval) appears to be the upper limit 0.778 and the lower limit 0.2266, with an average effect size value of 0.525 (z = 3.976; p = 0.000). This value is according to Cohen (1988) classification; it is in the medium effect size range.

According to both effects model; the average effect size value of these 11 studies combined shows that according to the Cohen classification (1988) it is “moderate”. According to this result; it can be mentioned that the effect of plyometric training on athletes' back muscle strength is moderate.

Figure 4 points out the forest plot of the effect sizes of the studies according to the random effects model. The black squares seen in the forest graph show the effect size of the study, and the horizontal lines on both sides of the square show the 95% confidence interval of the effect size of that study. Here, the length of the horizontal lines indicates the width of the confidence interval. The rhombus at the bottom of all the squares reveals the overall effect size of all studies (Ayaz and Söylemez, 2015). Again in Figure 4, the broadest confidence interval of Yalçınkaya (2016) is 2.959; it shows that the study of Ciğerci (2017) has the smallest confidence interval with -0.073. On the other hand, it is seen that the effect size of 1 study included in the study was negative and the effect size of the other 16 studies was positive. The lower limit of the effect sizes of these studies varies between -0.766 and 1.801 and the upper limit varies between 0.620 and 4.117.

When the publication type moderator is examined, the average effect size value of the studies of doctoral theses is 0.955 (95% confidence interval) lower limit is -0.113 upper limit 2.022 (Table 9). The average effect size value of the studies belonging to the research articles is 0.531 (95% confidence interval) lower limit -0.051 upper limit 1.113, the average effect size value of the studies of master's theses is 0.466 (95% confidence interval) lower limit 0.145 upper limit 0.7787. There is no statistically significant difference in these mean effect size values between the groups (p > 0.05).

When the training period moderator is examined; It is seen that the effect size value of the studies with 10 weeks training period is 0.615 (95% confidence interval), the lower limit is 0.100 and the upper limit is 1.131. The effect size value of the studies performed according to

**Table 5.** Descriptive information of studies included in the research for leg muscle strength.

| Write, Publication year | Female | Male | Publication type | Sports branch | Age | Training Time |
|---|---|---|---|---|---|---|
| Uzun, 2018 | | 30 | Master Thesis | Judo | 21 | 10 |
| Özgül, 2019 | | 32 | Master Thesis | Football | 14-18 | 8 |
| Ciğerci, 2017 | | 22 | Doctoral Thesis | Basketball | 15-17 | 9 |
| Çağlayan et al., 2018 | | 20 | Research Article | Wrestling | 21 | 8 |
| Nacaroğlu, 2018 | 12 | 12 | Master Thesis | Volleyball | 17-19 | 8 |
| Kıratlı, 2014 | 40 | | Master Thesis | Handball | 12-16 | 8 |
| Yalçınkaya, 2016 | | 24 | Master Thesis | Hill Skiing | 18-20 | 8 |
| Şeker, 2019 | | 24 | Master Thesis | Football | 21.5 | 8 |
| Yarayan, 2019 | | 40 | Master Thesis | Football | 13-14 | 8 |
| Kılıç, 2008 | | 30 | Master Thesis | Football | 13-15 | 10 |
| Ateş and Ateşoğlu, 2007 | | 24 | Research Article | Football | 16-18 | 10 |
| Güzel, 2020 | 50 | | Master Thesis | Volleyball | 14 | 8 |
| Arı, 2012 | 35 | | Master Thesis | Football | 14-16 | 12 |
| Nalbant and Kınık, 2018 | | 40 | Research Article | Football | 18 | 8 |
| Bavlı, 2009 | | | Doctoral Thesis | Basketball | 13-18 | 12 |
| Şanslı, 2017 | | 30 | Master Thesis | Wrestling | 15-19 | 12 |
| Savucu, 2001 | | 24 | Master Thesis | Basketball | 15-17 | 12 |

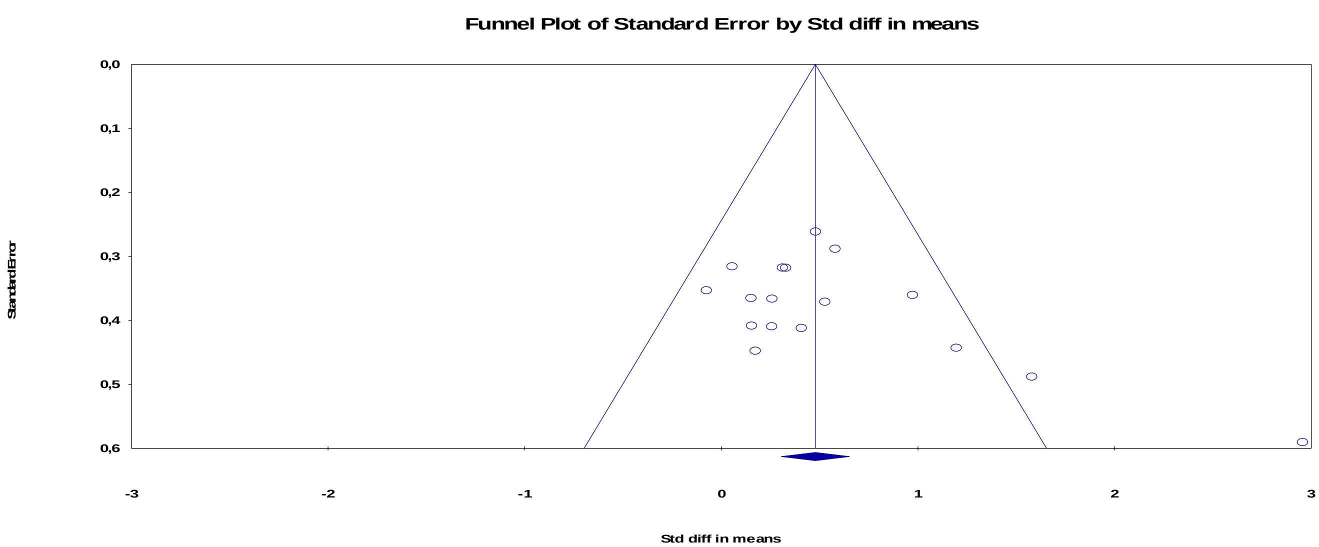


**Figure 3.** Funnel plot of leg muscle strength feature.

**Table 6.** Orwin's fail safe N results.

| Element | Values |
|---|---|
| Standard average difference in observed studies | 0.47818 |
| Standard average difference for "insignificant" value | 0.01000 |
| Standard difference average in lost works | 0.00000 |
| Required study number to bring the standard average difference below 0.01 | 796.000 |

**Table 7.** Heterogeneity test.

| Q-Value | χ2 | P- value | $I^2$ |
|---|---|---|---|
| 34.615 | 16.000 | 0.004 | 53.777 |

**Table 8.** Combined findings of studies according to fixed and random effects models.

| | N | Effect size | Standard error | Variance | Low limit | Upper limit | Z-value | P-value |
|---|---|---|---|---|---|---|---|---|
| Fixed effects | 17 | 0.478 | 0.088 | 0.008 | 0.306 | 0.651 | 5.433 | 0.000 |
| Random effects | 17 | 0.525 | 0.132 | 0.017 | 0.266 | 0.784 | 3.976 | 0.000 |

| Study name | Statistics for each study | | | | | | |
|---|---|---|---|---|---|---|---|
| | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
| uzun, 2018 | 0,261 | 0,367 | 0,134 | -0,458 | 0,979 | 0,711 | 0,477 |
| ozgul, 2019 | -0,073 | 0,354 | 0,125 | -0,766 | 0,620 | -0,206 | 0,837 |
| cigerci, 2017 | 1,582 | 0,489 | 0,239 | 0,624 | 2,539 | 3,238 | 0,001 |
| atakan vd., 2018 | 0,176 | 0,448 | 0,201 | -0,703 | 1,054 | 0,392 | 0,695 |
| nacaroglu, 2018 | 0,410 | 0,413 | 0,170 | -0,399 | 1,218 | 0,994 | 0,320 |
| kiratli, 2014 | 0,330 | 0,318 | 0,101 | -0,294 | 0,954 | 1,037 | 0,300 |
| yalcinkaya, 2016 | 2,959 | 0,591 | 0,349 | 1,801 | 4,117 | 5,008 | 0,000 |
| seker, 2019 | 0,157 | 0,409 | 0,167 | -0,645 | 0,958 | 0,383 | 0,702 |
| yarayan, 2019 | 0,058 | 0,316 | 0,100 | -0,562 | 0,678 | 0,183 | 0,855 |
| kilic, 2008 | 0,530 | 0,371 | 0,138 | -0,198 | 1,258 | 1,426 | 0,154 |
| ates vd., 2007 | 1,198 | 0,443 | 0,197 | 0,329 | 2,067 | 2,702 | 0,007 |
| guzel, 2020 | 0,581 | 0,289 | 0,083 | 0,015 | 1,147 | 2,013 | 0,044 |
| ari, 2012 | 0,975 | 0,361 | 0,130 | 0,268 | 1,683 | 2,702 | 0,007 |
| nalbant, 2018 | 0,314 | 0,318 | 0,101 | -0,310 | 0,937 | 0,986 | 0,324 |
| bavli, 2009 | 0,482 | 0,262 | 0,069 | -0,032 | 0,995 | 1,840 | 0,066 |
| sansli, 2017 | 0,154 | 0,366 | 0,134 | -0,563 | 0,870 | 0,420 | 0,674 |
| savucu, 2001 | 0,259 | 0,410 | 0,168 | -0,545 | 1,062 | 0,631 | 0,528 |
| | 0,525 | 0,132 | 0,017 | 0,266 | 0,784 | 3,976 | 0,000 |

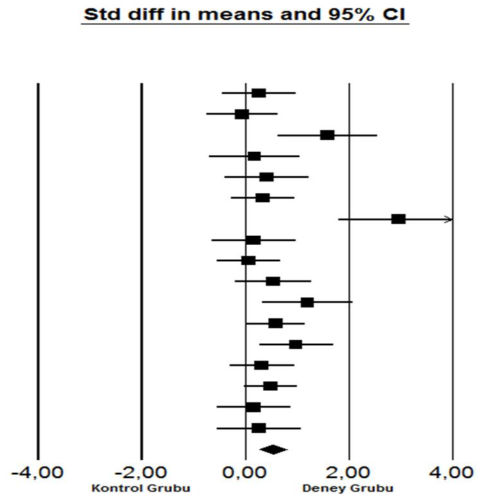


**Figure 4.** Forest graph belong to studies' random effects model.

**Table 9.** Categorical moderator results related to the effect of plyometric training on leg muscle strength.

| Publication type | N | Effect size | Standard error | Low limit | Upper limit | Q-Value | Df (Q) | P-Value |
|---|---|---|---|---|---|---|---|---|
| Doctorate Thesis | 2 | 0.955 | 0.545 | -0.113 | 2.022 | 3.938 | 1.000 | 0.047 |
| A. Article | 3 | 0.531 | 0.297 | -0.051 | 1.113 | 3.343 | 2.000 | 0.188 |
| Master Thesis | 12 | 0.466 | 0.164 | 0.145 | 0.787 | 25.855 | 11.000 | 0.007 |
| In-group | | | | | | 33.135 | 14.000 | 0.003 |
| Intergroup | | | | | | 0.744 | 2.000 | 0.689* |
| | | | | | | | | |
| Training Time | | | | | | | | |
| 10 Weeks | 3 | 0.615 | 0.263 | 0.100 | 1.131 | 2.709 | 2.000 | 0.258 |
| 12 Weeks | 4 | 0.482 | 0.167 | 0.154 | 0.810 | 2.971 | 3.000 | 0.396 |
| 8 Weeks | 9 | 0.446 | 0.207 | 0.040 | 0.852 | 22.793 | 8.000 | 0.004 |
| In-group | | | | | | 28.473 | 13.000 | 0.008 |
| Intergroup | | | | | | 0.271 | 2.000 | 0.873* |
| | | | | | | | | |
| Sports Branch | | | | | | | | |
| Basketball | 3 | 0.702 | 0.344 | 0.028 | 1.375 | 4.930 | 2.000 | 0.085 |
| Football | 7 | 0.415 | 0.171 | 0.081 | 0.750 | 9.287 | 6.000 | 0.158 |
| Wrestling | 2 | 0.162 | 0.283 | -0.393 | 0.718 | 0.001 | 1.000 | 0.970 |
| Volleyball | 2 | 0.525 | 0.237 | 0.061 | 0.989 | 0.116 | 1.000 | 0.733 |
| In-group | | | | | | 14.334 | 10.000 | 0.158 |
| Intergroup | | | | | | 1.685 | 3.000 | 0.640* |

the training period of 12 weeks is 0.448 (95% confidence interval) and the lower limit is 0.154 and the upper limit is 0.810. It is observed that the effect size value of the studies performed according to the 8-week training period is 0.444 (95% confidence interval) and the lower limit is 0.040 and the upper limit is 0.852. Since the training time data of 1 study was not shown, the training time was not included in the moderator analysis. These effect size values do not indicate a statistically significant difference between the groups ($p > 0.05$).

When the sports branch moderator is examined, it was determined that the effect size value of the studies of the basketball sports branch is 0.702 (95% confidence interval) and the lower limit is 0.028 and the upper limit is 1.375. The effect size value of the studies of the football sports branch was found to be 0.415 (95% confidence interval), the lower limit was 0.081, the upper limit was 0.750. The impact size of the studies of the wrestling sport branch was found to be 0.162 (95% confidence interval) lower limit -0.393 upper limit 0.718. It is seen that the effect size value of the studies of the volleyball sports branch is 0.525 (95% confidence interval), the lower limit is 0.061 and the upper limit is 0.989. The sports branch mentioned in all three studies was not included in the moderator analysis, since there was no other study to be seen in only one study and there was no other study to compare. These effect size values did not show a statistically significant difference between the groups ($p > 0.05$).

## RESULTS AND DISCUSSION

According to the results of back muscle strength meta-analysis, the effect size of plyometric training on back muscle strength was 0.404 in the fixed effects model. According to the random effects model, it was determined to be 0.408. According to these results, the effect of plyometric training on back muscle strength is in the middle effect size range according to Cohen effect size classification (1988). The findings of our research showed that; plyometric training is moderately effective on back muscle strength and back force can be improved with plyometric training.

In a study by Ateş and Ateşoğlu (2007), the effect of plyometric training on back force was 109.37 ± 12.50 kg before the training in the control group; Average 111.25 ± 12.77 kg after training. In the results of the experimental group, it was observed that the back muscle strength pre-training values were 115.25 ± 11.9 kg, while the mean values after training were 126.08 ± 12.17 kg.

Cicioğlu (1995) found that there was a significant improvement in the back muscle strength parameter of basketball players after 8 weeks of plyometric training applied to 14-15 age group basketball players.

Ağılönü and Kıratlı (2015) in their study with 40 handball athletes aged 12-16, 8-week plyometric trainings were applied. The post-test findings of this study, which examined the effect of plyometric training on physical fitness parameters, found that there were significant differences in parameters of back strength.

According to Kaya (2015), in a study in which 37-wrestlers examined the effect of 8-week plyometric training on motoric parameters, he stated that the experimental group who performed plyometric training showed a statistically significant difference in back muscle strength.

In the study carried out by Demirci in (2016), in the study where female volleyball players aged 14-16 investigated the effects of 8-week plyometric studies on physical parameters, the experiment performed plyometric training two days a week in addition to the 8-week volleyball training. The control group did only volleyball training. According to the research results; In addition to the volleyball training, a significant difference was found between the pre and posttest back muscle strength of the experimental group performing plyometric training. In the literature review, it was seen that; plyometric workouts contribute positively to the development of back muscle strength.

According to the results of our meta-analysis study of leg muscle strength, the effect size of plyometric training on leg muscle strength was 0.478 in the fixed effects model; According to the random effects model, it was determined to be 0.525. According to these results, the effect of plyometric training on leg muscle strength According to Cohen's (1988) effect size classification, "medium level" effect size shows the range. According to the results of our research, plyometric training is moderately effective on leg muscle strength and leg muscle strength can be improved with plyometric training.

Rubley et al. (2011) reported that plyometric training improves body lower limb muscle strength. In the study carried out by Rahimi and Behpur (2005). They found that plyometric training performed 6 weeks and two days per week improved leg strength of athletes.

Yıldız (2001) in the study titled "The effect of the 8-week plyometric training program on the vertical jumps of footballers and some physical and physiological parameters" of the experimental group's leg muscle strength values, pre-test 125.83 ± 7.56 kg, and post-test, found that there was a significant difference between 142.54 ± 8.17 kg values ($p < 0.01$).

Sevim et al. (1996) in the study titled "Examination of the Effect of Combined Strength Training on the Performance Development of Elite Female Handball Players in the Age Group of 18–24," found there was a significant difference between the pretest and posttest values of the subjects ($p < 0.01$).

In the study of Bayraktar (2008), the pre-test mean of the leg muscle strength of the experimental group was 45.58 ± 14.49, it was determined that the post-test mean was 53.20 ± 13.59 and this result was significant for the experimental group.

A study of Çavdar (2006) which investigated the effect of 10-week plyometric training on jump performance for football players between the ages of 12-14, found a significant difference in the mean muscle strength of the subjects ($p < 0.05$). The results found in the literature review we conducted show similar results with our study. There is a direct proportional development between the plyometric training method and the leg muscle strength.

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