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Meta analysis of the effects of resistance training on the lower limb muscle strength of basketball players

The objective of the study is to comprehensively evaluate the effects of resistance training on the improvement of lower limb motor function of basketball players. During the study the following methods were applied: Elsevier, SCI-E, CNKI and other databases were searched to collect the relevant randomized controlled experiments on the effects of resistance training on the lower limb muscle strength of basketball players. The search time was set to March 2020, and the references of the included literatures were retrospectively searched. The quality of the literature was evaluated. Statistical analysis was conducted using RevMan 5.3 software to compare the effects of training programs and intensity on the sports performance of basketball players using odds ratio and 95 % confidence interval as effect indicators. As a result, a total of 14 literatures and 313 experimental samples were included. Compared with the control group, the results showed that resistance training could significantly improve the running height of basketball players (SMD=-4.92, 95 %CI (-6.31, -3.54), P<0.00001). The resistance training could significantly improve the longitudinal jumping of basketball players (SMD=-1.69, 95 %CI (-2.11, -1.28), P<0.00001). The resistance training could improve the speed of basketball players at 20m sprints (SMD=0.24, 95 %CI (0.04, 0.43), P=0.02). The resistance training could significantly improve the standing long jump of basketball players (SMD=-11.46, 95 %CI (-18.09, -4.83), P=0.0007). It was concluded that resistance training can improve the lower limb movement ability of basketball players.

Keywords: basketball, resistance training, strength exercise, plyometrics, strength of lower limb muscles.

Introduction

Invented in 1891, basketball has evolved into one of the world's most popular and widely viewed sports. There is a great amount of basketball leagues all over the world, such as China's CBA league, NBA league in the US, EuroLeague, etc. In recent years, 3X3 basketball games have become popular all over the world. As the improvement of competition level, the players are required to have more excellent athletic ability; it is largely dependent on the ability to produce maximum neuromuscular strength [1]. Therefore, the players shall achieve a relatively high level of strength, and turn it into achievements to the greatest extent. The player's good lower limb muscle strength and function are the key factors of their basketball performance [2–4], and it is the guarantee for their daily activities and training [5, 6], so the scientific and rich anti-group training program to help athletes achieve the best athletic ability has been given attention [1, 7, 8]. Some coaches and researchers have experimented that heavy load resistance training [9, 10], explosive resistance training [11, 12], electrical stimulation training [12], vibration training [13], plyometric training, etc. are more effective methods to improve jumping ability and leg muscle strength [14–16]. In contrast, there are also some authors who believe that these training modalities do not significantly improve lower limb athletic ability [17–21], and some of them even report negative effects [22]. Moreover, there are few studies on the improvement or improvement of basketball players' lower limb muscle strength and athletic ability by resistance training methods in China, and there are some controversies about the formulation of basketball players' lower limb muscle strength training plan. In view of this, this paper uses Meta-analysis method to quantitatively and comprehensively analyze the literatures at home and abroad on different resistance training methods to improve the lower limb muscle strength of basketball players; discusses the possible heterogeneity and bias of the included literatures, and quantitatively analyzes the results to obtain more scientific and regular effect results. This paper also analyzes the influence of different resistance training methods on basketball players' achievements, such as running height, longitudinal jumping, 20-m sprints and standing long jump. It is expected to provide theoretical basis and practical scheme for the improvement of basketball players' lower limb muscle strength and sports performance.

Methods and materials

1. Document Retrieval

The computer retrieval databases are as follows: Elsevier, SCI-E, and CNKI databases. The Chinese search words are "篮球、运动员、抗组训练、肌力训练、下肢肌力、运动功能", etc., the English search words are "basketball, athletes, sportsman, strength training, lower limbs, FMA", etc. For different databases, the corresponding combination of subject words, free words and keywords are selected. A total of 36,199 literatures were obtained. After deduplication and research direction preliminary screening, 18,902 literatures were remained. Further reading the title and abstract, 842 literatures were retained, and after reading the full text and excluding conferences and reviews, articles unrelated to basketball, 87 literatures were remained. Finally, after excluding no data and specific indicators and non-lower limb muscle strength influence indicators, 14 literatures were finally included for Meta-analysis (Figure 1) [23–36].

1.1 Literature review criteria

The included literatures would have a direct impact on the reliability and validity of the Meta-analysis results. In order to include scientific research, strict included criteria are required: 1) The included research shall be Chinese and English literatures of randomized controlled trials of basketball players' resistance training; 2) The experimental subjects shall be basketball players, and the experimental data include the basic conditions and training indexes of the subjects before and after the experiment; 3) Exercise intervention shall be greater than or equal to 2 times/week. The total duration of the experiment shall be at least 6 weeks.

1.2 Data information extraction

The standardized procedures and forms are strictly followed, and the basic information, sample size, age of subjects, experimental design, intervention time, overall intervention time, attrition rate, etc. of the included literatures are used as preliminary indicators of literature bias and heterogeneity. Results of index data: The mean (X) and standard differences (SD) of the indexes and effect sizes of the subjects' approach run and touch, longitudinal jump, 20-m sprints, standing long jump, etc. According to the data required in this study and the data format processing using RevMan5.3 software, the data converter in the software is used to extract the data included in the literatures and unify the format.

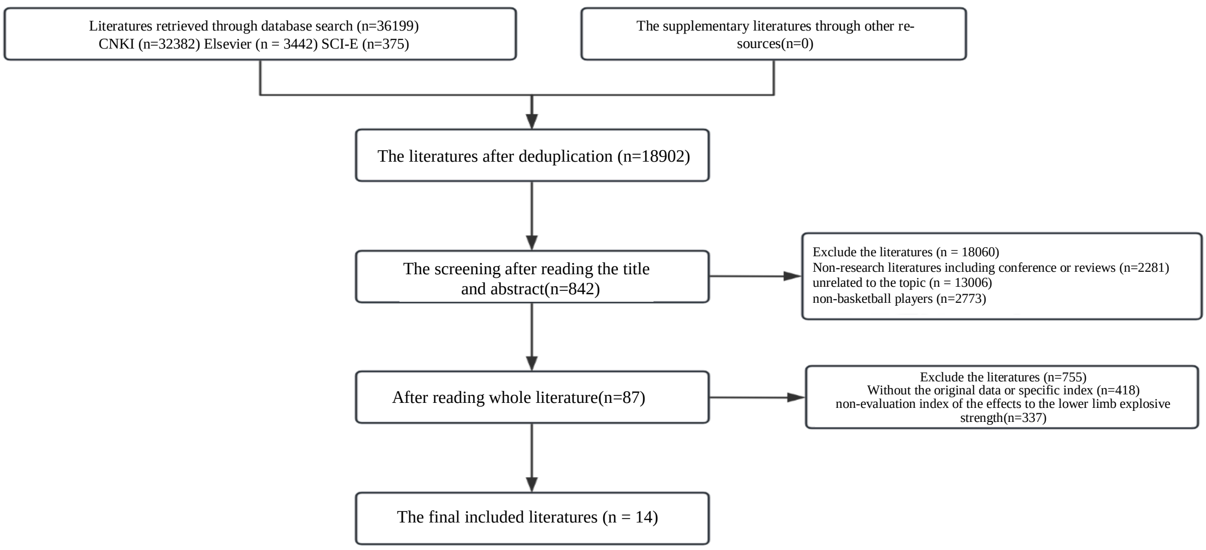

Figure 1. Literature Selection Flow Diagram

1.3 Quality evaluation

The quality of the included literature was evaluated according to the Literature Quality Evaluation Criteria Manual recommended in Cochrane Manual 5.1.0.

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1.4 Data statistical processing

RevMan5.3 is mainly used to evaluate publication bias and test heterogeneity, merge data and draw bias and forest maps; The data to be processed in this paper are continuous data, and the effect size MD (Mean Differences) fixed and random effect models have 95 % confidence intervals. The judgment of heterogeneity is mainly based on I^2, and when $I^2 < 50$ %, the fixed effect model is adopted; When $I^2 \geq 50$ %, the random effects model is adopted. The significance level $\alpha = 0.05$.

Results and Discussion

2 Basic information and quality discussion of the included literatures

In total, 36,199 literatures were obtained. After preliminary elimination of duplicates, 18,902 records remained. Further reading of the title and abstract excluded 18,060 studies that did not meet the inclusion criteria. After preliminary screening, 87 literatures were retained. After the full-text review and quality evaluation, 14 literatures were finally included, consisting of 10 Chinese and 4 English studies.

Table 1 shows the basic information of the included literature in the Meta-analysis, and the sample size is 313 participants in the included literature, and the subjects are all basketball players; All included studies examined resistance training. In particular, plyometric training, which is commonly used in foreign studies, involves rapid and powerful contraction after muscle elongation. This muscle activity method is named as the "Stretch-Shortening Cycle (SSC)". This training method will make the muscles stretch quickly, thus stimulating the proprioceptors of the muscle spindle, allowing them to transmit information to the central nervous system and make reflexes, thus prompting more muscle fibers to deliver more energy. Studies have pointed out that the time of resistance training should be 2-3 times a week for each large muscle group.

Table 1

Basic Information Included Research

The included literature (first author)	**Number of sample**	**Age**	**Gender**	**Training method**	**Duration (weeks)**	**Training volume**	**Quality Score (PEDro)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Approach run and touch							
Gan Liju	6	21.08±1.41	Male	HISRT+LBFRT Comprehensive Training	8	3 times/week	4
Gan Liju	6	21.08±1.41	Male	HISRT training	8	3 times/week	4
Yin Wei	7	19.71±0.37	Female	Core strength training	12	3 times/week	4
Yin Wei	7	19.86±0.37	Female	General resistance training	12	3 times/week	4
Zhao Qichao	6	21.00±0.894	Male	Single leg resistance training	10	3 times/week	4
Zhao Qichao	6	21.00±1.265	Male	Two legs resistance training	10	3 times/week	4
Hu Chengye	12	19.08±1.03	NA	Rapid telescopic compound training	8	3 times/week	3
Li Shaosong	8	18~22	Male	Single leg flexion hard stretch	6	2 times/week	3
Li Shaosong	8	18~22	Male	Two legs flexion hard stretch	6	2 times/week	3
Yang Zhongjun	8	18.75±1.58	Male	Maximum resistance training	8	3 times/week	4
Yang Zhongjun	8	19.38±1.77	Male	Sub-Maximum resistance training	8	3 times/week	4
Yan Yufeng	8	18.8±1.35	Male	Resistance training	8	2 times/week	4
Li Ning	12	20.79±0.64	Male	Plyometric training	12	3 times/week	4
Ma Tianze	14	16±0	Male	Lower limb burst training	8	3 times/week	4
General average	8.29	19.26	NA	NA	8.86	2.79 times/week	NA
20M sprints							
Gan Liju	6	21.08±1.41	Male	HISRT+LBFRT Comprehensive Training	8	3 times/week	4
Gan Liju	6	21.08±1.41	Male	HISRT training	8	3 times/week	4
Bogdanis	33	8.1±0.7	Female	Plyometric training	8	3 times/week	5
Zhang Xiaodong	13	14.5±0.5	Female	Video resistance training	6	2 times/week	4
Zhang Xiaoqing	13	14.5±0.5	Female	Supervised resistance training	6	2 times/week	4
Li Ning	12	20.79±0.64	Male	Plyometric training	12	3 times/week	4
General average	13.83	11.15	NA	NA	8.00	2.67 times/week	NA

Continuation of Table 1

1	2	3	4	5	6	7	8
Longitudinal jump							
Bogdanis	33	8.1±0.7	Female	Plyometric training	8	3 times/week	5
Ziv	15	NA	Female	Plyometric training	NA	NA	3
Zhang Xiaodong	13	14.5±0.5	Female	Video resistance training	6	2 times/week	4
Zhang Xiaodong	13	14.5±0.5	Female	Monitoring resistance training	6	2 times/week	4
Verma	22	10~11	Female	Plyometric training	6	3 times/week	4
Verma	14	10~11	Male	Plyometric training	6	3 times/week	4
Verma	22	14~15	Female	Plyometric training	6	3 times/week	4
Verma	14	14~15	Male	Plyometric training	6	3 times/week	4
Cheng	8	17.1±0.8	Male	Plyometric training	8	2 times/week	4
Li Shaosong	8	18~22	Male	Single leg flexion hard stretch	6	2 times/week	3
Li Shaosong	8	18~22	Male	Two legs flexion hard stretch	6	2 times/week	3
Ma Tianze	14	16±0	Male	Lower limb burst training	8	3 times/week	4
General average	15.33	10.08	NA	NA	8.00	2.67 times/week	NA
Standing long jump							
Li Shaosong	8	18~22	Male	Single leg flexion hard stretch	6	2 times/week	3
Li Shaosong	8	18~22	Male	Two legs flexion hard stretch	6	2 times/week	3
Hu Chengye	12	19.08±1.03	NA	Rapid telescopic compound training	8	3 times/week	3
Zhao Qichao	6	21.00±0.894	Male	Single leg resistance training	10	3 times/week	4
Zhao Qichao	6	21.00±1.265	Male	Two legs resistance training	10	3 times/week	4
Li Ning	12	20.79±0.64	Male	Plyometric training	12	3 times/week	4
Ma Tianze	14	16±0	Male	Lower limb burst training	8	3 times/week	4
Bogdanis	33	8.1±0.7	Female	Plyometric training	8	3 times/week	5
General average	12.38	15.44	NA	NA	8.50	2.75 times/week	NA

2.1 Literature bias evaluation

The PEDro scale was used to access the literature quality [37, 38], which is a randomized controlled study quality evaluation form with a scoring design of 11 items. Each criterion is scored as “yes” or “no”, with total scores on the PEDro scale ranging from 0 to11 points. The items are as follows:

1. The included criteria of subjects clearly described
2. Randomly assigned
3. Assignment hidden
4. Similar baselines for key indicators
5. Subject blinding
6. Therapist blinding
7. Evaluator blinding
8. > 85 % of subjects performed at least one primary outcome measure
9. Subjects with measurement results shall follow the protocol treatment or undergo intention-to-treat analysis
10. The statistics among groups for at least one primary outcome reported
11. The point estimates and confidence intervals for at least one primary outcome reported

2.2 Meta-analysis results

2.2.1 Meta-analysis of the effect size of running height

A total of 14 controlled trial experiments were included in the study on the effect size of running height of basketball players before and after intervention in the resistance training [34, 29, 30, 33, 27, 28, 36, 32, 31], among which Yin Wei, Li Shaosong, Yang Zhongjun, Gan Liju, Zhao Qichao’s literatures contain 2 resistance training programs; Figure 2 represents a Forest Map of the Meta-analysis results of the ef-

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fect size of running height. The low heterogeneity in the study can be seen from Figure 2 (X^2 = 16.69, I^2 = 22 %, P = 0.21), therefore, the Meta-analysis shall adopt the fixed effects model. The analysis results show that resistance training intervention has a significant effect on basketball players' running height [SMD =-4.92, 95 % CI(-6.31, -3.54), P < 0.00001].

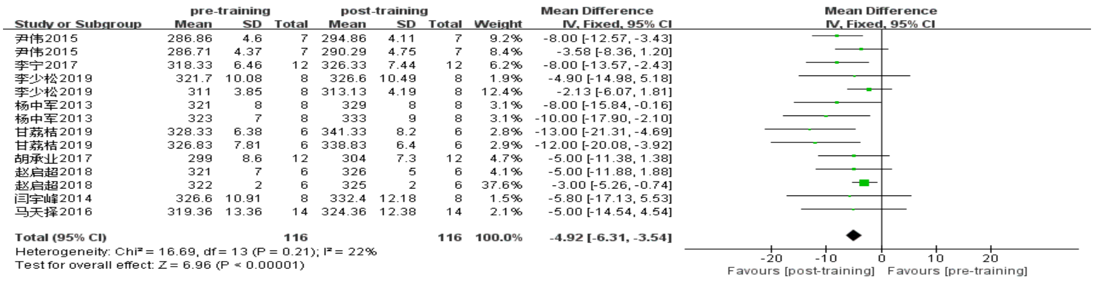

Figure 2. Forest Map Of Efficient Response Volume Of Approach Running Meta-Analysis

2.2.2 Meta-analysis of the effect size of longitudinal jumping

A total of 12 trial experiments were included in the study on the effect size of longitudinal jumping of basketball players before and after intervention in the resistance training [23, 24, 25, 26, 30, 31, 35], among which Bogdanis, Cheng, Zhang Xiaodong, Li Shaosong's literatures contain 2 resistance training programs, Vema's literature contains 4 training groups including the male and female of 2 age groups; In Figure 2, it shows a Forest Map of the Meta-analysis results of the effect size of longitudinal jumping. The low heterogeneity in the study can be seen from Figure 3 (X^2 = 18.06, I^2 = 39 %, P = 0.08), therefore, the Meta-analysis shall adopt the fixed effects model. The analysis results show that resistance training intervention has a significant effect on basketball players' longitudinal jumping [SMD =-1.69, 95 % CI(-2.11, -1.28), P < 0.00001].

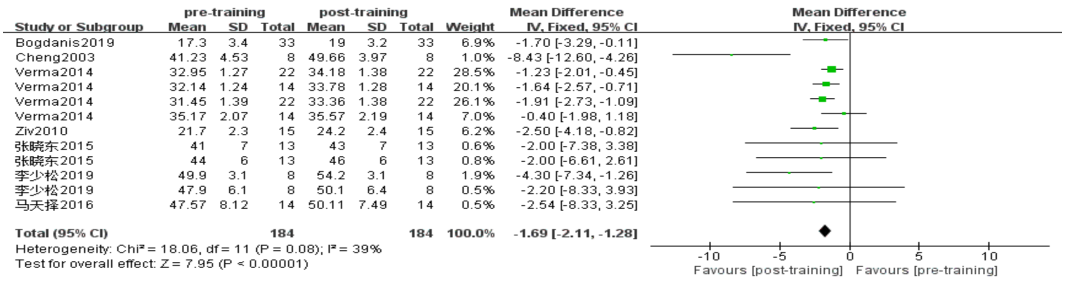

Figure 3. Forest Map of Meta-Analysis of Longitudinal Jump Effector

2.2.3 Meta-analysis of the effect size of 20-m sprints

A total of 6 trial experiments were included in the study on the effect size of 20-m sprints of basketball players before and after intervention in the resistance training [23, 35, 29, 27], among which the studies by Zhang Xiaodong, Gan Liju contained two resistance training programs; Figure 4 demonstrates a Forest Map of the Meta-analysis results of the effect size of 20-m sprints. The heterogeneity in the study can be seen from Figure 4 (X^2 = 30.17, I^2 = 83 %, P < 0.0001), therefore, the Meta-analysis shall adopt the random effects model. The analysis results show that resistance training intervention has a significant effect on basketball players' 20-m sprints [SMD =0.24, 95 % CI(0.04, 0.43), P = 0.02].

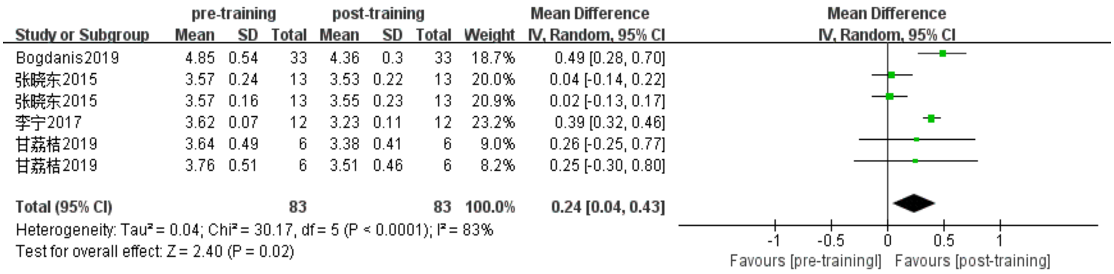

Figure 4. Funnel Map Of Meta Analysis On Effect Size Of 20m Acceleration Run

2.2.4 Meta-analysis of the effect size of standing long jump

A total of 8 trial experiments were included in the study on the effect size of standing long jump of basketball players before and after intervention in the resistance training [23, 30, 28, 36, 31], among which the studies by Li Shaosong, Zhao Qichao contained two resistance training programs; Figure 5 shows a Forest Map of the Meta-analysis results of the effect size of standing long jump. The heterogeneity in the study can be seen from Figure 5 (X^2 = 33.45, I^2 = 79 %, $P < 0.0001$), therefore, the Meta-analysis shall adopt the random effects model. The analysis results indicate that resistance training intervention has a significant effect on basketball players' standing long jump performance [SMD =-11.46, 95 % CI(18.09, -83), $P < 0.0007$].

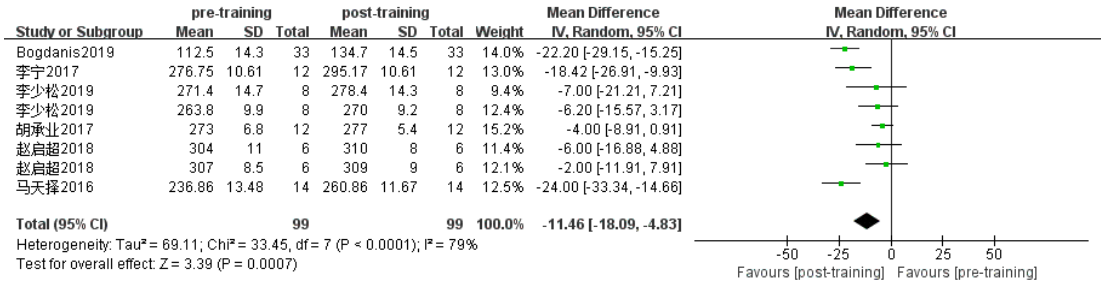

Figure 5. Funnel Map Of Standing Long Jump Effect Size Meta-Analysis

2.2.5 Subgroup analysis

Because of the heterogeneity between the 20-m sprints and standing long jump groups included in the study, and because of the large age gap in the longitudinal jumping, the subgroup analysis is conducted. The ages of longitudinal jumping are divided into ≤ 11 years old, 11 years old < resistance training group ≤ 15 years old, and > 15 years old; Figure 6 indicates the subgroup analysis results of the combined longitudinal jumping effect size data for the age resistance training group ≤ 11 years old, 11 years < resistance training group ≤ 15 years old, and 15 < resistance training groups. It can be seen from Figure 8 that there is heterogeneity in longitudinal jumping data analysis of age ≤ 11 years old (X^2 = 1.93, I^2 = 0 %, $P < 0.00001$), the 95 % confidence interval total effect size [SMD =-1.54, 95 % CI(-0.08, -1.01), $P < 0.0001$]; The analysis heterogeneity of age 11-15 (X^2 = 2.82, I^2 = 0 %, $P = 0.42$), the 95 % confidence interval total effect size [SMD =-1.16, 95 % CI(-2.32, -0.90), $P < 0.00001$]; The analytical heterogeneity of age > 15 (X^2 = 4.28, I^2 = 30 %, $P = 0.23$), the 95 % confidence interval total effect size [SMD =-4.88, 95 % CI(-7.00, -2.76), $P < 0.00001$]. It can be seen that resistance training has significant effect on the longitudinal jumping effect of different age groups.

Figure 7 shows the subgroup analysis results of the combined 20m sprints effect size data for the age resistance training group 1, resistance training group 2, and the trial experiments group. It can be seen from Figure 9 that the heterogeneity of 20m sprints data analysis between the training group (resistance training group 1 and resistance training group 2 are collectively referred to as the training group) and the trial experiments group (X^2 = 1.59, I^2 = 0 %, $P < 0.00001$), 95 % confidence interval total effect size [SMD = 0.22, 95 % CI(0.15, 0.29), $P < 0.00001$]; Resistance training group 1 and resistance training group 2 analysis heterogeneity (X^2 = 0.17, I^2 = 0 %, $P = 0.68$), 95 % confidence interval total effect size [SMD = 0.03, 95 % CI(-0.13, 0.20), $P = 0.7$].

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Figure 8 demonstrates the subgroup analysis results of the combined standing long jump effect size data for the age resistance training group 1, the age resistance training group and the trial experiments group. It can be seen from Figure 10 that the heterogeneity of 20m sprints data analysis between the training group and the trial experiments group (X^2 = 3.17, I^2 = 37 %, P = 0.21), 95 % confidence interval total effect size [SMD =-8.06, 95 % CI(-11.50, -4.61), P < 0.00001]; Resistance training group 1 and resistance training group 2 analysis heterogeneity (X^2 = 0.91, I^2 = 0 %, P = 0.34), 95 % confidence interval total effect size [SMD =-3.97, 95 % CI(-11.42, 3.49), P = 0.30].

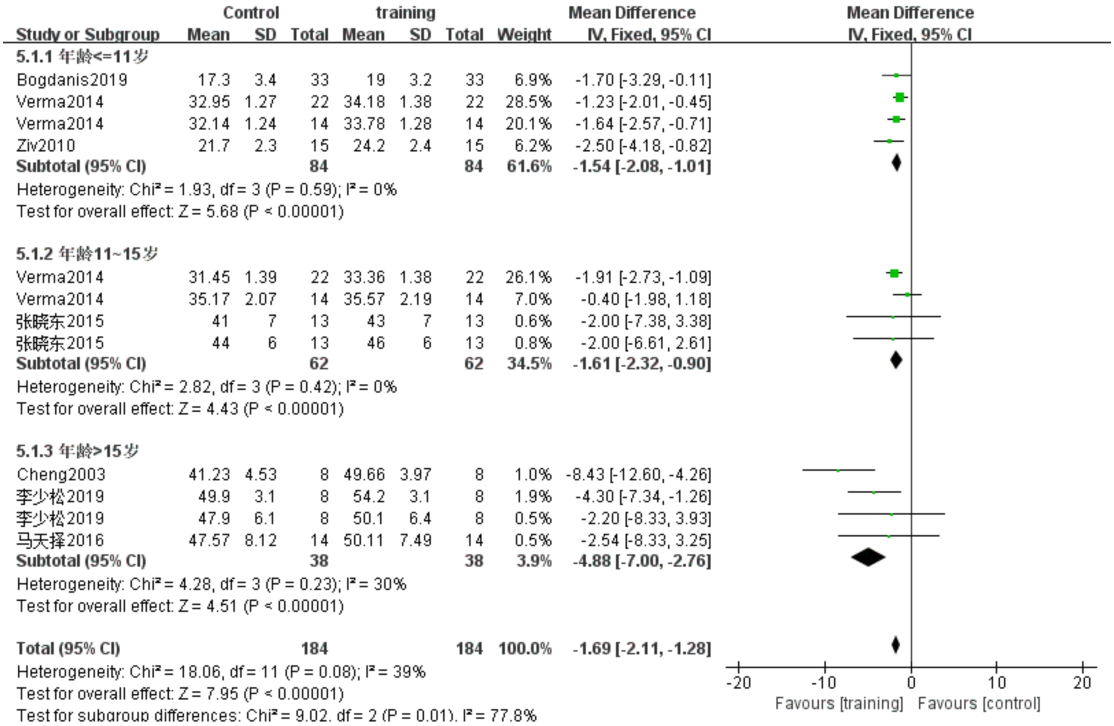

Figure 6. Subgroup Forest Map Of Longitudinal Jump Effect Size

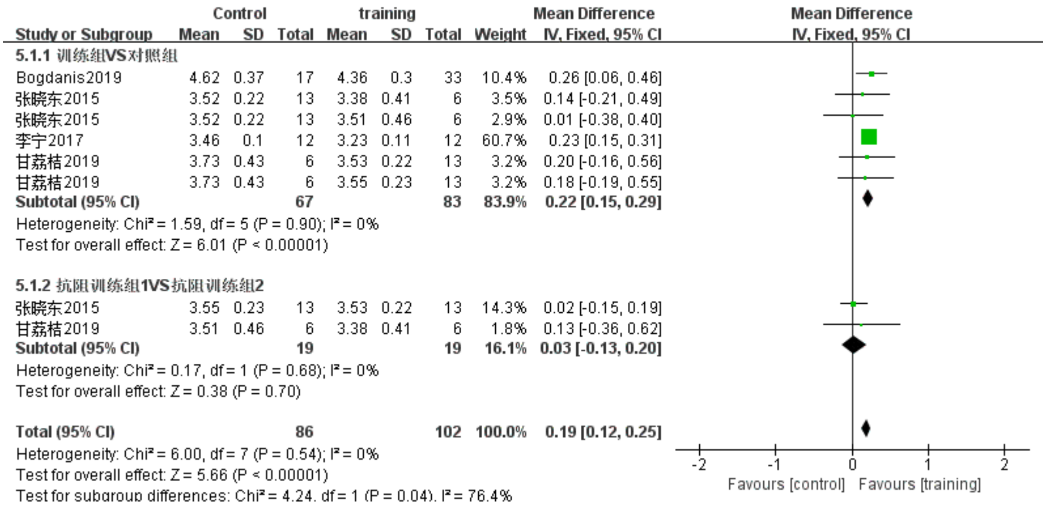

Figure 7. 20m Acceleration Effect Subgroup Forest Diagram

Note. Group 1 of Zhang Xiaodong 2015 is the supervised resistance training, and Group 2 is the video resistance training; Group 1 of Gan Liju 2019 is HISRT resistance training, and Group 2 is HISRT + LBFRT comprehensive training.

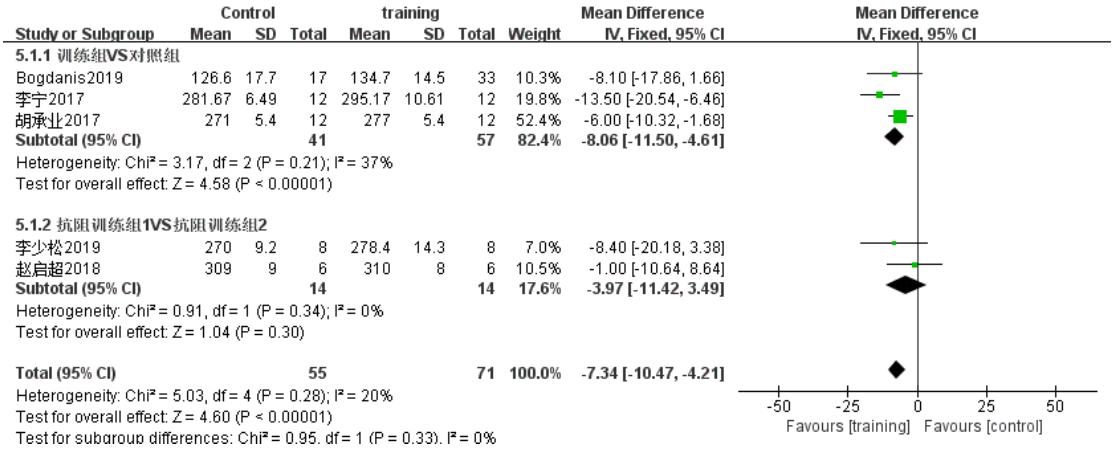

Figure 8. Forest Map Of Standing Long Jump Effect Size Subgroup

Note. Group 1 and Group 2 of Li Shaosong 2019 and Zhao Qichao 2018 are both two legs resistance training and single leg resistance training.

Conclusions

Because of the restriction of basketball court and rules, basketball players are required to obtain greater body acceleration in a short time and space to improve their bounce and air superiority ability. Therefore, the requirements for the strength quality of basketball players, especially the strength of lower limb muscles, are particularly critical. Therefore, in the literature included in this paper, the running height, the longitudinal jumping, the 20-m sprints and the standing long jump are selected as the intervention and evaluation indexes of Meta-analysis. Through the Meta-analysis of the literature included in this paper, it is confirmed that the 8-week resistance training is conducive to the improvement of athletes’ ability to run up and touch height ($P < 0.05$); Among them, before and after training and the comparison of components showed that different forms of resistance training interventions for 6 weeks had significant effects on the explosive force of basketball players' lower limbs. In addition, the effect of plyometric resistance training is particularly significant for the improvement of athletes' longitudinal jumping and touching ability of different ages ($P < 0.05$).

The analysis of the research results of 20-m sprints in the training group and the trial group showed that 8 weeks of resistance training significantly improved the ability of 20-m sprints ($P < 0.05$); HISRT resistance training and HISRT + LBFRT Comprehensive Resistance Training is not significant ($P > 0.05$) to improve the ability of 20-m sprints.

The analysis of the results of the study on the standing long jump in the training group and the trial group shows that, 8 weeks of resistance training had a significant effect on the training intervention to improve the stationary long jump ability ($P < 0.05$); HISRT resistance training and HISRT + LBFRT comprehensive resistance training is not significant ($P > 0.05$) on the training intervention to improve the stationary long jump. However, because of the small sample size and study inclusion, the comparison results are treated cautiously and different resistance effects all improve lower limb muscle strength.

To sum up, more high-quality resistance training intervention studies are required to provide reliable basis for effective intervention programs for lower limb muscle strength of basketball players, so as to consolidate and expand the results of this Meta-analysis. It is suggested that future research may quantify the variation law of training intensity and interval time corresponding to resistance training methods. The results of this study support that resistance training lasting for more than 6 weeks, 2-3 times per week, is an effective training strategy to improve the lower limb muscle strength and athletic performance of basketball players.

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