Medical Research Archives

European Society of Medicine

OPEN ACCESS

Published: December 31, 2023

Citation: Taneja K, Singla D, at al., 2023. Effect of Exercise training on Physical Fitness among Gymnastic Athletes: Systematic Review and Metanalysis, Medical Research Archives, [online] 11(12). https://doi.org/10.18103/mra.v11i12.4780

DOI
https://doi.org/10.18103/mra.v11i12.4780

ISSN: 2375-1924

REVIEW ARTICLE

Effect of Exercise Training on Physical Fitness among Gymnastic Athletes: Systematic Review and Metanalysis

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ABSTRACT

Objective: To determine the effects of exercise training on physical fitness parameters among gymnasts.

Methods: From 20 Dec 2022 to finish on 31 July 2023, an elaborate search was performed with these electronic databases (SCOPUS, PubMed, Science direct, ERIC) as well as on other sources of grey literature. The included studies were assessed using PEDRO Physiotherapy Evidence Database scale. Studies that are based on experimental design were only included to assess the physical fitness components in gymnastic players.

Results: Eight articles on exercise training in gymnast met all the inclusion criteria. Fair standard of quality of studies were noted. The findings of the research were quite credible. It indicated that jumps (n=6) of various types like vertical jump, countermovement jumps and drop jumps which were the most investigated performance parameter in gymnasts, followed by trunk muscle endurance (n=2), agility (n=1) and apparatus specific performances (n=1). Most of the physical training improved the lower limb power and trunk endurance in the gymnast. While there is a lack of evidence about strength, flexibility and balance parameters, which are of utmost importance for a gymnast hence the need to be studied.

Conclusion: With this systematic review we are trying to know what form of training is most beneficial for the gymnasts and it also established a strong case for the additional advantageous effects of physical training on physical fitness in gymnasts in particular.

Keywords: physical training; athletes; strength; power; resistance; medicine ball; agility; power, gymnast, gymnastic athlete.

Introduction

A single physical attribute cannot lead to an extraordinary performance. Therefore, holistic fitness is of critical importance to most of the sports, particularly in individual sports when compared to the team bound sports. Appropriate explosive strength or power, maximal strength, sprinting, flexibility, change of direction and balance ability is pivotal and key factor for the performance of an athlete.[1,5,20]

Artistic gymnastics is a sport of early specialisation as an athlete enters the high intensities of training during pre-pubertal years itself. In gymnastics relative strength is more important than absolute strength, so more focus is on body weight training to physically prepare gymnasts for powerful performance.[2] When we began to train an athlete at younger age it develops better power and strength which in turn allows achievement of maximal potential and ultimately lead to the long-term athlete development (LTAD). Gymnastics as a sport requires sufficient explosive power of lower limb along with maintenance of the body control. Progression within gymnastics requires the continuous development of new and increasingly complex skill with heightened scores of their performance in competitions as well.[3,4]

Exercise training implies that any type of interventional training in the form of Progressive Resistance Exercise (PRE), plyometric, neuromuscular training is being given to athlete which might bring changes to their physical parameters.[2,17,15,21]

Currently there is no reliable and valid measurement tool to evaluate the specific physical fitness abilities to infer about the successful competition in either men's or women's gymnastics. Previous studies have examined possible correlations between a gymnast's level of competition or intensity of training and various singular physical fitness trait which is used to interpret the performance of a gymnast.[4,18] It is observed that till date no previous systematic review on gymnastic population and their physical fitness have been explored with the intervention of physical training. Although previous studies have incorporated athletes as their participants from the range of different sports but as the effects of exercise training will vary depending on the background of sports of the athlete.[5,13,16,19]Therefore, their findings cannot be generalised to gymnastic athletes.

Due to the above reasons, the purpose of this study was to conduct a systematic review that provided updated information on the performance and physical fitness in gymnastic discipline. Hence, to know which type of training is the most appropriate to identify gymnasts with talent and better abilities, this review will be helpful as performance assessment as well as act as an essential step for progress to know the potential for the particular sport.

Methods

STUDY PROTOCOL

The present systematic review is conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) structure and reporting guidelines. The primary research question that needs to be studied "the effect of exercise training on athletic performance in Gymnasts".

PROTOCOL AND REGISTRATION

The protocol for this review is conducted according to the PRISMA and it was prospectively registered in the International Prospective Register of Systematic Reviews: https://www.crd.york.ac.uk/prospero/, CRD42023417691.

SEARCH STRATEGY

SCOPUS, PubMed, ScienceDirect and ERIC were used to search comprehensively for this article. The duration of the search was from the commencement date till July 2023 from each of the search engines following keywords were used to search the database: "exercise training " OR "fitness training " OR "physical training " OR "speed" OR "power" OR "strength" OR "endurance" OR "flexibility" OR "agility" OR "physical activity " OR "physical exercise " OR "physical therapy" OR "exercise " OR "fitness" OR "rehabilitation" OR "aerobic exercise" OR "functional performance" OR "exercise therapy " AND "physical endurance" AND "gymnastic player" OR "gymnastic athlete " OR "Gymnast". Additionally, supplementary searches were conducted using Google Scholar.

To begin the selection of the studies to be included, a review of all the titles was done before examining abstracts and full-text versions. Also, the entire text of the studies was examined in accordance with inclusion and exclusion criteria. Two authors screened the titles, abstracts, and full-text versions of studies which were found independently. If there were potential discrepancies between the two authors during search and review purposes, then it was resolved through consensus.

INCLUSION CRITERIA

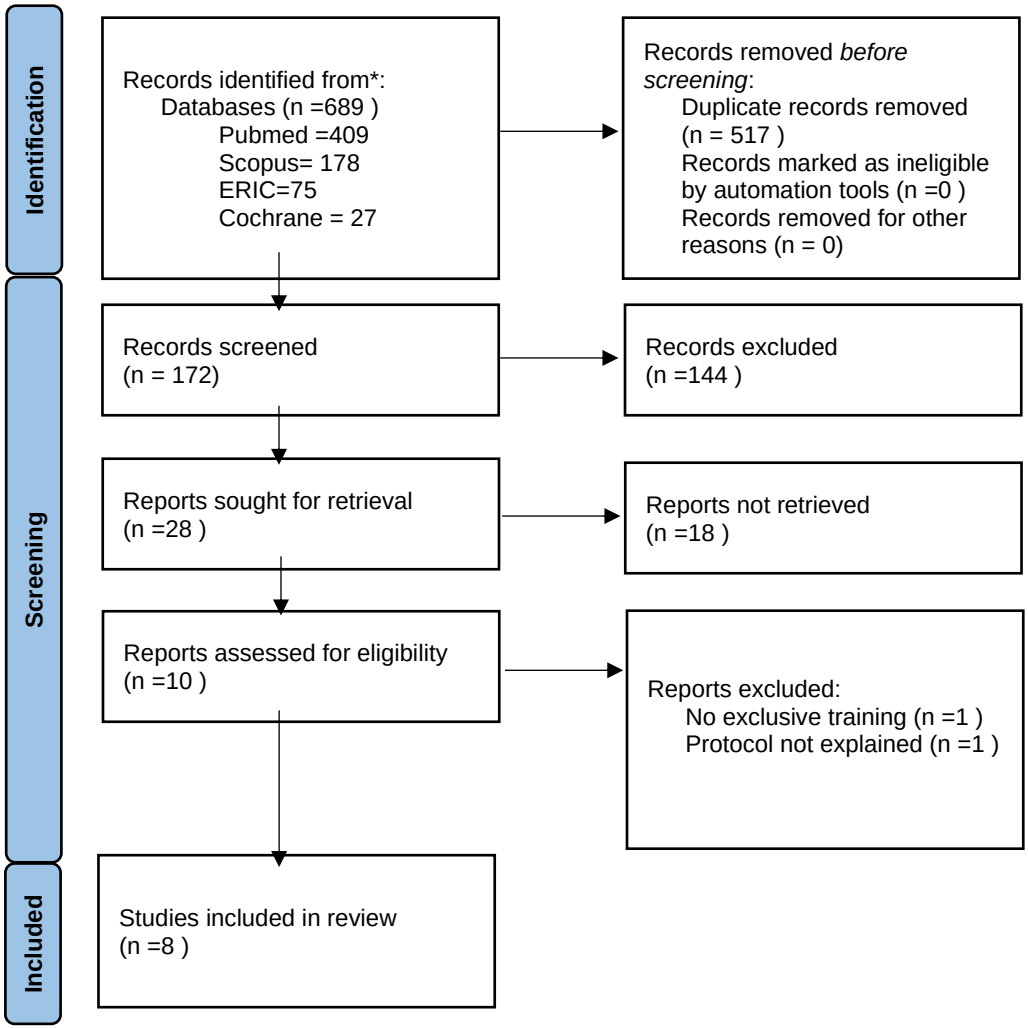
The PICOS is used to define the Eligibility Criteria for Population, Intervention, Comparison, and outcome. (Table 1).

Table 1: PICOS Strategy

P – Population	Gymnastic athletes
I-Intervention	Any form of physical training
C- comparison	Control group
O- Outcome	Any physical parameter
S- study design	RCTs

The following inclusion criteria had to be fulfilled by the articles to be a part of this study:
(1) papers using randomized controlled trials or crossover studies
(2) papers consisting of the effect of exercise training on athletic performance irrespective of age and gender
(3) having full text available in the English language only were included
(4) participants must be healthy gymnastic players (male and female)
(5) Studies that involve a combination of two or more types of exercise training methods

EXCLUSION CRITERIA
(1) Unpublished articles, conference papers, research articles from meeting proceedings, dissertations, or Ph.D. thesis
(2) Duplicates from the studies chosen based on the inclusion criteria
(3) If the exercise training intervention were combined with any nonexercised training and included any unsupervised training
(4) Papers describing the effect of exercise training on any other athletic performance or involving non-gymnasts



Results

THE PHYSIOTHERAPY EVIDENCE DATABASE (PEDRO) ASSESSMENT

The Physiotherapy Evidence Database (PEDro) Scale was utilized to assess the methodological quality of all the studies which were included. This scale consists of 11 items (refer to Table 2), which are answered yes or no, and 1 score is given if the answer is Yes and zero if the answer is No. The mean of total studies was calculated to classify the studies as being poor, fair, good, and excellent on the basis of the total score. Only one study has a score of excellent and 5 studies had a score of good and 2 studies scored as fair. We have got a mean score of 5.3 in total stating it as fair quality overall.

Author	Total PedRo score	Eligibility criteria specified (item does not score)	Random allocation	Concealed allocation	Similar groups of baselines	Blinding of subjects	Blinding of therapists	Blinding of assessors	Measure of one key outcome from 85 % sample	Intention to treat analysis	Variability and point measurement
Barbaret al [6]	6/10	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Paula et al [7]	6/10	Yes	yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Moeskops et al[2]	4/10	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes
Hall et al [3]	5/10	Yes	Yes	No	yes	No	No	No	Yes	Yes	Yes
Cabreias et al[10]	6/10	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes
Gregary et al [11]	7/10	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Dallas et al [12]	4/10	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes
Gabriele et al [13]	5/10	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes

POPULATION CHARACTERISTICS

Characteristics of the population of included studies were evaluated on these factors: 1. Sample size – A total size of 282 of all the selected studies were taken and it ranges from 9 to 190 with a mean of 35. 2.Gender: Most of the studies included only female athletes[1,2,3, 7, 10 ,11,13] and only one study included male athletes.[12] 3. Age: It varied from 7 years to 22 years. None was over 23 years of age and the mean age of 15.1 years. 4. Training: All athletes have a background in gymnastics training with them. 5. Type of gymnastics at the competitive level: Most of the gymnasts are Rhythmic gymnasts[6,7, 10], three studies included Artistic gymnasts [2, 12, 13] while 2 studies have not mentioned the type of gymnasts. [3,11]

INTERVENTIONAL CHARACTERISTICS

In total about 7 different interventional programs were studied in the included studies (Table 3) among which were Plyometric training, [6,3, 11,13] core and plyometric training together [10], Core training alone [7] and Neuromuscular training.[2] The duration of studies included range from 4 weeks to 12 months period with only one study of one-time intervention.[15] Almost every study had 1-3 sessions per week ranging from 20 – 60 mins and all studies were RCTs with control and experimental group being there as its composition. Table 3:

S.no.	Title	Author and Year	Methodology	Sample and Design of the study	Outcome measures	Results With SD and mean	Main finding
1	Analysis of the influence of plyometric training in improving the performance of athletes in rhythmic gymnastics	*Barbara Raquel Agostin*[1] 2017	12 weeks plyometric training : two-leg jumps; alternate-leg bounding; step jumps and drop jumps from a box for 20 mins each session	30 female rhythmic gymnasts: control group 15 athletes (Mean age ± SD: 15.2±1.5 years; and an experimental group (EG) of 15 athletes (Mean age ± SD: 15.4±1.2 years Pre -post test	Vertical jump, horizontal jump and agility (square test) were performed at 5 different moments.	VJ: mean height recorded for the CG increased from 34.27 cm to 44.0 cm, while that of the EG increased from 35.80 cm to 50.93 cm, (p=0.001) HJ: an increase of 13.52%, while in the EG it increased from 1.69 m to 2.05 m, an increase of 21.30%. Agility: 11.24 % reduction in time from 7.32 secs to 6.58 secs	Addition of plyometric exercises leads to better performance than the group trained with normal exercises, with greater strength in the lower limbs in vertical jump and horizontal jump, and improved agility
2	Effect of 12 Weeks Core Training on Core Muscle Performance in Rhythmic Gymnastics	Esteban-García, P[7]2021	12 weeks of core training with 8 forms: hollowing, bracing, dissociation, cat-camel, quadruped, front bridge, side bridge, supine bridge	24 national women rhythmic gymnasts, age 13.95 years A randomized controlled study	Body composition, isometric strength of trunk, core endurance and core muscle electromyographic activity were measured (EMG) after 12 weeks of core training	Within-group analysis of the TG showed an increase between pre- and post-training in prone bridge (p = 0.044, d = 0.5; 95% CI of MD = 0.083 s, 1.131 s).	Core strength training leads to improvements in body composition, as well as improvements in trunk strength and increases in muscle (EMG) activity
3	Individual Responses to an 8-Week Neuromuscular Training Intervention in Trained Pre-Pubescent Female Artistic Gymnasts	Moeskops , Paul J. Read[2]2018	8 weeks of NMT : two weekly sessions that lasted approximately 35 min each, which replaced their normal gymnastics conditioning	Thirty-four female artistic gymnasts aged between 6 and 12 years (n = 17 experimental group and n = 17 control group)	Leg stiffness, reactive strength index (RSI), movement proficiency (deep overhead squat and in-line lunge), and trunk muscular endurance (flexor and extensor tests deep squat and in-line lunge (left and right lead leg), sub-maximal hopping, drop jump, and trunk endurance holds	EG resulted in significantly more positive responders for measures of leg stiffness (41% versus 12% responded positively), extensor muscular endurance, (76% versus 29%), and competency in the deep overhead squat, (76% versus 29%) and in-line lunge (left lead leg) (65% versus 18%). Conversely, the number of positive responders for RSI (53% versus 61%), the flexor endurance test (88% versus 53%), and the right in-line lunge (47% versus 35%) were not significantly different between groups	Most young gymnasts responded positively to neuromuscular training from the perspective of improving movement proficiency and trunk endurance
4	Effect of Plyometric Training on Handspring Vault Performance and Functional Power in Youth Female Gymnasts	Hall E, Bishop DC, Gee[3]2016	6 weeks of plyometric training for 40 mins twice a week (both UL and LL) with gymnastic training	20 female gymnast (12.5 age)	Vault performance (run-up velocity, take-off velocity, hurdle to board distance, board contact time, table contact time and post-flight time) and CMJ height	A significantly greater change for the PTG than CG for run-up velocity (P = 0.002, ES = 0.48 [small]), take-off velocity (P = 0.005, ES = 0.77 [moderate]) hurdle to board distance (P = 0.027, ES = 0.54), board contact time (P = 0.016, ES = 0.49, table contact time (P = 0.029, ES = 0.25 and CMJ height (P = 0.037, ES = 0.26. However, no significant difference was found between the PTG and CG for pre-flight time (P = 0.67, ES = 0.09, shoulder angle on vault (P = 0.81, ES = 0.04 and hip angle on vault (P = 0.14, ES = 0.25).	The results shows that PT caused 'small to moderate' significant improvements in run-up velocity, take-off velocity, hurdle to board distance, board contact time, table contact time and post-flight time

S.no.	Title	Author and Year	Methodology	Sample and Design of the study	Outcome measures	Results With SD and mean	Main finding
5	Influence of plyometrics on jump capabilities in technical and aesthetical sports	Gabriela Mlsnová[13]et al 2017	30-weeks plyometric training program twice a week	Fifteen artistic gymnasts VG (age 12.4 ± 0.7 years); , fifteen fitness girl VF (age 13.8 ± 1.9 years), fifteen dancers VD (age 13.8 ± 2 years); and fifteen girls of general population VC (age 13.9 ± 1.5 years)	Countermovement jumps without and with arms swing and 10- second series of repeated vertical jumps done with ergometer (Fitro Jumper)	In the countermovement jump without arm swing was observed improvement height of the jump 3.4 ± 1.4 cm ($p < 0.00001$), in the countermovement jumps with arm swing 5.7 ± 1.5 cm ($p < 0.00001$), in difference of height of the jump between countermovement jump with and without arms swing 2.3 ± 1 cm ($p < 0.00001$), in ten second series of repeated vertical jumps without arms swing in the height of jump 4.2 ± 1.6 cm ($p < 0.00001$) and in power in active take off phase 8.8 ± 2.2 W.kg-1 ($p < 0.00001$)	We can conclude the effect of plyometric exercises was effective in combination with specific-strength training program for gymnasts
6	The Effects of an Eight-Week Integrated Functional Core and Plyometric Training Program on Young Rhythmic Gymnasts	Cabrejas C, Solana-Tramunt M, Morales J, Nieto[10] 2023	8 weeks of plyometric and core training	44 young (age = 10.5 ± 1.8 years old; peak height velocity, PHV = 12.2 ± 0.6 years old) female rhythmic gymnasts and randomly allocated them into a control group (CG) and an experimental group (EG) A randomized parallel clinical trial	Outcomes: countermovement jump (CMJ) and single-leg CMJ (SLCMJ) tests, conducted using a force platform	The EG obtained significantly better results in all variables, CMJ and SLCMJ ($p < 0.01$) tests.	An integrated functional CPT program improved explosive strength in a group of young rhythmic gymnasts and had a large impact on aspects of RG-specific performance
7	Effect of Plyometric Training on Jumping, Sprinting and Change of Direction Speed in Child Female Athletes	Gregory C. Bogdanis, Olyvia Donti 1, Athanasia Papia , Anastasia Donti , Nikolaos Apost [11]	Plyometric training for eight weeks	50 gymnast (age 7- 9 year) a repeated measures design	10 m sprint 20 m sprint 5+5m 10+10 COD 1 leg CMJ 2 leg CMJ Drop jump Squat jump Standing long jump	Improvement of one- and two-leg CMJ in PG had a greater effect size than CG (0.72 and 0.67 vs. 0.34 and 0.18, respectively). Group time interactions were found for 10 and 20 m sprint tests ($p = 0.018$ and $p = 0.011$, respectively) and for 10 + 10 m COD ($p = 0.008$) with the post hoc test showing improvement only for the PG ($p = 0.001$, 0.001, and 0.003 and $d = 1.1$, 1.14, and 0.6, respectively)	Supplementary plyometric training increased sprint and COD performance more than regular gymnastics training, while jumping performance was equally improved in both groups
8	Acute enhancement of jumping performance after different plyometric stimuli in high level gymnasts is associated with post-activation potentiation	George Dallas , Panagiotis pappas[12]2019	Conditioning protocol (PAP) that consisted of 10 repetitions of the Rondat exercise with 15 seconds between each repetition or 2 sets of 5 tuck jumps with a 30 seconds interval between sets	Thirty–five high level male and female artistic gymnasts Nineteen females (age: 19.21±3.95 years, 16 male (age: 21.75±4.19 years, one time study	DJ before and after two different conditioning stimuli	DJ height main effects for time ($F=21.137$, $P=0.001$)	Our results suggest that high intensity contractions such as Rondat, and medium-intensity contractions, performed during a warm-up or as part of a training session may positively affect jumping performance

OUTCOME AND MEASURES

As primary results, we evaluated the effect of exercise training on the various fitness parameters of the gymnastic athletes, majorly the quantitative parameters. The following outcome variables were assessed by the authors of the selected studies to determine athletic performance: Strength, power, and agility. Eight of the included studies found that exercise training in the form of physical training did improve the physical parameters of a gymnast.

META-ANALYSIS

All data were calculated and analysed by MedCalc Software. The analysis model was a random effect model. The standardised Mean Deviation and Standard Deviation with 95 percent CI were calculated, which indicated the overall pooled effects.

HETEROGENEITY

Statistical heterogeneity (I^2) and overall effect test were calculated, and the threshold value of 0.05 was used for statistical significance. It ranges between 0.00 to 77.32 for the analysis of jumps as a parameter. Statistics (5.433) with df (5) and *p* values (0.36) were examined to provide a test of the null hypothesis that all studies shared a common effect size. If all studies shared a similar effect, the Q value would be approximately equal to the degrees of freedom. The I^2 statistic (I^2 =7.98) identified the proportion of the observed variance that reflected the differences in true effect sizes as opposed to sampling error.

EFFECT OF EXERCISE TRAINING ON JUMPS

Most of the studies have given positive effects on lower limb explosive power in the form of countermovement jumps (CMJ) and vertical jumps (VJ) [6, 2, 3,10,11,12]. Among these studies one study has used force plates to measure the drop jumps (DJ) and CMJ[10] which has provided the most accurate results. Plyometric led to repeated stimuli of explosive training which in turn led to improvement of jumping abilities like Vertical jump [6], Drop jump [2,11], Countermovement jumps [3,13,11] and Squat jump [11].

Jumps were measured and found that Bogdanis with CMJ (SMD= 0.655 ,95 %CI 0.0501 to 1.261) and Cabrejas with VJ (SMD 0.655 ,95%CI 0.0402 to 1.269) found the most effective as well similar effects in other jumps with an important difference. Then Hall with CMJ (SMD 0.290 CI-0.615 to 1.195) and Mlsnova with CMJ (SMD 0.555, CI 95 %-0.188 to 1.297) and then Barbara with VJ (SMD 1.452, CI 95% 0.629 to 2.275) and lastly Dallas VJ (SMD 0.450 CI -0.0275 to 0.928) with low to moderate certainty evidence overall.

Table 4: Effect of training on Jumps [11,10,3,13,6,12]

Study	N1	N2	Pre-Mean	Post mean	Pre SD	Post SD	SMD	95%CI
Bogdanis et al 2019	33	17	18.1	20.1	3.2	2.9	0.655	0.0501 to 1.261
Cabrejas et al 2023	23	21	0.19	0.21	0.03	0.03	0.655	0.0402 to 1.269
Hall et al 2016	10	10	43.5	45.3	6.1	5.8	0.290	-0.615 to 1.195
Mlsnová et al 2017	15	15	28.8	32.1	6.4	5.1	0.555	-0.188 to 1.297
Barbara et al 2017	15	15	35.8	46.07	6.97	6.79	1.452	0.629 to 2.275
Dallas et al 2019	35	35	24.3	27.6	6.92	7.56	0.450	-0.0275 to 0.928
Total (fixed Effects)	131	113	--	--	--	--	0.632	0.374 to 0.889
Total (random effects)	131	113	--	--	--	--	0.636	0.366 to 0.907

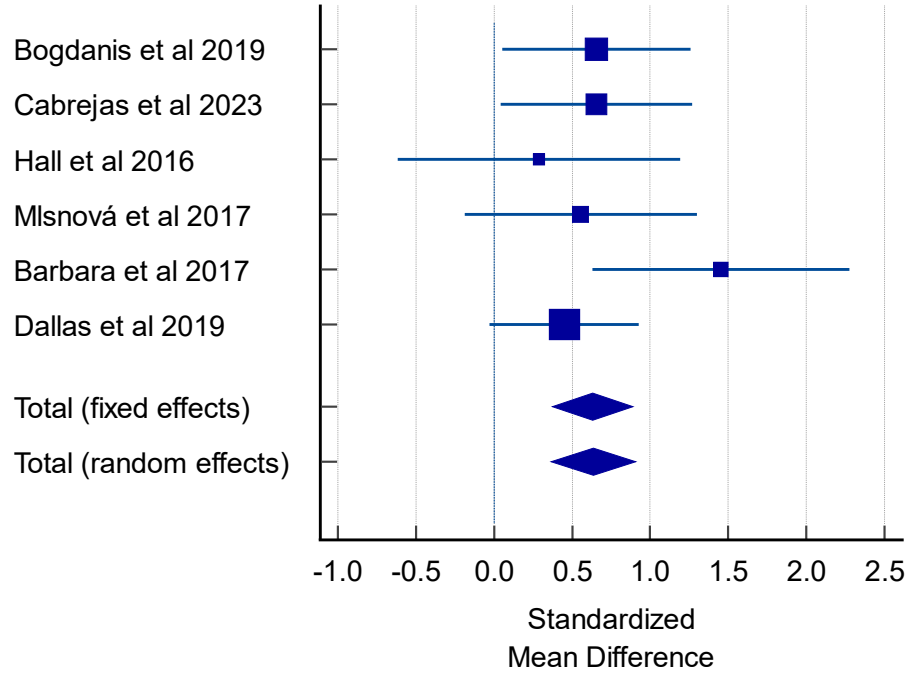
Heterogeneity: q= 5.43 p=0.365

N1 = no. of participants in experimental group N2 = no. of participants in control group

Pre mean = pre value of the mean of the experimental group Post mean = post value of the experimental group

Pre SD = pre value of the standard deviation of the experimental group Post SD = post value of the standard deviation of the experimental group

SMD= standardized Mean Difference, CI= confidence interval



Effect of exercise on Core

Paula et al[7] found that with the advent of core training, body composition which included the lean mass of the trunk and bone mass, they improved along with the isometric strength of the trunk which was measured using prone bridge core endurance test. (Biering Sorenson test)

Another study by Moeskops also studied strength and endurance of trunk muscle specifically and found positive effects as well.[2]

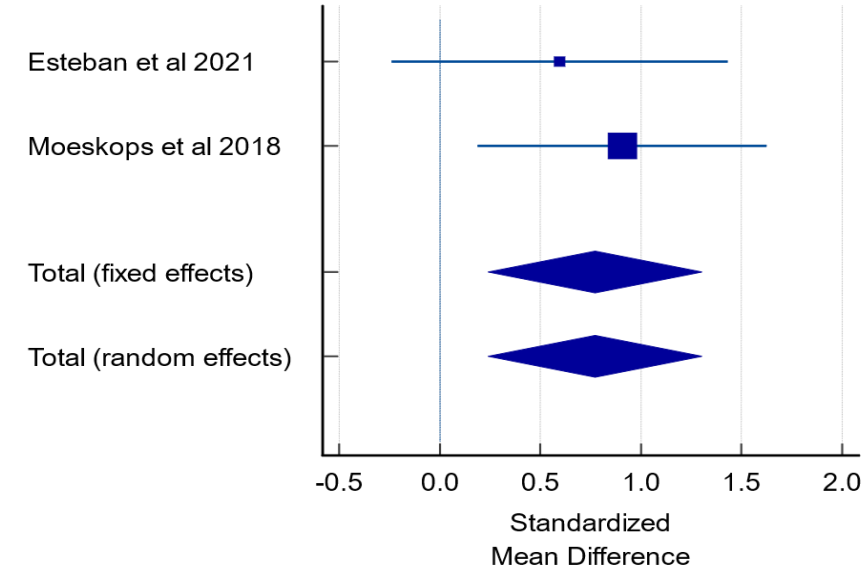
When compared the core strength or trunk muscle endurance, the results are respectively: Esteban (SMD 0.596 95 %CI -0.241 to 1.432 and Moeskops (SMD 0.907 ,95%CI 0.189 to 1.625). Hence there are significant effects on core strength by physical training interventions.

Table 5: Effect of exercise training on Core [7,2]

Study	N1	N2	Pre mean1	Post Mean2	PreSD1	Post SD2	SMD	95 %CI
Esteban[7]	12	12	27.99	31.06	13.86	16.57	0.596	-0.241 to 1.432
MoeskopS et al[2]	17	17	100.5	179.2	72.0	95.8	0.907	0.189 to 1.625
Total (fixed Effects)	29	29	--	--	--	--	0.772	0.240 to 1.304
Total (random effects)	29	29	--	--	--	--	0.772	0.240 to 1.304

Heterogeneity: q= 0.336 p=0.561
N1 = no. of participants in experimental group N2 = no. of participants in control group
Pre mean = pre value of the mean of the experimental group Post mean = post value of the experimental group

Pre SD = pre value of the standard deviation of the experimental group Post SD = post value of the standard deviation of the experimental group



SMD= standardized Mean Difference, CI= confidence interval

Effect of Exercise on Agility

In one of the studies [6] it was observed that there was a reduction in time to do an agility test by about 11.24 percent after the intervention of plyometric training, that is the test time reduced from 7.32 to 6.58 seconds which was statistically significant.

Discussion

This is the first systematic review conducted to determine the effect of exercise training on physical performance parameters in gymnasts. The objective is to understand what various types of exercise training have been beneficial for the gymnastic population in improving its physical performance parameters. The outcome measures involve strength, power, agility, core, flexibility, and balance in gymnasts. We have 8 studies that were included in this review which were rated as 5.3 and fair quality overall to have a methodological quality in PEDro scores. The results reflected that the exercise training of various forms in addition to their routine gymnastic training has a large effect on improving jump height and lower limb power [3.13] and a moderate effect on improving sprint ability [11] with muscle endurance capacity of core.[7] There could be many performance parameters which have not been studied in detail to arrive at some conclusive results for gymnasts.

It is suggested that most exercise training tends to improve the performance parameters in gymnasts[3, 11]. Since there is no single training factor analysis for various variables, it revealed that the effects cannot be concluded. We found different combinations of protocols with variable durations while combining the findings of research studies, or this review, thus, making it difficult for us to compare the effects amongst different studies. (Table 3) Most of the researchers have used plyometric training as their mode of training, some resistance or PRE, while some utilized a combination of plyometric and resistance. Although one of the studies used core training as well. Different protocols were followed across studies with variations in the study time ranging from 6 weeks to 12 weeks protocols, therefore the concrete conclusion is difficult to arrive at. The Dosimetry of exercise or intervention varied with 2 – 3 sessions per week[3.6.7] with one[12] studied the acute effect of a single session of plyometric stimuli for 3-week period.

Also, research populations have been marked in the studies that are included. There were different research populations chosen by the different researchers in context to age, gender, and level of competition[12]. Also, many studies have 12-14 age as the average age of participants while 2 of the studies [2,11] had much younger participants of 6-9 years of age. Since gymnastic is a sport of starting at early stage of life which justify the age groups.

In terms of gender, seven studies [3,1,2,7,11,10,13] had female gender as their participants with ages (10.5- 15), while one of the studies have their gymnasts as male,[12] in fact it included both male and female as their participants. Considering the level of competition, one of the studies [12] belonged to the adult age group i.e., elite gymnasts (15 and

above) as the participants and other studies [13, 11] have non–elite gymnasts as the participants. Hence, we recommend more studies on Male gymnasts with variable level of competitions for standardization of the results. Therefore, future dose-response studies are different gender and age groups to be present for effective comparison across research studies.

It has been observed that physical training especially the form of plyometrics can improve the performance of athletes as it tends to improve the arm – leg coordination along with power. It was seen in the study by Barbara et al that the jumping ability score improved by 57 %, and that 43 % of this is due to gains in muscle strength only. Therefore, it was observed that vertical jumps are measures of explosive strength capacity and anaerobic power as well.[6]

As training is an added intervention to their normal routine sports activity during the intervention period, therefore, it will be difficult to conclude the independent contribution of each protocol being given. While some authors counter the need to clarify about the improvement achieved is due to the type of interventional training or rather increase in the number of hours by an athlete for the training. [6] In most of the studies, it is seen that jumps have improved positively and they are key indicators of power and is due to improved production of force and neuromuscular responses [3]. Plyometrics has been an inexpensive way of training and along with that, it leads to the repeated stimulus of explosive training causing improvement of jumping abilities.

In relation to the effects of intervention, studies were found with plyometric training as the intervention protocol for gymnasts for better performances. In one of the studies other than plyometrics where core training was given.[7] Core stability might contribute to the gymnast's performance as it would facilitate the transmission of forces generated by the lower body to the upper body during technical elements and ultimately it would enhance balance control.[3] The positive data on the gymnasts' isometric strength after core training could reflect the positive effect of core training as a complementary training to gymnastic training.

The definition of agility is a rapid whole-body movement with a change of velocity or direction in response to a stimulus.[6] Physiologically agility tasks tend to demand a quick change from eccentric to concentric muscle movement in leg extensor muscles, so plyometric exercises have been seen to increase the production of muscle strength and movement efficiency by diminishing ground reaction times, hence improving the agility for a gymnast.[6]

In one of the studies where Neuromuscular training was the intervention, which included isometric endurance exercises along with traditional gymnastic shaping exercises specific to their apparatus can improve trunk muscle endurance better.[2]

It has been understood that muscle strength, agility, and jumping ability are associated with each other or it can be assumed that these fitness attributes share quite similar physiological and biomechanical adaptations to various exercise programs. Improvements in different attributes can be justified as this systematic review, involves several training approaches that combined vertical and horizontal drills along with unilateral and bilateral movements. As plyometric training is the most form of intervention that is used, it is more inexpensive to implement than any other training as it requires a small physical space. Younger athletes tend to take plyometrics as fun exercise as well. Also, it is seen that plyometrics may be useful in the reduction or prevention of injuries and hence most effective to be part of the training routine. There is added potential advantage seen with physical training as it gives an athlete a competitive advantage. Although this hypothesis should be explored more for future researches. Hence physical training should be an integrated approach when training an individual.

There was a study in which an Eccentric training led to improved performance of a gymnast which helps to implement a novel and efficient preparatory exercise, but since this study was specific to eccentric training and only ring apparatus performance was measured, it can't be used to derive a conclusion [8] and not included in this systematic review as well.

CONSIDERATIONS WITH PLYOMETRIC TRAINING

Before deciding on the program of performing plyometric training with correct progression and avoidance of overloading for prevention of injuries, we must start the program with low to moderate intensity and focus on its technical proficiency. The training should be with progressive overloading either by increasing the reps or increasing the difficulty. Along with care for progression there should be an appropriate recovery period of at least 24- 48 hours which allows minimizing of risks of injuries and enabling adaptations to occur for retention. Plyometric training leads to an increase in sprint velocity because of better force production by initiating more recruitments of Type II muscle

fibres. Also, the eccentric contraction of landing foot and knee flexion on plantar flexion activates the stretch reflex of the gastrocnemius and quadriceps, while the concentric movement allows the series elastic component to produce force.[3]

While in one of the studies [14] there was no external training and only effects due to gymnastic training is seen, it had found that gymnastic training in itself resulted in hypertrophic changes in muscles and improved neuromuscular coordination, especially in glenohumeral extensors and elbow joint extensors. Hence there cannot be a direct conclusion being derived as some of the variables are changed due to just the gymnastic training.

RELEVANCE OF GYMNASTIC TRAINING FOR LONG-TERM ATHLETE DEVELOPMENT

The gymnastic training is quite beneficial for a young athlete as it has led to increased bone mass quite early when compared to other sports. Also since puberty is the most appropriate time for bone strengthening, mechanical loading happening through athletic training will maximize the bone mineral gain. Since the bone mineral accrual mass increases which reduces the risk of osteoporosis later in life. Therefore, gymnastic training in itself has been found to be osteogenic for children and adolescents. Moreover, the addition of core training has the added benefits for athletes' general wellbeing. The main findings of Paula et al were that core training had led to an increase in trunk lean mass, bone mass, isometric strength, and endurance strength of the core muscles.[7]

ADVERSE EFFECTS

Relative safety of interventional training and intervention-related injuries were not reported in any of the included studies in our review. Taper strategy can help prevention of injuries and hence must be considered as it is related to overload-induced inflammation occurring from large eccentric loads. Also, the progression and prescription of exercise training are not clearly defined, its safety is under consideration.

Limitations

Acknowledge of potential limitations of this review must be known. Firstly, limitation in context with the intensity of exercises which wasn't clearly mentioned in reported studies. Secondly, all included studies have not mentioned any possible negative impacts hence it's not fully transparent in context with any pains, injuries, or other adverse effects. Thirdly, four of the studies have failed to score greater than 5 points on the PEDro scale and only one is of ultimate high quality. It's only because therapists as well as athletes were not blinded. There is the pooling of both youth and adult data on gymnasts due to a lack of studies in this specific population. Also, as there wasn't any reported technique of measurement of physiological maturity (i. e. Skelton age) there is heterogeneity across the studies. Hence future studies must attempt to overcome this as adaptations and fitness parameters vary considering physiological maturation in athletes. The evidence base should be expanded on other attributes of the gymnasts. None of the studies was done on disabled or para-athletes so these results can't be applied to para-athletes.

Future considerations

As of now, no studies were found on the measurement of balance and flexibility directly, although both are important for the performance of a gymnast considering the apparatus of floor and beam. As the growth, maturation, training experience, and cognitive development of two individuals of the same chronological age vary, so does their ability to train along with retention of training effects too. Therefore, more studies on a young or adolescent athlete or age-specific athlete will allow us to come to any specific conclusion about the intervention of training as every athlete responds in a different way when exposed to the training.

Conclusion

Although research has demonstrated that most of the forms of physical training tend to improve the physical parameters in the gymnast. However, researches that solely assessed the performance were limited. Although parameters have failed to account for derivation at a specific conclusion and differentiation between which specific training to be inculcated. The development of a standardized exercise protocol is here forth needed to have better comparisons for the gymnasts. Since very few articles are available for this review so they can't be dependent or relied upon completely but can be used as a guiding light.

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