THE EFFECT OF TRAINING IN MAXIMAL ISOMETRIC STRENGTH IN YOUNG ARTISTIC GYMNASTS

George C. Dallas[1], Paschalis Kirialanis[2], Costas G. Dallas[1], Vassilis Mellos[3]

[1]Kapodistrian University of Athens, School of Physical Education and Sport Science, Athens Greece
[2]Komotini, Greece
3University of Thessaly, Physical Education and Sport Science, Trikala, Greece

Original article

Abstract

Different methods have been developed for assessing muscle strength of various limbs in sport performance. The purpose of this study was to examine the maximal voluntary isometric strength in 57 young male gymnasts and 74 non-gymnasts. They were tested for isometric strength during force flexion and extension of upper and lower limbs during a 5-seconds maximal voluntary isometric strength for the right and left side respectively. The results showed significant differences between gymnasts and non-gymnasts (p<.05). Further, significant interaction revealed: a) for right side with respect to the force flexion at the elbow and shoulder joints; b) for the left side with respect to the force flexion for the elbow, shoulder and hip joint, c) with respect to the force extension of the right side for the elbow, shoulder, hip and knee joints, d) for the extension of the left side for elbow, shoulder, and hip joints. The above results must be taken under consideration by trainers seeking to improve the strength and overall training level of their athletes.

Keywords: *muscular strength; isometric contraction; artistic gymnastics.*

INTRODUCTION

Artistic gymnastics (AG) is a very difficult and complicated sport activity that involves bounding, jumping, tumbling, vertical landings, as well rapid accelerations and decelerations movements, which evoke high-impact loading strains, high strains rates and varied strain distribution patterns on the skeleton (Daly, Rich, & Bass, 1999; Dowthwaite & Scerpella, 2009; Farana, Jandacka, Uchytil, Zahradnik, & Irwin, 2014). Additionally, the permanent increase of exercises difficulty in various apparatus demand from early age the development of muscular strength in static strength elements (cross, blanche, Japanese handstand, e.t.c.) as well in dynamic conditions as an impact velocity of 8.5m/sec generate ground reaction forces which have been measured from 8 to 18 times body weight *(*McNitt-Gray, 1991; Osguven, & Berne, 1988). Gymnasts alone will not develop an adequate level of strength for advanced gymnastics that means a highly developed level of performance cannot be maintained even by intensive performance of the event itself (Bührle, & Werner, 1984). Muscular strength increases fairly linearly with chronological age from early childhood until approximately 13 or 14 years of age (mid-puberty) in boys (Parker, Round, Sacco, & Jones, 1990). The old notion that children could not benefit from resistance training due to inadequate levels of circulating androgens is not in valid (Faigenbaum, Kraemer, Cahill, & Roberts, 1996; Faigenbaum, Westcott, Loud, & Long, 1999; Sadres, Eliakim, Constantini, Lidor, & Falk, 2001; Stone, Sands, Carlook, Callan, Diokie, Daigle, Hartman, et al, 2004). At present, medical and fitness organizations support children’s participation in appropriately designed and competently supervised youth resistance training programs. Children’s that had following several weeks of strength training have reported significant improvements in strength (ACSM, 2000; Faigenbaum et al, 1996; Ramsay et al, 1990; Sewall, & Micheli, 1986; Weltman et al, 1986). Previous studies support that untrained children can enhance their upper-body strength and local muscle endurance by participating in a progressive resistance training program (Faigenbaum et al, 2001). Also, heavy-resistance training (or submaximal workloads, increase repetitive strength performance) is capable of enhancing single-repetition strength performance at maximum workloads (Hickson, Hidaka, & Foster, 1994; Hickson, Dvorak, Gorostiaga, Kurowski, & Foster, 1998). Fukunaga and his colleagues (1992) reported significant increases in upper arm isometric and isokinetic strength and lean (muscle and bone) cross-sectional area determined by ultrasound in preadolescent boys. The Position Statement on Youth Resistance Training published by National Strength & Conditioning Association from US upheld the more resent belief that properly supervised and well planned resistance training can be effective & safe in improving the strength of preadolescent and adolescent populations (Naughton, Farpour-Lambert, Carlson, Bradney, & Van Praagh, 2000). Currently different form of dynamometers such, isometric, isokinetic and isotonic dynamometer are used to assess muscular function with each form has its drawbacks. The stationary knee muscle dynamometer has shown to be more reliable in assessing knee muscle strength than hand-held dynamometer (Tood, German, & Gandevia, 2004). Muscle power has been limited to measuring only dynamic exertion in which work-amount appears as an external movement, because it has been generally evaluated from the dynamic workload or the rate of workload. Static muscular contraction has excluded the concept of muscle power, since the dynamic workload with static contraction is zero (0), and attention has focused only on evaluating maximal muscle strength (MAX).

Isometric tests are generally performed to quantify the maximal force and/or the maximal rate of force development (Hakkinen, & Komi, 1986). However, analysis of the developmental phase (the initial phase until reaching the maximal force) of the force-time curves during static explosive strength exertion has revealed the existence of individual differences and gender differences. For example, when a person exerts a static explosive strength maximally and rapidly, even if the peak force, namely maximal muscle strength (MMS), is the same, individual differences is found in the time to reach and there are people who can rapidly reach MMS and those who cannot (Demura, Yamaji, Nagasawa, & Minami, 2000). Several studies have investigated the effect of different types of training program in development of strength during pre-pubertal ages (during pre-adolescent). Data of Docherty and his colleagues (1987) has reported no significant strength gains after the intervention of a strength training program. On the contrary, numerous other studies comparing strength trained children with age and sex matched controls have shown strength gains are possible (Ozmun, Mikesky, & Surbukg, 1994; Mellos Dallas, Kirialanis, Fiorilli, & Di Cagno, 2013). To the best of our knowledge only few studies have evaluate muscular strength of gymnasts during training period. In all sports, the physical strength of both boys and girls of ages up to 11 years are similar whereas from 12 to 14 years, the boys are stronger than the girls (Maffulli, King, & Helms 1994). Parket et al. (1990) concluded that for non-athletic boys and girls, the isometric muscle strength increases continually until the age of 20. However, it has not been established whether this is the same for athletes. According to Maffulli, King, & Helms (1994) a plateau was observed for girls athletes at the age of 18 whereas the muscle strength of boy athletes continued to increase at the age of 18. Bassa and his colleagues (2002) have described the isometric and isokinetic knee torque in pre-pubescent male gymnasts six months after the beginning of the annual training period. To the author's knowledge there is a lack of data according the evaluation of isometric muscle strength after the end of the annual training period. Additionally, there are not previous studies that compare these results with those of previous annual training period in order to examine the level of improvement in isometric muscle. The main hypothesis of this study was that gymnastics training produces significant improvement on maximum isometric strength in young male gymnasts. Thus, the purpose of this study was to examine the effects of training on maximum voluntary isometric strength (MVIS) in young male gymnasts and to compare these results with the corresponding of previous annual training period.

METHODS

Fifty-seven pre-adolescent gymnasts (age: 10.00 ± 0.82 years; body mass 29.89 ± 4.02 Kg; body height: 131.88 ± 7.21 cm) and 74 non gymnasts (age: 10.00 ± 0.63 years; body mass 36.20 ± 4.04 Kg; body height: 137.19 ± 7.22 cm) volunteered to participate in this study. Gymnasts had a 4.5±1.0 training experience and they were from different gymnastics clubs from North Greece. Non gymnasts were students of elementary school that they had not any sport activity except lessons-courses of physical education. Both the children and their parents were informed about this research project and parental written consent was obtained. The study was designed according to the Declaration of Helsinki and was approved by the local Ethics Committee. The following exclusionary criteria were used: (a) children with a chronic pediatric disease, (b) children with an orthopedic limitation, and (c) children older than 12 years of age at the beginning of the study.

Participants had followed training programs of their clubs during their five years training with a frequency of 3 hours per day, for six days per week. Two measurements were performed, each one after the end of the annual training competition period, in order to evaluate the effectiveness of the current training program. Subjects were instructed, orally and in writing prior to first testing. All subjects participated in familiarization practice, organized before the testing procedures. During this time, they were taught the proper technique on each testing exercise, and any questions they had were answered. The strength testing was performed between 8am and 12 noon with the same investigators performing each test. A Kin-Com dynamometer (Kinetic Communicator II: Chattecx Corp, 101 Memorial Dr, Chattanooga, TN 37405) (Farrell, & Richards, 1986) was used to measure maximum voluntary isometric force (N) for elbow, shoulder, hip, and knee in flexion and extension of these joints. MVIS for the above muscles was measured on a dynamometer chair on which subjects were tested in a 90 degree angle during extension-flexion on both side in the following joints: elbow, shoulder, trunk, hip and knee (Era, Lyyra, Viitasalo, & Hikkinen, 1992; Kanehisa, & Miyashita, 1983). A great number of technical gymnastic skills are characterized by the application of isometric strength in order to preserve the body position, especially during static exercises as: standing scale in floor exercises, L-sit or straddle sit on various apparatus (still rings, parallel bars) hanging or support scales on still rings, e.t.c. During warm-up and especially at the end of a training session, gymnasts execute special types of isotonic or isometric exercises, e.g. handstand push up in bands, press to handstand, windhield wipers, levers, arch-hollow throws, e.t.c., in order to improve the muscular strength of various parts of the body.

Triplicate measures for five muscle groups were obtained with the highest values reported. Adequate test periods of three minutes were given between tests to ensure that the subjects' initial performance on each test was not affected by muscle fatigue. The strength's tests were performed from "different body positions" according the joints measurements. In all cases Velcro straps were used to stabilize the peripheral joints of participants. All subjects performed 10 minutes of stretching exercises before all testing and training procedures. All testing procedures were closely supervised, and uniform encouragement was offered to all subjects. After 5 min recovery each subject performed 3 trials for maximum isometric effort for extension and flexion of 5 seconds (Surakka, Virtanen, Aunola, Maentaka, & Pekkarinen, 2005) for the above mentioned joints. All three trials were used for the assessment of reliability, while the trial with the best value (Fmax) recorded and used for further statistical analysis.

A two-way MANOVA (group x measurement) with repeated measures on both factors was used followed by post-hoc pair wise comparisons with Bonferroni corrections of age groups within each athletic level and of athletic levels within each age group. The level of significance was set at $p < 0.05$. All values are presented as means ± SD. Interclass reliability coefficients were calculated and the respective results are presented in table 1.

RESULTS

Table 2 summarizes the means of maximum isometric voluntary strength of Force flexion in various joints. It is obvious that training had a positive effect on force increment in both groups except for flexion on left elbow in gymnasts. Moreover, percentage improvement was greater in non gymnasts compared with gymnasts.

Table 1.
Interclass reliability analysis for the force flexion and extension assessment of strength.

	Flexion	Extension
Elbow	.693	.683
Shoulder	.764	.764
Hip	.692	.692
Knee	.662	.669

Table 2
Maximum isometric voluntary strength of the sample of Force flexion (N).

	Gymnasts		Non Gymnasts	
	Measurement 1	Measurement 2	Measurement 1	Measurement 2
F flexion right elbow	13.76 ± 4.85	14.64 ± 6.01	10.89 ± 3.83	14.92 ± 6.78
F flexion right shoulder	17.73 ± 5.98	18.17 ± 7.36	12.39 ± 4.49	16.34 ± 7.55
F flexion right hip	18.69 ± 5.54	22.33 ± 8.64	14.15 ± 4.03	15.51 ± 5.90
F flexion right knee	10.80 ± 4.14	13.67 ± 6.07	9.53 ± 2.86	13.00 ± 5.34
F flexion Left elbow	13.97 ± 3.54	13.89 ± 4.61	10.99 ± 3.39	14.08 ± 5.22
F flexion left shoulder	17.69 ± 4.71	17.80 ± 6.73	12.19 ± 3.97	15.97 ± 5.65
F flexion left hip	17.40 ± 5.07	21.93 ± 7.63	13.69 ± 3.25	16.19 ± 6.49
F flexion left knee	10.05 ± 2.44	11.53 ± 4.81	9.09 ± 3.11	11.12 ± 5.03
F flexion body	30.11 ± 9.63	38.31 ± 11.65	18.00±4.27	30.18 ± 12.82

Table 3
Maximum isometric voluntary strength of the sample of Force extension (N).

	Gymnasts		Non Gymnasts	
	Measurement 1	Measurement 2	Measurement 1	Measurement 2
F extension right elbow	13.92 ± 4.37	13.27 ± 5.20	9.05 ± 2.19	10.36 ± 3.82
F extension right shoulder	25.74 ± 6.55	23.87 ± 8.41	16.41 ± 5.15	20.39 ± 8.22
F extension right hip	45.34 ± 13.95	44.44 ± 17.86	30.84± 7.91	41.00 ± 16.67
F extension right knee	25.17 ± 9.48	25.59 ± 12.61	19.29 ± 7.27	25.82 ± 13.98
F extension left elbow	12.24 ± 3.13	10.84 ± 4.33	9.12 ± 3.02	10.84 ± 4.33
F extension left shoulder	25.47 ± 6.34	22.72 ± 8.95	16.30 ± 4.43	19.46 ± 8.22
F extension left hip	43.84 ± 13.54	40.07 ± 16.98	28.49 ± 7.81	39.04 ± 17.92
F extension left knee	22.57 ± 7.47	28.25 ± 11.56	20.41 ± 8.36	27.28 ± 12.98
F extension body	58.81 ± 20.83	86.01 ± 24.83	47.08 ± 13.14	54.25 ± 22.68

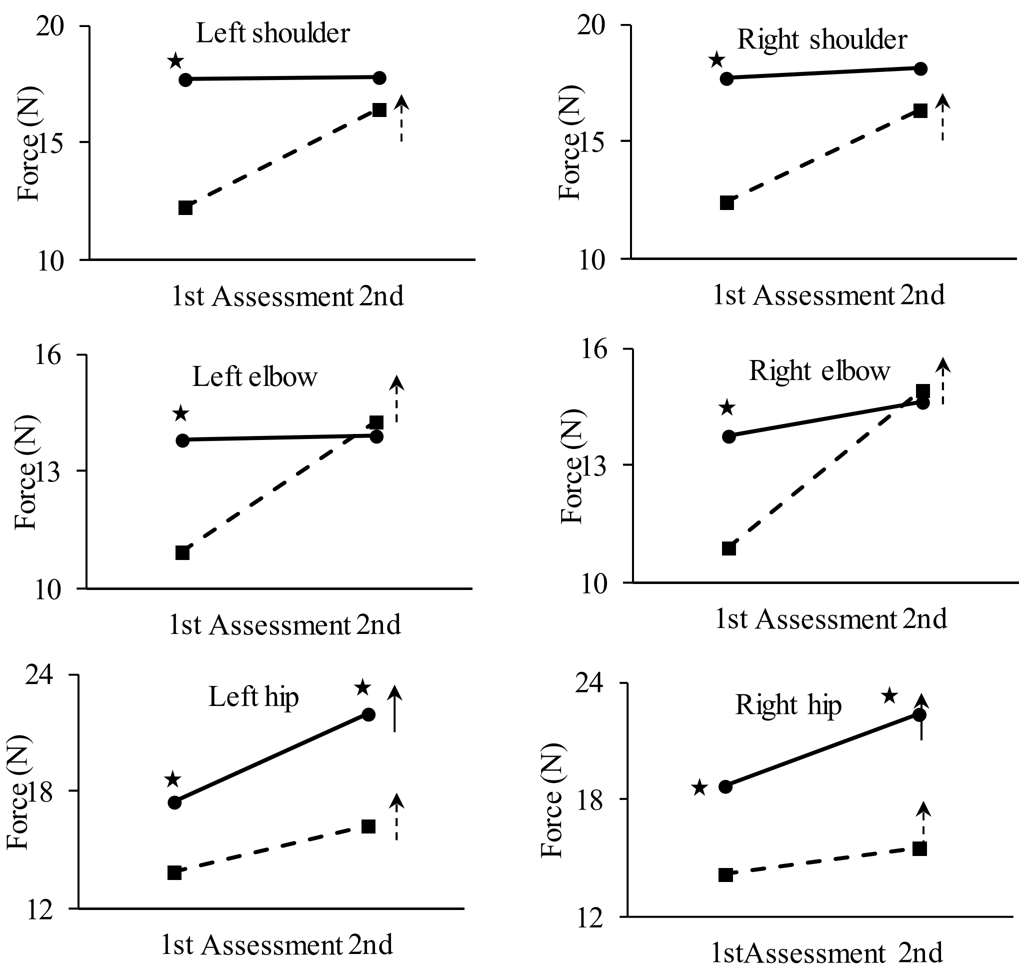

Figure 1. Force flexion mean values of different joints for the gymnasts (continuous lines) and non-gymnasts (dotted lines) groups at the two assessments. Statistically significant differences at the 0.05 level between the two groups at each assessment are denoted by asterisks. Statistically significant differences at the 0.05 level between the two assessments for each group are denoted by arrows.

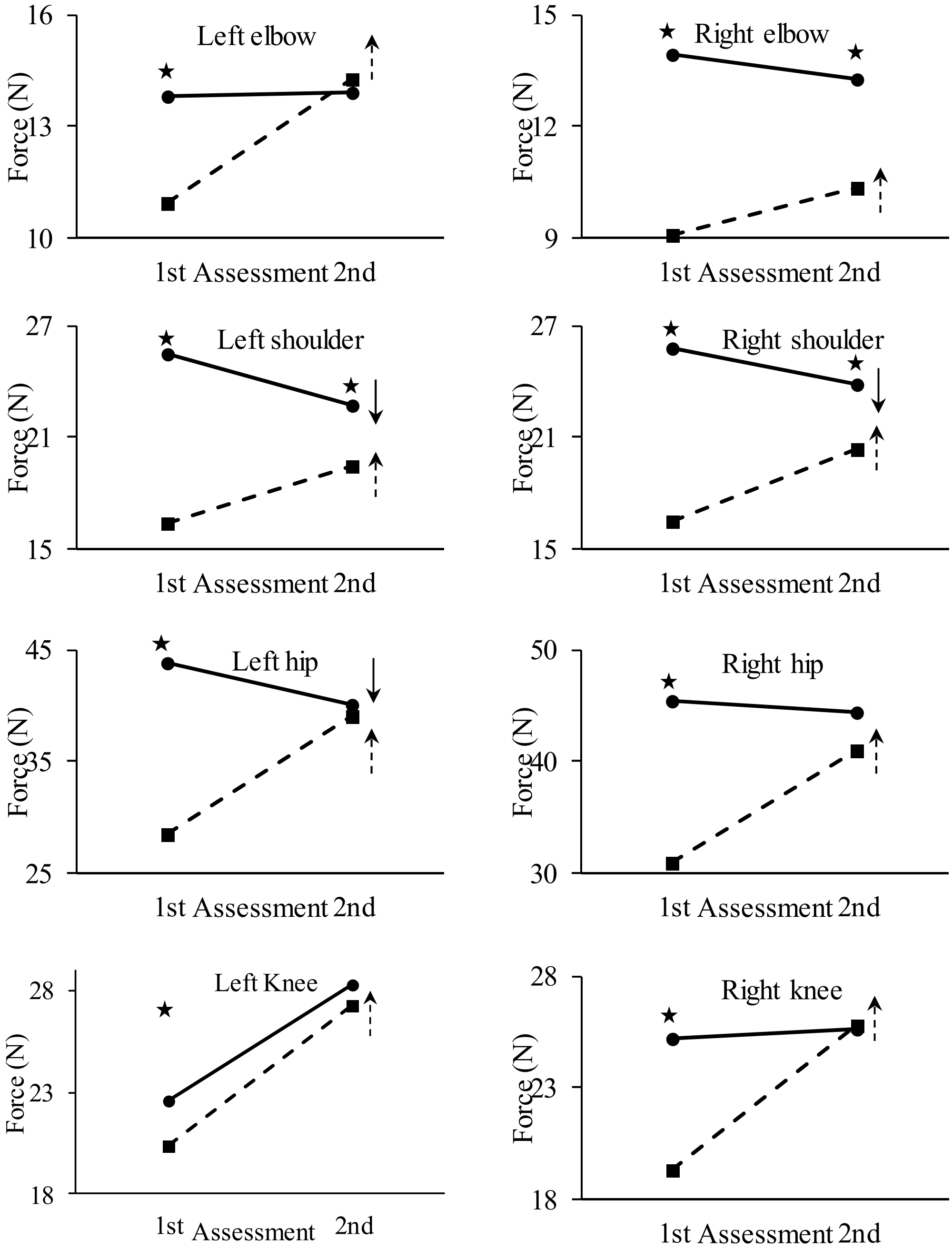

Figure 2. Force extension mean values of different joints for the gymnasts (continuous lines) and non-gymnasts (dotted lines) groups at the two assessments. Statistically significant differences at the 0.05 level between the two groups at each assessment are denoted by asterisks. Statistically significant differences at the 0.05 level between the two assessments for each group are denoted by arrows.

The 2 x 2 MANOVA revealed significant interaction between group (gymnasts and non gymnasts) and measurement (1st and 2nd assessment) with respect to the force flexion of the right side of elbow, shoulder, hip, and knee joints (F=8.103, p= .000 η^2= .928). The univariate post hoc 2 x 2 ANOVA's revealed that the interaction was attributed to the a) elbow (F=21.621, p=.000, η^2=.144), and b) shoulder (F=16.589, p=.000, η^2=.114) joints, respectively. The t-parameter estimates were significant for the first assessment a) for the elbow (t=3.859, p=.000), and b) for shoulder (t=5.590, p=.000). Finally, for the hip joint, significance was evident for both the first (t=5.157, p=.000) and second assessments (t=5.274, p=.000) (figure 1). With respect to the force flexion of the left side of elbow, shoulder, hip, and knee joints, the 2 x 2 MANOVA revealed significant interaction F=11.114, p= .000 η^2= .261). The univariate post hoc 2 x 2 ANOVA's revealed that the interaction was attributed to the a) elbow (F=21.838, p=.000, η^2=.145), b) shoulder (F=25.837, p=.000, η^2=.167) and c) hip (F=4.159, p=.043, η^2=.031) joints, respectively. The t-parameter estimates were significant for the first assessment for a) elbow (t=4.745, p=.000) and b) for the shoulder (t=7.275, p=.000). Finally, for the hip joint, significance was evident for both the first (t=4.774, p=.000) and second assessments (t=4.642, p=.000). The above findings may be found in figure 1.

The means scores of maximum isometric voluntary strength of Force extension in various joints are presented in table 3. It was mentioned that in majority of variables the training had a negative effect in Force extension on Gymnasts. On the contrary an increment was appeared in all examined variables on Force extension in both sides.

With respect to the force extension of the right side the 2 x 2 MANOVA revealed significant interaction (F=9.980, p= .000, η^2= .241). The univariate post hoc 2 x 2 ANOVA's revealed that the interaction was attributed to the a) elbow (F=11.390, p=.001, η^2=.081), b) shoulder (F=36.128, p=.000, η^2=.219), c) hip (F=24.614, p=.000, η^2=.160) and d) knee (F=14.863, p=.000, η^2=.103) joints, respectively. The t-parameter estimates were significant for the first (t=8.454, p=.000) and the second assessment (t=3.514, p=.001) for the elbow, and for the shoulder (t=9.029, p=.000 and t=2.047, p=.043 for the first and second assessment, respectively). However, significance was evident only for the first assessment a) for the hip (t=7.254, p=.000) and b) for the knee (t=4.033, p=.000) (figure 2). With respect to the force extension of the left side of elbow, shoulder, hip, and knee joints, the 2 x 2 MANOVA revealed significant interaction (F=11.219, p= .000, η^2= .263). The univariate post hoc 2 x 2 ANOVA's revealed that the interaction was attributed to the a) elbow (F=10.885, p=.001, η^2=.078), b) shoulder (F=25.380, p=.000, η^2=.164) and c) hip (F=38.569, p=.000, η^2=.230). The t-parameter estimates were significant for the first assessment a) for the elbow joint, (t=5.758, p=.000), b) for the shoulder (t=9.533, p=.000), and c) for the hip joint, (t=7.977, p=.000). Finally, for the knee joint, significance was not evident for the first (t=1.409, p=.161) and the second assessments (t=.192, p=.848). The above findings may be found in figure 2.

DISCUSSION

The purpose of this study was to examine the effects of training on maximum voluntary isometric strength (MVIS) in young male gymnasts and to compare these results with the corresponding of previous annual training period. The applied strength training program in AG between two annual periods has a positive effect on maximum voluntary isometric strength (MVIS) of young male gymnasts. The results showed significant differences between gymnasts and non-gymnasts (p<.05). In addition, significant differences were found in male gymnasts between two evaluation measurements (p<.05). A variety of training strategies (modalities) including mainly exercises with body weight in various apparatus, free weights as well as different combinations of sets and repetitions (amount of volume) has lead to produce (provide) an increment of MVIS and an adequate stimulus for strength development in young male gymnasts. Results of our study verify previous data which support a positive strength training effect in pre-adolescents athletes (Benjamin, & Glow, 2003; Falk, & Tenenbaum, 1996; Faigenbaum, 2007) and reject the old notion that strength training is ineffective for children (Faigenbaum et al, 1996; Stone et al, 2004). Also, our results support the notion that an improvement in muscle strength cannot be achieved by intensive performance of the event itself (Bührle, & Werner, 1984), but an adequate level of strength for advanced gymnastics can be achieved by participating in a progressive resistance training program (Bernhardt et al, 2001; Faigenbaum et al, 2001; Fukunaga, Funato, & Ikegawa, 1992). Gymnastics training requires the use of a considerable degree of upper arm limb's strength during performance on supporting and hangings apparatus (side horse, rings, parallel bars and fix bar) as well a considerable degree of lower limb's strength during performance on floor exercises and vaulting horse. The improvement of strength may allow gymnasts to perform more skilfully by increasing the jumps, leaps and pressure in various routines.

Special strength for gymnastics training must answer the demands of gymnastics. The principle of specificity implies that the exercise used in training should be similar to the exercises that must be performed in the competition routine. This special training is necessary to develop the strength and power in young gymnasts, which is the core for correct technical performance of gymnastics routines. The statistical differences between gymnasts and non-gymnasts in MVIC should be attributed to the long-term training adaptations. Heavy resistance strength training performed by male young gymnasts (in daily) may have produced long term training-induced increases in the MV neural drive to the muscles associated of MV (Faigenbaum et al, 1996). The important role of isometric strength has well demonstrated in various sports (McGuigan, Winchester, & Erickson, 2006; Stone et al, 2004; 2005) and provides a good indication of an athletic dynamic performance during MVIC testing. Maximum strength appears to be a significant (major) factor influencing performance in a variety of different sports (Stone et al, 2004). Douda et al (2002) point out that long-term training affects the muscle mass of the upper limbs in artistic gymnasts, due to the dynamic structure of supporting exercises.

AG is a sport where the production of large forces over relative long time periods would appear to be readily improved by strength training. MVIC is a simple way to evaluate and compare muscle strength in young male gymnasts because it is not confounded by issues of movement velocity and changing joint angle. It has been strongly influence the relationships that are observed with dynamic tasks (Haff et al, 1997). Future researchers may examine the effect of isometric strength training on the knee flexion and extension, of different joints of competitive gymnasts, at different age groups, in a variety of competitive levels, etc.

Results of the study showed that strength training program in AG between two annual periods has a positive effect on MVIS of young male gymnasts. These findings suggest that it could be useful to improve isometric strength in young male gymnasts' as this improvement facilitate the execution of technical exercises that gymnasts incorporate in their gymnastic routines. Moreover, this strength training program is useful not only for coaches designing the training programs for gymnasts but also for the prevention of injuries. Thus, gymnastics sports with high injury rates may benefit from strength training. Furthermore, a potential practical application of our findings is that the MVIC can be used by trainers to provide important information about MVIC to their gymnasts of same aged. An improvement of muscular voluntary isometric strength can be achieved through training program in young male gymnasts. It will be useful in order to overcome the high level of loadings during static elements in various apparatus.

CONCLUSIONS

This study supports that training program for strength development in male gymnasts resulted in increase in MVIS. The MVIS provides an efficient method for assessing isometric strength in young male gymnasts, differentiating gymnasts and non gymnasts. Strength is required for movements, and the level of strength determines, in part, the ease and effectiveness of performance in many day-to-day sport activities. Increasing size and strength of skeletal muscle is an important feature of childhood and adolescence. Strength gains are indeed possible when children's are placed on a proper progressive resistive exercise program. These findings must be taken into consideration by trainers to order an effective training program and improve the existent level of strength.

ACKNOWLEDGEMENT

We would like to thank participants of the study for volunteering their time. We also thank trainers and clubs directors for providing gymnastics clubs that were used in this study.

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Corresponding author:

George Dallas
National and Kapodistrian University of Athens
Physical Education and Sport Science
41, Ethnikis Antistaseos
Dafne, Athens 17237
Greece
phone: 0030 210 66 43 704
fax: 0030 693 65 92 665
e-mail: gdallas@phed.uoa.gr