THE EFFECT OF 10-WEEK ISOKINETIC TRAINING ON MUSCLE STRENGTH AND GYMNASTIC PERFORMANCE IN PREADOLESCENT FEMALE GYMNAST

George C. Dallas, Costas Dallas, Maria Maridaki

School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece

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Abstract

The purpose of this study was to investigate the effect of isokinetic training on muscle strength and gymnastic performance when added to traditional gymnastic training on handspring vault in preadolescent female gymnasts. Twenty female gymnasts with a mean age of 10.50 ± 1.19 years, height 125.50 ± 4.52cm, and body mass 27.30 ± 2.58 kg volunteered to participate in this study. A Cybex II Isokinetic dynamometer was used to measure the peak torque of the knee joint in extension at angular velocities of 60°/sec and 300°/ sec. A Casio EX-F1 (Tokyo, Japan) high speed video camera was placed perpendicular to the optical axis of springboard and vaulting horse. The subjects participated in 10-weeks training for three non-consecutive days per week, 2 hours per day, and separated into two equal groups. The experimental group (EG) followed a specialized training program (technical preparation and muscle strength via Cybex II), whereas the control group (CG) followed the traditional training program (technical preparation and muscle strength). Results showed no significant interaction was found for gymnastic score; however, a significant main effect was found for the time. No significant interaction effect among the three independent variables (group, time, side) was found for the knee extension at 60°/sec. However, the EG had a significantly higher mean values compared to the CG in the post-test. The interaction among the three independent variables with respect to the knee flexion at 300°/sec was not significant. However, the interaction between sides by group was significant. The 10-week isokinetic training added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance. Furthermore, results of our study support the claim that optimal performance is the result of a complex interaction of several factors.

Keywords: *isokinetic, handspring, vaulting, score, muscular strength, gymnastics.*

INTRODUCTION

Artistic gymnastics is one of the most popular and rapidly growing sports for young girls and there has been a definite trend toward younger gymnasts performing more difficult exercises (Cote, Salmela, and Russel, 1995). Many authors agree that a high level of strength is needed for a correct learning of technical movements and a low level of strength has negative influence on the development of technical skills (Brown, Wells, Schade, Smith, and Fehling, 2007). The term muscular strength refers to a measure describing an individual's ability to exert maximum muscular force statically or dynamically and defined as the peak force or torque developed during a maximal voluntary effort. Girls' ability to perform increases until the age of 13 or 14 years with little subsequent improvement (Malina, and Bouchard, 1991). Muscular strength in boys increases fairly linearly with chronological age, from early childhood until approximately 13 or 14 years of age (mid-puberty). In girls, strength improves linearly up until about 15 years of age, but there is no clear evidence of an adolescent spurt (Erlandson, Sherar, Mirwald, Maffulli, Baxter-Jones, 2008). The Position Statement on Youth Resistance Training published by the National Strength & Conditioning Association in the US upheld the more recent belief that properly supervised and well-planned resistance training can be effective and safe to improve the strength of preadolescent and adolescent populations (Naughton, Farpour-Lambert, Carlson, Bradney, and Van Praagh, 2000). Despite the old notion that prepubescents could not increase their strength due to insufficient levels of circulating androgens, other studies have reported significant improvements in strength following several weeks of strength training (American College of Sports Medicine, 1998; 2000; Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, et al, 1996; Faigenbaum, LaRosa Loud, O'Connell, Glover, O'Connell, and Westcott, 2001; Faigenbaum, Kraemer, Blimkie, Jeffreys, Micheli, Nitka, et al, 2009; Isaacs, Pohlman, and Craig, 1994; Ramsay, Blimkie, Smith, Garner, MacDougall, and Sale, 1990). Previous data demonstrated that children as young as 6 can improve muscle strength and power in order to achieve their maximal potential and complete the required skills when following age-specific resistance training guidelines (Bencke, Damsgaard, Saekmose, Jørgensen, Jørgensen, and Klausen, 2002; Falk, and Mor, 1996). Further, according to Seger and Thorstenson (2000), strength adaptation is sport-specific and athlete's specialization and training determine the muscle groups where the adaptations occur.

One type of strength movement is isokinetic; it has been shown to be relatively safe since once the movement is stopped the resistance is removed. This is an aspect that is extremely important when working with children (De Ste Croix, Deighan, Ratel, and Armstrong, 2009).

Isokinetic training allows maximal loading of a muscle throughout the full range of motion rather than at a specific angle as in an isotonic exercise, and the application of a specific isokinetic training program can efficiently restore imbalances in knee muscle strength (Gioftsidou, Ispirlidis, Pafis, Malliou, Bikos, and Godolias, 2008). Isokinetic training allows for maximal strength improvements and is usually combined with other types of strength training. Selecting low strength speed ($60°\cdot s^{-1}$), medium fast speed ($180°\cdot s^{-1}$) and high endurance speed ($300°\cdot s^{-1}$), isokinetic testing speeds are essential for optimal strength evaluation (Baltzopoulos, and Brodie, 1989).

Blimkie and Sale suggested that many girls might peak in strength before or during peak height velocity, with the magnitude of the strength gain being consistently greater in boys than in girls (Blimkie, and Sale, 1998). Additionally, the determination of the knee joint muscles activation in young gymnasts can provide useful information for better understanding of the mechanisms involved in strength production in athletic populations during developmental ages. Previous data indicated that isokinetic elbow and knee extensor and flexor develop in the same manner in boys and girls until the age of 10-11 (Gilliam, Villanacci, Freedson, and Sady, 1979). In another study Cools et al. (2007) compared the isokinetic muscle performance of the scapular muscles between elite adolescent gymnasts and nonathletic adolescents to identify differences in strength, endurance, and muscle balance based on high-level sport participation and found that elite gymnasts demonstrated higher values for the protraction peak force/body mass than the control group.

There are limited intervention studies on artistic gymnasts. Previous findings suggested that gymnastics intervention program improved strength of lower limbs in pre-adolescent athletes (Douda, Tokmakidis, and Tsiggilis, 1997; Pienaar, and Van der Walt, 1988). Bassa and his colleagues (2002) described the isometric and isokinetic knee torque in pre-pubescent male gymnasts six months after the beginning of the annual training period and concluded that long term gymnastics training is associated with increased torque in knee extensors but not knee flexors. Further, Golik-Peric, Drapsin, Obradovic, and Drid (2011) examined the effects of two different training protocols, isokinetic training and isotonic training, on registered initial thigh muscles strength asymmetry after 4 weeks of training in 38 athletes in various sports and found that the implemented training protocols significantly enhanced the strength of thigh muscles measured isokinetically and decreased the degree of muscle strength asymmetry. Study of Deley et al. (2011) examined the effects of a 6-week combined electromyostimulation (EMS) and gymnastics training program on muscle strength and vertical jump performance in 16 prepubescent gymnasts and found that improvement was found after three weeks of EMS training in the maximal voluntary torque (MVT). However, after the three-week point, no further increase was demonstrated. There was no significant MVT change in the control group. The lack of change in the control group following this study demonstrates that the significant improvement is a result of the training intervention and not regular growth in the population (Deley et al, 2011). Findings of Tabaković et al. (2016) showed that isokinetic training of knee extensors and flexor muscles increases functional correlation between speed and strength leading to improved performance of acrobatic elements in floor exercises.

The handspring vault is a technical gymnastic skill which demands considerable force and power output and is of paramount importance for a gymnast's vaulting development (Takei, 1998). In a recent study, Hall et al. (2016) examined the effect of plyometric training when added to habitual gymnastic training on handspring vault performance variables on twenty youth female competitive gymnasts and found significant improvements for run-up velocity, take-off velocity, hurdle to board distance, board contact time, table contact time and post-flight time. However, there were no significant improvements on pre-flight time, shoulder angle or hip angle on the vault for the plyometric training group. To the best of our knowledge, there are no other studies that examined the effect of isokinetic training on muscle strength and gymnastic performance in preadolescent female gymnast. Hence, the purpose of this study was to investigate torque-generating capabilities of pre-adolescent female gymnasts for the knee extensor-flexors muscles in relationship to the performance of handspring vault. It is hoped that this study will focus attention upon this important aspect of performance and stimulate interest in future scientific investigations in this area. Our working hypothesis was that biomechanical parameters, augmented by training techniques, influence the performance of female pre-adolescent gymnasts.

METHODS

Twenty female gymnasts with a mean age of 10.50 ± 1.19 years, height 129.50 ± 4.52cm, and body mass 27.30 ± 2.58 kg volunteered to participate in this study. They were engaged in gymnastics for at least 3 years at competition level and the study was carried out during the preparation period. Further, they must have participated in official competitions at least once and had no previous training experience with an isokinetic device. There were additional exclusion criteria such as: any lower limb injury in the previous 6 months or not being able to perform the handspring vault. Both the children and their parents were informed extensively about the experimental procedures and the possible risks or benefits of the project, and parental written consent was obtained before participation. All procedures were in accordance with the ethics of the Institutional Ethics Board of the University of Athens. The total group was separated randomly into two equal groups. The experimental group (EG) followed a specialized training program (technical preparation and muscle strength via Cybex II), whereas the control group (CG) followed the traditional training program (technical preparation and muscle strength). The physical characteristics of the subjects are presented in Table 1. There were no statistical differences in age, height, and body weight between the two groups or in their strength parameters.

Table 1

Physical characteristics and mean changes (±SE) of the subjects.

(n=20)	Pre EG (n=10)		Post CG (n=10)	
	Pre	Post	Pre	Post
Age	10.20 ± 1.03		10.80 ± 1.32	
Weight (kg)	26.80 ± 2.53	27.60 ± 2.99	27.80 ± 2.66	28.30 ± 2.98
Height (cm)	128.90 ± 5.02	129.60 ± 5.14	130.10 ± 4.15	130.70 ± 3.89

A Cybex II Isokinetic dynamometer was used to measure the peak torque of the knee joint. The knee extension and flexion were measured at angular velocities of 60°/sec and 300°/ sec. The latter velocity was selected because cine analysis of the take-off phase on springboard showed an angular velocity in excess of 300° per second. In addition, this velocity was chosen so that the participants could apply the strength in conditions similar to those encountered during the take-off phase of the springboard.

A Casio EX-F1 (Tokyo, Japan) high speed video camera was placed perpendicular to the optical axis of springboard and vaulting horse. The camera was set at 100fr/sec and placed on the right-hand side at 6.5m from the above materials to minimize the parallax error. The wall behind the vault area had horizontal and vertical reference axis. An electronic counter that establishes the true frame rate was used. The height of the vault was at 1.10 m and a Jansen-Fritzen springboard was used. Flat markers (spherical markers of 0.02-m diameter attached to the skin using a black double adhesive tape [creating also a white-on-black contrast]) were applied on the right side of the subject to locate the joints centers of ankle, knee, and hip. The measurements were obtained from two phases: a) from the last stride (hurdle step) to upward spring, b) from the strike of the horse until lift in the opposite direction upwards. A video camera was used to demonstrate the whole movement, from the start of the run-up phase to the completion of handspring vault during landing.

The EG followed a technical preparation and muscular activity that was obtained via isokinetic training program.

The CG followed the same technical program and traditional program for muscular activity containing lower limb strengthening exercises, such as jumping with both feet, squat jumps and generally exercises traditionally used. The subjects participated in a 10-week-training program for three non-consecutive days per week, 2 hours per day. Previous investigations have clearly demonstrated that resistance training twice per week is sufficient to enhance the muscle strength and local muscle endurance in children (Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, et al, 1996).

The typical training session consisted of a warm-up and all-around training. The strength testing was performed between 6 – 9pm with the same investigators performing each test. Gymnasts concentrated on the handspring vault technique to achieve better technical performance. After the typical training, the gymnasts performed two trials of the handspring vault and those with the higher score were analyzed for further statistical analysis. The performance of each subject on handspring vault was evaluated according to the Code of Point by two international judges (FIG, 2016) and the mean score was the final score for the handspring vault.

Each subject was given a familiarization period before testing to learn the correct exercise technique on the testing equipment, to reduce the influence of any learning effects, and to become familiar with general strength-training guidelines on the Cybex-II, followed by a pre-test performance. The subject was positioned and stabilized for the knee extension/ flexion test. Back "spacer" pads were used, if necessary, to establish a trunk angle of 90". The input shaft of the dynamometer was aligned with the axis of rotation of the subject's knee. The shin pad attachment was placed one to two centimeters proximal to the subject's lateral malleolus. Stabilization straps were secured about the shin, thigh, pelvis, and upper torso to prevent extraneous joint movements. Subjects were instructed to fold their arms comfortably across their chest to further isolate knee joint flexion and extension movements. During each testing session, subjects were allowed sufficient practice at each speed to ensure forceful, coordinated movements. A minimum of three submaximal extension/flexion cycles were required of each subject at each velocity to ensure execution of the full range of motion for each movement. Further, 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. The test protocol required the subjects to perform fifteen repetitions (3 sets of 5 repetitions for each velocity with a five-minute break between sets with full range of motion) in knee extension/flexion movement pattern at 60° sec^{-1} and it was repeated at 300° sec^{-1}, with both tests then performed on the contralateral limb. In the extension-flexion phase of the movement, the data collected relates to quadriceps and hamstring muscle activity respectively. The knee testing tables were used for testing the extension-flexion movement pattern at the knee joint. Subjects were given standardized instructions verbally and all were equally motivated by the tester to encourage maximum effort throughout the entire range of motion. Adequate test periods of five minutes were given between tests to ensure that the subjects' initial performance on each test was not affected by muscle fatigue.

The Statistical Package for the Social Sciences (SPSS) (Norusis, 1993), with repeated measures ANOVA, and t-parameter estimates as post hoc analysis were used (Grimm, 1993; Tabachnick, and Fiddell, 1996). Specifically, a 2 x 2 x 2 ANOVA examined the interaction effect of group (independent groups factor, with experimental and control groups), time (repeated measures factor, with pre and post test), and side (repeated measures factor, with left and right), with respect to the knee extension at 60°/sec and 300°/sec. Further, partial eta squared was computed as a measure of effect size. Significance was tested at the .05 level.

RESULTS

The interaction between group (EG vs CG) and time (pre-post test) with respect to the gymnastic score on handspring vault was examined. No significant interaction was found ($F = .032$, $p = .859$, $n^2 = .002$) and no significant effect for the group factor ($F = 1.889$, $p = .185$, $n^2 = .095$). Significant main effect was found for the time ($F = 7.310$, $p = .015$, $n^2 = 2.89$) and examination of the mean score revealed that the participants had a significantly higher mean score in post-test compared to pre-test. The performance score of the two groups in regards to the vaulting techniques were 6.73 ± 0.46 and 6.98 ± 0.43 in pre-test, and 6.80 ± 0.40 and 7.06 ± 0.37 in post-test for the experimental and the control group, respectively. The temporal parameters of the handspring vault are presented in Table 2.

Table 2
Temporal parameters on handspring vault.

	PRE		POST	
	EG	CG	EG	CG
Board support	0.13 ± 0.01	0.13 ± 0.01	0.13 ± 0.01	0.13 ± 0.01
1st flight phase	0.32 ± 0.03	0.33 ± 0.02	0.31 ± 0.02	0.33 ± 0.03
Hand support	0.36 ± 0.03	0.37 ± 0.02	0.35 ± 0.03	0.36 ± 0.03
2nd flight phase	0.47 ± 0.02	0.46 ± 0.01	0.48 ± 0.03	0.45 ± 0.03

Table 3
Descriptive data on peak torque of knee joint (Nm) (Standard deviation are presented in parentheses).

		Flexion				Extension			
		60º		300º		60º		300º	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
EG	RF	28.30	32.20	15.90	19.30	40.80	48.30	11.40	12.10
		(4.54)	(3.96)	(2.37)	(3.05)	(3.61)	(3.30)	(1.83)	(1.52)
	LF	26.20	29.20	13.60	16.00	38.90	45.50	12.78	13.00
		(5.05)	(4.30)	(2.36)	(2.53)	(4.30)	(4.62)	(2.78)	(2.86)
CG	RF	28.60	32.60	15.20	12.60	37.70	40.80	10.90	11.60
		(9.51)	(12.17)	(4.75)	(3.71)	(11.28)	(8.27)	(4.94)	(1.83)
	LF	26.70	21.80	13.70	12.10	40.10	42.90	11.10	12.30
		(7.49)	(4.87)	(6.25)	(2.46)	(11.73)	(4.97)	(3.57)	(2.11)

EG: Experimental group; CG: Control group; RF: Right foot; LF: Left foot

The interaction effect among group (EG - CG), time (pre - post), and side (left-right) with respect to the knee extension at 60°/sec was examined. No significant interaction effect among the three independent variables was found (F = .013, p = .912, n^2 = .001). The interaction effect of side by group (F = 2.209, p = .155, n^2 = .109) and time by side (F = .050, p = .825, n^2 = .003) were not significant either. However, the interaction effect of time by group approached significance (F = 3.893, p = .064, n^2 = .178), and the t-parameter estimates were examined accordingly as a post hoc analysis. For pre-test, no significant differences were found between the two groups (t =. -827, p = .419, n^2 = .037). In post-test, however, the results were significant (t = -2.663, p = .016, n^2 = .283) and examination of the mean values revealed that the EG had a significantly higher mean values compared to the CG in the post-test (Table 3).

The interaction among time (pre-test – post-test), side (left-right), group (experimental-control) with respect to the knee extension at 300°/sec was not significant (F = .481, p = .497, n^2 = .026). Accordingly, no other significant interaction (side X group, time X group, time X side) or main effect (time, side or group) was found (Table 3). Therefore, no post hoc analysis was obtained.

The interaction time by side by group with respect to the knee flexion at 60° was not significant (F = 2.626, p = .123, n^2 = .127). The interaction between time by side was significant (F = 3.940, p = .063, n^2 = .180).

The interaction among time (pre-post), side (left-right), and group (EG - CG) with respect to the knee flexion at 300°/sec was not significant (F = 3.396, p = .082, n^2 = .159). However, the interaction between side by group was significant (F = 7.999, p = .011, n^2 = .308) and the t-parameter estimates were examined in a post hoc analysis. Specifically, no significant differences between the two group were found with respect to the flexion scores on the left knee (t= -1.395, p = .180). However, significant differences between the two groups were found with respect to the right knee values (t = -2.706, p = .014). Examinations of the mean values revealed that the EG had a significantly higher mean value in the right knee than the CG, while no significant differences were evident between the two groups in the left knee.

DISCUSSION

This study examined the effects of 10-week isokinetic training on muscle strength and gymnastic performance in preadolescent female gymnast. The main finding was that both groups showed higher performance scores, but this difference was not significant between the two sets of measurements (pre- vs post-test). Another finding was that the knee strength at 60°/sec improved significantly in the EG after the 10-week intervention program in contrast to the CG that showed no significant improvement. Furthermore, the CG showed a significant reduction during knee flexion at both velocities which can be attributed to the type of training that was followed and which may not have been adequate exercise for the flexor knee muscles. Accordingly, the knee strength at 300°/sec revealed any significant improvement between these two measurements in neither group. However, it is well documented that one of the factors that influence performance score is springboard take-off velocity (Bradshaw, Hume, Calton, and Aisbett, 2010). The fact that no significant improvement was shown in knee strength at 300°/sec is one of the reasons why both groups failed to affect the take-off phase from springboard due to the fast duration of this phase.

Our results are in agreement with previous data that confirm the effectiveness of isokinetic training to improve muscular strength in healthy subjects (Ahmed et al, 2011) and trained athletes (Zebrowska, Zajac, Poprzecki, and Waligóra, 2005), and verify findings of Pienaar & Van der Walt (1988) and Douda et al. (1997) which stated that young gymnasts improved vertical jumping performance and explosive strength of lower limbs after a specialized training program. In addition, results of the present study agree with data of Faigenbaum and his colleagues (1996; 2001) that showed a significant improvement in muscular strength after an extensive period of practice. However, the results of the present study are opposed to those of Seger and Thorstenson which indicate that strength adaptations are specific to different sports and that athlete's specialization and training determine the muscle groups where the adaptations occur (Seger and Thorstenson, 2000). The correct performance of handspring vault requires the correct body position during various phases of the vault and sufficient explosive power and speed in the lower limb musculature in order to fulfil body rotation whilst maintaining body control (Marina, and Jemni, 2014). Furthermore, practicing under isokinetic training, an enhancement will be achieved in the knee muscle strength that may influence the balance of joint function (Gioftsidou, Ispirlidis, Pafis, Malliou, Bikos, and Godolias, 2008). Nevertheless, our findings support the view that both training modalities (isokinetic and traditional training) are equally effective in artistic gymnastics concerning the lower limbs strength.

However, isokinetic exercises have several advantages over other exercise modalities, such as: (i) that a muscle group may be exercised to its maximum potential throughout a joint's entire range of motion; (ii) it provides a safer alternative to other exercise modalities. Isokinetic training is safer than isotonic training because the dynamometer's resistance mechanism essentially disengages when pain or discomfort is experienced by the athlete; it is, however, not representative in the case of pushing the springboard where the push is made by both feet together. More specifically, isokinetic training may be used to quantify a muscle group's ability to generate torque or force, and it is also useful as an exercise modality in the restoration of a muscle group's pre-injury level of strength (Rochcongar, 2004). In addition, isokinetic training in preadolescent females does not generate fatigue from repeated isokinetic muscle actions (De Ste Croix, Deighan, Ratel, and Armstrong, 2009). Certain limitations, however, do not allow for generalization of the present findings. First, these findings may not be applicable to high level gymnasts or other categories of athletes or male athletes (De Ste Croix, Deighan, Ratel, and Armstrong, 2009). Further, other factors such as run-up velocity or upper arm strength that have not been examined in our study may influence the performance score.

CONCLUSION

This study investigated the effect of isokinetic training program on muscle strength and gymnastic performance in preadolescent female gymnast. However, handspring vault requires both technical skill and power production to achieve success. The 10-week isokinetic training that was added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance. However, further research should aim to examine whether the incorporation of additional specific exercises, such as sprinting or jumping movements, may have positive influence on the performance score. The results of our study confirm that optimal performance is the result of a complex interaction of several factors.

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Corresponding author:

George Dallas
National & Kapodistrian University of Athens
School of Physical Education and Sport Science
41, Ethnikis Antistaseos, 17237 Dafni, Athens
Phone: + 0030 210 727 6122
Fax: + 0030 210 727 6128
gdallas@phed.uoa.gr

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