Effects of resistance training with elastic resistance on performance of the hip flexion of ballet dancers

CDD. 20.ed. 792.8
796.073

http://dx.doi.org/10.1590/1807-55092016000400903

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Abstract

For development and support of movements with large range of motion, a dancer needs to develop flexibility and muscular strength. There is lack of scientific studies about the effect of the different training methods on the production of muscle strength in large ranges of motion. Thus, the objective of this study was to investigate the effects of a strength training program with elastic resistance on the torque, passive and active range of motion and the angle and time of contraction at largest hip flexion in classical ballet dancers. The study included 15 dancers who were divided into two groups: intervention group (n = 8) and control group (n = 7).During the study, all participants performed their usual routine of ballet classes, but the intervention group was submitted to strength training with elastic resistance, which occurred twice a week for six weeks. Torque, the passive and active range of motion, the angle and time of largest hip flexion were assessed during pre and post intervention period. One-way ANOVA (group) with repeated measures was used to identify the effects of the intervention. The intervention group showed increases in the torque when compared to the control group (intervention group = 38.47% and control group = 13.13%). Increments of 125.25% for the time of contraction at the largest hip flexion were observed only for the intervention group. No effects were identified for the other variables. The present findings showed that strength training with elastic resistance generates increases in torque and in the time of contraction at largest angle of hip flexion in classical ballet dancers.

Key Words: Torque; Range of motion; Elastic material; Muscle strength; Ballet.

Introduction

Ballet is a branch of dance that involves arts, technique and many physical capacities, including strength and flexibility[1-2]. The dancers perform movements of large articular amplitude that exceed the anatomical limits, so that along with high flexibility, muscle strength, either to movement performance and maintenance of desired position on elevated amplitudes, is somehow necessary[2-4]. Traditionally, technical skills and motors capacities necessary to movements of ballet are exercised through of a pre-determined sequence of steps[1, 5-6].

In spite of this methodology of training be the most utilized among ballet methods, the needed of implementation of a periodized resistance training routine have attracted the attention of instructors and dancers, once that the number of injuries in the skeletal muscle system in this modality is high, mainly in the inferior limbs[7-8], so that many young dancers have left the dance precociously. Moreover, there are many specific situations that lack of a personalized training to a better technical gesture and aesthetics.

The maximal hip flexion is, for instance, a condition of movement used frequently in many typical steps of ballet as well as the "développé devant", the "attitude devant" and the "grand battement devant", among others[9]. To a perfect technical execution of this steps it is important that the training of ballet prioritizes not only flexibility development of hip extensors, but also the fortification of flexors muscles and lateral rotators of hip, especially in the final of range of motion (ROM), once that there is the needed of carry out the movement in the technical standard, with endehors, that is, movements that presupposes an important lateral rotation of hip[4, 9].

The reason of problems confronted for the instructor and dancer in the evolution of hip flexion sustenance during large ROM is that, physiologically the muscles lose the capacity of strength production in the final of ROM[10-11]. This occurs due to the force-length relation, which determines that strength production depends of grade of superposition of cross-bridges that are limited when the muscle is extremely shortened[10]. Thus, to physiologically increase the capacity of the dancers in strength production in the final of ROM, it is important to promote higher overload in the large articular amplitudes.

One of the mechanical implements used in the conventional resistance training routine to increase strength production in the final ROM is the elastic material, with tubes and elastic bands. These kind of material has a progressive resistance as the implement extends, generating more tension when the deformation is larger[12-16]. Previous studies that used elastic materials in the training routine out of ballet environment have demonstrated positive results to the increment of strength in the final ROM[14-15]. However, in the consulted bases, studies that have investigated the effect of periodized resistance training with elastic resistance in the torque increase, final ROM and in the time of sustenance of hip flexion of classic ballet dancers were not found.

Thus, considering the lack of data in the literature and the constant need of technical enhancement, this study investigated the effects of six weeks of resistance training with elastic resistance in the muscle strength (expressed by torque), in the passive and active ROM, the angle of maximal sustenance and the time of sustenance in the larger possible ROM of the hip flexion in classic ballet dancers. The central hypothesis of this study is that the ballerinas, training with elastic resistance providing overload in the final ROM of hip flexion, will obtain better results in the performance of kinetic tests (maximal torque evaluation) and kinematic (passive and active range, angle and time of sustenance in the large ROM) compared to ballerinas that performed only the habitual ballet routine.

Method

Experimental design

This is an experimental study that evaluated the effects of six weeks of resistance training with elastic resistance in the kinetic and kinematic variables in classic ballet dancers. The study was approved by the Ethic committee of Caxias do Sul University (CEP n. 798.266). Before the beginning of the study, all subjects signed an informed consent and were informed that could leave the research at any time.

Participants

The participants were personally recruited from a ballet school localized at Caxias do Sul city. To participate, the ballet dancers should be participating on classic ballet classes for at least five years, training 6-15 h weekly for at least six months, aged between 15-22 years and be from female gender. The dancers that were not 18 years old were authorized for their parents to participate in the research. The inclusion criteria were: not be engaged in any resistance training program in the last six months, not present any muscle injuries in the last six months and not have any acute or chronic cardiorespiratory dysfunction that could preclude the performance in maximal strength test.

The ballerinas that satisfied all inclusion criteria were shared in two different groups: intervention group, that performed periodized resistance training with elastic resistance for the hip flexor and the control group that did not realized resistance training. The participant's allocation was pairwise based in the age and the experience time and a raffle assisted by sealed envelopes was done to determine the final group of each participant (TABLE 1). The raffle was performed only after all participants conclude the pre intervention evaluations. The responsible for the acquisition and treatment of data were blinded in relation to the randomization and allocation.

TABLE 1 - Basal characteristics of both groups.

	Intervention group (n = 7)	Control group (n = 7)
Age (years)	18.25 ± 2.49	17.57 ± 2.43
Height (m)	1.65 ± 0.04	1.62 ± 0.06
Bodymass (kg)	56.3 ± 4.07	56.74 ± 6.85

Mean ± SD.

Evaluation protocol

All participants were evaluated before and after six weeks. During this time, the experimental group performed resistance training with elastic resistance at home. The endpoints evaluated were: maximal passive ROM, maximal active ROM, maximum range of sustenance, time of sustenance and maximal torque of the hip flexors. The maximum range of sustenance corresponds to the maximum angle of hip flexion in which the ballerina can keep the inferior limb isometrically.

To register the kinematics variables a system of cinemetry with seven integrated cameras (VICON MX systems, Oxford Metrics Group, UK) was utilized. The kinematics data were collected in a sampling rate of 100 Hz. After one session of warming up that was englobed for sets of specific dynamic movements of ballet, reflexive markers were fixed in the following anatomic points according with the Plug in Gate (VICON MX systems, Oxford Metrics Group, UK) model: anterior superior iliac spine right and left, posterior superior iliac spine right and left, proximal third on the lateral surface of the right thigh and distal third on the lateral surface of the left thigh, condyle of the right and left knee (lateral), condyle of the right and left tibia, right and left malleolus (lateral), right and left heel and base of the distal phalanx of the third finger of the right and left foot.

During the test, it was asked to the ballerinas to support with the contralateral hand to the evaluated limb in an apparatus that simulated a typical support bar used in the ballet classes. Both inferior limbs were maintained in external rotation and the body was maintained erect. During this action, the ballerinas were instructed to do not do any extra movement. Firstly, to verify the maximum passive ROM, the dominant inferior limb of each participant was conducted by the own ballerina for the larger ROM of the hip flexion. To the rest of the evaluations, the superior ipsilateral limb was maintained according with the classic line of ballet: shoulder abduction, small elbow bending and forearm supination, becoming the upper limb slightly rounded in the side of the body. After positioned, each ballerina was asked to do a flexion dynamically the limb to the larger ROM. Afterwards, it was asked to each participant to repeat the movement of hip flexion and maintaining the limb in the large amplitude and as long as possible. Each action performed in the kinematic evaluation was executed three times with an interval of one minute between attempts. Only the dominant limb was evaluated.

After data acquisition, the analysis were performed in two phases, the first was consisted by the tridimensional reconstruction static and dynamic, register of angle information and time of sustenance and of maximum passive and active ROM during each attempt. Both phases were performed with the software of data collection (VICON MX systems, Oxford Metrics Group, UK). The higher value between attempts was considered to the statistical analysis.

The muscle torque was collected, posteriorly, using an isokinetic dynamometer Biodex System 4 Pro (Biodex Medical Systems, EUA). The participants were positioned in supine position with the dynamometer's seat, fixed at an angle of zero degree according to manufacturer's instructions. After set the position, the participants were asked to perform three five seconds maximum voluntary isometric contractions of hip flexion at 120º. An interval of three minutes was allowed between each attempt. Only the dominant inferior limb was evaluated and all participants were instructed to perform the test as fast and strong as possible[17]. The contraction that showed biggest peak of torque ($N.m^{-1}$) was used to posterior comparison.

Training protocol

One of the researchers of the study, professional of physical education, was responsible to instruct the training routine to the participants. The ballerinas performed the training routine in a place of own choice. To performer the training routine, the ballerinas needed a structure or point of fixation close to the ground allowing the elastic material fixation and an apparatus to support the body. There was no control in relation to the length of the elastic band during the training. After each training session, the participants did a short report to show the performance and the intensity of rating of perceived exertion (RPE) according to Borg scale, which consider 6 as slight effort and 20 extremely intense[18-19]. The reports were used to confirm the realization of training session and verification of intensity of perceived effort during a session (FIGURE 1). Thereby, it was possible to ensure qualitatively that the effort was slight and moderate in the two first weeks of training and gradually increased until the end of the study.

(0 = very slight effort nd 20 = extremely high effort).

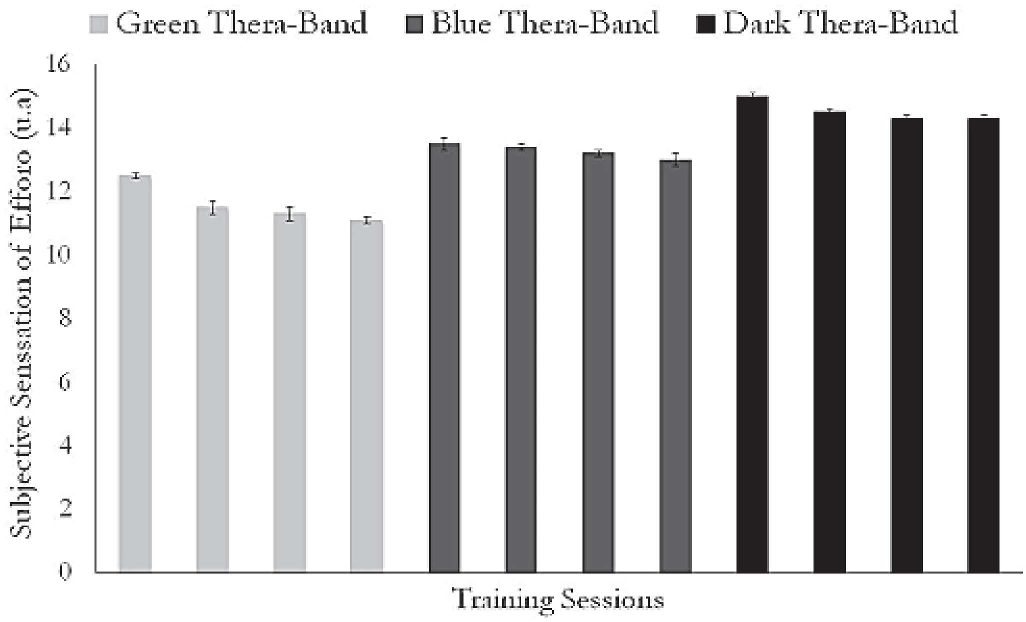

FIGURE 1 - Mean of effort intensity evaluated by Borg Scale.

The training was performed two times per week, during six weeks; with an interval between sessions of 48 h. The external resistance of participants was imposed by different levels of resistance of an elastic band (FIGURE 2). The level of resistance of the elastic material is graduated according to the color of the material, where the dark color represents the biggest resistance. To perform the training, the elastic band was fixed close to the ground and the other extremity was fixed in the foot of the ballerina. The velocity of movement during the training was chose for each ballerina.

One of the extremity of elastic band fixed at the door and the other extremity fixed at ballerina foot.

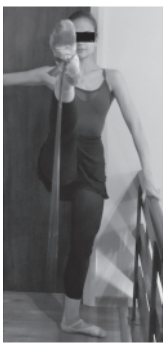

FIGURE 2 - Typical position used during training in the environment chosen by each participant.

The training consisted in performing several hip flexion movements. For this, the ballerinas remained standing, with the body erectus, with both inferior limbs in external rotation and with the knees extends. The ballerinas performed a hip flexion according with the number of sets and repetitions, as well as the color of elastic band determined to the week. One minute of rest was allowed between sets. After dynamic contractions, the participants performed isometric contractions in the maximum amplitude of hip flexion achieved for the time determined to the week. The training overload progression occurred progressively according with Fleck and Kraemer[20]. The details of training program are described at TABLE 2.

TABLE 2 - Protocol of training used in the present study.

	Weeks 1 to 2	Weeks 3 to 4	Weeks 5 to 6
Elastic band color	Green	Blue	Black
Repetitions	17- 20	14-17	12-14
Time of sustenance (s)	8	12	15
Number of sets	3	3	4
Rest	Until 1 minute	Until 1 minute	Until 1 minute
RPE	slight esforce	a bit heavy	Heavy

RPE: rating of perceived exertion according to Borg scale (0 = very slight effort and 20 = extremely high effort).

Ballet classes

Both groups performed the usual routine of ballet classes. These classes contemplate the traditional structure of ballet that generally is composed for three steps: movements performed to support the bar, without support bar, with large displacements[6]. In the first stage the ballerinas performed a pre-determined sequence of steps ("pliés", "battement tendu", "battement jeté", "rond de jambe à terre", "battement fondu", "rond de jambe en l'air", "battement frappé", "adagio", "petit battement", "grand battement" and stretching). Once the movements are performed, all physical capacities are developed[5]. In the second stage, the upper limb exercises ("port de bras"), whirls ("pirouettes"), fast movements and slow movements and jumps (for instance: "allegros", "adagio", waltz e "batterie"), were done without bar support[5]. Ending, the last stage emphasized the wide jumps - as well as "grand jetés", "temps levé" - and whirls of velocity (i.e. "chaîné", "pique tour")[1]. No mechanical implement is used during regular class. The duration of the ballet classes is about one and a half hour a day, and afterwards they have choreography training.

Statistical analysis

A descriptive analysis was run to show the data by mean and standard deviation. The data normality was verified and confirmed from Shapiro-Wilk test. To verify the time effect in the investigated variables the One-way ANOVA with repeated measures was performed. The data deployments were investigated in the syntax of the program directly in the combinations of interest through of tests of comparison LSD. To evaluate the practical effects of training the perceptual of variation of changes was calculated to all investigated variables. The T test to independent samples was used to compare the possible perceptual of increase between groups. The significance level was set at $\alpha \leq 0.05$.

Results

No difference was observed in the comparison of basal characteristics between groups ($p > 0.05$) (TABLE 3). The ANOVA test showed that there is a main effect of time ($p < 0.001$), where both groups increased the torque after six weeks. No significant differences between groups, before ($p = 0.764$) or after ($p = 0.131$) experimental period (TABLE 3).

When the perceptual of change were compared, the T test identified significant differences between groups ($p = 0.012$), where the experimental group showed 38.47% (SD = 20.25%) of increase in the torque versus 13.13% (SD = 11.10%) of increase found for control group (TABLE 3).

The ANOVA test showed a significant interaction between group and time ($p = 0.034$), where only the experimental group showed a significant increase in the time of sustenance (TABLE 3). There is no significant difference in the comparison between groups, neither before ($p = 0.241$), nor after ($p = 0.331$) experimental intervention.

When the perceptual of change was compared, the T test to independent samples showed significant difference between groups ($p = 0.015$), where the experimental groups showed 125.25% (SD = 64.72%) of increase for the time of sustenance, while the control group showed an increase of 26.88% (SD = 44.49%) (TABLE 2).

To the others evaluated variables (passive and active ROM and range of sustenance), the statistics applied did not find main effects or significant interaction ($p > 0.05$) (TABLE 3).

TABLE 3 - Results observed to all investigated variables to the intervention and control group.

	Intervention group			Control group		
	Pre	Post	Δ%	Pre	Post	Δ%
Torque (Nm)	41.02 ± 11.97	55.5 ± 13.26*	39	39.00 ± 13.58	43.81* ± 14.79	13#
ADM passiva (graus)	142.75 ± 12.87	144.75 ± 14.91	1	144.14 ± 9.59	143.57 ± 2.16	0
ADM ativa (graus)	125.00 ± 16.59	130.00 ± 9.63	4	129.28 ± 7.99	134.57 ± 11.17	4
Angulo de sustentação (graus)	89.87 ± 15.81	88.12 ± 12.98	-2	95.28 ±15.75	94.14 ± 17.43	1
Tempo de sustentação (s)	7.5 ± 1.77	16.5* ± 4.44	125	9.71 ± 4.75	13.00 ± 8.62	27

*Significant difference between pre and post intervention ($p < 0.01$);
Significant difference between groups ($p < 0.01$);
Δ% = perceptual change between pre and post intervention.

Discussion

The main finds of the present study was that: a) the resistance training with elastic resistance was able to generate higher percent increase of maximum isometric torque evaluated in the maximum amplitude of hip flexion compared to only conventional ballet training; b) the resistance training with elastic resistance was able to induce higher increase in time of sustenance in the maximum hip flexion amplitude compared to conventional training; c) the resistance training with elastic resistance did not induce changes in the amplitudes evaluated.

Previous studies have demonstrated that training with elastic materials is efficient to produce muscle strength increases in different populations. Cronin et al.[21] evaluated the effects of 10 weeks of ballistic training performed with and without elastic material attached to a squat machine in the muscle strength and power in trained young man. As results, the authors reported that the muscle strength, peak power and mean power increased significantly after both protocols. Moreover, the effectiveness to develop muscle mass in sedentary middle-age women[22] and in the dynamic strength and mobility in elderly people[23] have been demonstrated previously. Others authors have found similar increase in the level of muscular activation between resistance training performed with free weights and resistance training with elastic tube in your women[24].

There are also some studies that demonstrated superiors gains for strength production when some elastic material was added to traditional resistance training with free weight or machine[14-15]. Melo et al.[14] performed a training of knee extension in young active students of both genders during 8 weeks, where the intervention group performed training with elastics attached to the extension knee machine to increase the final load of ROM while the control group trained without elastic resistance. It was found that the training associated with elastic resistance increased significantly the maximum isometric contraction strength of knee extensors for intervention group in the 10º and 30º angle of knee flexion (0º = maximum extension), articular position where the quadriceps is relatively shortened. Wallace et al.[15] also found superior gains of muscular torque after training that used elastic implement associated with the resistance training performed with free weight when compared to the traditional resistance training in trained young women.

In the Anderson et al.[16] study, basketball and hockey players experienced a 7 weeks of training with elastic tubes associated with habitual routine of high intensity resistance training (85% of one repetition maximum). In that study both groups performed normal routine of specific training, but the control group did not perform elastic resistance to the resistance training. As result, either control group or intervention group showed significant increase of strength. However, the group that added elastic resistance to the normal training presented a significant increase of strength (3 times more) compared to control group. This result is similar to the present study, which showed higher increase of torque compared to the control group after six weeks of resistance training associated with elastic resistance. However, it is necessary to be prudent when analyzing this data, once both groups at the present study performed the regular routine of ballet classes.

In addition, the present study showed for the first time that the addition of elastic material was able to considerably increase the time of sustenance in maximum hip flexion. These results have important practical applications, since in ballet dancers, specially the corps de ballet, strength is required to ensure position maintenance during determined time[1, 5]. In our study, the objective of training was to increase the duration sustenance time of hip flexion in the largest possible amplitude (8, 12 and 15 seconds). The significant increases in this time (125.25%) may induce significant contribution to performance.

The initial expectative of the present study was about an increase of active ROM and also about the amplitude of sustenance of hip flexion; however, it was not confirmed. It is possible that this expectative was not confirmed because probably the ballerinas had already reached the maximum levels of ROM. Moreover, it is speculated that the high external resistance in some points was the reason to not reach the passive ROM. The overload increase impeded many ballerinas to perform the training in the maximal amplitude angle. The fact that the ballerinas did not train with their maximum articular amplitude in the last weeks may be considered a study limitation. However, it is believe that this possible limitation do not invalidates the torque results, once that the torque increase was observed at 120º of hip flexion. Although some studies[25-26] have suggested that the resistance training can induce lower degree in adjacent angle, 5 to 20º above or below of worked angle[27], it seems that in this study there is not strength transference to the ROM of ballerinas. More studies are necessary to evaluate the torque of adjacent angle to confirm or refute this speculation.

The overload control is one of the main variables to resistance training prescription[18, 28]. In this study, this control was done based on the rating of perceived exertion (RPE) measured through Borg scale, where it was observed a homogeneous progressive increase from moderate to very difficult over six weeks of training (FIGURE 1). The Borg scale is largely accept in the literature to intensity control of training[17-18], it is suggested that future studies use procedures of elastic materials calibration[12], and ROM[29] training control of each participant to obtain the register of training intensity. Moreover, it is recommended the inclusion of one repetition maximum test (1-RM) to become possible the determination of submaximal intensity of training. Thus, during the training it will be possible ensure that the ballerinas reach and maintain maximal amplitude in the movement.

In conclusion, the results of this study suggests that the resistance training with elastic resistance was able to increase the torque of hip flexion, as well as the time of sustenance of hip flexion in classic ballerinas. It is suggested that future studies carried out procedures of calibration of elastic materials, measurement of ROM and length of elastic bands during training and perform strength test to the precise control of training intensity. These measures possible can ensure the success also in the increase of sustenance amplitude and of active ROM, other important practical variable to ballet.

Resumo

Efeito do treinamento de força com resistência elástica sobre o desempenho da flexão de quadril em bailarinas clássicas

Para realização e manutenção de movimentos estéticos de grande amplitude articular, um bailarino necessita desenvolver além de flexibilidade, força muscular. Trabalhos científicos sobre o "ballet" apontam para uma lacuna com relação ao efeito de diferentes métodos de treinamento na produção de força muscular em grandes amplitudes de movimento. Assim, o objetivo deste estudo foi investigar os efeitos de um programa de treinamento de força com resistência elástica sobre o torque, a amplitude de movimento ativa e passiva, bem como o ângulo e o tempo de sustentação da flexão de quadril em bailarinas clássicas. Participaram deste estudo 15 bailarinas que foram divididas em dois grupos: grupo intervenção (n = 8) e grupo controle (n = 7). Durante o estudo, todas participantes mantiveram a rotina habitual de aulas de "ballet", porém o grupo intervenção realizou um treinamento de força com resistência elástica para os flexores de quadril, o qual foi realizado duas vezes por semana, durante seis semanas. Antes e depois de seis semanas, todas participantes realizaram medidas de torque, das amplitudes ativas e passivas, bem como do ângulo e tempo de sustentação da flexão de quadril. ANOVA de um fator (grupo) com medidas repetidas no tempo foi usada para identificar os efeitos da intervenção. O grupo intervenção apresentou incrementos de torque três vezes superiores ao grupo controle (grupo intervenção = 38,47% e grupo controle = 13,13%). Incrementos de 125,25% para o tempo de sustentação foram observadas somente para o grupo intervenção. Nenhum efeito foi identificado nas demais variáveis. Os achados mostram que o treinamento de força com resistência elástica gera aumentos no torque, bem como no tempo de sustentação de flexão de quadril em bailarinas clássicas.

Palavras-chave: Torque; Amplitude de movimento; Materiais elásticos; Força muscular; Ballet clássico.

References

1. Agostini BR. Ballet clássico: preparação física, aspectos cinesiológicos, metodologia e desenvolvimento motor. Várzea Paulista: Fontoura; 2010.
2. Franklin, E. Conditioning for dance: training for peak performance in all dance forms. Champaign: Human Kinetics; 2004.
3. Fração VB, Vaz MA, Ragasson CAP, Muller JP. Efeito do treinamento na aptidão física da bailarina clássica. Movimento. 1999;11:3-15.
4. Hamilton WG, Hamilton LH, Marshall P, Molnar M. A profile of the muscle skeletal characteristics of elite professional ballet dancers. Am J Sports Med. 1992;20:267-73.
5. Bertoni IG. A dança e a evolução: o ballet e seu contexto teórico - programação didática. São Paulo: Tranz do Brasil; 1992.
6. Crist LA. Ballet barre and center combinations: word descriptions. Highstown: Princeton Book; 2000.
7. Nilson C, Leanderson J, Wykman A, et al. The injury panorama in a Swedish professional ballet company. Knee Surg Sports Traumatol Arthrosc. 2001;9:242-6.
8. Milan KR. Injury in ballet: a review of relevant topics for the physical therapist. J Orthop Sports Phys Ther. 1994;19: 21-9.
9. Clippinger K. Anatomy and kinesiology: principles and exercises for improving technique and avoiding common injuries. Champaign: Human Kinetics; 2007.
10. Granzier HL, Akster HA, Ter Keurs HE. Effect of thin filament length on the force-sarcomere length relation skeletal muscle. Am J Physiol. 1991;260:1060-70.
11. Gordon AM, Huxley AF, Julian EF. The variation in isometric tension with sarcomere length in vertebrate muscle fibres. J Physiol. 1966;184:170-92.
12. Loss JF, Koetz AP, Soares DP, et al. Quantificação da resistência elástica oferecida por bandas elásticas. Rev Bras Ciênc Esporte. 2002;24:61-72.
13. Hughes CJ, Hurd K, Jones A, Sprigle S. Resistance properties of Thera-Band tubing during shoulder abduction exercise. J Orthop Sports Phys Ther. 1999;29:413-20.
14. Melo MO, Brodt GA, Gomes LE, et al. Effects of added elastic tubes on open-chain knee extensor strength training. Sports Biomech. 2013;12:195-203.
15. Wallace BJ, Winchester JB, McGuigan MR. Effects of elastic bands on force and power characteristics during the back squat exercise. J Strength Cond Res. 2006;20:268-72.
16. Anderson CE, Sforzo GA, Sigg JA. The effects of combining elastic and free weight resistance on strength and power in athletes. J Strength Cond Res. 2008;22:567-74.
17. Sahaly R. Maximal voluntary force and rate of force development in humans: importance of instruction. Eur J Appl Physiol. 2001;85:345-50.
18. Buckley JP, Borg GAV. Borg's scales in strength training; from theory to practice in young and older adults. Appl Physiol Nutr Metab. 2001;36:682-92.
19. Carvalho VO, Bocchi EA, Guimarães GV. The Borg scale as an important tool of self-monitoring and self-regulation of exercise prescription in heart failure patients during hydrotherapy. Cir J. 2009;73:1871-6.
20. Fleck SJ, Kraemer WJ. Fundamentos do treinamento de força muscular. Porto Alegre: Artmed; 2006.
21. Cronin J, McNair PJ, Marshall RN. The effects of bungy weight training on muscle function and functional performance. J Sports Sci. 2003;21:59-71.
22. Colado JC, Triplett NT. Effects of a short-term resistance program using elastic bands versus weight machines for sedentary middle-aged women. J Strength Cond Res. 2008;22:1441-8.
23. Zion AS, Meersman R, Diamond BE, et al. A home-based resistance-training program using elastic bands for elderly patients with orthostatic hypotension. Clin Auton Res. 2013;13:286-92.
24. Andersen LL, Andersen CH, Mortensen OS, et al. Muscle activation and perceived loading during rehabilitation exercises: comparison between dumbbells and elastic resistance. J Strength Cond Res. 2010;90:538-49.

25. Kitai D, Sale D, Specificity of joint angle in isometric training. Eur J Appl Physiol. 1989;58:744-8.
26. Knapik JJ, Mawdsley RH, Ramus MU. Angular specificity and test mode specificity of isometric and isokinetic strength training. J Orthop Sports Phys Ther. 1983;5:58-65.
27. Barak Y, Ayalon M, Dvir Z. Transferability of strength gains from limited to full range of motion. Med Sci Sports Exerc. 2004;36:1413-20.
28. Barbanti VJ. Treinamento físico: bases científicas. São Paulo: CLR Balieiro; 1996.
29. Thomas M, Muller T, Busse MW. Quantification of tension in Thera-Band and Cando tubing at different strains and starting lengths. J Sports Med Phys Fitness. 2005;45:188-98.

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Submitted: 01/27/2015
Revised: 06/13/2015
Accepted: 09/29/2015