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original article

Chronic effects of resistance exercise using reciprocal muscle actions on functional and proprioceptive performance of young individuals: randomized controlled trial

Efeitos crônicos do exercício resistido com contrações recíprocas no desempenho funcional e proprioceptivo de indivíduos jovens: ensaio controlado aleatório

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Abstract – Studies have suggested that benefits from resistance exercise (RE) using antagonist muscle pre-activation could be transferred to functional activities. However, chronic studies using pre-activation through reciprocal actions in neuromuscular performance and functional activities are scarce. The aim of this study is to compare the effects of 12 RE sessions using reciprocal muscle actions and a traditional mode on functional and proprioceptive performance of young individuals. Forty eight young subjects were randomized into two groups: 1) reciprocal training (RT, 3 sets; 10 repetitions; knee flexion immediately followed by knee extension), 2) traditional training (TRA, 3 sets. 10 repetitions; knee extension). Pre and post evaluations were characterized by balance tests, hop tests (HT) and "8" shape circuit (RC8). ANOVA 2X2 of mixed model was applied to analyze differences between pre and post-training conditions and between groups. For overall and anterior-posterior balance, no significant differences were found between RT and TRA (p>0.05). Similarly, no post-training differences were found. The medial lateral balance in the dominant limb showed no significant differences in post-training for both groups (p = 0.94), but the non-dominant limb showed significant differences between groups (p<0.01). In HT, significant post-training increases were found within groups (p<0.01), but no differences were found between them (p=0.90). RC8 was different between groups (p=0.03), indicating better post-training running time for TRA. Resistance exercise caused transfers to balance and functional performance, and training with reciprocal muscle actions showed better rates for HT and medial lateral knee balance.

Key words: Functional performance; Knee; Muscle strength; Physical Therapy; Resistance exercise.

Resumo – *Estudos sugerem que benefícios do exercício resistido (ER) com pré-ativação da musculatura antagonista podem ser transferidos para atividades funcionais.* *No entanto, estudos crônicos utilizando a pré-ativação no desempenho neuromuscular e nas atividades funcionais são escassos. O estudo teve por objetivo comparar os efeitos de 12 sessões de ER com ações recíprocas e um modelo tradicional no desempenho funcional e proprioceptivo de indivíduos jovens. Quarenta e oito homens foram aleatorizados em 2 grupos: 1) treinamento recíproco (TRE, 3 séries; 10 repetições; flexão do joelho imediatamente seguida pela extensão do joelho); 2) treinamento tradicional (TRA, 3 séries; 10 repetições; extensão do joelho). As avaliações pré e pós foram caracterizadas por testes de equilíbrio, salto unipodal em distância (SUD) e corrida em formato de "8" (CR8). Aplicou-se uma ANOVA 2X2 de modelos mistos para analisar diferenças entre as condições pré e pós e entre os grupos. No equilíbrio global e anteroposterior, não foram encontradas diferenças significantes entre os grupos TRE e TRA (p>0,05). Do mesmo modo, não foram encontradas diferenças pós-treinamento. O equilíbrio mediolateral no membro dominante não demonstrou diferenças significantes pós-treinamento (p=0,94), mas o membro não dominante demonstrou diferença significante entres os grupos (p<0,01). No SUD, houve aumentos significantes pós-treinamento nos grupos (p<0,01), mas sem diferença entre ambos (p=0,90). A CR8 apresentou diferença entre grupos (p=0,03), com melhor tempo de corrida do TRA pós-treinamento. O ER gerou transferências para o equilíbrio e testes funcionais, e o treinamento com ações recíprocas apresentou melhores indicativos para o SUD e equilíbrio mediolateral do joelho.*

Palavras-chave: *Desempenho funcional; Exercício resistido; Fisioterapia; Força muscular; Joelho.*

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INTRODUCTION

Resistance exercise (RE) is considered one of the most efficient ways to enhance functional capacity of the neuromuscular system. Muscle strength gain, improvement in balance and motor coordination are among its specific effects[1,2]. Therefore, the importance of including RE in the context of health, human performance and rehabilitation of the musculoskeletal function is clear[3].

According to Wikstrom et al.[4], muscle strength gain resulting from RE represents a relevant clinical application as it can promote dynamic stability and improve performance. However, in order to obtain such benefits, RE must be carried out with the purpose of balancing the agonist/antagonist muscles of a specific joint. A strategy widely studied over the last few years involves the pre-activation of the antagonist musculature[5-7]. Pre-activation can be carried out through previous contraction of the antagonist muscular group, immediately followed by contraction of the agonist group[8,9]. In this study, the pre-activation model was adopted as training of a reciprocal contraction (TRE) routine. Previous studies have shown that individuals who adopt pre-activation obtained acute positive effects in generating muscle strength of the agonist group[10], and improve their performance by generating higher work levels[7] and better efficency[11]. However, these results are found either in transversal studies or in short-term training studies.

According to Zatsiorsky et al.[12], the effects of RE on musculoskeletal function can be explained as a transference of gains, as demonstrated by Wilson et al.[13]. In their study, Wilson et al. demonstrated that after 8 weeks of RE in the 1RM test, gains were 21% for crouching exercise, 21% for vertical hop performance and 2% for running performance. These results show that gains obtained from RE for lower limbs may cause effects on other exercise or sport modalities and functional movements. In this context, training with antagonist pre-activation could produce positive effects related to gain in neuromuscular ability, which is needed by many functional activities that require motor control of primary and stabilizing muscles[14].

An interesting factor of antagonist pre-activation is the possibility of working the entire musculature of a specific joint with equal intensity, providing balance in the joints generated during agonist muscle action and therefore favoring the improvement of the functional performance. However, there is lack of chronic studies that investigate the effects of RE with pre-activation on neuromuscular and functional variables. Therefore, the aim of this study was to assess the chronic effects of 12 TRE sessions with traditional model (TRA) without antagonist pre-activation on the functional and proprioceptive performance of young healthy individuals. A hypothesis is outlined sustaining that TRE will present higher magnitude of transferring the effects using functional and proprioceptive tests, when compared to training model without pre-activation (TRA).

METHODS

Study design

Randomized controlled trial for a period of 6 weeks. Participants were randomly assigned into two training groups as shown in Figure 1.

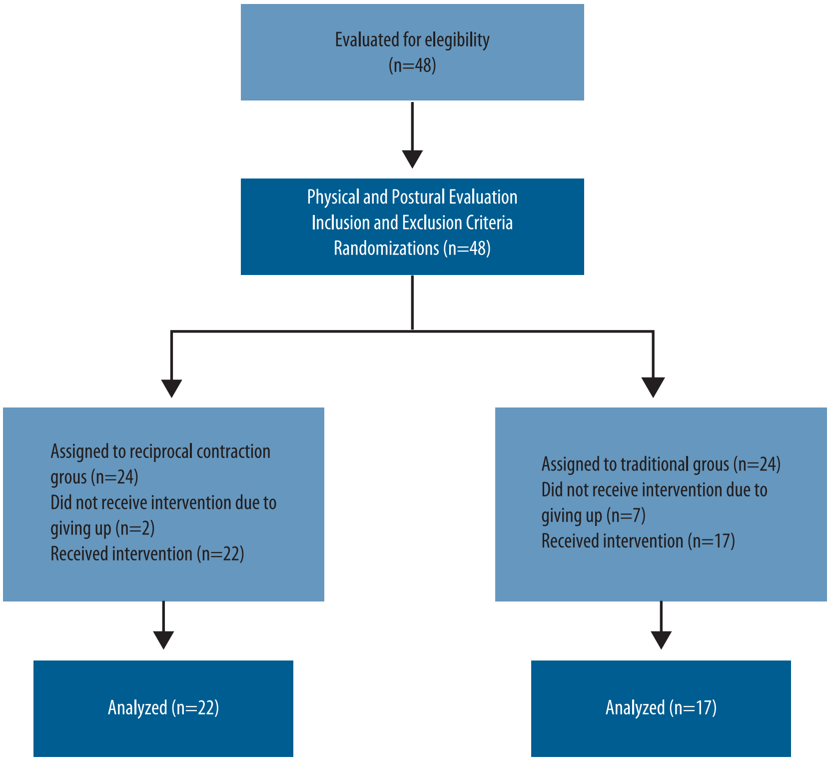

Figure 1. Study flowchart.

Participants

Sample size calculation was carried out using the GPower software, version 3.1.9, considering statistic power of 80%, α-value of 5% and moderate size of effect, indicating minimum sample of 26 individuals. For this study, 48 healthy young males were included (age 20.9 ± 2.2 years; height 1.8 ± 0.1 m; mass 75.0 ± 8.2 kg). Sample characterization is shown in Table 1. Volunteers were recruited at the University Campus by explaining the study objectives and showing posters. Subsequently, volunteers´ physical evaluation was carried out, followed by conducting the inclusion and exclusion criteria.

Table 1. Characteristics of the study participants, divided into two training groups.

Variables	Groups		p-value
	TRE (n = 22)	TRA (n = 17)	
Age (years)	20.1 ± 1.9	20.2 ± 2.3	0.6
Height (m)	1.7 ± 0,1	1.8 ± 0.1	0.7
Mass (kg)	72.2 ± 10.2	71.9 ± 8.0	0.3
BMI (kg/m^2)	23.5 ± 3.3	22.9 ± 2.6	0.5

TRE: Reciprocal, TRA: Traditional, BMI: Body Mass Index

Inclusion criteria were: being male, aged 18-25 years, not having participated in any RE over the last 6 months preceding the beginning of the study and to be available for training for a period of 6 weeks. Exclusion criteria were: any kind of cardio-respiratory condition, or metabolic disease, or osteo-myo-articular back injury, ankle and/or knee joint injury, any neurological and/or proprioceptive condition or deficit and those who missed two or more training sessions. All volunteers were given instructions about the objectives and procedures of the study and were invited to participate after signing the free and informed consent form, which was approved by the Institutional Ethics Research Committee (Process n. 112/12).

Participants were randomly divided into two training groups: 1) reciprocal training (TRE, n = 24) or 2) traditional training (TRA, n = 24). For the randomization process, sealed opaque envelopes containing the name of the intervention group were used. Subsequently, participants started the study and were given an envelope containing the intervention group they were assigned to. A researcher, unaware of the purposes of the research, was responsible for the process.

Training Protocol Description

Participants attended the laboratory twice a week over 6 weeks (at intervals of at least 48 hours between each), making up a total of 12 training sessions in isokinetic dynamometer. There is consensus in literature indicating that the effect of neural and morphological adaptations on strength production levels occurs after six weeks, during which a transition between neural and morphological training effects occurs. Since literature describes results concerning pre-activation in short-term trainings (from 2 to 3 training sessions) or transversal studies, our study adopted the minimum time required for the stabilization of gains from neural factors (6 weeks).

Training sessions for both groups (TRE and TRA) were characterized by 3 series of 10 maximum concentric isokinetic repetitions at $60°.s^{-1}$, with intervals of one minute between each series[15,16], described as follows: 1) reciprocal training group (TRE, concentric reciprocal exercise of agonist and antagonist knee muscles, characterized by flexion movement of the knee immediately followed by its extension at each repetition), 2) traditional training group (TRA, only concentric exercise of the knee extensor muscles was carried out; knee was flexed in passive mode).

Training was carried out using a Biodex System 4 dynamometer (*Biodex Medical Systems, Shirley, New York, USA*). Calibration was performed according to manufacturer´s recommendations. Participants were positioned on a chair, with possibility of free and comfortable flexion and extension movement of the knee, where extension was defined as 0° and flexion as 90°, using flexion-extension movement amplitude of 80° (excursion from 90° to flexion up to 10°). The femur´s lateral epicondyle was used as the knee´s reference axis of rotation when aligned to the device´s rotation axis. The position of each participant was recorded and repeated on each training day (chair height, chair depth, chair position on the track, dynamometer arm and position).

All participants were trained by the same researcher. During the study period, participants were advised not to do any additional resistance exercise sessions.

Evaluation procedures

Participants were submitted to motor performance and postural balance functional evaluations, which were carried out over three visits to the laboratory. In the first visit, familiarization with all tests was carried out, and then, after a period of 48 hours, the first evaluation, known as pre-training evaluation, was conducted. After 48 hours from the last training session, post-training session was conducted (Figure 1).

Initially, the Athlete Single Leg Stability Testing (ASL) was applied using the balance platform. The ASL test was carried out in an instability condition (level 4), characterized by 2 series of 20 seconds for both lower limbs (dominant and non-dominant). The position adopted was with supporting leg in a semi-flexed position and the counter-lateral with knee flexed at 90º, arms crossed and hands resting on shoulders[17]. For this study, Balance System platform (Biodex Medical Systems, Shirley, New York, USA) was used. Calibration was carried out according to manufacturer´s recommendations. Based on the test, global, anteroposterior and medial-lateral balance indexes were obtained.

After a five-minute period, the Hop Test (HT) was applied, in which participants were asked to stand on one limb, with counter-lateral knee flexed at 90° and hands resting on their hips. After verbal command, participants were asked to jump the longest possible distance. The test was repeated three times, bilaterally with one-minute intervals between each hop. The average values were taken for analysis according to guidelines by Magee et al.[18]. After a five-minute interval, an agility test was conducted, which consisted of running into an ”8” shape circuit of 10m long by 4m wide[19]. Participants were asked to run at their highest possible speed. The test was conducted once and the time spent, in seconds, was considered for analysis.

A previous study carried out by Ross et al.[20] showed intraclass correlation coefficient (CCI) of 0.92 for the HT test, whereas for the”8” shape circuit running test, another study[21] obtained 0.87 for CCI. For balance indexes, Malaysia et al.[22] demonstrated CCI indexes of 0.85, 0.78 and 0.84 for global, anterior-posterior and medial lateral, respectively, indicating high reliability of the balance platform.

Data analysis

Data were analyzed using the *Statistical Package* for the *Social Sciences* (SPSS) software, version 21.0. The independent variable used was training group (TRA and TRE). Dependent variables were: Unipodal Balance Indexes (ASL); Time obtained in the agility test (running in “8”, in seconds) and distance in the HT test (in mt). The Kolmogorov-Smirnov test was applied in order to verify data normality assumptions. As assumptions were met, parametric tests were applied.

Initially, the t *student* test for independent samples was applied, aiming to compare the sample characteristics between TRE and TRA groups (Table 1). Using the t *student* test for paired samples, values of dominant limb (D) and non-dominant limb (ND) for the balance and jumping tests were compared. This analysis showed that only the medial lateral balance index presented differences between D and ND limbs, for both groups. Therefore, for balance variables, except for the medial lateral, data for the dominant limb were used. Finally, Analysis of Variance (ANOVA) 2X2 for mixed models was applied in order to verify differences between pre- and post-training conditions and between training groups. Significance was set at 5% ($p<0.05$).

RESULTS

Forty-eight individuals were assessed for eligibility and were included in this study. However, during the training period, two participants from the TRE group and seven from the TRA group gave up the study. The remaining 39 participants received the original interventions and were included for subsequent analyses (Table 1).

The values for global and anterior-posterior balance indexes measured at pre- and post-training moments are illustrated in Figure 2. For both indexes (global and anterior-posterior), intergroup analysis showed no significant difference between TRE and TRA (p=0.23 and p=0.70, respectively). Similarly, no significant differences were found between pre- and post-training moments for TRE and TRA groups (p=0.54 and p=0.32, respectively).

The index values for the medial lateral balance of D and ND limbs are shown in Table 3. For D limb, no significant difference was found (p=0.94) between pre and post-training moments. Similarly, TRE and TRA groups did not show significant differences (p=0.33). However, there was a significant difference for the ND limb between pre and post-training moments for both TRE and TRA (p<0.01) groups. Figure 3 shows that the TRE group presented an increase in the medial lateral balance index, closer to the average when compared to the traditional group (which presented higher variability). In the intergroup analysis, no significant difference between groups was found (p=0.82).

Data concerning HT and agility test ("8" shape running) are shown in Table 2. Regarding HT, the comparison between groups showed no significant difference (p=0.90). However, significant difference was found between pre- and post-training moments, indicating that both TRE and TRA had gains on the hop test after training. It was clear that the TRE group had higher percentage gains when compared to the TRA group (Table 2)

Regarding the time for the "8" shape running time, the comparison between groups showed significant difference (p=0.03) in post-training, indicating a better running time for the TRA group. However, no significant differences were found between pre- and post-training moments for any of the groups (p=0.74).

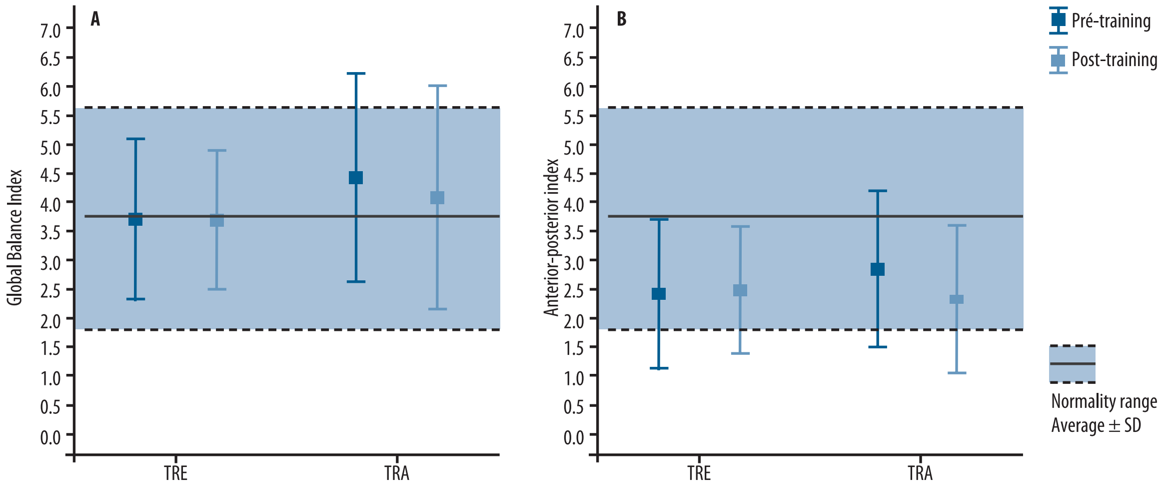

Figure 2. Values of Global Balance (A) and Anterior-posterior Balance (B) at pre and post-training moments for reciprocal contraction group (TRE) and traditional group (TRA). Normality ranges are presented as mean ± standard-deviation, based on the Balance System platform´s reference data.

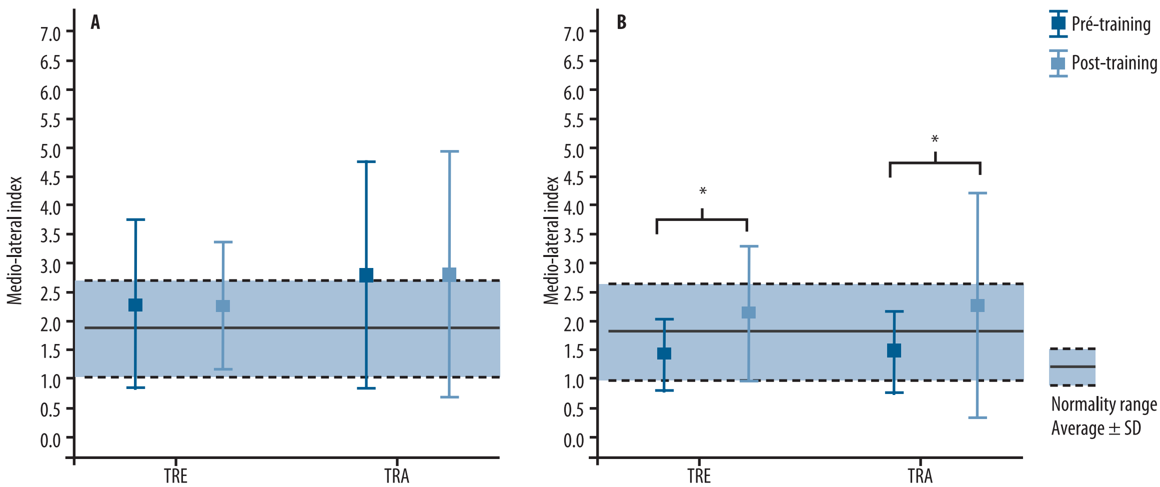

Figure 3. Index values of Medio-lateral Balance of dominant limb (A) and non-dominant limb (B) at pre- and post-training moments,for the reciprocal contraction (TRE) and traditional (TRA) groups. Normality ranges are presented as mean ± standard-deviation, based on the Balance System platform´s reference data (Significant Difference between pre- and post-training moments: *p<0.01).

Table 2. Values for the Hop Test and "8" format circuit in pre- and post-training moments of ST, for reciprocal (TRE) and traditional (TRA) groups. Values are shown as mean ± standard-deviation.

	Hop Test (m)			"8" shape circuit (sec)		
	Pre	Post	**Δ%**	Pre	Post	Δ%
TRE	1.50 ± 0.17	1.61 ± 0.15*	7.3	8.3 ± 0.6	8.5 ± 1.1‡	2.4
TRA	1.56 ± 0.22	1.58 ± 0.19*	1.2	8.1 ± 0.4	7.8 ± 0.4‡	-3.7

TRE: Reciprocal, TRA: Traditional. Significant difference between Pre and Post- training moments: *p=0.00. Significant difference between TRE and TRA groups: ‡ p=0.03. Δ%: Percentage variation between pre- and post-training moments.

DISCUSSION

The aim of this study was to compare the effect of twelve resistance exercise sessions of TRE modality with traditional model, regarding the functional and proprioceptive performance of young individuals. The results partially confirm the initial hypothesis, considering that for the hop test, participants achieved longer distances, but both groups were efficient in post-training. Moreover, global and anterior-posterior balances were not affected by any of the two training modalities. However, significant improvements were found on the medial-lateral balance of the ND limb for both groups. For the "8" shape running circuit, it was observed that in post-training, TRA group obtained better results compared to TRE group.

In this study, 12 RE sessions did not show significant gains in the global and anterior-posterior balance, corroborating results found in the study conducted by Heitkamp et al.[23]. However, for global balance, TRE and TRA groups showed indexes close to those recommended by the *Balance System* platform. Concerning the anterior-posterior balance, both groups began with recommended indexes. However, after intervention, only TRE group remained in the normality range. Apparently, the traditional format is not interesting when the main focus is to balance the knee´s anterior-posterior musculature as only the anterior musculature was trained. These results corroborate those presented by a previous study[4], which recommends that in order to obtain better balance, anterior and posterior muscles should be trained at the same intensity.

Paterno et al.[17] showed the effect of 6 weeks of RE sessions and neuromuscular training, and as in our study, balance evaluations were carried out using the ASL test, level 4. The results reported by Paterno and colleagues showed significant effects from intervention for global and anterior-posterior balance, which can be justified by the training modalities used (strength, plyometric and balance exercises), unlike our study. A factor that could justify the lack of results could be the fact that in this study, the training volume was not adjusted, as the study by Paterno et al.[17] had a periodicity, in which the training overload was adjusted by evaluators according to observations they made in the participants´ evolution. Furthermore, in the study by Paterno et al.[17], the training consisted of exercises aimed at hip, pelvic and thorax muscular groups. On the other hand, this study focused on the agonist and antagonist knee musculature. This fact by itself imposes a limitation when comparing the results.

Heitkamp et al.[23] adopted 2 series of 5 repetitions at 80% of maximum repetition with the same intervention time used in this study (12 sessions). However, they used isoinertial devices (legpress and a flexing table). The authors showed that there was no significant effect on the dynamic balance, corroborating our study. Still regarding the study by Heitkamp et al.[23], no adjustment was made on exercise intensity. Apparently, an increase in the training volume or in the intervention time could cause positive effects on balance indexes as the results of the TRE group provided indications for better balance in the anterior-posterior direction, in accordance with a previous study[17].

Previous results regarding the medial lateral balance did not show significant gains after resistance exercise for the dominant limb, corroborating previous study[17]. However, significant results were found for the non-dominant limb for both groups in post-training, which result was not expected. Surprisingly, the results for the non-dominant limb were better for the TRE group, considering that the values obtained were close to recommendations. In the study conducted by Paterno et al.[17], no significant results were obtained for the medial lateral balance, and no significant difference was found between limbs (D and ND), unlike our results. It could be inferred that these differences are due to methodological variations, as Paterno et al.[17] trained several muscular groups. According to Tessitore et al.[24], there are differences in the coordination of counter lateral limbs, which can be influenced by training. In this case, it can be assumed that differences of coordination between dominant and non-dominant limbs of our sample could have been affected differently by training.

Concerning HT, both TRE and TRA groups showed significant gains, 7.3% and 1.2%, respectively. Fitzgerald et al.[25] showed that HT is commonly used as a representation of physical performance and widely used for clinical assessment in order to measure dynamic balance. In turn, Sekiya et al.[26] reported that HT can provide qualitative data regarding quadriceps and hamstring muscular strength. However, there is no consensus in literature as to which muscular group becomes more involved in functional activities. Li et al.[27] showed a correlation between hamstrings during functional activities involving the knee joint, whereas other studies[28,29] found correlation only with the quadriceps musculature. Our results corroborate those by Sekiya et al.[26], in which jumping gains were observed in TRE and TRA groups. These effects demonstrate transference of gains acquired by resistance exercise for functional activities, with some indications of higher efficiency for TRE group, even though there is no difference in relation to TRA group. Apparently, the strengthening of agonist and antagonist muscles provides better results for functional exercises such as jumping[4,27].

The results for the “8” shape running did not show significant effects for TRE and TRA groups after training. However, significant differences between groups at the post-training moment could be observed. Pasanen et al.[28] investigated a muscle warm-up program over 6 months, including running techniques, balance jumping and muscle strengthening exercises of soccer players. The authors showed significant effects on the “8” shape running in accordance with results for TRA group (2.4% reduction in the running time), while TRE group showed a 3.7% increase. Thus, traditional training produced a better response than reciprocal one, corroborating the results by Maynard and Ebben[5], who demonstrated that the pre-activation of the knee´s flexor muscles produced acute deleterious effects on the agonist muscle group (quadriceps). Thus, it could be inferred that the performance of activities such as running can benefit from training aimed only at the primary muscular groups (agonist). However, this assumption should be confirmed in further studies.

Our study presented some limitations. Initially, it is possible to suppose that longer training, over more than 6 weeks, could favor the proprioceptive response as there would be higher levels of muscle strength from training sessions over 8 weeks or longer. Another limitation was the lack of blind evaluators during the evaluation process, which is an issue to be considered in future studies using resistance exercise, regardless of exercise modality being adopted. The training characteristic, focused on only one joint (knee) could also have limited interpretations and results, as both proprioception and musculoskeletal function depend on the interaction among different kinematic chains. Finally, for future studies, we suggest considering the reciprocal action model for longer training protocols and to include exercises that involve more muscular groups, mainly ankle, knee and hip joints.

CONCLUSION

This study showed that resistance exercise provided transference for balance and functional tests in a sample of healthy young individuals. Despite the absence of significance, training carried out on the reciprocal contractions modality showed better indexes for the hop test performance and medial lateral balance of the knee. However, exercise modality with no pre-activation showed better results for running performance. The findings show that the use of reciprocal contractions can be included in exercise programs that use resistance exercise when the focus is the dynamic joint balance.

REFERENCES

1. Kraemer WJ, Ramamess NA. Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc 2004;36(4):674-88.
2. Fleck SJ,Kraemer WJ. Fundamentos do treinamento de força muscular. 3. ed. Porto Alegre: Artmed, 2006.
3. American College of Sports Medicine (ACMS).Diretrizes para os teste de esfoço e sua prescrição. 5ª ed. Guanabara Koogan, 2007.
4. Wikstrom EA, Tillman MD, Chmielewski TL, Borsa PA. Measurement and evaluation of dynamic joint stability of the knee and ankle after injury. Sports Med 2006;36(5):393-410.
5. Maynard J, Ebben WP. The effects of antagonist prefatigue on agonist torque and electromyography. J Strength Cond Res 2003;17(3):469-74.
6. Balsamo S, Tibana RA, Nascimento DC, Farias GL, Petruccelli Z, Santana FS, et al. Exercise order affects the total training volume and the ratings of perceived exertion in response to a super-set resistance training session. Int J Gen Med 2012;5:123-7.
7. Carregaro RL, Cunha RR, Cardoso JR, Pinto RS, Bottaro M. Effects of different methods of antagonist muscles pre-activation on knee extensors neuromuscular responses. Braz J Phys Ther 2011;15(6):452-9.
8. Miller JP, Croce RV, Hutchins R. Reciprocal coactivation patterns of the medial and lateral quadriceps and hamstrings during slow, medium and high speed isokinetic movements. J Electromyogr Kinesiol 2000;10(4):233-9.
9. Jeon HS, Trimble MH, Brunt D, Robinson ME. Facilitation of quadriceps activation following a concentrically controlled knee flexion movement: the influence of transition rate. J Orthop Sports PhysTher 2001;31(3):122-9; discussion 30-2.

10. Burke DG PT, Holt LE. The influence of varied resistance and speed of concentric antagonistic contractions on subsequent concentric agonistic efforts. J Strength Cond Res 1999; 13(3):193-7.
11. Robbins DW, Young WB, Behm DG, Payne WR. The effect of a complex agonist and antagonist resistance training protocol on volume load, power output, electromyographic responses, and efficiency. J Strength Cond Res 2010;24(7):1782-9.
12. Zatsiorsky VM, Kraemer WJ. Ciência e prática do Treinamento de Força. 2a ed. Phorte, 2008.
13. Wilson GJ, Murphy AJ, Walshe A. The specificity of strength training: the effect of posture. Eur J Physiol 1996;73(3-4):346-52.
14. Kisner C, Colby LA. Therapeutic exercise. Foundations and techniques. 5thed. Philadelphia: Davis Company, 2007.
15. Ratamess NA, Alvar BA, Evetoch TK, Housh TJ, Kibler WB. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 2009;41(3):687-708.
16. Parcell AC, Sawyer RD, Tricoli VA, Chinevere TD. Minimum rest period for strength recovery during a common isokinetic testing protocol. Med Sci Sports Exerc 2002;34(6):1018-22.
17. Paterno MV, Myer GD, Ford KR, Hewett TE. Neuromuscular Training Improves Single-Limb Stability in Young Female Athletes. J Orthop Sports Phys Ther 2004;34(6):305-16.
18. Magee DJ. Avaliação musculo esquelética. 4a. ed. São Paulo: Manole, 2005.
19. Fonseca ST, Magee D, Wessel J, Reid D. Validation of a performance test for outcome evaluation of knee function. Clin J Sports Med 1992: 2(4):251-6.
20. Ross MD; Brian L, Patrick J. Whelan PJ. Test-Retest Reliability of 4 Single-Leg Horizontal Hop Tests. J Strength Cond Res 2002;16(4):617-22.
21. Gross TM, Everts JR, Sarah E, Roberson BS, David S, Roskin BA, et al. Effect Of Donjoy Ankle Ligament Protector And Aircast Sport-Stirrup Orthoses On Functional Performance. J Orthop Sports Phys Ther 1994;19(3):150-6.
22. Arifin N, Abu Osman NA, Wan Abas WA. Intrarater test-retest reliability of static and dynamic stability indexes measurement using the biodex® balance system during unilateral stance. J Appl Biomech 2014;30(2):300-4
23. Heitkamp HC, Horstmann T, Mayer F, Weller J, Dickhuth HH. Gain in strength and muscular balance after balance training. Int J Sports Med 2001;22(4):285-90.
24. Tessitore A, Perroni F, Cortis C, Meeusen R, Lupo C, Capranica L. Coordination of soccer players during preseason training. J Strength Cond Res 2011; 25(11):3059-3069.
25. Fitzgerald GK, Lephart SM, Hwang JH, Wainner RS. Hop tests as predictors of dynamic knee stability. J Orthop Sports PhysTher 2001;31(10):588-97.
26. Sekiya I, Muneta T, Ogiuchi T, Yagishita K, Yamamoto H. Significance of the single-legged hop test to the anterior cruciate ligament-reconstructed knee in relation to muscle strength and anterior laxity. Am J Sports Med 1998;26(3):384-8.
27. Li RC, Maffuli N, Hsu CY, Chan KM. Isokinetic strength of the quadríceps and hamstrings and functional ability of anterior cruciate ligament deficient knees in recreational athletes. Br J Sports Med 1996;40:161-4.
28. Pasanen K, Parkkari J, Pasanen M, Kannus P. Effect of a neuromuscular warm-up programme on muscle power, balance, speed and agility: a randomised controlled study. Br J Sports Med 2009;43(13):1073-8.
29. Iton H, Kurosaka M, Yoshiya S, Ichihashi N, Mizuno K. Evaluation of functional deficits determined by four different hop tests in patients with anterior cruciate ligament deficiency. Knee Surg Sports Traumatol Arthrosc 1998;6(4):241-5.

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