ORIGINAL RESEARCH

The contract-relax proprioceptive neuromuscular facilitation (PNF) stretching can affect the dynamic balance in healthy men

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OBJECTIVE: This study aimed to investigate the effect of the contract-relax proprioceptive neuromuscular facilitation (CR PNF) stretching protocol on dynamic balance.
METHODS: Twenty healthy young male performed two sessions in a randomized order; a session with CR PNF stretching protocol, and a session without the stretching protocol. Bipedal dynamic balance was measured in anterior-posterior and medio-lateral directions before and after the completion the two experimental sessions with eyes opened and closed.
RESULTS: the present study showed that there is no significant difference between the two sessions (with vs without the CR PNF stretching protocol) in the anterior-posterior direction. However, in the medio-lateral direction, the CR PNF stretching protocol significantly enhanced dynamic balance, when compared with the no stretch protocol condition.
CONCLUSION: This study concluded that CR PNF stretching might be effective to improve dynamic balance control.

KEYWORDS: Postural control, proprioceptive neuromuscular facilitation, Proprioception, Stretching.

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INTRODUCTION

Stretching procedures are usually performed as a pre-strategy to the physical activity that follows; there are several techniques that may be used including static, dynamic, ballistic, and proprioceptive neuromuscular facilitation (PNF).[1] In this way, each technique may present different effects on balance control tasks that have been shown to play a fundamental role in many physical activities and may contribute to a successful performance.

Dynamic balance can be defined as maintenance of a center of mass over a base of support when moving or when an external perturbation is applied to the body.[2] Previous studies evaluated the effects of static or dynamic stretching on static and dynamic balance performance.[3-8] Static balance was altered prior of passive stretching[9] and after a single 3-min stretching of the calf muscle.[7] Dynamic stretching was significantly better than static stretching in dynamic balance which consists of a swinging platform on the medial axis.[10]

Static stretching for the bilateral quadriceps femoris, hamstrings, gastrocnemius, and soleus has no effect on the dynamic balance in a healthy subject.[5] The acute effects of unilateral ankle plantar flexor static-stretching significantly increased the Center of Pressure (COP) area in the stretched limb compared with the non-stretched limb when tested immediately after the main intervention.[2]

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Similarly, a static stretching protocol lasting 45-seconds does not affect the dynamic balance, whereas a moderate 15-second stretching protocol induced significant improvements in dynamic balance performance by increasing postural stability.[3]

Nelson et al.[8] found that static stretching improved dynamic balance for non-balance trained individuals, but not for those with greater balance experience.

Handrakis et al.[4] found that the Dynamic Stability Index of the static stretching group was significantly smaller than that in the no stretching group.

Additionally, the visual system plays an important role in balance control, and the postural sway increases in the absence of vision.[11,12] It would be interesting to know how the addition or removal of vision influences the effects of warm-up with/without stretching on dynamic balance performance. Static stretching procedures can impair static balance control ability and increase the postural sway, but largely compensated by the inclusion of vision.[7]

There is a lack of studies about the effect of PNF stretching on dynamic balance control. There is also a need to know if PNF stretching is beneficial or detrimental to postural performance. Only two studies[6,13] investigated the effects of both Contract Relax Agonist Contract PNF and Hold-Relax PNF stretching protocol on balance performance. In the study by Ryan et al.[13] the Contract Relax Agonist Contract PNF strategy to the hamstrings, plantar flexors, and hip flexors was performed under two different conditions: (1) warm-up and stretch and (2) stretching condition. In the warm-up and stretching condition, a 6-minute treadmill warm-up at 65% of maximum heart rate reserve was applied before Contract Relax Agonist Contract. They suggested that the Contract Relax Agonist Contract PNF stretching with or without warm-up improved medio-lateral (ML) stability and that Contract Relax Agonist Contract is a useful protocol for improving the said ML stability.[13] A unilateral stance was used to evaluate the balance performance.[13] Lim et al.[6] found that the static-stretching and the Hold-Relax PNF stretching on hamstring muscle have no significant effects on static balance in adults.

Therefore, the aim of this study was to investigate the acute effects of contract-relax PNF stretching on dynamic balance control during open and closed eyes in healthy men. It was hypothesized that (1) the contract-relax PNF stretching will decrease the balance sway more than any contract-relax PNF stretching and (2) the absence of vision will increase the postural sway irrespective of the stretching protocol.

METHODS

Subjects

Twenty young, healthy male subjects (age: 21.3 ± 2.34 years; height: 177.7 ± 6.9 cm; total body mass: 69.2 ± 11.51 kg) volunteered for this study. They were all classified as recreationally active.[14-20] This study was designed to determine if a regimen of static stretching exercises after a familiarization period would improve a person's ability to maintain a stabilometer in a neutral position and whether stretching had the same effect on individuals with extensive involvement with balancing tasks. Forty-two college students (21 male, 21 female They engaged in some form of physical activity for at least 30 minutes, 3-4 days per week.[(14)] Exclusion criteria were a history of back or lower extremity injury that required surgical intervention, vestibular dysfunction, or current injury making the subjects unable to participate. This study was approved by the University research ethics committee and all subjects read and signed an informed consent form (#74/12).

Procedures

All subjects visited the laboratory in three separate sessions, with 48-72-hours between them, and all subjects were instructed not to engage in any physical activity for 48 hours before the testing sessions. In the first session, all subjects underwent anthropometric measurements and a familiarization with the balance test. This was composed of the contract-relax PNF stretching protocol performed in eight different trials, four in the anterior-posterior (AP) and four for in medio-lateral (ML) dynamic balance control. Two trials in each direction were performed with eyes opened and two trials in each direction were performed with eyes closed. This first session took approximately 20 minutes. In the second and third sessions, all subjects performed a 5-min submaximal warm-up[15,16] on a cycle ergometer (Monark 894E, Stockholm, Sweden) at 70 rpm,[16] and the following procedures were performed: (a) intervention session: 5-min. of warming-up + 10 minutes of contract-relax PNF stretching protocol, and (b) control session: 5-min. of warming-up + 10 minutes of rest. The sequence was randomized for all the subjects to avoid carryover effects. [(3,9)] Balance variables were measured immediately before and after each complete session. Each session lasted 15 minutes, and all subjects performed the sessions at the same time of day to minimize the effect of circadian variation. They were also instructed to keep their dietary habits and to report any changes in physical activity or sleep patterns within the period of the study.

Balance evaluation

For the balance evaluation the COP displacement was measured at a sampling rate of 40 Hz using a calibrated static stabilometric platform (PostureWin, Techno Concept, Cereste, France; 12 bit A/D conversion).

All subjects kept on a seesaw device (Stabilomètre; Techno Concept; radius 55 cm and arrow of 6 cm) to test dynamic balance that generated instability (Figure 1) in the AP or ML direction.[17]

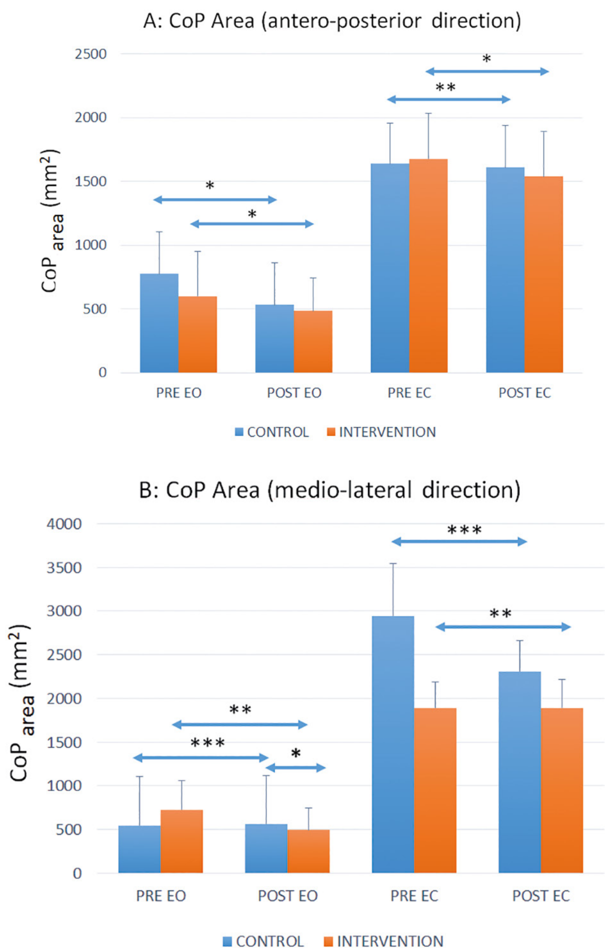

Figure 1 - Mean and standard deviation of COParea in (a) AP direction, and (b) ML direction before (Pre-test) and after (Post-test), each session (CO and IS), and under two visual conditions (EO and EC).* indicates significant differences, $p < 0.05$; ** indicates significant differences, $p < 0.01$; and *** indicates significant differences, $p < 0.001$. CO: control; IS: intervention; EO: eyes opened, and EC: eyes closed.

Before and after each session, participants were asked to remain standing as still as possible on the platform with their arms along the body, with their bare feet forming a 30° angle relative to each other (inter-malleolar distance of 5 cm). Each of the two directions (ML and AP) were performed with eyes opened and eyes closed. In the eyes opened condition, participants were instructed to look ahead at a white cross placed on a wall 2 m away, at eye level. In the eyes closed condition, they were asked to keep their gaze horizontal in a straight-ahead direction. Two trials were performed in each experimental condition for a total of 8 trials for each subject. Each trial lasted 25.6-sec for the AP and ML dynamic balance directions. A resting period of 10 seconds was allowed between trials to avoid any possible neuromuscular fatigue effects. Each trial was presented in a random order to cancel learning or fatigue effects. Data collection was initiated after subjects adopted the required posture on the platform, stabilized their position and signaled the experimenter that they were ready to begin. During the recording session, the experimenter remained near the subject for security without touching him or providing additional instructions and took care that the posture was maintained throughout the trials.

Intervention Session

Lower limb muscles in both legs were passively stretched by the researcher during 10-min of contract-relax PNF protocol, in the following manner: (a) subjects kept in standing position, a knee flexion was performed to stretch the quadriceps femoris muscle; (b) subjects kept lying down, the hip was flexed in knee extension for the hamstring muscles; (c) subjects kept lying down, the ankle was moved in dorsiflexion for the tibialis anterior muscle; and (d) subjects kept lying down, the ankle was moved in plantar-flexion for the triceps surae. The subject performed a maximal isometric contraction to the target muscle during 5-sec for the agonist muscle, followed by 5-sec of relaxation, and 5-sec of static-stretching. All subjects had a right dominant leg based on the limb used for kicking the ball.

Data analysis

To evaluate the balance performance of subjects, two postural parameters were calculated in this study for each direction (AP and ML): the COP_{area} corresponding to the 90% of confidence ellipse, and the $COP_{Velocity}$ corresponding to the sum of the COP displacement scalars divided by the sampling time. Each parameter was averaged for two trials per condition and per subject in order to obtain a representative measure of the postural behavior.

Statistical analysis

The normality and homogeneity of variances within the data were confirmed with the Shapiro-Wilk and Levene tests, respectively. For each dynamic postural condition (AP and ML), a repeated measures ANOVA (2 sessions × 2 test × 2 vision) were used to assess the effects of session (control vs. intervention), test (Pre- vs. Post-test) and vision (eyes opened vs. eyes closed) on the dependent variables $COP_{Velocity,}$ and COP_{Area}. The Scheffé post-hoc test was performed. All statistical tests were processed using STATISTICA Software (version 8.0; StatSoft, France). Mean and standard deviation (SD) values were calculated for each parameter. The effect size (*d*) was calculated to verify the magnitude of the differences by Cohen's *d* calculator. The results were based on the following criteria: 0.20–0.49 small effect, 0.50–0.79 medium effect, and ≥ 0.80 large effect (18). An alpha error < 5% was used to determine statistical significance.

RESULTS

No intercurrences occurred during the experiment.

For COP_{Area} in AP direction (Figure 1a) we observed a main effect for test (F = 125.56, $p < 0.001$, partial eta

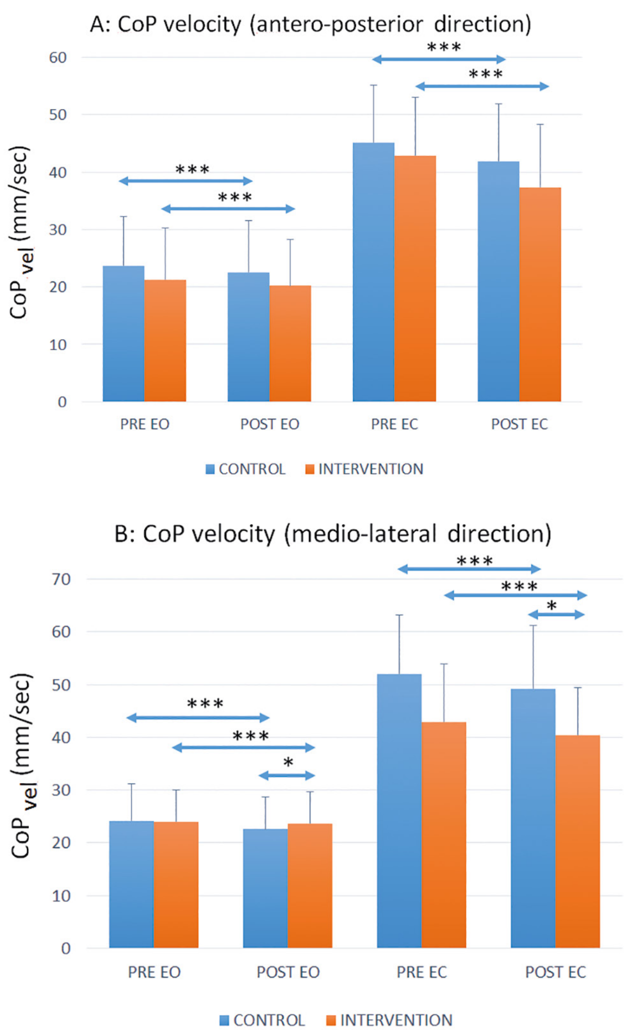

Figure 2 - Mean and standard deviation of COPvelocity in (a) AP direction, and (b) ML direction before (Pre-test) and after (Post-test), each session (CO and IS), and under two visual conditions (EO and EC).* indicates significant differences, p < 0.05; ** indicates significant differences, p < 0.01; and *** indicates significant differences, p < 0.001. CO: control; IS: intervention; EO: eyes opened, and EC: eyes closed.

squared η_p^2=0.86, observed power = 1), but not for session (F = 0.35, p = 0.55, η_p^2 = 0.86, observed power = 0.08), or vision (F = 4.18; p = 0.054, η_p^2 = 0.18, observed power = 0.49). All interactions (session * test, session * vision, test * vision and session * test * vision) were not significant (p > 0.05). The COP_{Area} in AP direction decreased significantly after control session in eyes opened (p = 0.02, d = 0.46: medium) and eyes closed (p = 0.0017, d = 0.03: small), and after intervention session in eyes opened (p = 0.019, d = 0.32: small), and eyes closed (p = 0.022, d = 0.18: small). Session and vision have no significant effects (p > 0.05) on COP_{Area} in AP direction.

For COP_{Area} in ML direction (Figure 1b) we observed a main effect of session (F = 4.53; p = 0.046, η_p^2 = 0.19, observed power = 0.52), test (F = 56.22; p < 0.001, η_p^2 = 0.74, observed power = 1) and vision (F = 4.4; p = 0.049, η_p^2 = 0.18, observed power = 0.51). A significant interaction was found for session by test (F = 7.15; p = 0.015, η_p^2 = 0.27, observed power = 0.72), but all other interactions were not significant (p > 0.05). The COP_{Area} in ML direction decreased significantly after control session in eyes opened (p < 0.001, d = 0.04: small), and eyes closed (p < 0.001, d = 0.38: small) , and after intervention session in eyes opened (p = 0.009, d = 0.42: small), and eyes closed (p = 0.0014, d = 0.0001: small). The Post hoc analysis showed significantly (p = 0.022, d = 0.04: small) lower COP_{Area} in ML direction after the intervention compared to control session in eyes opened condition. Additionally, the suppression of vision significantly (p < 0.05) increased the COP_{Area} in ML direction irrespective of the session and the test.

For $COP_{Velocity}$ in AP direction (Figure 2a) we observed a main effect of test (F = 219.44; p = 0.000, η_p^2 = 0.92, observed power = 1) and vision (F = 9.45; p = 0.006, η_p^2 = 0.33, observed power = 0.83), but not for session (F = 3.59; p = 0.073, η_p^2 = 0.15, observed power = 0.43). A significant interaction was found for test by vision (F = 5.17; p = 0.034, η_p^2 = 0.21, observed power = 0.57), but all other interactions (session* test, session * vision and session * test * vision) were not significant (p > 0.05). Post hoc analysis revealed that $COP_{Velocity}$ in AP direction decreased significantly after control session in eyes opened (p < 0.001, d = 0.21: small) and eyes closed (p < 0.001, d = 0.28: small), and after intervention session in eyes opened (p < 0.001, d = 0.17: small), and eyes closed (p < 0.001, d = 0.6: meduim). Moreover, post-hoc analysis showed that $COP_{Velocity}$ in AP direction increased significantly when the vision was removed.

For $COP_{Velocity}$ in ML direction (Figure 2b) we observed a main effect of session (F = 8.71; p = 0.008, η_p^2 = 0.31, observed power = 0.8) and test (F = 82.46; p = 0.001, η_p^2 = 0.8, observed power = 1), but not significant for vision (F = 1.8; p > 0.05, η_p^2 = 0.08, observed power = 0.24). A significant interaction was found for session by test (F = 15.76; p < 0.001, η_p^2 = 0.45, observed power = 0.96), but all other interactions were not significant (p > 0.05). Post hoc analysis revealed that $COP_{Velocity}$ in ML direction decreased significantly after control session in eyes opened (p < 0.001, d = 0.27: small) and eyes closed (p < 0.001, d = 0.19: small) and after intervention session in eyes opened (p < 0.001, d = 0.03: small) and eyes closed (p < 0.001, d = 0.19: small). Post hoc analysis showed significantly greater $COP_{Velocity}$ in ML direction for intervention session compared to control session in eyes opened (p = 0.03, d = 1.01: small) and significantly lower for intervention session compared to control session in eyes closed (p = 0.04, d = 8.79: large). Suppression of vision has not a significant effect (p > 0.05) on increasing the COP_{Area} in ML direction.

DISCUSSION

The purpose of the present study was to investigate the effect of contract-relax PNF stretching on dynamic balance control using ML and AP directions. The most important findings in the present study were the significant decrease of the COP_{Area} and $COP_{Velocity}$ for dynamic balance in both directions (AP and ML) with eyes opened and closed, corroborating our hypothesis. As far as we know, it was the first study to test contract-relax PNF's effects on dynamic balance performance. Additionally, there are different theories about what can be considered as a "good balance", so during this study, we have considered as a balance improvement when the COP variables presented lower values on post-test.[19,20] The COP_{Area} and $COP_{Velocity}$ decreased significantly after control and intervention session. The COP_{Area} was significantly affected by vision in ML direction, and for $COP_{Velocity}$ in AP direction. The postural sway increased when the vision was removed in all conditions. Furthermore, the interaction between session and test was statistically significant for COP_{Area} and $COP_{Velocity}$ in ML direction. The COP_{Area} showed that intervention session was better than control session in eyes opened condition and $COP_{Velocity}$ showed that control session was better than intervention session in eyes opened condition and, finally, the intervention session was better than control session with eyes closed. We found that intervention and control session reduced the dynamic balance control in both directions (AP and ML). Furthermore, this study demonstrated that in ML dynamic balance control was significantly improved after the intervention session compared to control session. However, there was not a significant difference in AP direction of dynamic balance control between sessions. The improvement in ML stability may be because of the actual warm-up, neurological facilitation from the contract-relax action, and irradiation overflow from the antagonist-contract phase.[13]

Because this was the first study to test contract-relax PNF's effects on balance performance, it is speculative to say if contract-relax PNF is beneficial or detrimental to performance. It is difficult to compare our results with previous findings because no study has investigated the effect of contract-relax PNF stretching on balance control. Only two studies[6,13] that investigated the effects of other types of PNF stretching on postural balance. Contract Relax Agonist Contract PNF stretching with or without warm-up improved ML stability and it is a useful protocol for improving the ML stability.[13] Static stretching and hold-relax PNF stretching have no significant effects on static balance in adults with hamstring muscle tightness.[(6)] PNF stretching is thought to have its effect via two main pathways; autogenic and reciprocal inhibition.[21] The contract-relax procedures lead to increased tension on the Golgi tendon organ through the isometric contraction.[22] This is thought to lead to autogenic inhibition, overcoming the myotatic reflex and reducing the neural activity in the stretched muscle. Etnyre and Abraham[23] provided support for this theory by assessing the excitability of the motor neuron pool (indicated by the Hoffmann reflex response) of the soleus muscle during static stretching and PNF (both contract-relax and Contract Relax Agonist Contract techniques). All methods resulted in decreased excitability, although the contract-relax and Contract Relax Agonist Contract methods resulted in greater decreases in excitability than static stretching. Furthermore, the CRAC method led to a greater and more sustained decrease in excitability than the contract-relax method alone. The authors attributed this to an additive effect of autogenic and reciprocal inhibition.[23]

In the scientific literature, there is a lack of studies on how PNF stretching influences the balance control. Our findings agreed with literature. Static stretching improved dynamic balance,[3,4,8] but showed that has negative effects on balance.[7,9,10]

Dynamic stretching has a better balance performance than static stretching, because dynamic stretching elevates muscle temperature,[24] stimulates the nervous system[25] and increases electromyographic amplitude, which may result in a positive effect of dynamic stretching on muscle activation.[26] In the present study, eyes closed enhanced dynamic balance control. We can consider that the use of 5 minutes of warm-up only in the present study represents a general warm-up, whereas the 5 minutes of warm-up coupled with 10-min of CR PNF stretching represents as a general warm-up with a specific warm-up added on. A general aerobic warm-up of 5 to 10-min is more effective than stretching at increasing blood flow to working muscles, increasing muscle temperature, improving delivery of oxygen and energy substrate, increasing nerve impulse velocity, and removing metabolic waste products.[27]

Additionally, the present study proved that vision has statistically significant effects upon $COP_{Velocity}$ in the AP direction and upon COP_{Area} and $COP_{Velocity}$ in the ML direction; this result was similar to what was reported by Nagano et al,[7] who found that for postural parameters, vision had statistical significance. Our results agree with previous reports of improved human balance control with visual imput, but of impaired balance control without it.[7,28-30] It is also notable that the interaction between test and vision was statistically significant for $COP_{Velocity}$ in the AP direction. Consequently, we suggest that the increased balance sway during standing was attenuated by vision during the post-test in eyes opened condition.[7]

In order to have optimal balance, it is necessary that the three afferent systems of proprioception, vision and vestibular provide the necessary information for adequate performance.[31] The visual system plays a major role in balance control, and postural sway increases in the absence of vision.[11,12] Vision has been shown to effectively compensate for the loss of other sensory fields.[32,33] The present study showed that dynamic balance control was improved in the post-test in both conditions (eyes opened and closed), and this result was due to visual input.[7]

A limitation of this study is that we did not evaluate the agonist-antagonist relationship, range of motion, and ligament laxity during all sessions. Futures studies should include electromyographic analyzes during the balance test (pre- and post-test) to determine the cause of enhancement of dynamic balance control.

CONCLUSION

The present study confirms that the application of contract-relax PNF stretching decreases the Medio-Lateral dynamic balance when compared to control session. In addition, both sessions enhanced the dynamic balance control (AP and ML directions) in young recreationally active men.

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CONFLICT OF INTEREST

Authors declare no conflict of interest regarding this project.

AUTHOR PARTICIPATION

Amine Ghram: acquisition of data, interpretation of data and writing the article; Mohamed Damak: interpretation of data, writing the article and final approval of the submitted version; Fatma Rhibi: analysis of data, critical review of article and final approval of submitted version; Paulo Henrique Marchetti: interpretation of data, writing the article, critical review of the article and final approval of submitted version.

A FACILITAÇÃO NEUROMUSCULAR PROPRIOCEPTIVA POR CONTRAÇÃO-RELAXAMENTO PODE AFETAR O EQUILÍBRIO DINÂMICO EM HOMENS SAUDÁVEIS.

OBJETIVO: Este estudo teve como objetivo investigar o efeito de um protocolo de alongamento por facilitação neuromuscular proprioceptiva de contração-relaxamento sobre o equilíbrio dinâmico.

MÉTODOS: Vinte jovens saudáveis do sexo masculino realizaram duas sessões oredenadas aleatoriamente; uma sessão com protocolo de alongamento por facilitação neuromuscular proprioceptiva de contração-relaxamento, e uma sessão sem esse protocolo. O equilíbrio dinâmico bipedal foi medido nas direções ântero-posterior e médio-lateral antes e após a conclusão das duas sessões experimentais, com os olhos abertos e fechados.

RESULTADOS: O estudo mostrou que não há diferença significativa entre as duas sessões (com vs sem o protocolo de alongamento) no sentido ântero-posterior. No entanto, na direção médio-lateral, o protocolo de alongamento aumentou significativamente o equilíbrio dinâmico, quando comparado com a condição de protocolo sem alongamento.

CONCLUSÃO: Este estudo permite concluir que o protocolo de alongamento por facilitação neuromuscular proprioceptiva de contração-relaxamento pode ser eficaz para melhorar o controle de equilíbrio dinâmico.

PALAVRAS-CHAVE: controle postural, facilitação neuromuscular proprioceptiva, propriocepção, alongamento.

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