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Research Article

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Benefits of Static Stretching, Pliates® and Elastic Bands Resistance Training on Patients with Relapsing-Remitting Multiple Sclerosis: A Longitudinal Study

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Abstract

Objective: To compare the effects of Pilates®, a 30 s static stretching protocol and elastic bands resistance training on lower and hand-grip strength, rachis morphology, flexibility and body balance among RRMS patients.

Methods: Twenty-two subjects affected by relapsing-remitting multiple sclerosis (RRMS, EDSS ≤ 6) were randomly divided into 3 groups whose members each performed 16 weeks of training. Stabilometry, rachis morphology, sit and reach, handgrip and sit to stand tests were performed three times: T0, after a month of learning training protocols; T1, after eight weeks of training; and T2, after sixteen weeks of training.

Results: Static stretching group. Spinal Mouse (inclination line between ThSp1 and S1 from a standing position): T0 vs. T2, -55%; Sit and Reach test: T0 vs. T2, +15%. Pilates group. Sit and Reach test: T0 vs. T2, +15%; Sit to Stand test: T0 vs. T2, +31%. Elastic group. Stabilometry with eyes open: T0 vs. T1, -51%; stabilometry with eyes closed: T0 vs. T1, -52%; sit to stand test: T0 vs. T2, +39%.

Conclusion: Static stretching, Pilates and resistance training are useful to increase the autonomy in the daily life of people with MS thanks to the adoption of these three different training methods.

Keywords: Multiple sclerosis; Physical exercise; Quality of life; Body balance; Muscle strength; Flexibility

Abbreviations A: Area defined by the orthostatic center of pressure (mm^{-2}); APS: Average anterior-Posterior Speed of the center of the body ($mm \times s^{-1}$); CoP: Center of Pressure; ES: Effect Size; EDSS: Expanded Disability Status Scale; EG: Elastic bands Group; Incl: Inclination Corresponding to the Inclination Line between ThSp1 and S1; IPS: Information Processing Speed; LSp: Lumbar Segment between the last thoracic (ThSp12) and the first sacral (S1) vertebrae; MLS: Average Medial-Lateral Speed of the center of the body ($mm \times s^{-1}$); MS: Multiple Sclerosis; P: Perimeter P described by the orthostatic center of pressure (mm); PG: Pilates Group; PP: Primary-Progressive; PR: Progressive-Relapsing; RR: Relapsing-Remitting; SP: Secondary-Progressive; SS: Static Stretching; SSG: Static Stretching Group; ThSp: Thoracic Segment between the first (ThSp1) and the last (ThSp12) thoracic vertebra; ThSp1: the first Thoracic Vertebra; ThSp12: the last Thoracic Vertebra; S1: the first Sacral Vertebra

Introduction

Multiple sclerosis (MS) is a chronic-degenerative and auto-immune disease, which affects the central nervous system and brings about a progressive loss of myelin, an essential component of nerve cells that allows them to conduct electric stimuli along the nerve fibers. In MS, four disease types have been defined [1] relapsing-remitting MS (RRMS), which is characterized by clearly defined acute relapses or exacerbations, followed by either complete or partial remission of symptoms, with no symptoms worsening between the said attacks; primary-progressive MS (PPMS), characterized by slowly worsening symptoms from onset and the absence of any acute relapses; secondary-progressive MS (SPMS), which begins as relapsing-remitting MS but then transitions to include a slow worsening of symptoms without improvements or remissions; progressive-relapsing MS (PRMS), which involves a progression from onset with occasional acute relapses along the way. A cure has not yet been discovered, even though the effects of the disease can be restricted. MS patients can suffer from somatosensory, cognitive or organic-muscular damage and the clinical course is extremely variable and the life expectance is reduced [2]. Indeed, physiotherapy may be an effective form of rehabilitation, especially in the presence of progressive MS [3]. Environmental factors, such as exposure to cigarette smoke or vitamin D deficits seem to be associated with both pediatric and adult onset of MS [4]. One of the most debilitating consequences of MS is muscle spasticity, which is a disorder in neuromuscular reciprocal inhibition with a greater excitation of the muscle-tendon strain reflex that accounts for arrhythmic movements of the musculoskeletal system by affecting ambulation, decreasing muscle strength and increasing the risk of falls [5]. Skjerbæk et al. [6] have investigated the negative influence of fatigue and pain-related symptoms on MS patients' performance in the "six minute walk test". Fatigue should be adequately controlled by means of pharmacological therapies and physical activity [7] as well as different coping strategies [8]. Regular fitness training correlates with improvements in the quality of life and a reduction in

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fatigue perception among MS patients [9,10], and resistance training in particular is very useful for this aim [11]. The effects of on MS patients have been studied [12] and incremental improvements in body balance, joint mobility and upper body muscle strength have been observed. Marandi et al. [13] compared the Pilates method with microgravity exercises among MS patients and the outcomes revealed positive benefits on dynamic body balance, in keeping with Freeman et al. [14], who demonstrated that Pilates also positively influences ambulation. Moreover, 10 weeks of proprioceptive training prove to be efficacy in the improvement of the stability and in the reduction of the energy required to maintain it [15]. On the other hand, static stretching (SS) is believed to be a valid technique in the presence of chronic-degenerative diseases in reducing spasticity and normalizing muscle tone, along with the maintenance or the increase in the extensibility of slack tissues [16]. The role of physical exercise, especially cardiorespiratory fitness, muscle strength, endurance and muscle-tendon flexibility, is fundamental in order to preserve and improve residual motor abilities of people with MS [17]. Furthermore, a positive correlation between the independence in the daily life activity and the healthcare quality has been demonstrated [18]. Hence, the purpose of this study was to compare the following training methods: Pilates, a 30 s static stretching protocol and resistance training with elastic bands, with the ultimate goal to highlight the most effective treatment to modify significantly lower body strength, rachis morphology and body balance among MS patients.

Methods

Participants

Twenty-two subjects affected by relapsing-remitting multiple sclerosis (RRMS) were enrolled in this study. They provided their formal approval for the participation in this study by signing a specific written informed consent form. Furthermore, the authors certify that all applicable institutional and governmental regulations concerning the ethical use of human participants were followed during the course of this research. The exclusion criteria required that none of the patients had practiced the same physical activity used in this study in at least the preceding 12 months and that all of them were in possession of a certificate of good health and eligibility for non-competitive physical activity released by their physician. Furthermore, no pharmacological treatments were used and no changes in diet were required during both the test and intervention periods. Moreover, the subjects had to have been relapse-free during the previous 6 months to take part in the study. In addition, no patients were hospitalized and all were affiliated to the Italian Multiple Sclerosis Association (AISM). Afterwards, they were randomly divided into 3 groups: the first group (SSG), which included 8 people (age 50 ± 18 years, weight 64 ± 13 kg, height 167 ± 10 cm, expanded disability status scale (EDSS) 4 ± 2), that performed 30 s static stretching protocols; the second group (EG), which included 7 subjects (age 52 ± 10 years, weight 56 ± 5 kg, height 160 ± 6 cm, Expanded Disability Status Scale (EDSS) 3 ± 2), who performed resistance training by means of elastic bands; and the last group (PG), which included 7 participants (age 45 ± 6 years, weight 63 ± 15 kg, height 164 ± 6 cm, Expanded Disability Status Scale (EDSS) 2 ± 2), who underwent the Pilates protocol. The study flow chart is presented in Figure 1.

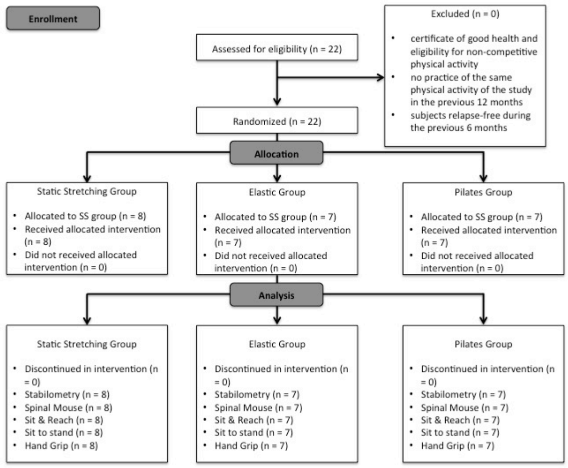

Figure 1: Study flow chart.

Functional assessments

The evaluations were performed in order from the metabolically least demanding to the most, in other words: stabilometry, rachis morphology, sit and reach, hand grip and sit to stand. The three groups were tested three times: T0, after a month of learning training protocols, to identify the baseline performance; T1, two months after T0, to evaluate the effects brought about by the first eight weeks of training; and T2, two months after T1, to evaluate the effects brought about by sixteen weeks of training. The functional evaluation took place in the Adapted Training and Performance Laboratory at the University of Turin.

Stabilometry

The assessment of bipodalic body balance was executed by means of a stabilometric platform (Tecnobody Prokin PK 214 P, Bergamo, Italy), once with eyes open and once with them closed. Both the trials had duration of 60 s with 60 s of passive recovery between them. The following variables related to the center of pressure (CoP) were taken into consideration: average anterior-posterior speed (APS) of the center of the body (mm x s-1), average medial-lateral speed (MLS) of the center of the body (mm × s^{-1}), area (A) defined by the orthostatic center of pressure ($mm^{-}2$), perimeter (P) described by the orthostatic center of pressure (mm).

Sit and reach

To assess the improvement of the flexibility of the posterior kinetic chain, the Sit and Reach test was used. It took place by means of a metal and wood parallelepiped (height 30 cm, width 50 cm, depth 51 cm) on which a 80 cm-long metal binary was applied along center line. On this, a movable carriage, supporting a digital distance measurement device (Bosch GLM 150 Professional, Bosch GmbH, Stuttgart, Germany; accuracy ± 1 mm, measurement time between 0.5 and 4 s, laser class 2) was installed. The foothold was located 30 cm from the origin of the binary, where a metal plate was set, with the aim of standardizing the assessments. On the vertical side of the foothold, a wood triangle, with its base oriented upwards and its vertex oriented downwards, thereby forming a 36° angle named Piok's angle, was positioned in order to identify the correct positioning of the feet on its oblique sides. The participant starts from a sitting position with their legs extended and without shoes. The operator, after having verified that the feet were in full contact with the triangle to avoid their pronation and supination, supervised the starting position, with hands superimposed on the movable carriage. The participant then chose which hand to place on top, and this was kept constant during the subsequent experimental sessions in order to guarantee the reliability of the test. Then, participants were required to bend their trunk progressively forward as much as they could until they felt pain. This procedure was repeated only once to avoid it became a stretching training technique.

Spinal mouse

To monitor rachis morphology, a lateral inclinometer (Spinal Mouse, Idiag, Volketswil, Switzerland) allowing reliable measurement [19] on the sagittal plane was used. The spinous processes were identified via palpation and labeled with a demographic pencil. The data were detected with the sliding of the instrument along the rachis from C7 to S1 with a sampling frequency of 150Hz. The final outcome was the accurate description of all the vertebral corps and the following variables: thoracic segment (ThSp), between the first (ThSp1) and the last (ThSp12) thoracic vertebrae, lumbar segment (LSp), between the last thoracic (ThSp12) and the first sacral (S1) vertebrae, inclination (Incl), corresponding to the inclination line between ThSp1 and S1. All the measurements were performed once and the protocol of data acquisition included: a test from the standing position, in which the participants looked forward, with the feet in line with the shoulders, knees extended and arms along the sides; a test of the maximum flexion of the trunk in which, from a stationary position, the trunk was bent as much as possible while keeping the knees extended; and a test of the maximum extension of the trunk, in which the arms are crossed on the thorax and the maximum backward trunk extension was performed.

Hand grip

The hand-grip test was performed by means of a hydraulic hand-held dynamometer (Baseline, Fabrication Enterprises, White Plains, NY, USA). The subject was seated on a chair with the arm completely extended towards the ground and performed the maximum voluntary hand-grip contraction for 3 ± 1 s. They performed 3 trials for each hand and the best was recorded.

Sit to stand

To perform the sit to stand test, a specific wood and iron bench with a height of 43 cm [20] was utilized. A 1 cm-rigid rubber cushion was positioned to soften the impact of the hip on the seat. The width (70 cm) and depth (100 cm) were chosen to allow the positioning of the Optojump (Microgate srl, Bolzano, Italy) on the sides of the bench, where, to guarantee the safety of the participant during the execution of the tests, a seat-back (height 33 cm) and two lateral bars (height of 1 m from the ground, and a length of 1.30 m) were located 40 cm from the anterior part of the seat and to its sides respectively. Another 1 m-high security bar, which could be opened and closed to allow the participants to enter and leave the test area, was located 1 m in front of the seat-back. The whole structure was fixed to the ground to avoid any movements of the bench during tests, which consisted of counting of the total number of occasions the subject managed to sit down and stand up from the bench in 30 s [21]. The start occurred when the participant was in the upright position with the legs at the same distance apart as the shoulders and an operator checked the correctness of the movements.

Intervention

Each training session began with a warm-up including joint mobility and muscle flexibility exercises aiming to increase body temperature and muscle-tendon elongation. In the static stretching group (SSG), a development phase with 3 sets of 30 s of static stretching exercise was adopted. The recovery time between sets was 30 s and all the exercises utilized are reported in Table 1. The subjects performed the SS protocols twice a week.

Exercise	Muscle gropus
Hand extension	Arm and forearm
Side-bending of the trunk	Lateral region of the abdomen
Dorsal bending of the foot	Gastrocnemius and soleus
Anterior bending of the trunk	Lastissimus dorsi
Lunges with the anterior leg resting on a step	Ileo-psoas, quadriceps
Upper limbs extension	Arm and forearm
Bending of the lower limb on the hip	Hamstrings
Bending of the leg on the gluteus	Quadriceps
Lower limbs abduction from a sitting position and feet against each other	Adductors
Anterior bending of the trunk from a sitting position with legs extended	Hamstrings, lumbars
Bending of the lower limb on the hip with internal rotation	Gluteus, lumbars

Table 1: Exercises utilized by static stretching group (SS) in the static stretching protocols with the related muscle groups elongated.

The elastic band group (EG) performed two muscle strength training sessions each week by means of elastic bands. The protocol involved 3 sets of 10 repetitions, with 30 s of recovery between sets (Table 2).

Exercise	Muscle groups
Internal and external rotation of the arm*	Rotator cuff
Bench press sitting on a chair*	Pectoral major
Forearm bending (Curl)*	Biceps brachii
Side raises*	Lateral delt
Arm extension behind the head*	Triceps brachii
Lower limbs abduction*	Tensor fasciae latae
Lower limbs adduction with elastic ball*	Adductors
Lower limbs extesion foreward starting from a bent position*	Quadriceps

Squat (starting and touching a chair in the return phase)*	Quadriceps, hamstrings
Crunch	Rectus abdominis

Table 2: Exercises utilized by the elastic band group (EG) in the resistance training protocols with the related muscle groups trained. * = exercise performed sitting on a chair.

Exercise	Muscle groups
Hip retroversion	Rectus abdominis
Half curl and Criss Cross	Rectus abdominis and obliquous abs
Roll down and Roll up facilitated	Rectus abdominis
Side leg lift	Tensor fasciae latae
Saw	Lumbars, lastissimus dorsi, hamstrings
Spine stretch	Lumbars, lastissimus dorsi, hamstrings
Cat stretch	Lumbars, lastissimus dorsi
Mermaid	Rectus abdominis and obliquous abs
Bridge	Hamstrings, lumbars
Plank with leg lift	Lumbars, hamstrings
Single leg circles	Rectus abdominis, quadriceps, hamstrings
Side kick	Hamstrings, quadriceps

Table 3: Exercises utilized by pilates group (PG) in the static stretching protocols with the related muscle groups elongated or strengthened.

The Pilates group (PG) was assigned a Pilates protocol to be repeated twice a week. It included 2 sets of 8 repetitions of each exercise with a resting time of 30 s between sets (Table 3).

Statistical methods

Data are presented as mean and standard deviation (± SD). Friedman's ANOVA and Dunn's post hoc were used to investigate differences between test sessions. The significance level was set at $p<0.05$ and the percentage differences were calculated with the following formula: % difference=((FV-IV)/IV) * 100, where IV: Initial Value; FV: Final Value. For interpretation of the relevance of differences, effect sizes (ES) were calculated and interpreted as follows: 0.2 to <0.6, small; 0.6 to <1.2, medium; 1.2 to <2.0, large; 2.0 to <4.0, very large; and ≥ 4.0, extremely large [22].

Results

No significant variations concerning unlisted parameters emerged from this research. In the static stretching group, the Spinal Mouse showed a significant difference in the test concerning the inclination line between ThSp1 and S1, performed from a standing position between T0 and T2 ($p<0.05$, -55%, ES=0.67). Moreover, the Sit and Reach test highlighted a significant improvement between T0 and T2 ($p < 0.05$, +15%, ES=0.36). In the Pilates group, The Sit and Reach test revealed a significant variation between T0 and T2 ($p<0.05$, +15%, ES=0.4), while the Sit to Stand test pointed out significant differences between T0 and T2 (ANOVA: $p<0.05$; post hoc: $p<0.01$, +31%, ES=1.21). Taking into consideration the elastic group, the stabilometry showed a significant differences concerning the ellipsis area when performed with eyes open (T0 vs. T1, $p<0.05$, -51%, ES=0.52) and closed (T0 vs. T1, $p<0.01$, -52%, ES=1.69). Meanwhile, the sit to stand test showed significant improvements between T0 and T2 ($p<0.05$, +39%, ES=1.83).

Discussion

The main goal of this study was to evaluate the effects of training protocols by means of Pilates, elastic bands and static stretching on muscle strength, muscle-tendon flexibility and body balance among patients affected by multiple sclerosis. Although, in the past, physical training was not recommended for MS patients as it was thought that it would accelerate deterioration, now it is often part of therapy in conjunction medication. However, since MS is incurable, rehabilitation mainly focuses on improving residual abilities and mobility rather than aiming for full recuperation [23]. Individuals with a high self-efficacy or those that spend more time in participating in physical activity report less physical impact of MS on their quality of life and thus an increased physical independence [24]. Moreover, 70% of patients reported impairments on complex attention tasks [25] and physical activity also seems to be associated with information processing speed (IPS) [26]. Additionally, although moving a spastic muscle to a new position may increase symptomatology, daily stretching of muscles to their full length helps to manage the tightness of spasticity, one of the most common symptoms of MS, thereby allowing for optimal movements [27]. In this study, the Sit and Reach test highlighted a significant improvement between T0 and T2 (+15%) following both the static stretching and the Pilates protocols, in accordance with Oliveira et al. [28], who demonstrated the efficacy of these two kinds of training methods on muscle-tendon flexibility among older women. Furthermore, 6 weeks with 2 training sessions of stretching and yoga are the minimum time required to show significant reductions in fatigue-related symptoms among MS patients [29]. In addition, stretches in weight bearing positions let patients achieve higher ankle torques, probably as a result of the use of the body to apply a constant force [30]. These results corroborate and justify the minor frontal inclination of the rachis which emerged from the test with Spinal Mouse, which showed a significant difference (-55%) after sixteen weeks of training. This demonstrates the greater body and postural control acquired by participants after training. Lim et al. [31] studied the effect of a Pilates protocol on nineteen individuals affected by unilateral chronic hemi-paretic strokes, and they highlighted significant improvements in both static and dynamic body balance. However, among the MS patients involved in this study, this technique was useful in improving performance in the Sit and Reach and the Sit to Stand test after 16 weeks of training, with no effects on body balance, confirming the greater utility of other training methods to this end, such as core stability [14]. Our outcomes seem to be consistent with a previous study [32] which revealed the great importance of Pilates in the improvement of performance in the sit to stand test after 8 weeks of training. In the research presented herein, 16 weeks of training were necessary to observe significant variations: this could be a consequence of the different protocols utilized. Küçük et al. [32] adopted two different versions of the sit to stand test: in the first, patients were asked to sit on a bed set at a standard height from the floor and stand up once, while, in the repeated sit to stand on/from a chair, they were asked to sit on a chair set at a standard height and stand up 3 times. On the other hand, in this study, the indications provided by Milanović et al. [21], according to which the total number of times the subject manages to sit down and stand up from the bench in 30 s were counted, were followed. In addition, Pilates is believed to be effective in improving sitting posture while reducing shoulder and back pain as well as the value in the Multiple Sclerosis Impact Scale among MS patients relying on a wheel chair [33]. In any case, the importance of Pilates to improve the quality of life has been confirmed, as well as that of exercise therapy, which can help to reduce fatigue in MS patients [34]. However, resistance training should be preferred, because it is not usually accompanied by an increase in core temperature, as seen during endurance training. Therefore, unpleasant feelings caused by the exacerbation of symptoms, as brought about by endurance training, are more rarely experienced [35]. In addition, resistance training should focus on hamstrings and quadriceps muscles which are positively correlated with gait characteristics [36]. Nevertheless, moderate-intensity cycling proved to be beneficial in reducing fatigue and may help in its chronic management among MS patients [37]. Besides this, visual cognition impairments are present in 14% of MS patients [38]: however, in the present study, after 8 weeks of training, the protocol with elastic bands proved to be efficacious to improve stabilometry, performed with eyes both open and closed, as well as the sit to stand test, which showed significant improvements after sixteen weeks of training. This means that, after this kind of training, patients become stronger and more powerful on the one hand and more able to manage their balance on the other. These outcomes corroborate those of a previous study [39], which showed that a very short circuit training program with elastic bands designed for MS patients generates modest improvements in power, an increase in functional capacity and a reduction of their perception of fatigue. Additionally, 6 weeks of isokinetic strength training are sufficient to increase maximum strength and reduce the levels of fatigue in the ankle dorsiflexors of MS patients [40], which showed that a very short circuit training program with elastic bands designed for MS patients generates modest improvements in power, an increase in functional capacity and a reduction of their perception of fatigue. Similarly, the same training period performed three times per week by means of seated rowing, chest press, leg extension and leg press exercises significantly improved performance in the 10 m timed walk test, the 3 min step test and the timed up and go test, with no significant effects on balance [41]. The discrepancies between the previous two studies and this one, concerning the effects of strength training on body balance, can be attributed on the one hand to the different instruments utilized for assessment, and on the other hand to the different type of contraction performed: in this research, the use of elastic bands instead of gym machines or calisthenics exercises can account for a continuous and greater stimulus of neuro-muscular coordination, which reflects positively on body balance. Nevertheless, in keeping with Backus et al. [42], which proposed different training programs though non-specific for the hand-grip strength, this parameter did not showed significant improvement in the present study as well. Additionally, short-term progressive strength training can be considered a valid means to improve the quality of life of people living with relapsing-remitting MS and mild to moderate walking difficulties, since it reduces physical fatigue and increases both muscle strength and endurance. However, the benefits do not persist after complete interruption of the training [43]. Besides this, the present study has some limitations. The first aspect to consider is the limited number of participants. On the one hand, the use of parametric statistical calculations should have been possible due to a lager sample, also bringing about higher effect sizes values. On the other hand, a larger number of subjects could have allowed the creation of a control group to compare their functional evaluations with those of the three treatment groups of this study. In addition, considering the difficulty to find many subjects with the same type of MS and who respect the inclusion criteria, the option to lead multi-centered studies must be considered in the future. Besides this, the intervention of this research could have ameliorated also the pathological condition of the participants, in addition to their physical abilities. Consequently, it can be interesting to verify if physical training is able to stabilize the progression of multiple sclerosis; hence future researches could perform a magnetic resonance, to monitor the progression of the inflammation process and the volume of MS plaques, as well as a bone densitometry, to study the effects of physical training on bone mineral density among people affected by multiple sclerosis.

Conclusion

This study provides useful indications with regard to the rehabilitation and the improvement in the quality of life of people affected by relapsing-remitting multiple sclerosis. In particular, static stretching is useful in increasing the motor control of the rachis and flexibility, as well as the Pilates protocol, which also improved performance in the Sit to Stand test. Moreover, the latter is affected by resistance training by means of elastic bands, which in turn helps the management of body balance. The practical implications which emerged from this study allow us to hypothesize an increment in autonomy in the daily life of MS sufferers thanks to the adoption of these three different training methods.

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