Acute effects of mat Pilates exercises on flexibility: A comparison between young and elderly women

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Abstract

Until today, no one has evaluated the effect of mat Pilates exercises performed on one training season, on the joint flexibility of elder and younger individuals. Therefore, the aim of the present study was to assess the acute effect of mat Pilates exercises on lower extremities joint flexibility between young and older women. A total of 16 women aged between 65-76 years old and 18 younger women aged 24-35 years old volunteered to participate in the study. All participants completed 5 selected mat Pilates exercises ten times (1x10), alternately for each leg, which were repeated once more, in random order (2x10). Measured indices included range of motion after the completion of the exercise, during hip extension and abduction, and during knee and ankle flexion and abduction with the knee flexed. The analysis of variance for repeated measures used to compare the two age groups prior to and after the implementation of the training protocol, revealed a significant improvement ($p \leq 0.001$)in all participants, with the improvements being similar in both age groups. The findings suggest that joint ROM can be ameliorated in the same degree in both young and older women with the use of selected mat Pilates exercises performed in full ROM. Additionally; the findings provide useful information on the design and implementation of Pilates training programs aiming to increase joint flexibility among women of all ages.

Key Words: Pilates; ROM; Joint Flexibility; Elderly women; Young women; Exercise;

Introduction

Flexibility is considered as the ability of a joint to move within full range of motion (ROM) (Holland et al. 2002). In contrast, inflexibility is the term describing restricted joint movement, induced mainly due to the shortening of the competing muscle groups (Alter 1996). A pivotal factor of adequate joint flexibility is the connective tissue elasticity-encircling both the myofibrils and the muscle as a whole (Sapega et al. 1981, Alter 1996), although according to Hutton (1992), the role of connective tissue in joint flexibility appears to be exaggerated.

Age is an important criterion decreasing joint flexibility throughout the course of life, but according to Milne et al. (1981) this effect should not be considered *de facto*. During the preadolescence and adolescence period of life, joint flexibility is in a constant increase (Corbin and Noble1980), but this increment is haltered during early adulthood, followed by a decline in the mid-to-late twenties for both men and women (Bell and Hoshizaki 1981). Hampered flexibility appears even more evident in those aged above 40 years old (Misner et al. 1992) and is further pronounced among the elderly (Klein et al. 2002).

Aging consists of a physiological process associated with degradation in the flexibility of the connective tissue, resulting in reduced joint ROM (Campanelli 1996). These changes are primarily associated with soft-tissue constraints which can further deteriorate flexibility by reducing collagen, the main component of both fibrous and connective tissue, forming ligaments and tendons (American College of Sports Medicine 1998). Additionally, aging alters the crystallinity of the collagen fibres by increasing fibre diameter and subsequently reducing extendibility (American College of Sports Medicine 1998).

Aging induced decreased joint ROM inflexibility affects both the mobility and balance of older people, reducing their ability to perform everyday activities (Klein et al. 2002). Irrespectively of the age, imbalances in lateral muscular development and in flexibility of certain muscle groups can contribute to bad body posture, whereas body posture and reduced gait during walking are mainly the result of poor hamstring muscle flexibility (Grabiner et al. 1993).On the contrary, adequate joint flexibility combined with muscle power can improve movement independency of elderly individuals and ameliorate their ability to perform everyday activities (Hughes et al.1996).The attainment of adequate ROM and strength of the knee flexor and extensor muscles improves body stability in the elderly, safeguarding them from possible falls (Studenski et al. 1991).Although in the elderly, collagen is less mobile and responds slower during stretching compared to younger people, according to literature, stretching exercises can minimize ROM reductions during older age (Alter1996, Wallmann 2009).

Today, a plethora of static stretching and dynamic flexibility protocols are used to increase flexibility. In elder individuals, static stretching is considered more effective (Feland et al. 2001, Ferber et al. 2002, Zakas et al. 2005), due to its simplicity(Bandy and Irion 1994) and safety during implementation compared to other stretching variations (Ferber et al. 2002). However, static stretching induces limited benefits, restricted to the elongation of the competitive muscles involved during exercise and without a meliorating muscle strength, aerobic capacity or movement coordination, all needed for attaining moving independency of the elderly (Hughes et al. 1996). These characteristics can be improved with a dynamic flexibility protocol, involving technical elongation exercises of the muscles, performed in a slow and controlled pace and in full joint ROM (Fredrick and Szymanski 2001, Hedrick 2000).

Pilates consists of an appropriate training method for the elderly, since it has a dynamic manner, it is performed in a slow and gentle pace without imposing musculoskeletal stress. It issue table and safe for all age groups and body types (Caldwell et al. 2009), and this is why it also considered as a successful rehabilitation procedure (Latey 2002).Among younger individuals, Pilates is appropriate for those interested in increasing their physical activity level, while attaining a harmonious body and perception (Kiley, 1999). The performance of Pilates induces multiple benefits among all age groups, including increased quality of life, agility, movement coordination, muscle power and strength, static and dynamic posture, etc. (Phrompaet et al. 2011).

Pilates exercises have been shown to be effectively improve flexibility. However, little is known about the effects of Pilates in the elderly. Although static stretching exercises have used to assess joint flexibility among the elderly (Feland et al. 2001, Klein et al. 2002, Zakas et al. 2005, Zakas et al. 2006b), limited studies have evaluated the results of dynamic type exercises performed in a slow and gentle pace, such as Pilates. These limited studies have used younger individuals (Rogers and Gibson 2009, Sekendiz et al. 2007) or middle-aged participants (Kloubec 2010) with research on the elderly remaining scarce (Babayigiz-Irez et al. 2011). Additionally, none of these studies has assessed the effects of Pilates on joint ROM, but rather focused on other characteristics, such as muscle strength and power, body stability and posture, or body composition. Until today research has only focused on the implementation of Pilates training programs lasting for several weeks, without assessing the acute effects of a single training session (Schroeder et al. 2002).

Although in the elderly, the response of the elastic components of the muscle is slower during stretching, the importance of adequate joint ROM in attaining body stability, avoiding falls (Gehlsen and Whaley 1990) and improving everyday movement autonomy (Cunningham et al. 1993) illustrate the need for research evaluating the acute effects of a single training session of Pilates exercises on the joint ROM of elderly women. Therefore, the aim of the present study was to compare the acute effects of selected mat Pilates exercises on the lower extremities joint flexibility between younger and elderly women.

Methods

Participants

A total of 34 adult women, all volunteers, formed the study's sample. Of those, 16 were considered elderly, aging between 65 to 76 years old (mean age 69.0±5.5 years, mean height 163.2±3.5 cm and body weight of 68.4±8.4 kg), and the remaining 18 were much younger with an age range of 24 to 35years (mean age 30.0±4.7 years old, stature 168.2±4.3 cm and body weight of 71.2±6.8 kg). Inclusion criteria involved being apparently healthy, not receiving any medication and abstaining from any systematic exercise/stretching protocol (such as Pilates) during the last year prior to the study, as well as lack of musculoskeletal injuries. Prior to participation, all women were screened by an experienced physician, who verified their ability to participate in the study and recorded their medical history. Written consent to participate in the study was also attained, according to the principles issued by the Ethics Committee of the Aristotle University and the Helsinki declaration. Women who did not fulfil the aforementioned criteria were excluded from the study (a total of 3). Detailed information was provided concerning the aims and nature of the study, as well as possible risks associated with the scientific protocol. During the study, participants were allowed to continue with their usual daily activities. The protocol was performed indoors, in yoga and Pilates equipped class.

Experimental Protocol

Both age groups performed the same protocol, in random order. All women were familiar with Pilates from previous participation in communal exercise classes. Additionally, they were familiar with the measurements taking place during the study and abstained from any physical activity exercise on the days prior to and during the implementation of the protocol.

The experimental protocol comprised of selected mat Pilates exercises elongating the competitive muscles of the joints. The exercises and the measurements were the same for both age groups and were performed under the same conditions. Each exercise was performed in a slow and gentle manner, leading to the extreme joint extension, with coordinated breathing, repeated ten times (1x10), with an extra repetition(2x10) using the alternating leg, in order to reduce exercise breaks and muscle fatigue.

The protocol included pre-exercise flexibility measurements, followed by a 5-min introduction to Pilates preparing the spine and the trunk for a neural positioning with the use of diaphragmatic breathing and concentration, required in Pilates.The protocol was followed by the implementation of selected mat Pilates exercises for a total of 10 min and the post-exercise flexibility measurements.

Mat Pilates exercises

The mat Pilates exercises used were selected according to joints involved during their implementation, as well as according to the scientific literature's recorded barriers for Pilates exercises among the elderly. The adopted exercises included: (1) *Single Straight Leg Stretch-Modification*, for the dynamic elongation of the rear thigh muscles. (2) *Front-Back*, for the dynamic elongation of the iliopsoas muscle. (3) *Up-Down*, for the dynamic elongation of the adductor muscles. (4) *Single Leg Kick*, for the dynamic elongation of the front thigh muscles. (5) *The Leg Pull Down*, for the dynamic elongation of the rear calf muscles. An experienced trainer specialized in Pilates selected the exercises.

Flexibility measurement

Five ROMs of the lower extremities (hip flexion, hip extension, hip abduction, knee flexion and ankle dorsiflexion with the knee flexed) were measurement. All joints were measured with the use of a Myrin flexometer (Lic Rehab. 17183 Solna, Sweden) according to the Ekstrand et al. (1982) method. This flexometer is a modification of the Leighton flexometer and consists of a circular scale with a weighed pointer controlled by gravity attached to the centre. The variation coefficient for the goniometric measurements method was high (1.9±0.7%).

All measurements, except for the ankle dorsiflexion, were performed on an adjustable bench on the right side. Only the right side of the body was measured since the statistical analyses of the recruitment data failed to show differences between the right and left body sides among participants ($p>0.05$). Each movement's initial and final positions were passively measured starting from a 0° point, as defined by the American Academy of Orthopaedic Surgeons (1965). Maximal flexibility was determined as the point where the joint attained end range, which was defined as the point at which the examiner felt muscle restriction (Ferber et al., 2002). All pretest and post-test measurements were taken at approximately the same time of day, while participants abstained from any training or other type of exercise during the 48h preceding the experiment. The reliability coefficient of each measurement was high: hip flexion $r=0.92$, hip extension $r=0.91$, hip abduction $r=0.93$, knee flexion $r=0.91$and dorsiflexion $r=0.92$.

Statistical Analyses

The statistical analysis was performed with a 2x2 Analysis of Variance model (ANOVA) with repeated measures for both factors. The first repeated factor was flexibility measurement and had two stages (initial and post-exercise). The second repeated factor was the mat Pilates exercises protocol that had two levels (younger individuals and older individuals). Differences between factors were assessed with paired t-tests. In regards to the lateral deviation, we used data from the right side, given that there was no significant difference in comparison to the left side. The level of significance was set at 95% ($p<0.05$).

Results

No differences were observed in the joint ROM between the studied groups after the implementation of the Pilates protocol ($F=1.32$, $p>0.05$), showing that the joint ROM is more affected by the performed protocol rather than from the age of participants. On the contrary, significant differences were observed in the initial joint ROM between groups, with the younger women demonstrating higher ROM compared to the elder ones ($p\leq0.05$).

Analysis of variance failed to show a significant interaction between joint flexibility measurement (initial and post-exercise) and age groups, indicating that the selected exercises were effective in improving joint ROM similarly between both age groups. Analysis of variance with repeated measures showed significant differences in the measurements performed prior to and after the flexibility protocol among the elderly women concerning the hip flexion ($F=101.25$, $p\leq0.001$), hip extension ($F=81.75$, $p\leq0.001$) and abduction ($F=64.22$, $p\leq0.001$), knee flexion ($F=184.67$, $p\leq0.001$) and ankle dorsiflexion ($F=90.33$, $p\leq0.001$). Among younger participants significant differences were recorded in initial and post-exercise hip flexion ($F= 103.40$, $p\leq0.001$), hip extension ($F=82.02$, $p\leq0.001$), hip abduction ($F=63.14$, $p\leq0.001$), knee flexion ($F=185.86$, $p\leq0.001$) and ankle dorsiflexion ($F=90.22$, $p\leq0.001$).

Paired t-tests were used to compare initial and post-exercise joint ROM and the results showed significant improvements for all joints in both age groups ($p\leq0.001$ for all), (Figures 1-5).The recorded improvements among the elderly ranged between 4.6-8.8 degrees, whereas among the younger women ROM was increased between 4.8-8.9 degrees.

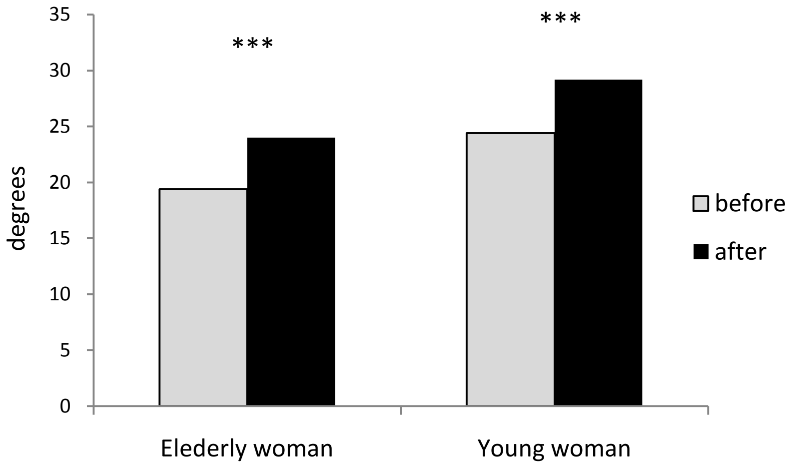

Figure 1. Range of motion during hip flexion, before and after the implementation of selected Pilates exercises, between older and younger women. *** $p\leq0.001$

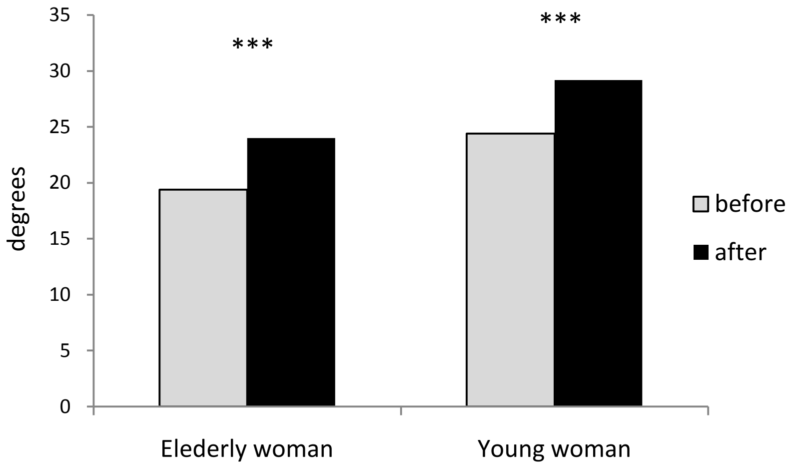

Figure 2. Range of motion during hip extension, before and after the implementation of selected Pilates exercises, between older and younger women. *** $p\leq0.001$

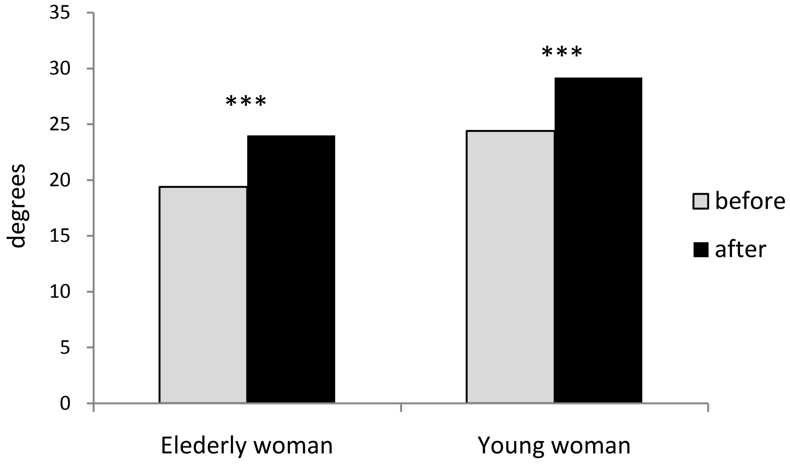

Figure 3. Range of motion during hip abduction, before and after the implementation of selected Pilates exercises, between older and younger women.*** p≤0.001

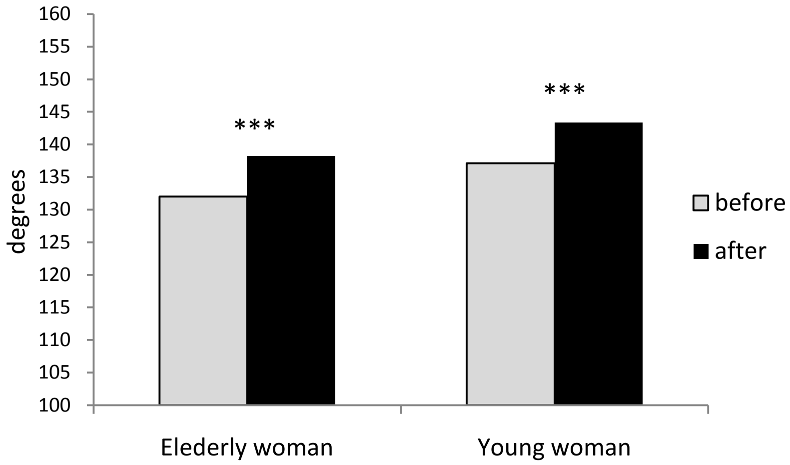

Figure 4. Range of motion during knee flexion, before and after the implementation of selected Pilates exercises, between older and younger women. *** p≤0.001

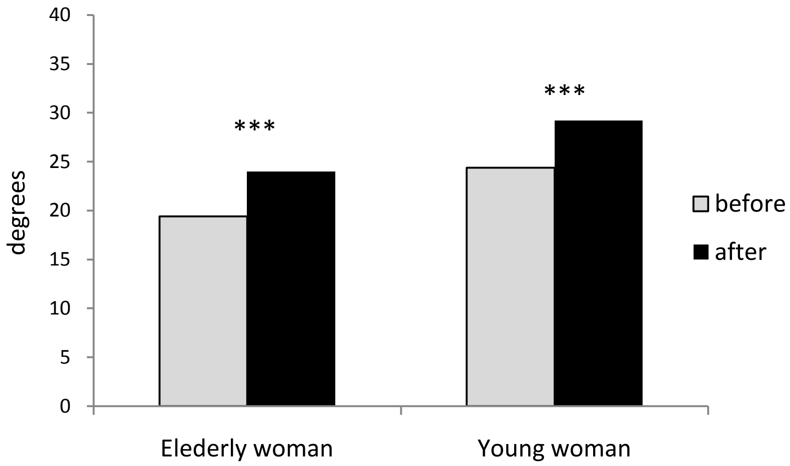

Figure 5. Range of motion during ankle dorsiflexion, before and after the implementation of selected Pilates exercises, between older and younger women.*** p≤0.001

Discussion

The aim of the present case-control study was to compare the acute results of a repeated Pilates exercise session (1x10 times) on the flexibility of lower extremities joint ROM, between young adult and elder women. The results revealed that although joint ROM was at baseline significantly reduced in the elderly, Pilates exercises performed in a dynamic slow pace and in full ROM, repeated 20 times, induced significant improvements in joint flexibility, among both age groups. The findings indicate that improvements in joint ROM of either age group are not dependent only on the age of the individuals, but are most likely, multi factorial.

The results herein cannot be directly compared to similar studies conducted among elderly or younger individuals, mainly due to methodological differences. However, the findings are in agreement to studies on younger individuals involved in acute Pilates resistance reformer sessions(Schroeder et al. 2002), as well as with studies conducted on elderly women with the implementation of a static stretching training protocol (Feland et al. 2001, Zakas et al. 2005).The present findings suggest that dynamic muscle elongation is induced by certain mat Pilates exercises and that this static stretching produced elongation is equally significant in improving joint flexibility in both young and elderly individuals, when performed in full ROM. However, further research is needed in order to delineate the acute effect of mat Pilates exercises on the joint ROM of the elderly.

Several studies have assessed the effect of Pilates exercises on participants of different training levels and age groups. Phrompaet et al. (2011), Sekendiz and associates (2007) as well as Rogers and Gibson (2009) demonstrated elevated joint flexibility among young individuals (Amorim et al. 2011), after the adoption of a Pilates training protocol lasting for several weeks. Kloubec (2004) reported similar findings on young and middle-aged subjects and Babayigit-Irez et al. (2011) on elderly women (aged≥60 years old), with the implementation of 12-weeks Pilates training protocol. The findings herein concerning the elderly are in total agreement to previous research on the acute effect of Pilates.

In the present study, higher baseline joint ROM was demonstrated among younger women compared to the elder ones. This finding is in full accordance to previous studies (Bell and Hoshizaki 1981, Misner et al. 1992, Klein et al. 2002, Campanelli 1996), and was attributed to the gradual loss of connective tissue elasticity experienced with increasing age, since the connective tissue consists of a pivotal factor affecting joint flexibility. However, the exact relationship between age and joint flexibility remains vague. Studies in children demonstrated gradually decreasing flexibility during the school years until the onset of puberty, and from then onwards increments were experienced throughout adolescence (Micheli 1983). Several researchers however, do not consider age to be a factor limiting flexibility, but suggest that other criteria might be more crucial, such as an individual's daily activities (Milne et al. 1981) or even differences in the instruments used to measure flexibility (Harris 1969). As a possible explanation for the reduction in joint flexibility during early school years, researchers have suggested that the prolonged sitting position required at classes and while studying sited at a desk (Milne et al. 1981), or the adoption of a less physically active routine, with increased screen time (television and computer games) (Alter 1996).Thus, research suggests that as far as children are concerned, joint flexibility is not affected by age, but rather consists of the epiphenomenon of specific muscle group elongation experienced during everyday activities.

In children, the performance of everyday activities resulting in muscle elongation is in fact restricting joint flexibility, whereas in the elderly, increasing age is associated with reduced joint ROM while performing everyday activities. However, literature is vague on whether this restricted ROM is the result of the connective tissues gradual loss of elasticity or rather the effect of everyday activities involving less muscle elongation and inducing a smaller-adapted ROM. Van der Poel (1998) postulated that the muscle length is completely dependent on how the muscle is used. Famisis (2015) failed to record improvements in the lower extremities joint ROM of soccer-players, while using a session of calisthenics exercises with restricted ROM, but reported significant improvements in flexibility, when calisthenics exercises were performed in full ROM as an extra session. Additionally, although in the elderly collagen appears less mobilised and adapts slower during stretching, according to literature, reductions in joint ROM can be minimized via systematic stretching training (Alter 1996, Wallmann 2009). Further research is needed in order to assess the degree of involvement of age or the performance of restricted ROM activities on the reduced ROM demonstrated in the elderly. However, it is important to note that the present study showed improvements on each joint's ROM among the elderly with 20 repetitions performed in full ROM, despite the reduced elasticity of the connective tissue during that age.

Although the assessment of the mechanisms involved in ameliorating joint flexibility among elderly women was not included among the aims of the present study, it is important to note the lack of literature explaining this process. The majority of researchers are currently accepting the involvement of connective tissue as an intrinsic factor reducing muscle length and subsequently joint flexibility, caused by the restricted elasticity associated with aging (Campanelli 1996, Feland et al. 2001, Sapega et al. 1981). According to this theory, the main causal factor for increased elasticity of the connective tissue and joint ROM among younger and elder individuals is the elevated muscle temperature. However, the protocol herein did not include warming-up of the involved muscle groups prior to the Pilates session. The pre-Pilates exercises performed involved the pelvis and the trunk and are not considered as warming-up exercises. After all, several studies have failed to demonstrate improvements in joint flexibility as a result of increased temperature in either soccer-players or elder women (Zakas et al. 2006a, Zakas et al. 2006b), suggesting the possible involvement of muscle contraction characteristics during muscle elongation rather than the involvement of the connective tissue. Hutton (1992) stressed that the potential role of the connective tissue as a restrictive factor for flexibility appears exaggerated whereas, in parallel, the importance of muscle contraction characteristics is underestimated. According to Hill (1968) and

Magid and Law (1985), the initial resistance response of the muscle during elongation is actually propelled by the myosin cross bridges, a proportion of which is connected to act in. When a muscle is experiencing dynamic or passive elongation, a great proportion of myosin cross bridges is disconnected from act in, resulting in increased length. In the present study, one cannot postulate that the recorded increases in joint flexibility of elder women are the result of various muscle contraction elements, and further studies are needed in order to delineate the possible mechanisms explaining flexibility improvements among the elderly.

Conclusion

The present findings indicate that the implementation of mat Pilates exercises with 20 repetitions in a single training session can induce lower extremities joint ROM improvements among younger and elderly women. Additionally, joint ROM is improved in a similar degree among younger and elder women, when selected Pilates exercises are performed in full ROM.

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