

Effects of Calisthenics and Pilates Exercises on Coordination and Proprioception in Adult Women: A Randomized Controlled Trial

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Objective: To assess and compare the effects of 6 mo of Pilates and calisthenics on multijoint coordination and proprioception of the lower limbs at the 3rd and 6th mo of training. **Design:** Randomized, controlled, assessor-blinded, repeated-measures. **Setting:** University research laboratory. **Participants and Intervention:** Healthy, sedentary, female participants age 25–50 y were recruited and randomly divided into 3 groups: a calisthenic exercise group (n = 34, mean age \pm SD 40 \pm 8 y, body-mass index [BMI] 31.04 \pm 4.83 kg/m²), a Pilates exercise group (n = 32, mean age \pm SD 37 \pm 8 y, BMI 31.04 \pm 4.83 kg/m²), and a control group (n = 41, mean age \pm SD 41 \pm 7 y, BMI 27.09 \pm 4.77 kg/m²). The calisthenics and Pilates groups underwent related training programs for 6 mo, while the controls had no specific training. **Main Outcome Measures:** Coordination and proprioception of the lower extremities with concentric and eccentric performances in the closed kinetic chain assessed with the monitored rehab functional squat system at baseline and at the 3rd and 6th mo of training. **Results:** For the within-group comparison, coordinative concentric and eccentric deviation values were significantly decreased for both dominant and nondominant lower limbs at pretraining and at the 3rd and 6th mo posttraining in the calisthenics group ($P < .05$). In contrast, there was no improvement in the Pilates group throughout the training. However, for comparisons between groups, the baseline values of coordinative concentric and eccentric deviations were different in the calisthenics group than in Pilates and the controls ($P < .05$). There were no differences in the proprioception values of either visible or nonvisible movement in any group throughout the training ($P > .05$). **Conclusions:** It seems that calisthenic exercises are more likely to improve coordination of the lower extremity after 3 and 6 mo of training than Pilates exercises. Calisthenic exercises may be useful for individuals who require improved coordination.

Keywords: exercise therapy, kinesthesia, sports

Proprioception was first defined by Charles Bell as the fundamental anatomical basis for sense, perception, and movement, and most contemporary authorities describe it as a specialized variation of the sensory modality of the sensation of joint movement (kinesthesia) and joint position (joint-position sense).¹ Coordination has been defined as a cooperative interaction between the nervous system and skeletal muscles and therefore encompasses proprioceptive abilities in a broader sense that includes neuromuscular control.²

Recently, whether proprioception and coordination can be trained with special training regimens or exercises has been questioned, because proprioceptive deficit,

muscle weakness, and lack of coordination and joint-position sense are known predictors of musculoskeletal disorders.^{3,4} Therefore, it is important to assess proprioception and coordination and determine the effects of different training methods and exercises on them.

Calisthenics and Pilates exercises are common training regimens that have both been used in rehabilitation and sports training. Both types of exercises are simple enough for a beginner to master in a relatively short period, fit well with the guidelines set forth by the American College of Sports Medicine, and can be adapted for rehabilitation or a workout for skilled athletes that may enhance performance and prevent injuries.^{5,6} Calisthenic exercises comprise several short muscle contractions intended to increase body strength and flexibility using only one's body weight with movements such as bending, jumping, swinging, twisting, kicking, and many other activities engaging the arms, legs, torso, neck, and back—essentially every muscle group in the human body.^{6,7} The various central and peripheral effects of calisthenics on different populations have been discussed in the literature.^{8–12} In contrast, Pilates has been promoted as an

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exercise regimen to increase muscle endurance and flexibility of the abdomen, low back, and hips and improve dynamic postural control, balance, and joint movement around the low-back–pelvic–hip complex.⁵ The effects of this type of training on functional capacity, fatigue, personal autonomy, mental parameters, and life quality have also been mentioned in the literature.^{12–14} However, the effects on coordination and joint-position sense for the lower extremities remain unclear.

Therefore, the current study aimed to assess and compare the effects of 6 months of Pilates and calisthenics on coordination and proprioception of the lower limbs with eccentric and concentric performances in a closed kinetic chain after 3 and 6 months of training.

Methods

Healthy, sedentary, female participants age 25 to 50 years who had not performed any regular physical activity for at least 2 years were recruited for this study. They included

270 women enrolled in the sports center, each with a health certificate from a general practitioner, who were assessed for eligibility with a questionnaire that included 7 items about physical disability.

Women were not admitted to the study if any of the following criteria were present: systemic pathology including cardiopulmonary and inflammatory joint disease; prior history of injury or surgery relating to a lower extremity and any pain for more than 3 months; active intervention in the last 3 months, including corticosteroid or hydrodilatation injection or physiotherapy; or anti-inflammatory medication in the past 2 weeks.

All subjects read and signed the university's approved consent form. Participants were randomly divided into 3 groups: a calisthenic exercise group, a Pilates exercises group, and a control group. All subjects were evaluated pretraining, posttraining, and at 3 and 6 months. The follow-up chart for participants is displayed in Figure 1.

At the end of 6 months, 107 participants were evaluated. Thirty-four of the subjects (mean age \pm SD 40 \pm

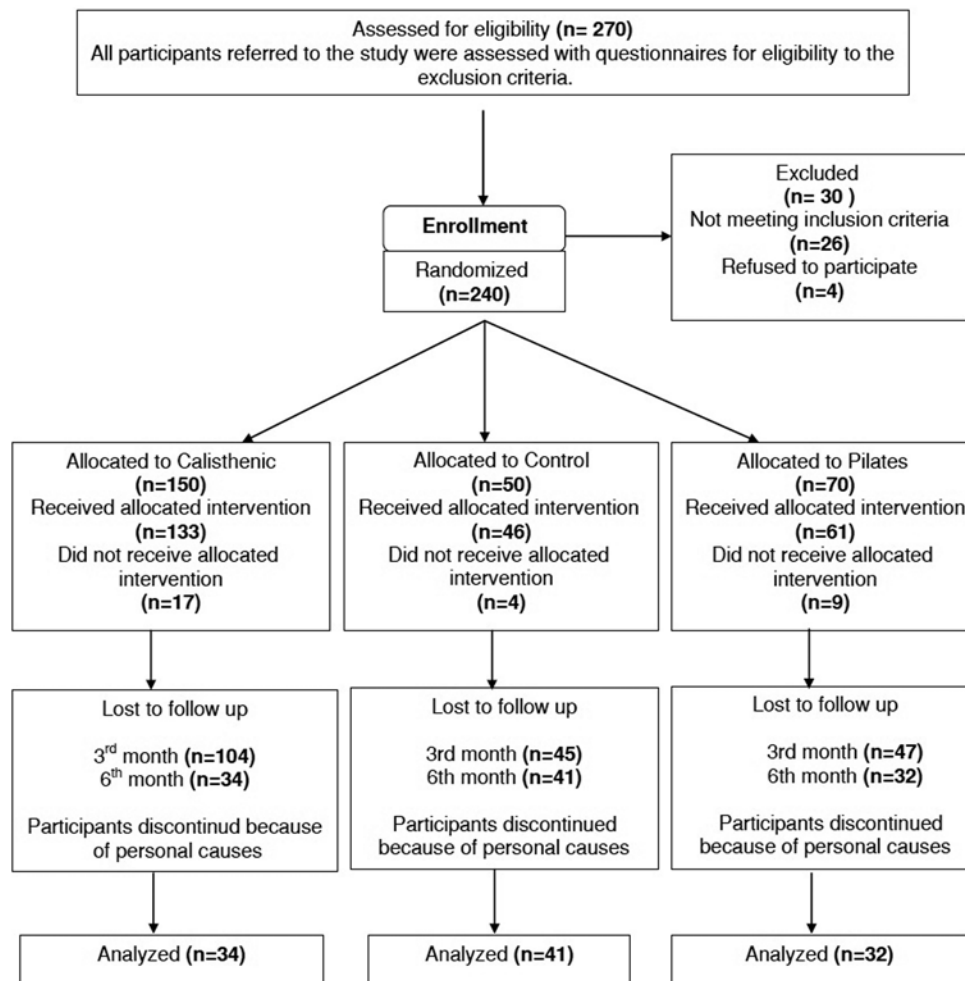


Figure 1 — The follow-up chart of the participants.

8 y, body-mass index [BMI] $31.04 \pm 4.83 \text{ kg/m}^2$) were in the calisthenic exercise group, and 32 of them (mean age \pm SD 37 ± 8 y, BMI $31.04 \pm 4.83 \text{ kg/m}^2$) were in the Pilates exercise group. The intervention groups had related group-training programs 3 d/wk for 6 months. Forty-one of the subjects were in the control group (mean age \pm SD 41 ± 7 y, BMI $27.09 \pm 4.77 \text{ kg/m}^2$) and did not perform any regular physical activity or exercise. The physical characteristics of the groups were similar.

All evaluations were conducted by the same examiner (D.O.), who used a standardized protocol to ensure the consistency of subject positioning, instructions, and overall testing procedures, and the examiner herself was blinded to the groups' intervention. Before the tests, all subjects were informed about the particular requirements of the tests. They performed an appropriate warm-up exercise program including basic stretching exercises for the lower extremities and then started the testing procedure.

Testing Procedure

The system used in this study was the functional squat system introduced by Monitored Rehabilitation Systems (Functional Squat System Machine, Monitored Rehabilitation Systems, Harlem, The Netherlands, MRS-E0203), which mimics the movement-coordination pattern of a squat jump under the control of external load. The system enables evaluation of the lower extremity throughout the concentric and eccentric phases of the functional squat movement (Figure 2). The concentric phase was defined as the concentric quadriceps contraction starting in a half-squat position and ending in full knee extension. The eccentric phase was defined as the eccentric quadriceps contraction starting in full knee extension and ending in 90° of knee flexion (the half-squat position).

The system has been found valid and reliable for the assessment of motor coordination and proprioception.^{15–17} The tracking-trajectory test for the evaluation of motor coordination during multijoint closed kinetic chain

action of the lower limb musculature has proven to be a useful tool, with .70 to .80 ICC test–retest reliability.^{15,16} Nevertheless, the ICC for a repeated-measures knee proprioceptive test was .94.¹⁷ Moreover, the system was used for both assessment and rehabilitation of different groups in previous studies.^{18–20}

In this study, coordination and proprioception tests were used after the piece of equipment was introduced to the subjects and each person became familiar with it. Participants were instructed to lie on the bed of the functional squat system, supine with both legs lifted up, hips and knees flexed to 90° , and feet in full contact on the platform of the machine in a half-squat position (Figure 2). They were asked to extend the knees to 0° with full contact of their feet to determine the minimum and maximum range of motion of the lower extremity. The first procedure was to specify the test for the subject, because the extremity length and range of motion differ from subject to subject, and this procedure was performed before every test application. Ten concentric–eccentric repetitions were performed as a warm-up. After the warm-up, the subjects were allowed a 30-second practice session before testing started. Then, the coordination test was performed unilaterally with a load minimizing force control (5 kg); this test consisted of 60 seconds of target tracking during eccentric and concentric contractions of the lower limb. The participants were provided ongoing visual feedback of their position by means of a cursor (a sort of target) displayed on a monitor in front of them that was connected to a computer and the system. They were instructed to match the criterion trajectory as accurately as possible during both eccentric and concentric phases of the coordination test. Sixty seconds of target tracking were completed unilaterally, and the same procedure was repeated with the contralateral leg. The data obtained from distance sensors (an optical wheel) were used to calculate tracking errors. The software automatically calculated the absolute average error (in cm) and the standard deviation of the average error. Both the average and the standard deviation error were independently quantified as a function of the action mode (concentric vs eccentric) and of the tested lower limb (dominant vs nondominant). Side-to-side differences in the trajectory-tracking error were calculated and described as a percentage of the deficit. The deviation and deficit results were then analyzed.

In the proprioception test, the same testing position and preparations were performed as for the coordination test but were performed bilaterally. The participants were instructed to keep the red crosshair sign on the blue line on the computer screen by eccentric and concentric contractions of the lower extremities even after the visual aid disappeared. The total test time was 60 seconds (Figure 3). After completion of the test, the differences between the deviations recorded with and without visual input were evaluated through the concentric and eccentric phases of movement. The software again automatically calculated the nonvisible and visible deviations of the movement, and the standard deviation of the average error (in cm) was measured as an outcome.



Figure 2 — Functional squat system positioning.

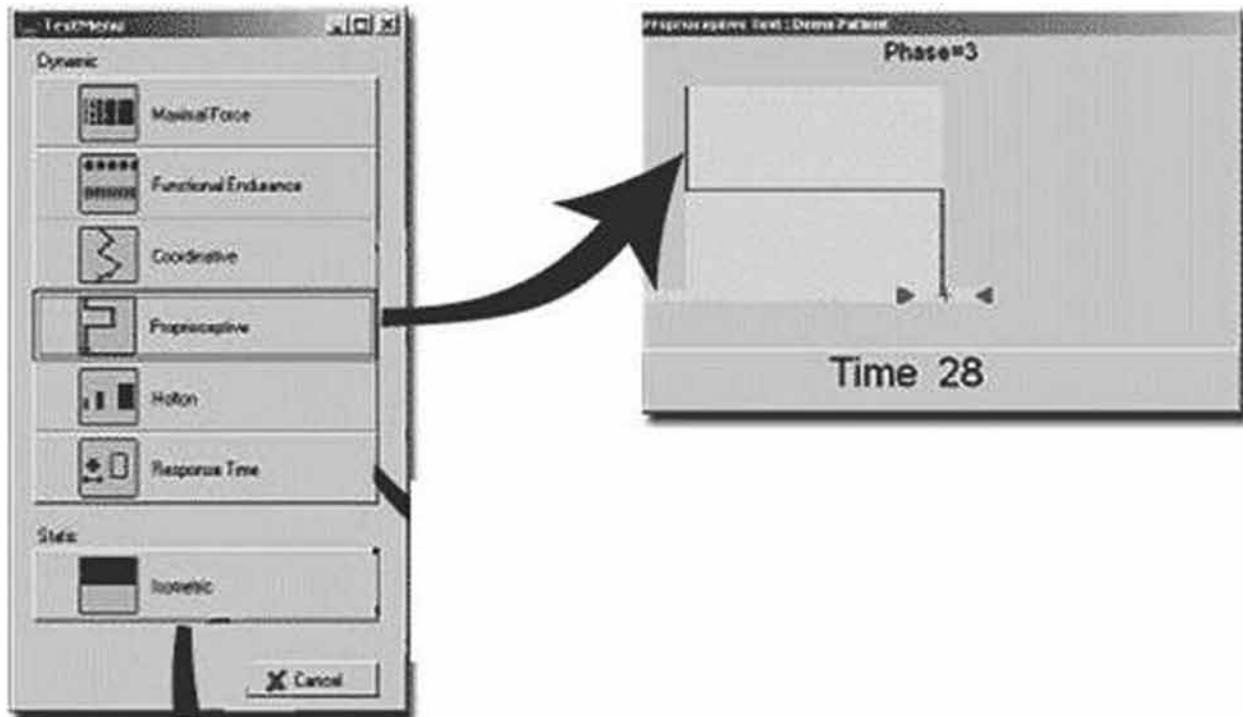


Figure 3 — Proprioceptive analysis modes of the system.

Training Procedure

The calisthenic exercise program was designed according to the American College of Sports Medicine's recommendations for healthy adults. Cardiorespiratory fitness, body composition, muscle strength, and endurance parameters were taken into account to design the program. The exercise program was performed at 60% or 70% of maximal heart rate for 24 weeks, 3 d/wk, with 50-minute sessions of low- to moderate-intensity aerobic and calisthenic exercises. The exercise program included 10 minutes of warm-up exercises; 25 minutes of aerobic exercises; 10 minutes of exercises for the abdominal, hip, and leg muscles; and 5 minutes of cooldown and stretching exercises.^{6,7}

The Pilates exercise program concentrated on the following main principles: efficient breathing, mental concentration, relaxation, correct spine elongation and alignment, correct abdominal muscle control over spine stability and mobility, correct function of each upper and lower limb, precision, flowing integrated movement, and achieving muscle strength and stamina.²¹ Mat-work exercises including supine lower abdominal muscle strengthening, prone posterior hip muscle strengthening, side-lying posterior hip muscle strengthening, supine upper abdominal muscle strengthening, and knee strengthening were performed. The specific names of the exercises were hundred preparation, hundred, half-roll-up, single-leg circle, rolling like a ball, single-leg

stretch, crisscross, spine stretch forward, spine stretch side, saw, swan, single-leg kicks, swimming, side leg lifts, side leg circles, and side leg bananas bridge. All exercise repetitions were increased progressively from 6 to 15. The lever arm, base of support, extremity positions, surface, and mental concentration were used as progression components during the exercises throughout the program.^{5,21}

Statistical Analysis

Data analyses of the differences between and within groups were performed using statistical SPSS-PC+ (SPSS, Inc, Chicago, IL) software. The results for the measurements of the 3 settings were provided with means and standard deviations. Repeated measures were used for statistical analyses within groups. The Bonferroni method of post hoc analyses was used for a comparison between the 3 groups. The level of significance for all statistical analyses was set at $\alpha < .05$.

Results

For the within-group comparison, coordinative concentric deviation values were significantly decreased for both the dominant and nondominant lower limbs at pretraining and at 3 and 6 months posttraining in the calisthenics group ($P < .05$; Figure 4). There was also a difference between the dominant and nondominant extremities of

the calisthenics group: The nondominant side had better results at the beginning and at the later stages of training ($P < .05$). In contrast to the calisthenics group, there was no improvement in the Pilates group throughout the training. However, for comparisons between groups, the baseline values of coordinative concentric deviation were different in the calisthenics group for the nondominant side than in the Pilates group and for the dominant side

than in the Pilates and control groups ($P < .05$; Figure 4). In addition, for the nondominant side, the coordinative concentric deviation of the Pilates group was significantly lower than those of the other groups at the baseline ($P < .05$; Figure 4).

Similar effects were observed on eccentric evaluations of coordination: The calisthenics group improved throughout the training stages, whereas no significant

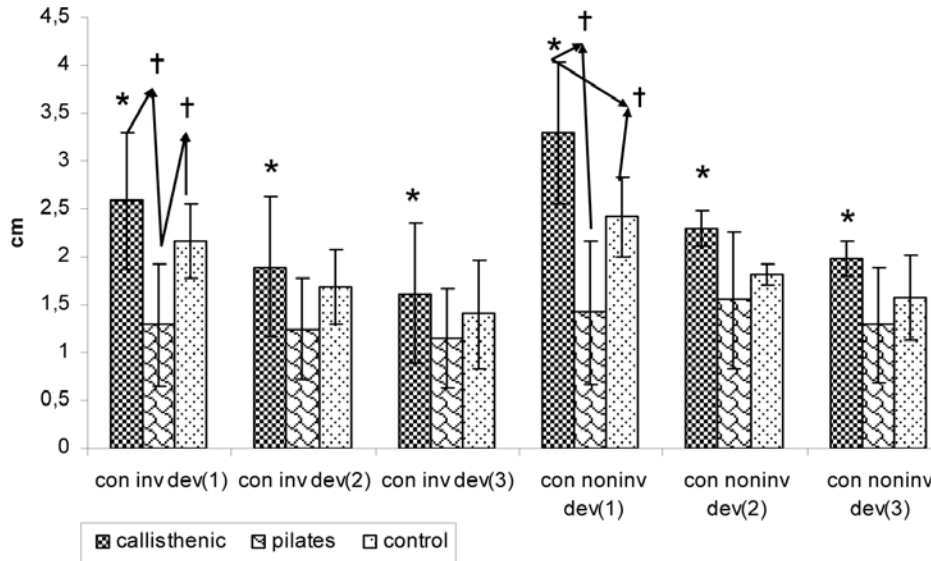


Figure 4 — Coordinative concentric (con) deviation (dev) results for dominant (noninv) and nondominant (inv) sides (1) at baseline, (2) at 3 months, and (3) at 6 months. * $P < .05$ pretest to posttest within groups. † $P < .05$ between groups.

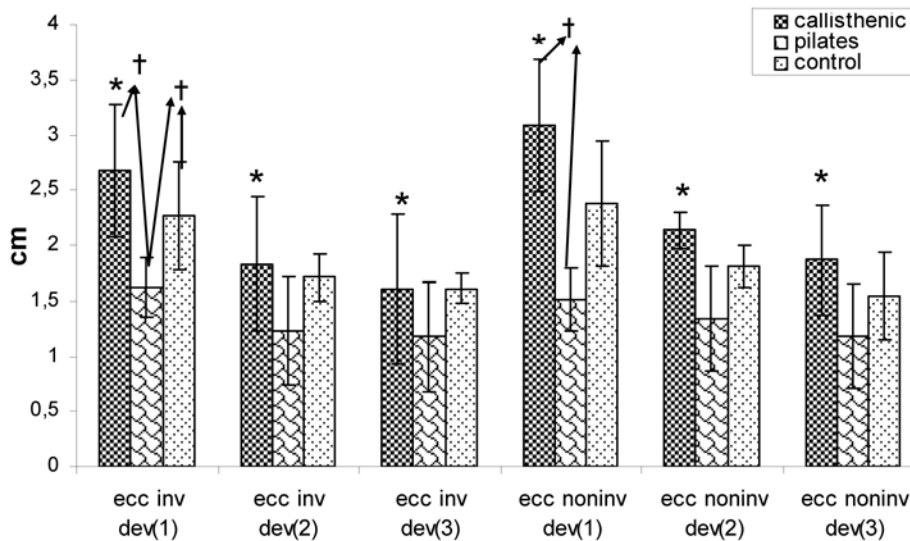


Figure 5 — Coordinative eccentric (ecc) deviation (dev) results for dominant (noninv) and nondominant (inv) sides (1) at baseline, (2) at 3 months, and (3) at 6 months. * $P < .05$ pretest to posttest within groups. † $P < .05$ between groups.

decrease was shown for the Pilates and control groups (Figure 5). The nondominant side's improvement was better ($P < .05$).

Deficit results, which were specific to dominant versus nondominant sides, were not different between or within groups for concentric and eccentric phases (Figure 6). There were not any differences in proprioception values on either visible or nonvisible movement within groups throughout the training. However, the results were significantly lower in the Pilates group than in the other groups at baseline ($P < .05$; Figure 7).

Discussion

In this study, coordination and proprioception were assessed in a closed kinetic chain squat position with concentric and eccentric phases. It was shown that calisthenic-type exercises are more likely to affect lower limb coordination, both in concentric and eccentric phases of movement. Nondominant extremity improvement was better than on the dominant side. However, neither calisthenics nor Pilates exercises showed any improvement in proprioception in a closed kinetic chain.

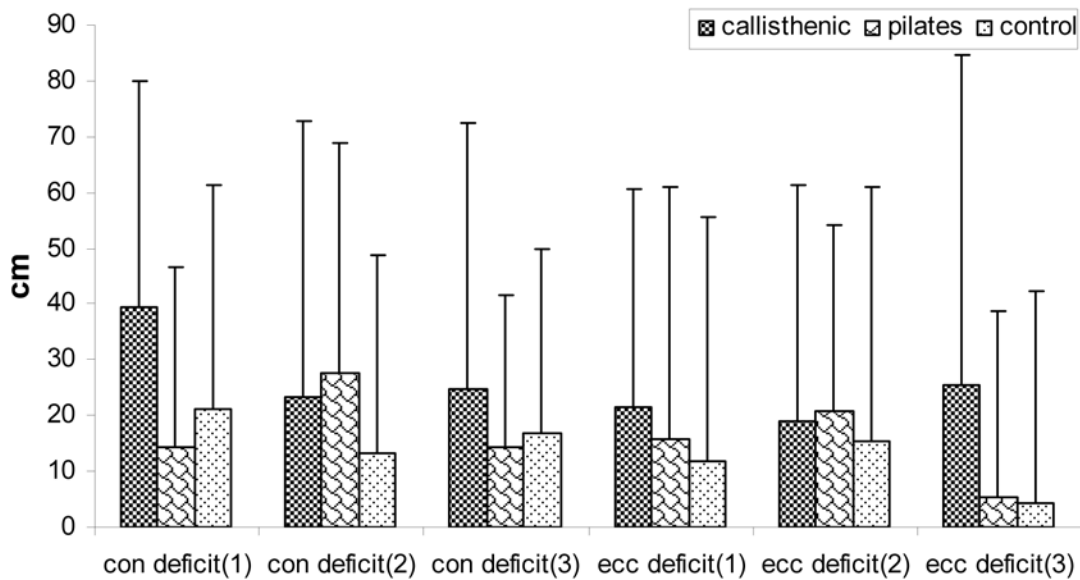


Figure 6 — Concentric (con) and eccentric (ecc) coordination deficits (1) at baseline, (2) at 3 months, and (3) at 6 months.

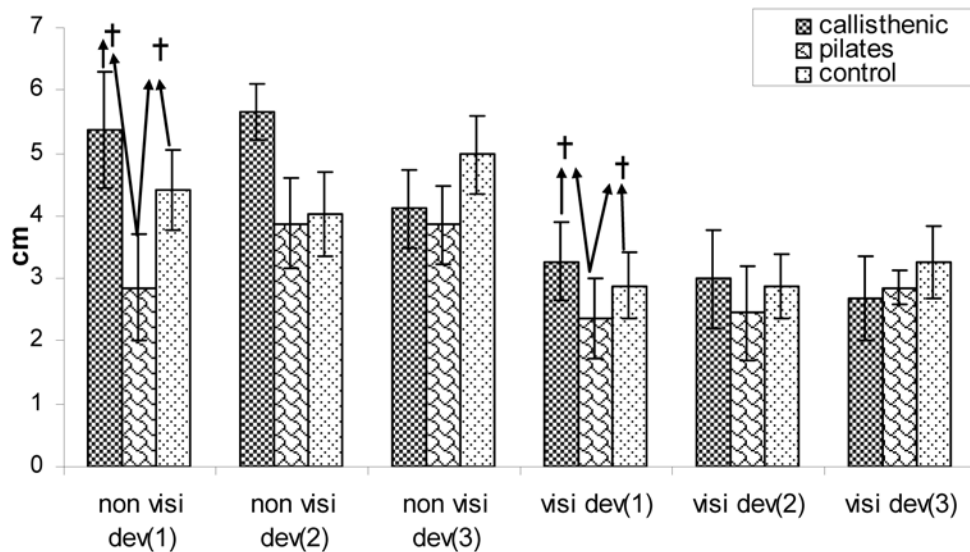


Figure 7 — Proprioceptive nonvisible (non visi) and visible (visi) deviations (dev) of the movement (1) at baseline, (2) at 3 months, and (3) at 6 months. † $P < .05$ between groups.

Proprioceptive acuity is an essential component of injury prevention and rehabilitation, because proprioceptive deficits may be responsible for many acute and chronic injuries, especially in the lower extremities.²² However, this component is often ignored because of the complexity of the assessment, reassessment, and training. The assessment of neuromuscular control includes the measurement of cortical, spinal-reflex, and brainstem pathways. The evaluation of this complex neuromuscular system allows a more detailed explanation of afferent control mechanisms.² Clinicians have difficulty assessing proprioception because they cannot isolate movement sense without sophisticated equipment; they cannot prevent patients from gaining movement cues from the postures at the start and end of the movement. Thus, assessing the joint in a closed kinetic chain of the lower limb for motor coordination and joint-position sense, as well as the concentric and eccentric mechanisms of muscle contractions, has become increasingly important through the use of such equipment. Several researchers have used different position-testing devices including commercial isokinetic dynamometers, electromagnetic tracking devices, and custom-made jigs, as well as video analyses, to evaluate proprioception.^{23–25}

In our study, the closed kinetic coordination and proprioception tests in the functional squat system were chosen as an assessment method because they may mimic the functional performance of the entire lower extremity, with full contact of the feet and impulsion of the body such that the testing enables the desired probability of sensing. Some research has indicated that measurements without weight bearing cannot reproduce or model real life.^{3–23} Regarding primary motions of the lower extremity, such as the landing phase of walking, running, and jumping, they can all be considered closed kinetic chain activities. However, a test such as balance that includes weight-bearing procedures can provide extra sensations that may directly affect joint receptors.²⁶ It has been indicated that tests that focus on tracking ability have more to do with the contributions of the cerebellar and proprioceptive systems than with static and dynamic motor control.¹ Our tests, especially the coordination test, include this criterion of tracking ability with trajectory motions.

Furthermore, whether proprioception can be trained with exercise regimens has been questioned. In their review, Ashton-Miller et al³ examined whether targeted exercises improve proprioception; their results showed little evidence to support such a conclusion and suggested that the appropriate experiments remain to be conducted. The current study hypothesized that calisthenic or Pilates training could allow an individual to improve the probability of detecting limb-segment position in the context of a certain tracking-trajectory task and enhance proprioception in terms of the 2 classic proprioceptive modalities: accuracy of joint-position sense or the threshold for detecting joint movement and coordination. The only difference was observed in coordination in the calisthenics group. The difference between groups can be explained

by the characteristics of exercises, such that calisthenics are a form of dynamic exercise consisting of a variety of rhythmical movements intended to increase body strength and flexibility with movements such as bending, jumping, swinging, twisting, or kicking, using only one's body weight for resistance. Because most of the exercises are weight bearing, this might improve the coordinative motions. Moreover, significant improvement was observed on the nondominant side with the calisthenics. This result may indicate the loading characteristic of the exercise. Similar to improvements observed in the current study, Marmeleira et al²⁷ showed that a calisthenics-based creative dance program could improve proprioception by means of knee joint-position sense, knee kinesthesia, and arm positioning at 12 weeks follow-up. In contrast to calisthenics, Pilates exercises are generally done in the open kinetic chain. They mostly focus on stabilization of the core, the powerhouse of the body. The common view with Pilates is that any change created in the core region can affect the quality of distal segmental motion. In addition, Pilates may help force radiation. Due to that radiation, some changes in the distal segments may be observed. Kloubec⁵ demonstrated that in active middle-aged men and women, exposure to Pilates exercise for 12 weeks, for two 60-minute sessions/wk, was enough to promote statistically significant increases in abdominal endurance, hamstring flexibility, and upper-body muscle endurance. Participants did not demonstrate improvements in either posture or balance compared with the control group.⁵ Some studies showed improvements in balance with Pilates.^{12,28} This core stabilization may improve balance, but it seems that it did not affect multijoint coordination and proprioception of the lower extremity in our Pilates group. In Pilates, some special apparatuses may also be used. In this study, we could use any special equipment. Thus, the potential to improve proprioception and coordination using the apparatus should be taken into account for future studies.

Previous investigations into the use of calisthenics as a way to improve strength, body composition, flexibility, bone-mineral density, and inflammatory markers have been described in the literature,^{8,29,30} but proprioception itself has never been observed as in the current study. The design of the study, training duration, and assessment timings could be considered strengths of the study because it has been declared that to alter one's proprioceptive acuity one would need to design a prospective, randomized, controlled experiment involving the training of subjects over weeks, months, or possibly even years to develop their proprioceptive acuity.³

The dropout numbers and high standard deviations of the deficits could be considered weaknesses and limitations of the study. There was a high dropout rate in all 3 groups such that the number of participants ultimately analyzed was small. The major reason for the high dropout rate might be related to the intensive, long-term training duration. Another potential reason might be related to the lack of exercise habits, as well as the social and economic responsibilities of this group of women in our

community. In spite of this high dropout rate, the remaining numbers were sufficient to demonstrate a meaningful difference between groups. However, there is a lack of calculated effect size in this study. Further studies could be conducted on larger groups, both sedentary and athletic. The deficits, including both negative and positive outcomes, resulted in standard deviations larger than the results reported.

Another potential limitation of the study was that the baseline results of the calisthenics group were worse than the others. The reason might involve individual motor-learning skills. Furthermore, paying attention to a cue might be important for performance during testing. It could be suggested that this group might have improved attention and performance.

A further limitation of the study might be the method we used to measure proprioception; it was somewhat different than that of previous studies. It was not pure knee-joint proprioception, but rather was a multijoint approach in a squat position. We believe that it may mimic performance and suits daily life motions with concentric and eccentric phases in a closed kinetic chain while preventing the afferent effects of external weight and surface. It might be helpful to additionally assess with weight-bearing positions in future studies. In this study, healthy groups were used. A further question is whether the same results would be found with different populations such as athletes that are strongly in need of proprioceptive abilities to prevent injuries.

Conclusions

The current results indicate that calisthenic exercises are more likely to improve coordination of the lower extremity after 3 and 6 months of training than Pilates exercises. This finding suggests that calisthenic exercises may be useful for individuals who require improved coordination.

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