

Effects of physical training on proprioception in older women

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Abstract

Older adulthood is accompanied by declines in muscular strength, coordination, function, and increased risk of falling. Resistance training increases muscular strength in this population but its effect on proprioception is unknown. To evaluate the effect of resistance training on proprioception, community dwelling older women completed a three-month exercise study. A resistance training (RT) group (N=19) underwent supervised weight training three times per week while a non-strength trained control (NSTC) group (N=19) performed range-of-motion activities that mimicked the movements of the RT group without the benefit of muscle loading. Subjects were evaluated at baseline, 6, and 12 weeks for strength and proprioception. Muscular strength was assessed by measuring the subject's one repetition maximum performance on four different exercises. Static proprioception was measured by the subject's ability to reproduce a target knee joint angle while dynamic proprioception was measured by the subject's ability to detect passive knee motion. The RT group made significant strength improvements compared to the NSTC group. Proprioception significantly improved in both groups by 6 weeks. Our findings suggest that improvements in proprioception can be obtained via regular activity that is independent of heavy muscle loading.

Keywords: Strength, Elderly, Aging, Women, Kinesthetic

Introduction

Older adulthood is accompanied by lower levels of physical fitness, which can impair functional performance as assessed by activities of daily living¹⁻³. One component of the decline in functional performance is the loss of coordination that may underlie the increased risk for falling and fracture⁴⁻⁸. Loss of coordination may involve the decline in the ability of the older adult to sense the position of the body and limbs in space (i.e., proprioception). However, the effect of proprioceptive loss associated with aging^{9,10} and whether it can be regained through physical activity is unknown.

Age-related decreases in muscle strength and mass have also been suggested to account for some of the reduced functional performance in older adults¹¹⁻¹⁴. The loss of muscle strength is reversible in older adults through the use of resistance exercise¹⁵⁻¹⁷, and improves physical performance

in this population^{18,19}. Interestingly, the strength gains obtained from resistance training are the result of both muscular and neural adaptations^{20,21}. The latter include reflex motor unit facilitation of contraction, enhanced motor unit synchronization, and inhibition of the Golgi tendon organs, all of which may have a positive effect on proprioception. However, to the authors' knowledge, there are no reports directly examining the effects of strength training on static and dynamic joint proprioception in healthy older adults. Therefore, the purpose of this study was to investigate the effect of resistance training on proprioception in older women. Gaining insight on the impact of various modes of exercise on the physical declines associated with aging is important in regard to the design and implementation of effective training programs for the older adult.

Methods

Subjects: Community dwelling older women aged 65 years or older were recruited from the local metropolitan area to participate in a three-month exercise study (Table 1). Potential participants were excluded if they were diabetic or had a total knee replacement. Additionally, subjects were asymptomatic of joint pathology that would preclude them

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Figure 1. Dynamic proprioception testing.



Figure 2. Static proprioception testing.

Group	N	Age (yrs)	Weight (kgs)	Height (cm)	BMI (kg/m ²)
Resistance Trained (RT)	18	69.3±4.9	69.9±22.5	159.9±5.6	27.0±3.6
Non-Strength Trained Controls (NSTC)	16	70.0±3.4	69.5±10.3	160.3±5.7	27.0±5.7

Values presented as mean ± SD

Table 1. Group demographic data.

from exercising. Guidelines set forth by the American College of Sports Medicine were followed to preclude subjects that were at high risk to participate in exercise programs. All participants were independently mobile. Subjects (n=38) initially were screened by telephone and scheduled for baseline data collection. All subjects completed a University approved Informed Consent Statement which explained the risks and benefits associated with participating in the study. In addition, subjects filled out a health history medical questionnaire. Prior to data collection, subjects were randomly assigned to either the resistance-training (RT) group or the non-strength training control (NSTC) group. Subjects were then evaluated for proprioceptive sense of their right knee and muscular strength. Following collection of baseline data subjects were informed of their group assignment.

Training Protocol: The RT subjects (n=19) trained three times per week under direct supervision. Subjects arrived at various times on assigned days and were supervised at a ratio of two subjects per trainer. Subjects began training at a resistance weight equal to 80% of their one repetition maximum using Hammer Strength resistance training machines for each of the following exercises: bench press, seated row, double leg press, hamstring curl, bicep curl, and calf press. In addition, triceps extensions were performed using an overhead pulley machine, and ankle dorsiflexion exercises were performed using stack weights in a pulley system with

the subjects seated and the resistance strap draped over the dorsum of their feet. The first week of training consisted of one set of 10 repetitions for each exercise with an additional set added for week two. Three sets of 10 repetitions were performed for each exercise after week two. Subjects were encouraged to perform as many repetitions as possible on their third set of each exercise. If subjects were able to perform 12 or more repetitions on the third set of the exercise, the training weight was increased for the following exercise session by 5 and 10 pounds for upper and lower body exercises, respectively. Each exercise session began and ended with a 3-minute brisk walk.

Subjects in the NSTC group (n=19) participated in a supervised, group led activity session twice per week and performed one additional session on their own at home. They were given an instructional manual describing the exercises and repetitions of each movement to perform. The manual was used during the supervised exercise sessions for the first two weeks to improve subject understanding of the exercises to be performed at home during their unsupervised session. This group performed movements that mimicked the exercises the RT group performed, but without the external resistance. One-meter sticks made of 3/4" PVC pipe were used to mimic the upper body exercises performed by the RT group. The NSTC group also began and ended each session with a 3-minute brisk walk.

Following six weeks of training, both groups were re-test-

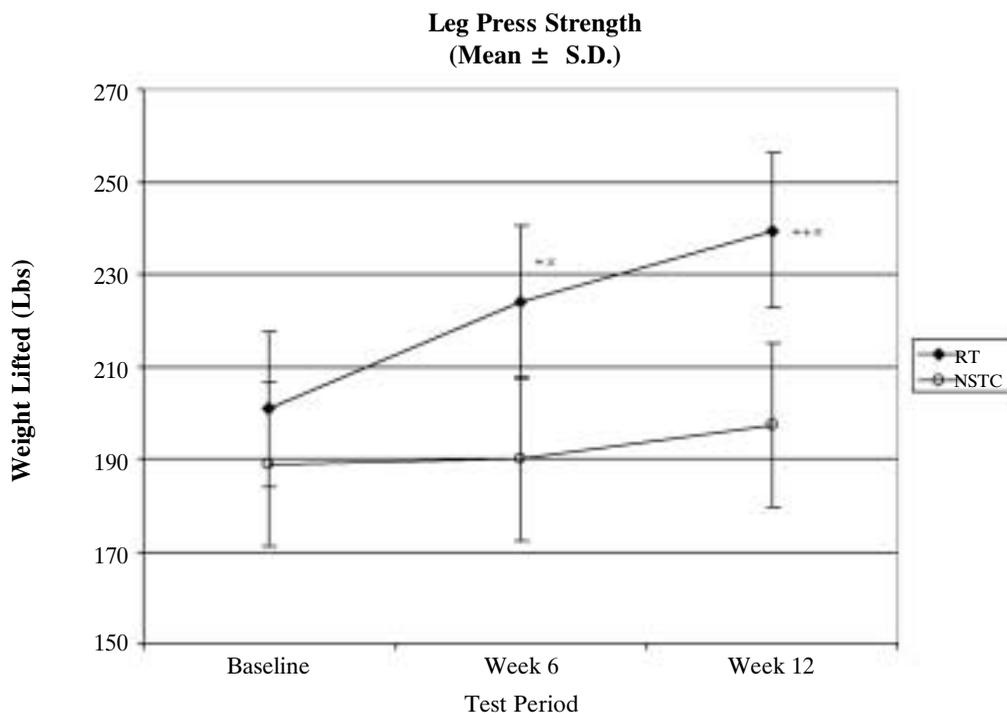


Figure 3. Leg press strength. * indicates a significant increase compared to the baseline measure; # indicates a significant difference compared to the NSTC group; + indicates a significant increase compared to the 6 week measure. The statistical significance level was set at $p \leq 0.05$.

ed for proprioception and strength. Subjects did not exercise during the week of re-testing. After the retesting at week six, subjects continued training for an additional six weeks, thus totaling 12 training weeks. Following the twelfth week subjects were again re-tested. All testing was conducted by the same testers, at the same time of day, in the same sequence and environment as the baseline testing. Additionally, the test administrators were blinded as to the subject group assignment to control for potential testing bias.

Proprioceptive Measurements: Proprioceptive measures of each subject's right knee were evaluated by determining the subject's ability to detect passive motion (dynamic proprioception) and reproduction of a target angle (static proprioception). Dynamic proprioception was tested using a proprioception testing device (PTD). The PTD (see Figure 1) was similar to the testing device described by Lephart²² and was constructed in our laboratory. It consisted of a movement arm driven by an electric motor with a variable speed controller. Subjects were seated in a high chair with their feet off the floor and the front edge of the seat positioned approximately 10 centimeters proximal to the popliteal crease. This allowed the subject's leg to hang down without touching the forward edge of the seat and reduced skin contact that could provide undesired sensory input during testing. The subject's feet were placed in pneumatic boots inflated to 45 mmHg to normalize sensation for both feet. This was necessary since the PTD movement arm was

attached to the subject via the tip of the right pneumatic boot. The left leg was allowed to hang freely while the right leg was suspended at 45° of knee flexion. The test was demonstrated to the subjects while they could see all the components of the PTD. A small speaker headset was placed in each ear and a large hearing protection headset was placed over them to eliminate the subject's ability to hear during testing. The speaker headset was connected to an audio player that provided white noise, thus preventing the subjects from hearing the sound of the PTD motor during testing. The tester could communicate with the subjects as long as the white noise, was not turned on. Subjects were blindfolded to prevent visual input during the test. Subjects were given five familiarization trials, one without white noise or blindfold, one with only the blindfold and three with blindfold and white noise. Test trials consisted of turning on the white noise, which was a cue for the subject to pay close attention to the sensations in their right knee. Subjects were told that once they heard the white noise, their leg would begin to move within 60 seconds at a speed of 0.50 degrees per second in either direction (i.e., flexion or extension). When they sensed a change in the position of their right knee joint angle, they were to immediately disengage the PTD movement arm by pushing a hand held switch. An integrated timing setup allowed for determination of the time between initiation of movement by the tester and disengagement of the PTD movement arm by the subject. This time

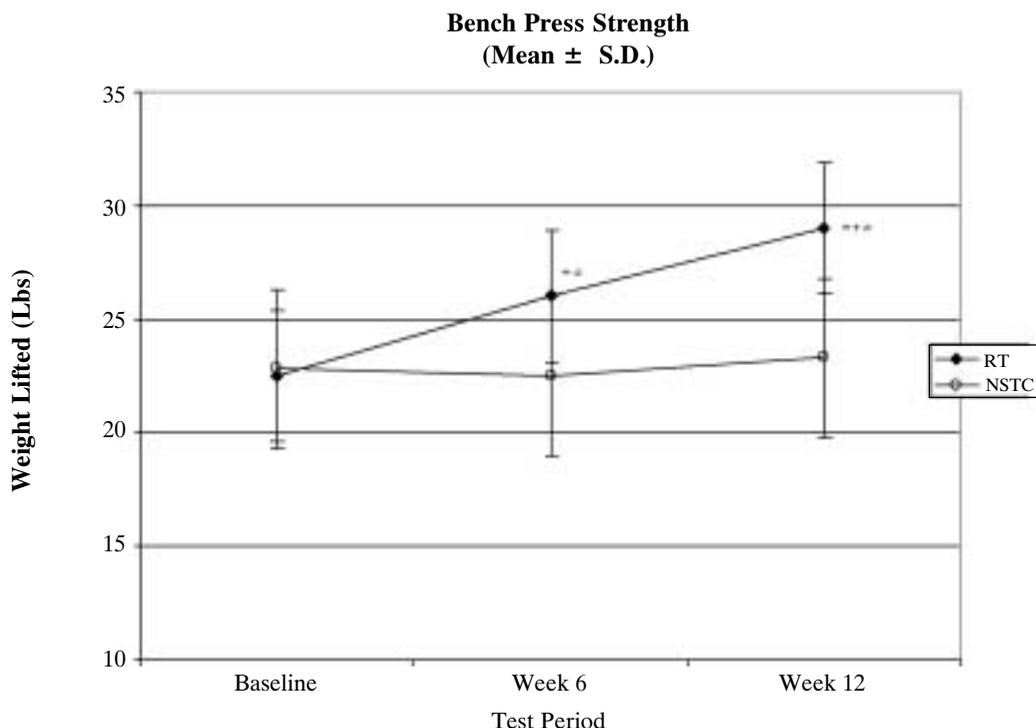


Figure 4. Bench press strength. * indicates a significant increase compared to the baseline measure; # indicates a significant difference compared to the NSTC group; + indicates a significant increase compared to the 6 week measure. The statistical significance level was set at $p \leq 0.05$.

interval was referred to as the time to detection of passive movement (TDPM). Although subjects were informed that the tester had up to 60 seconds before the movement arm was engaged, the tester engaged the movement arm within 5 seconds on each trial except the third. The third trial was initiated at 15 seconds to make sure the subject was not randomly pushing the switch. Ten trials were performed, five in the direction of flexion and five in the direction of extension. The order of trials interspersed flexion with extension, but the order was the same for each subject. After each trial the knee was returned to 45° of flexion before starting the next trial.

To test static proprioception we evaluated the ability to reproduce a target joint angle (RJA). Subjects were seated on a table with both legs hanging unobstructed over the side so that no part of the lower leg touched the table (Figure 2). A towel roll was placed under the right thigh so that the right knee would flex approximately 90°. A Leighton Flexometer™ was strapped to the outside of the right ankle and zeroed with the knee flexed at 90°. The test procedure was explained, and subjects were given one familiarization trial with their eyes open and a second with eyes closed. For testing, subjects placed both hands behind them on the table for balance and closed their eyes. The subject’s right lower leg was passively raised until the flexometer read 45°. The subject was then instructed to concentrate on the sensation of that joint angle while the leg was held at that position for 5

seconds. The leg was then lowered back to 90° and the subject was instructed to immediately extend the leg back to the target angle. The degrees off target were recorded. Five trials were taken with the target angle being 45° each time. Subjects were not informed that the target angle was the same for each trial.

Prior to the study, the test re-test reliabilities of the protocols for the dynamic and static proprioception tests were evaluated on 25 subjects aged 21 to 35. The time to detection of passive motion was 2.00 ± 0.38 seconds and 1.90 ± 0.54 seconds for the first and second weeks of testing, respectively. There was no significant difference between the measures and the intraclass correlation was .87. For the static proprioception measures, the average off target differences were the same at 5.5 ± 0.6 degrees for both weeks. The intra-class correlation was $r = 0.84$. This pilot data indicated that there was no test-to-test learning or familiarization effect. Because of these findings a third group of subjects, which did nothing over the 12-week experimental period was felt to be unnecessary.

Strength Assessment: After proprioception testing, Hammer Strength training machines were used to assess each subject’s one repetition maximum for the exercises of bench press, seated row, double leg press, and seated hamstring curl. Subjects were seated in each machine and machine adjustments (seat height/position) were made and recorded to insure identical setup during follow-up testing. Subjects

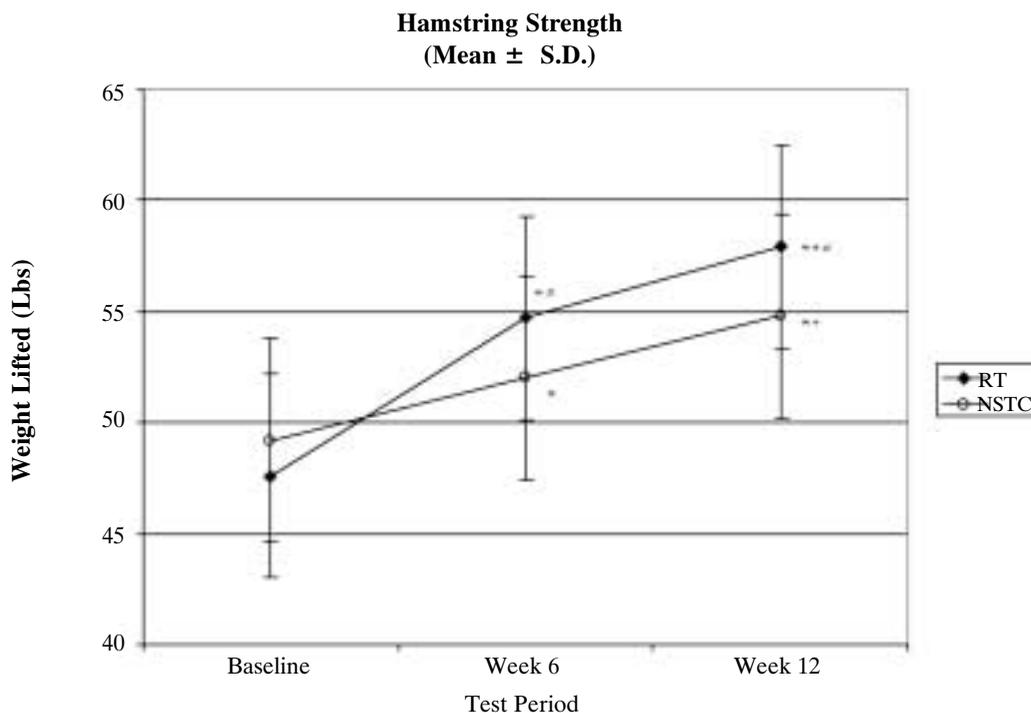


Figure 5. Hamstring strength. * indicates a significant increase compared to the baseline measure; # indicates a significant difference compared to the NSTC group; + indicates a significant increase compared to the 6 week measure. The statistical significance level was set at $p \leq 0.05$.

were familiarized with each machine and given five warm-up repetitions. One repetition maximum was determined for each exercise within six trials or less.

Statistical Analysis: To evaluate significant differences between the groups, and over time, a two-way (group \times time) repeated measures analysis of variance (RMANOVA) was performed to compare initial proprioception scores and strength measures to the 6- and 12- week scores. Statistical significance was set at $p < 0.05$. For the proprioceptive measures effect size (ES) was calculated using the formula $(M_1 - M_2)/s$, where s was the pooled standard deviation of the two means (M_1 and M_2) being compared²³. Effect sizes of ≤ 0.2 , 0.3 to .7, and ≥ 0.8 were considered small, moderate, and large, respectively²³.

Results

Descriptive measures of the two groups are shown in Table 1. The RT group lost one subject to an injury aggravated by the training and the NSTC group lost three subjects, one to aggravation of an old injury and two to non-compliance.

Significant gains in strength were noted in the RT group from baseline to 6 weeks and from 6 to 12 weeks for all strength measures (Figures 3-6). Additionally, strength gains in the RT group were significantly greater than the changes in the NSTC group in all cases. In NSTCs, there was no sig-

nificant change in strength for double leg press and bench press. This group did significantly improve on the seated row test by 12 weeks and in the hamstring curl test by 6 weeks.

Both groups noted significant improvements in dynamic proprioception (Figure 7) and static proprioception (Figure 8) by 6 weeks. There was no significant improvement between 6 and 12 weeks, nor was there a difference between RT and NSTC at any time point. Based on calculations of the effect size, the resistance exercises performed by the RT group indicated a moderate effect on dynamic ($ES = -0.6$) and static ($ES = -0.7$) proprioception. The unweighted movements performed by the NSTC group demonstrated moderate to high effects on dynamic ($ES = -0.9$) and static ($ES = -0.3$) proprioception.

Discussion

Static and dynamic proprioception significantly improved in both treatment groups by 6 weeks with the trend for improvement continuing out to 12 weeks. Several studies have indicated that neural adaptations occur in the first 6 to 8 weeks of strength training^{24,25}. The mechanism by which proprioception is improved is beyond the findings of our study, however one could speculate that the controlled movement patterns require increased sensory feedback. Regular practice or training of complex movement patterns may increase the body's reliance on afferent input which may

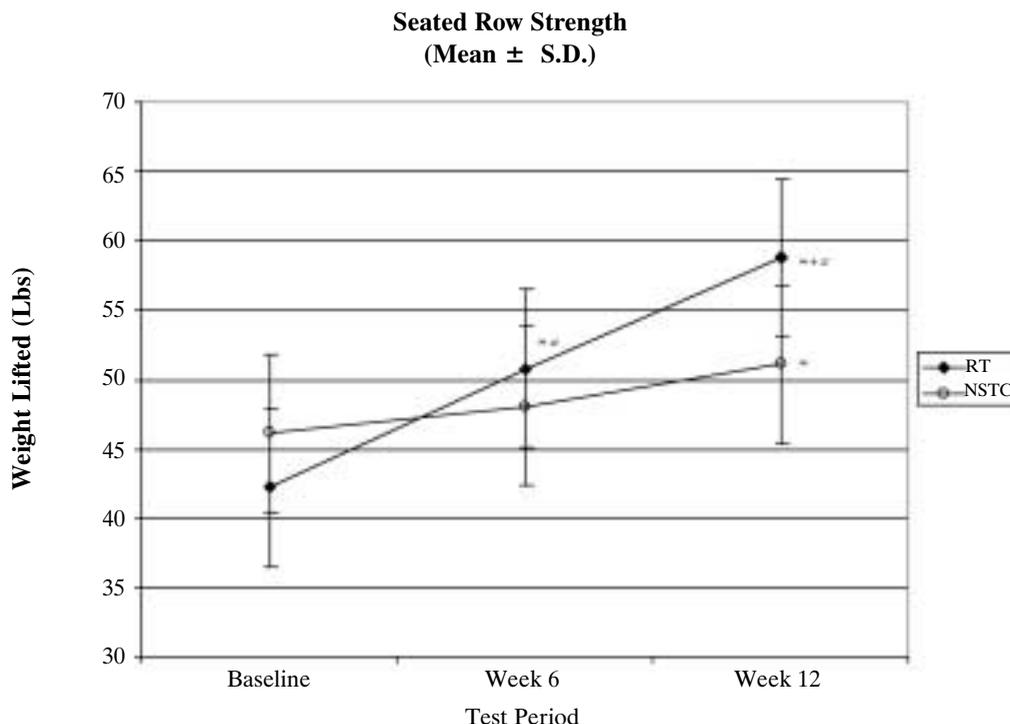


Figure 6. Seated row strength. * indicates a significant increase compared to the baseline measure; # indicates a significant difference compared to the NSTC group; + indicates a significant increase compared to the 6 week measure. The statistical significance level was set at $p \leq 0.05$.

in turn lead to a resensitization of peripheral sensory receptors. Interestingly, our findings suggest that coordinated movement patterns without muscle loading can improve proprioception similar to that of resistance training in older adult women.

It could be argued that because we did not have a pure control group (i.e., no structured activity), we actually may be seeing an improvement in proprioception due to familiarization with the testing. While this is a possibility we feel it is remote for the following reasons. First, prior to undertaking this study the proprioception device was tested for reliability using both young and old adults. Subjects were tested and then re-tested every 7 days for 3 weeks. Neither population of adults showed a trend towards improved scores with increasing testing frequency²⁶. There were no significant differences between test dates and the intraclass correlations were $r=0.84$ for static proprioception testing and $r=0.87$ for the dynamic proprioception testing. Learning effect did not appear to be a factor from one test to the next. Additionally, the proprioception tests in this study were performed every 6 weeks, further decreasing the chances of familiarization bias due to the long time lapse between testing sessions. Finally, on these tests there is nothing that practice can do to improve performance. Formulation of tactical strategies (i.e., learning) to shave off time on physical tasks has been documented to improve performance in functional testing in older adults. However, on the proprioception tests

there is nothing to practice. Literally, all the subject can do is focus on either the sensing of movement (e.g., dynamic proprioception) or feel of a specific joint angle (e.g., static proprioception). It could also be argued that improvements in reaction time may account for some improvement in the dynamic proprioception tests. However, for the same reasons as mentioned above, it is the authors' opinion that this is minimized since it was not observed in the reliability testing and that there was no attempt in the training to improve reaction time. Additionally, the time interval between tests was 6 weeks, making it difficult for any learning effect to sustain itself. For all of the above reasons, we feel the measured improvements in proprioception are real and not experimental artifact.

In 1996, the Surgeon General reported²⁷ that resistance exercise may help the elderly enhance muscular strength, improve mobility, and prevent falls. Our findings indicate that improved proprioception can also occur as a result of regularly performed resistance training. However, it appears that the improvement in proprioception is independent of the loading associated with the resistance training, and more than likely due to the coordinated motor patterns required to perform the exercises. Improvements in proprioception resulting from regular exercise may help explain some of the noted improvements in functional tasks that have been observed in older adults after training that are independent of strength gains²⁸⁻³⁴.

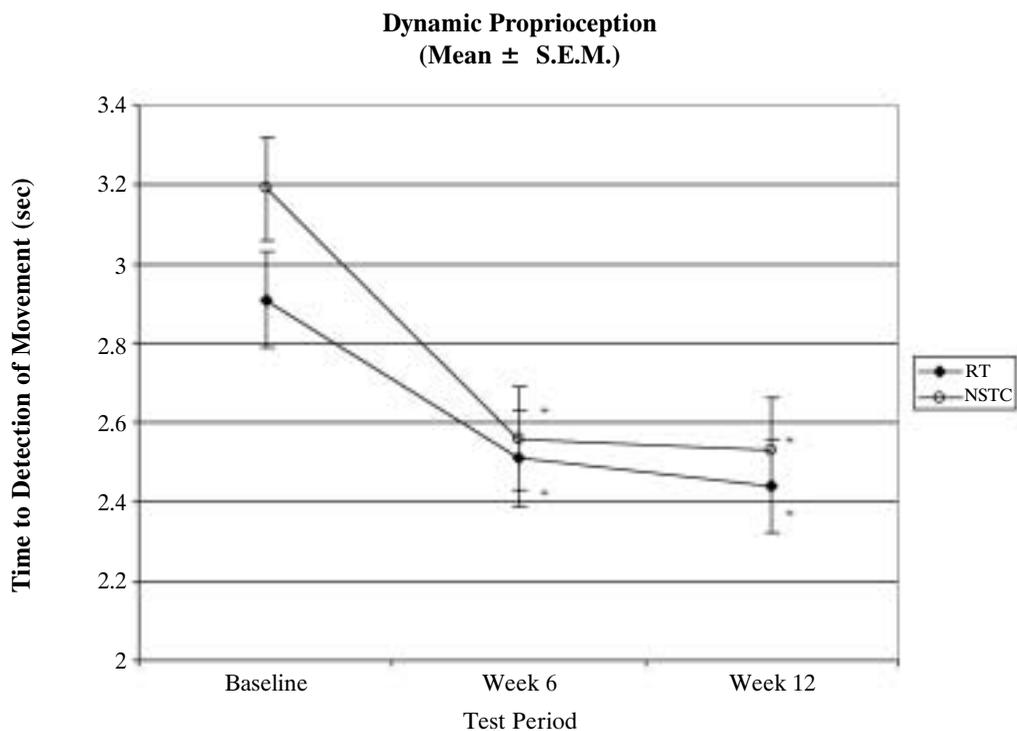


Figure 7. Dynamic proprioception. Decreases in time to detection of movement indicate an improvement in proprioception. * indicates a significant change ($p \leq 0.05$) from the baseline measure.

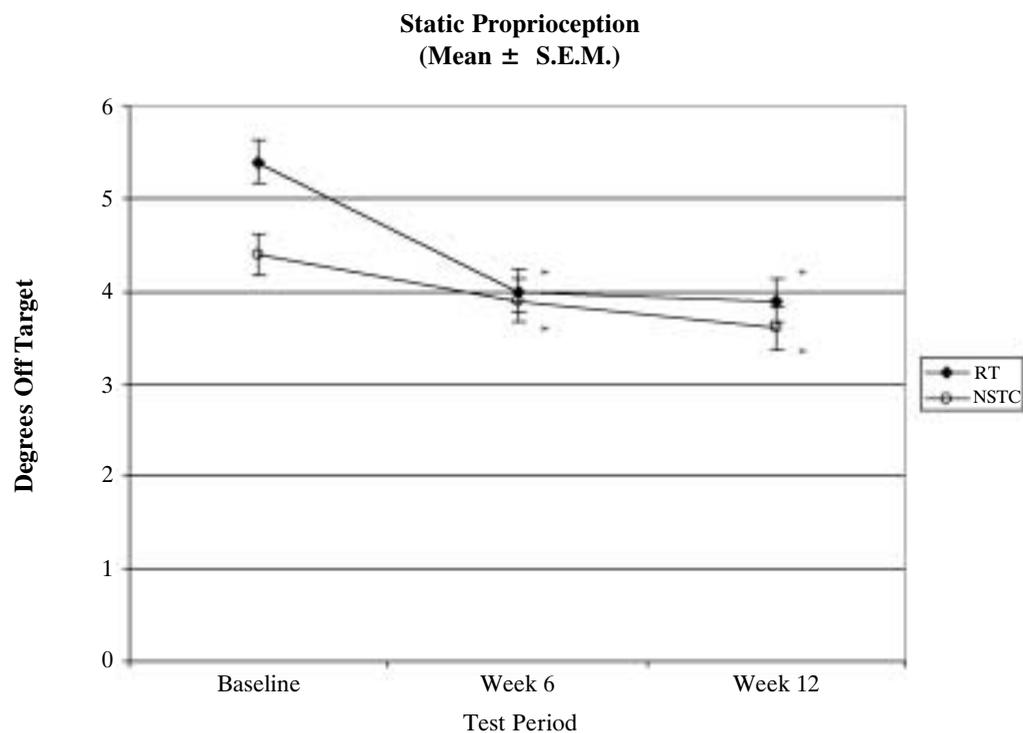


Figure 8. Static proprioception. A decrease indicates an improvement in static proprioception. * indicates a significant change ($p \leq 0.05$) from the baseline measure.

Conclusion

It appears that regularly performed coordinated movements, even those with minimal external loading, improve proprioception. This finding supports the growing consensus that a physically active lifestyle can play a role in preventing the physical deterioration associated with aging and a sedentary lifestyle. The extent to which the observed improvements in proprioception may impact physical functioning and risk for falling in the older adult population is not clear but certainly a promising area for further investigation.

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