Core Strengthening and Balance in the Geriatric Population

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ABSTRACT

Aging usually reduces muscle capacity in the core muscles of the body causing a reduction in functional abilities and activities of daily living. In the present investigation, we evaluated the effect of an exercise regimen on strength training in the core muscles, balance, and reach. Thirteen subjects underwent 20 minutes of exercise per day, 3 days a week, for a period of 1 month using a 6 Second Abs machine (Savvier, LP, Carlsbad, CA), eliciting exercise on the rectus abdominis, transversus abdominis, and back extensor muscles.

Balance and functional reach were assessed before and after the exercise program. Before exercise, the average maximum reach in the subjects was 15.4 ± 5.2, 16.9 ± 5.7, and 15.7 ± 4.8 cm for reach in the forward, right, and left directions, respectively. After training, reach increased to 22.4 ± 5.9, 20.6 ± 4.0, and 22.5 ± 5.3 cm in the respective directions. Associated with that movement, during maximum reach in the forward, right, and left directions, the reach angle of the body changed from 1.91° ± 2.76°, 2.31° ± 0.9°, and 0.9° ± 3.1° before training to 5.33° ± 1.83°, 4.72° ± 1.83°, and 2.42° ± 1.1° after the 1-month training program, showing a corresponding increase associated with the increased reach of these subjects. Not only were reach and the critical angle at which the subject exceeded his or her limit of stability increased, but tremor was reduced significantly for these subjects after training.

The results show that even if older individuals are engaged in a basic fitness program, training is very beneficial to increasing their independence and functional activities of daily living.

INTRODUCTION

Aging is associated with a loss in muscle strength. This, in itself, would be a limiting factor in daily activities, but aging is also associated with loss of peripheral motor and sensory nerves,[1-3] loss of both vision and control of the eye through the vestibular and visual cortex,[4] increased blood pressure during exercise,[5] and an increase in isometric endurance.[6] Peripheral blood flow at rest and during exercise is decreased as is the hyperemia following exercise.[7] These disabilities, secondary to the normal aging process, can lead to loss of balance and poor gait in the older population.[8,9]

Many types of programs have been developed to increase muscle strength and balance.[8,9] Lifting weights slowly at loads set to fatigue the muscle in short periods of time, called anaerobic exercise,[10] can cause muscle enzymes to favor glycolysis, and DNA is transcribed to build actin and myosin in muscle.[10-14] This allows the muscle to build strength and increase its ability to work without oxygen.[15] In contrast, light repetitive work (aerobic exercise), which requires high blood flow for energy and oxygen delivery, causes the muscle to transcribe genomes on DNA to increase the concentration of enzymes in the Krebs cycle and for beta oxidation of fats to better make use of the muscle's ability to burn fats.[12,16] Aerobic training also elicits an increase in angiogenesis in capillaries and an increase in mitochondrial surface area and density to allow better oxygen and fuel delivery to tissue for aerobic exercise.[17] Aerobic exercise training also increases function in the cardiopulmonary system, which lowers triglycerides, inflammatory cytokines, C-reactive protein, and increases collateral circulation in the heart.[18]

However, for the older population, while good cardiopulmonary conditioning is a goal, the most immediate concern is simply accomplishing activities of daily living (ADL). ADLs are frequently impaired due to weakness in core muscles such as the rectus abdominis, transversus abdominis, and the internal and external oblique muscles.[19] This results in an inability to reach objects away from the body.

Studies show that strengthening core muscles does aid in functional abilities.[20,21] Using large exercise machines to strengthen the abdominal and lower back muscles can allow someone in a wheelchair to have more effective bowel and bladder programs, to sit straighter in the chair, get less scoliosis, and to have better reach without losing his or her balance.[22] This increase in functionality translates into better performance in ADLs. This in turn leads to great psychological gains by allowing a person to be more independent.

However, with ever-rising costs in rehabilitation and even health spas, it becomes important to develop exercise techniques and devices to allow individuals who are disabled to exercise at home.[23] One such device is the 6 Second Abs machine (Savvier, LP, Carlsbad, CA). This machine provides a progressive increase in resistance with a built-in timer so that individuals can exercise their abdominal muscles and lower back muscles from the sitting position.[24,25] These devices are marketed at most sports stores in the United States and, for those who are not disabled, have offered a unique way to build abdominal muscle strength that is more effective than conventional sit ups.[24,25] The purpose of this investigation was to see if the device would help older people achieve better balance. Because the device allows people to exercise in the seated position, it allows safer exercise than lying on the floor or standing in a population with limited mobility.

SUBJECTS

Thirteen subjects participated in this study; the average age of the subjects as shown in Table 1 was 73.1 ± 7.3 years. The average height was 65.6 ± 3.8 cm, and the average weight was 68.2 ± 12.7 kg. Twelve of the subjects were women and one was a man. The oldest subject in the group was 82, and the youngest was 61. All subjects in the studies were engaged in a fitness program that included the 6 Second Abs machine workout at the La Fetra Senior Center in Glendora, California, 2 days a week and did 1 additional day of exercise with the machine independently.

All protocols and procedures were approved by the committee on human experimentation at Azusa Pacific University, and all subjects signed a statement of informed consent.

Table 1. General Characteristics of Subjects

	Age (years)	Height (cm)	Weight (kg)
Mean ± SD	73.1 ± 7.3	65.6 ± 3.8	68.2 ± 12.7

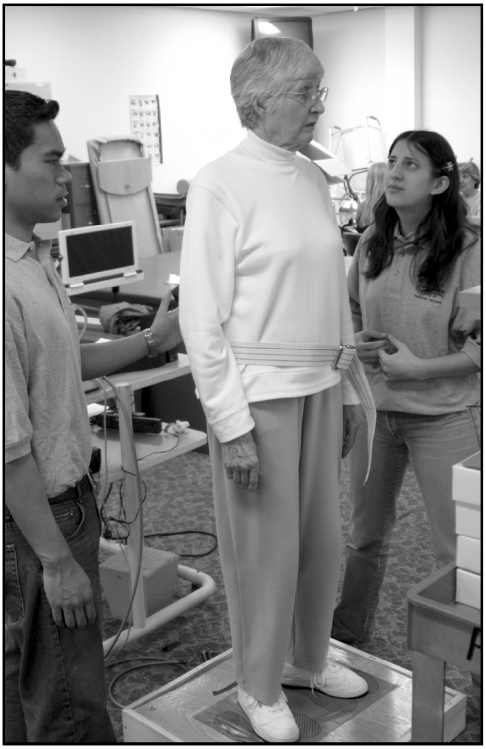

Figure 1. A typical patient standing quietly on the center of the balance platform.

METHODS

6 Second Abs Machine

The 6 Second Abs machine is a commercial exercise device that consists of a rectangular plastic frame with rubber bands on the inside to adjust resistance. Resistance can be increased in a number of different stages so that it becomes increasingly difficult to compress the rectangle.

As the machine is compressed to the first, second, and third clicks position with 3 different resistance bands, there is a linear increase in load. The upper part of the rectangle is placed under the subject's arms (under the triceps muscles bilaterally) or held in the subject's arms against the chest while the base of the rectangle is placed on of the middle of the quadriceps muscles. Both the upper and lower rectangles are padded.

Measurement of Muscle Strength

Muscle strength was measured in the abdominal and back muscles. The subjects were in the seated position with their backs at 90° in reference to the hips. A strap was placed around the subject's chest just below the axilla and connected to a strain gauge force sensor. Strength was then assessed for flexion and extension as the highest of 3 maximal efforts in each muscle group; 1 minute separated the contractions. A complete description is given elsewhere.[24,25]

Assessing Balance during Functional Daily Activities

Balance was assessed by a balance platform similar to the Smart Balance Master (NeuroCom Internation, Inc., Clackamas, OR). However, a similar device was built from two sheets of plywood and a ramp. The 1-inch plywood plates (Figure 1) were separated by four metal bars connected to strain gauges. Each bar was positioned at 90° with reference to the other bar. As such, strain gauges were placed at 0°, 90°, 180°, and 270°. With the subject standing in the center of the platform, leaning in any direction was then transduced through strain gauges mounted on the metal bars to an electrical output, so that the deviation and center of gravity could be assessed. The output of the strain gauges was connected to four strain gauge amplifiers (Biopac Inc., Santa Barbara, CA) and digitized with a 12-bit A/D converter (Biopac Inc.). The digitized

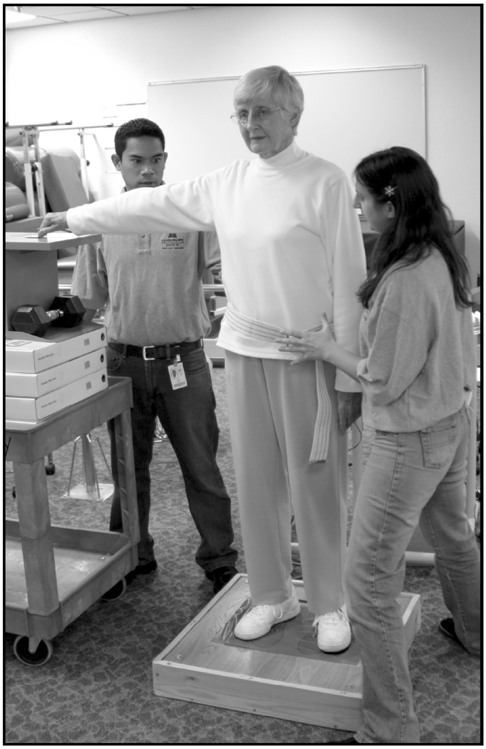

Figure 2. A typical subject reaching to the right but not to the fully extended position while standing on the balance platform. A gait belt was used for safety but was not touched by the investigators during reach.

data were sorted on a computer for later analysis.

Procedures

Subjects exercised 3 days a week for a period of 4 weeks. On any exercise day, 10 minutes of passive stretching was accomplished before the test exercise to minimize any chance of soft-tissue injury. Four different exercises were then accomplished to exercise the rectus abdominis muscles; subjects placed the 6 Second Abs machine equally across the mid thigh of both legs and flexed the abdominals by leaning forward, using the rectus abdominis muscles. The weight was set such that with repetitive contraction of the muscles over 6-second cycles of contraction, the muscle fatigued in 5 minutes. If, on any one day, 5 minutes of exercise was accomplished

Table 2. Average Strength of Subjects

	Average Strength (kg)	
	Flexion	Extension
pre	31.8	34.2
post	43.2	45.6
difference	11.4	11.4
t-Test	0.001	0.001

in any one exercise position, the workload was increased by 5 pounds such that on the next day they fatigued within the 5-minute period. In this manner, having accomplished exercise over a period of 30 days, the workload was progressively increased

In addition to this 5-minute bout of exercise, with the subject in the sitting position facing forward, two other bouts of exercise were accomplished with the subject facing 45° to the left and 45° to the right. In these cases, the machine was placed on one knee, such that the external oblique muscles were exercised. Once again, the workload was progressively increased over the 1-month period. For the final 5 minutes of exercise each day, subjects, again seated, placed the 6 Second Abs machine against their upper back and leaned backward and pushed against a wall from their seats to exercise their lower back muscles.

At the start and end of the month, strength was measured in the rectus abdominis and lower back muscles as described in the Methods section. On both occasions, balance was assessed. Subjects stood in the middle of the balance platform and reached at eye level to the furthest extent of their reach in the forward, left, and right directions (Figure 2). A gait belt was worn, and a physical therapist guarded the patients so they could not fall. A complete description of the technique is given elsewhere.[26]

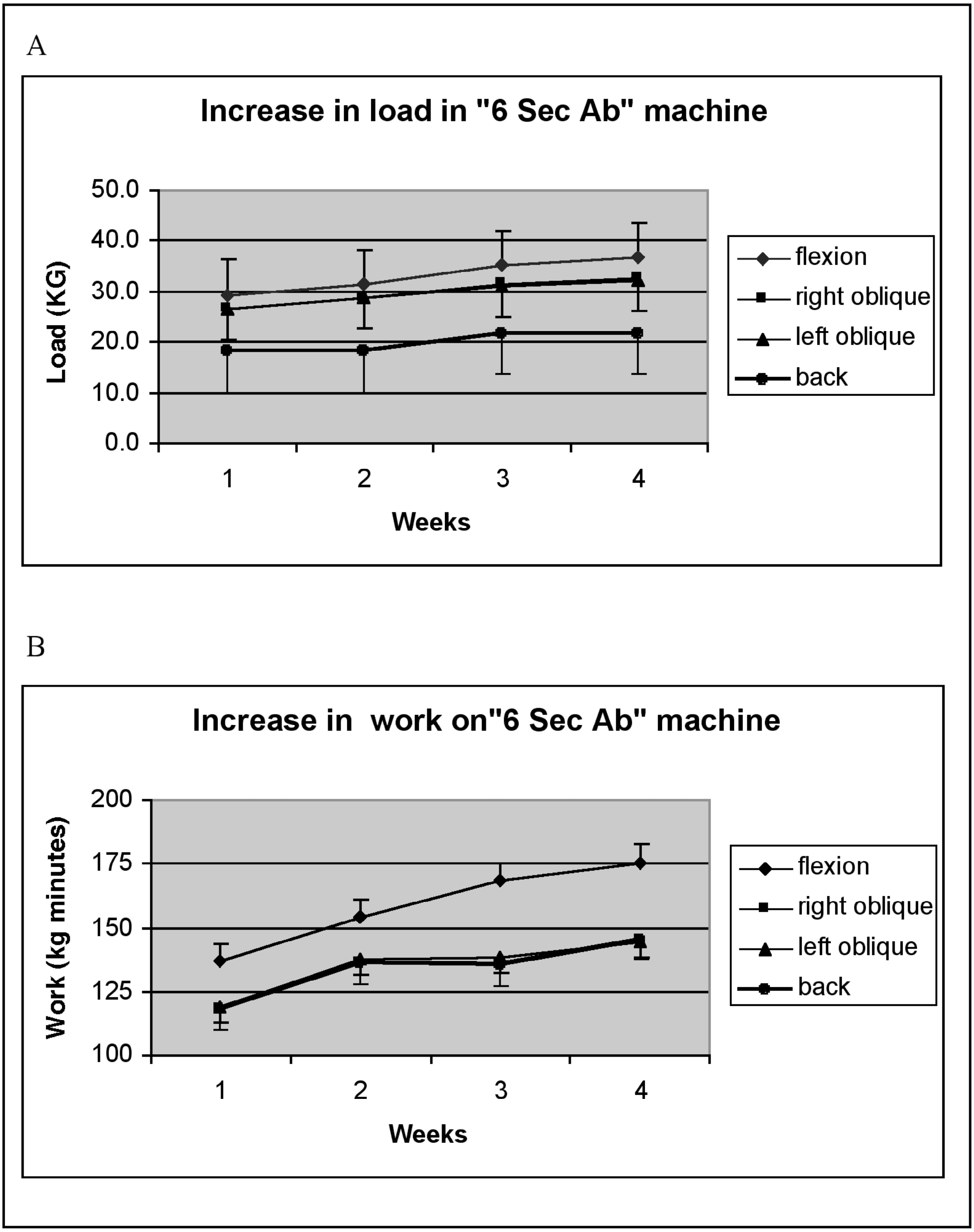

Figure 3. The loads (kg) (A) used by the subjects for their daily exercise each week for the 1-month program for flexion of the abdominal muscles, right and left oblique and back extension exercises). The average data for the group of 13 subjects ± the standard deviation. (B) Illustrates the calculated work loads accomplished each week.

RESULTS

Prior to exercise, the strength of the subjects, as shown in Table 2, for extension was 34.2 ± 10.2 kg while during flexion the average strength of the group was 31.8 ± 11.1 kg. After the 1-month training period, strength increased to 45.6 ± 16.9 kg for extension and 43.2 ± 14.6 kg for flexion. This increase in strength for both abdominal

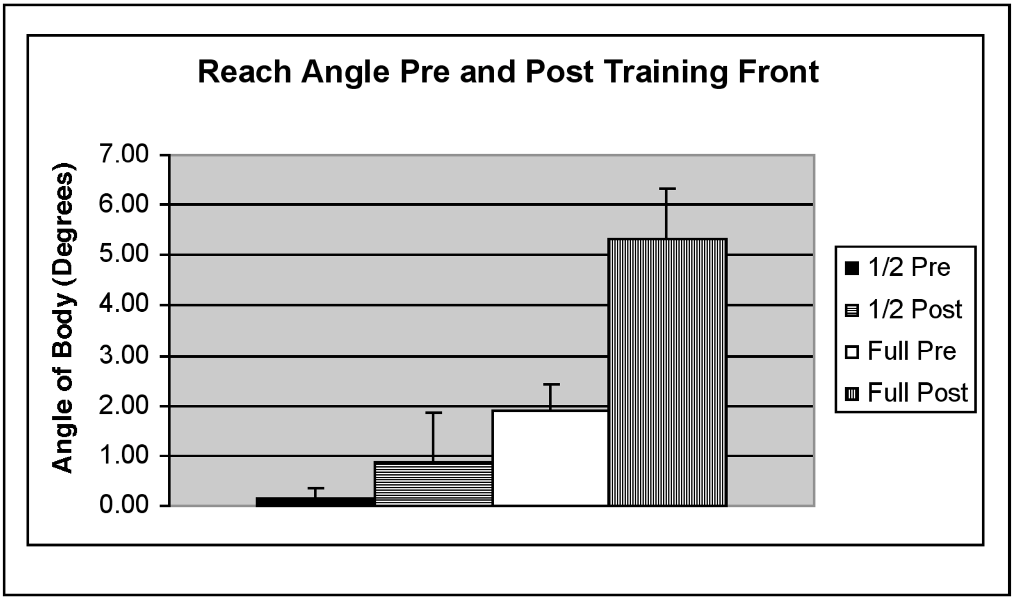

Figure 4. The angle of body at the limit of stability (maximum reach) for the subjects reaching in the forward directions for full reach and half reach before and after the 1-month training period. Each point shows the mean for the group ± the standard deviation.

flexors and extensors was 11.4 kg and was significant (*P*<0.01). The increase in strength was not surprising since, as shown in Figure 3A, there was progressive increase in the work and the load the subjects could tolerate on the abdominal machine for 5 minutes of exercise throughout the 1-month period. The average compliance for the exercise was 93% ± 19% for the group over 1 month. As shown in Figure 3B, the increase in work was 28.3% ± 7.2%, 23.3% ± 6.8%, 21.2% ± 5.9%, and 21.9% ± 5.8% for flexion, right oblique, left oblique, and back extension exercises, respectively. Whereas the maximum reach for the subjects averaged 15.38 ± 5.23, 16.92 ± 5.74, and 15.73 ± 4.87 cm for the forward, right, and left directions before the 1-month exercise program and, after the program, the respective reach was 22.4 ± 5.4, 20.7 ± 4.0, and 22.5 ± 5.3 cm. The increase in reach associated with the training averaged over 7 cm and was significant (*P*<0.01). This increase in reach is expressed as a percent of initial reach.

The increase in the maximum angle of the body's center of mass during maximum reach in pre- and post-training for the forward direction is shown in Figure 4 for full reach and at half the reach distance. Figure 5 shows data for reach in the right direction; during full reach the body mass was shifted forward. This improved with physical training on the 6 Second Abs machine. As shown in these figures, forward maximum reach angle increased by 178% while that on the right and left side increased by 178% and 256%, respectively.

As shown in Figure 6, there was also significant tremor associated with reach. When examining tremor in the 8-Hz (muscle spindle, peripheral tremor) and 25-Hz bands (central tremor caused by cerebellum or basal ganglia function), both types of tremor increased as might be expected during reach (Figure 6). The increase in tremor at rest compared with maximum reach for the reach in the forward direction was almost 50%. Similar findings were seen for reach in the left and right directions. These data are not

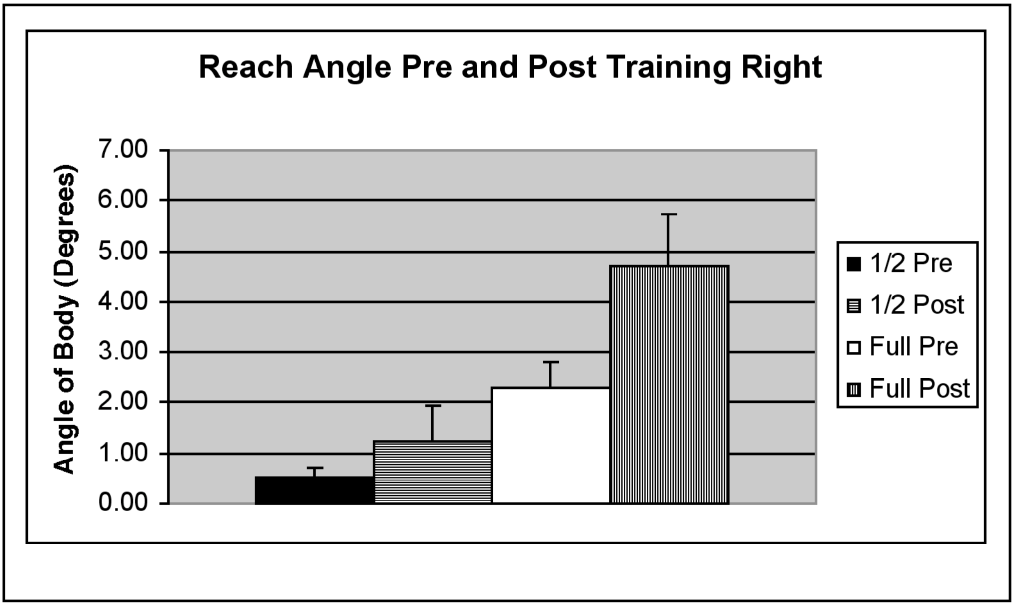

Figure 5. The angle of the body at the limit of stability (maximum reach) during the reach test for full and for half reach before (pre) and after (post) the 1-month exercise program. Each point is shown as the mean ± the standard deviation.

shown in this figure since results were comparable, tremor increasing by 48% ± 11% and 52% ± 14% during reach to the maximum extent in the right and left directions. After the 1-month training program, tremor was reduced significantly during reach as shown for both frequencies illustrated in Figure 6 ($P<0.01$). But as cited above, reach was greater. With the center of mass of the body further away from the core, it would be expected that tremor would actually increase, not decrease.

To fully understand the implication of these results, tremor at the 8 Hz frequency for forward reach has been plotted in Figure 7 in relation to reach distance, a better and more accurate picture is seen. Here, at the same reach distance in the forward direction, tremor was reduced in the 8 Hz band in these figures by more than 75% after the 1-month training program. This same relationship was seen for the side reaching measurements. In all cases, tremor, at the same reach distance was significantly reduced after a month of training ($P<0.01$).

DISCUSSION

It has been well established that aging is associated with a loss in muscle strength.[1,2] Muscle strength is lost not only to the radial muscles such as the gastrocnemius but to the axial muscles in the central core of the body, making balance difficult. There are also deficits in the neurological, vestibular, and visual systems.[4] It is the combination of the two and the resulting lack of reflex coordination that leads to loss of balance and poor gait in older individuals.[8,9,26] This loss in reflex ability as well as muscle strength in the rectus abdominis, transversus abdominis, and external oblique muscles reduces functional ADL for people over 60 years of age.[19]

It has been shown previously that strengthening of core muscles does aid in functional abilities.[20,21] Generally this is accomplished with large exercise machines and involves significant time at a health spa or gym.[22] Memberships may be costly. However, the costs are low compared with hospital-based or outpatient physical therapy. Since most

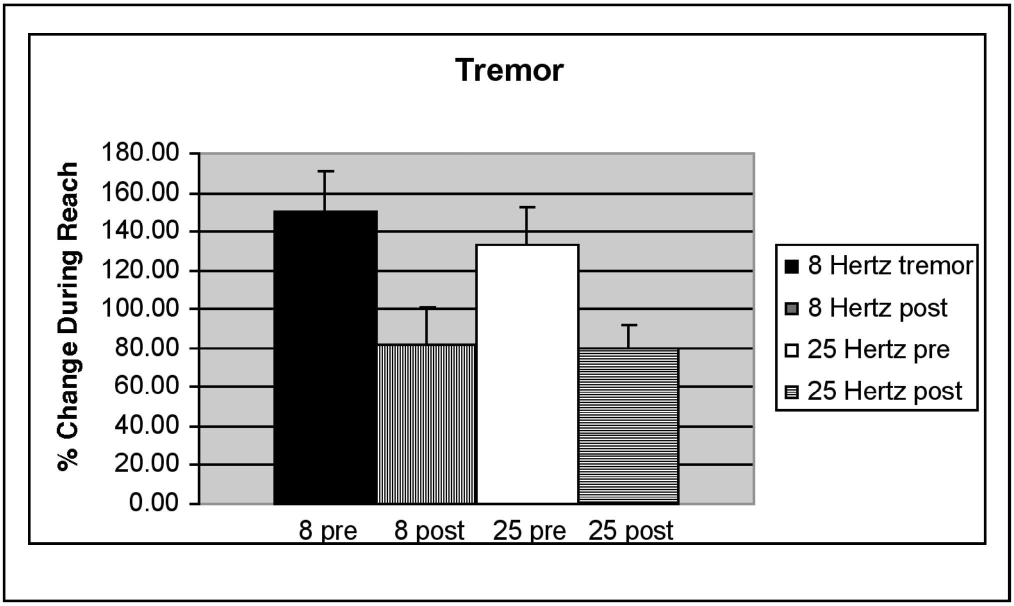

Figure 6. Tremor in the 8-Hz and 25-Hz bands in the balance platform when reaching in the forward direction before and after the 1-month training regimen. Data are shown only during the maximum reach.

seniors have limited income, use of major exercise equipment at large health clubs and physical therapy centers is usually impractical and impossible, especially under the new payment schedule provided by Medicare for physical therapy, which limits therapy to less than $2000 per year for seniors.

Whereas numerous studies have shown the benefits of exercise training in a therapeutic environment on core muscle strengthening, only a few studies have shown dramatic improvements with simple exercise equipment that can be used in the home environment. It is interesting that all individuals engaged in the studies were involved in an exercise program at a senior center. As such, they can be classified as physically active, and they were fit for their age. However, the limits of stability in the forward and side directions were still diminished compared with controls. Normally, when a person leans to reach something, the limit of stability, or the point where they lose their balance, is at an angle of the central axis of the body away from vertical of approximately 4º in the back direction, 8º in the forward direction, and 6º in the side directions. Here, the initial angle at the limit of stability was only a fraction of that in the forward and side directions. The initial maximum angle they could reach before losing their balance was 2º in the forward and 2º in the side directions. However, after a 1-month exercise program in this group of geriatric subjects, the limits of stability increased 5.5º in the forward direction and 4.7º in the side reach directions. This was still an angle less than that of younger people. However, the program was only 1 month and the improvement was dramatic. Perhaps a longer program would allow them to lean further, but there are still neurological deficits that may not be possible to be overcome in this population. This group was also physically active. Seniors who are not as active may have even less reach and may have more to benefit from this exercise p r ogram.

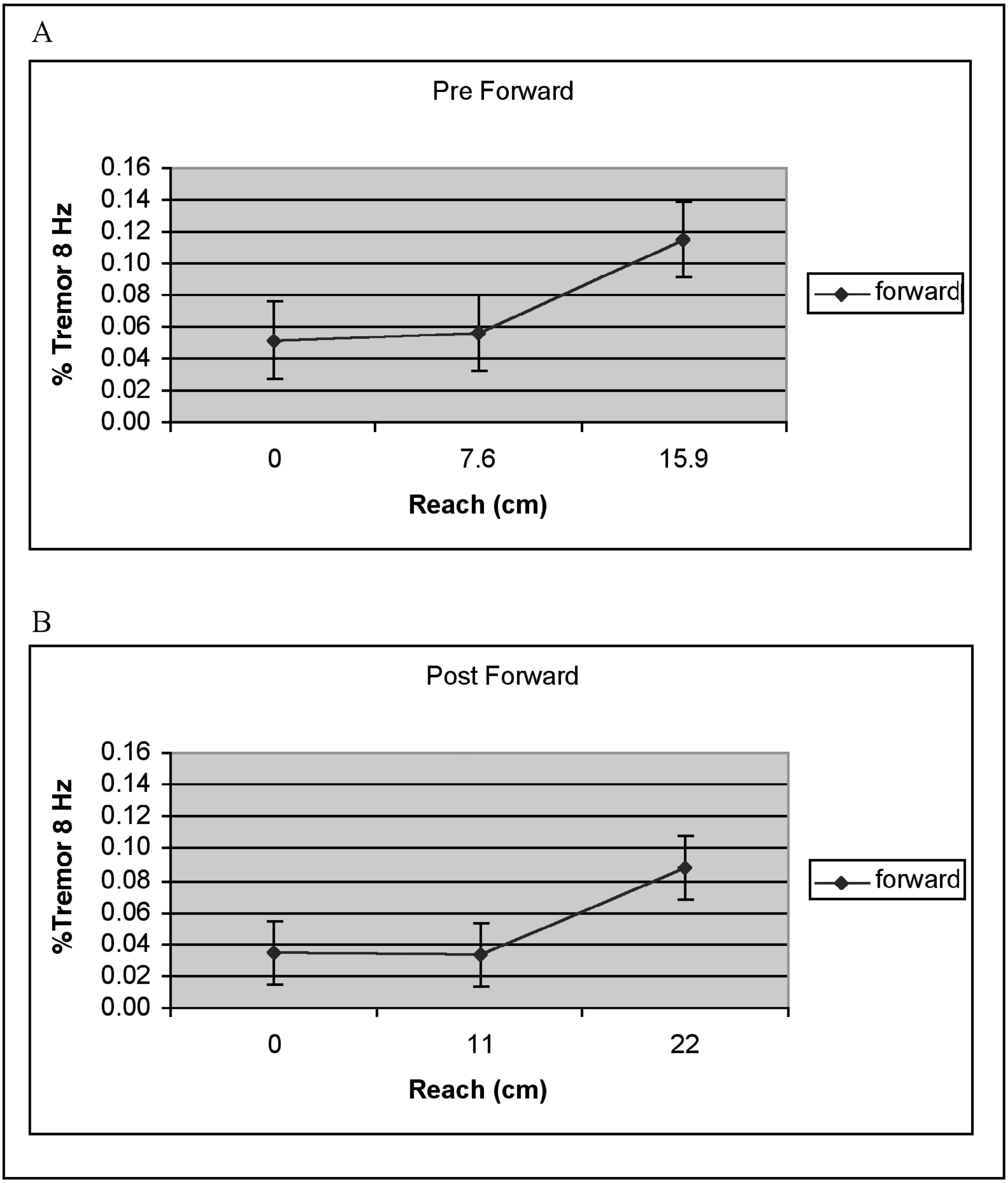

Figure 7. Muscle tremor with the subject leaning forward at each of the 3 reach positions (A) before and (B) after the 1-month training period. Tremor is shown as a percentage of total force on the platform as an average for the subjects ± the standard deviation.

What is of interest is that this group was active and attended weekly exercise programs but still had limited balance and reach. This simple exercise device, which could be used at home, targeted key muscles in the abdominal and lower back area, which translated to an increase in muscle strength and functional reach in all three directions. Thus, without specific strengthening of core muscles, standard exercise programs involving stretching may not be as effective as believed at increasing functional reach. This is not to say that these exercise programs are not good. These programs promote flexibility and cardiovascular fitness, which are critical for the geriatric population, but for maintaining functional ADL, an exercise device such as the one described here would be a great adjunct to therapy. Furthermore, the reduction in tremor after training and the greater reach should translate into less falls, a leading killer of the geriatric population.[8]

Tremor is associated with dropping objects and frustration with simple tasks such as reaching in a cabinet to get a can of food. The sharp reduction in tremor after core training is logical. If the core muscles are stronger, then it is easier to steady the limbs during a reach. Better reach with less tremor could make life less frustrating and can lead to increased quality of life in this population. The reduction in both tremor bands shows that motor control is improved at the central and peripheral level with core strengthening, probably leading to fewer falls.

REFERENCES

1. Resnick HE, Vinik AI, Schwartz AV, et al. Independent effects of peripheral nerve dysfunction on lower-extremity physical function in old age: the Women's Health and Aging Study. *Diabetes Care.* 2000;23:1642-1647.
2. Resnick HE, Stansberry KB, Harris TB, et al. Diabetes, peripheral neuropathy, and old age disability. *Muscle Nerve*. 2002;25:43-50.
3. Hof PR, Morrison JH. The aging brain: morphomolecular senescence of cortical circuits. *Trends Neurosci*. 2004;27:607-613.
4. West CG, Gildengorin G, Haegerstrom-Portnoy G, et al. Is vision function related to physical functional ability in older adults? *J Am Geriatr Soc*. 2002;50:136-145.
5. Petrofsky JS, Lind AR. Aging, isometric strength and endurance and the cardiovascular responses to static effort. *J Appl Physiol.* 1975;38:91-95.
6. Petrofsky JS, Laymon M. The effect of aging in spinal cord injured individuals on the blood pressure and heart rate responses during fatiguing isometric exercise. *Eur J Appl Physiol*. 2002;86:479-486.
7. Petrofsky JS, Besonis C, Rivera D, et al. Heat tolerance in patients with diabetes. *J Appl Res*. 2003;3:28-34.
8. Stevens JA, Olson S. Reducing falls and resulting hip fractures among older women. *MMWR Recomm Rep*. 2000;49(BR-2):3-12.
9. Jensen J, Nyberg L, Rosendahl E, et al. Effects of a fall prevention program including exercise on mobility and falls in frail older people living in residential care facilities. *Aging Clin Exp Res*. 2004;16:283-292.
10. Astrand PO, Rodhal K. *Physiology of Work Capacity and Fatigue*. New York, NY: McGraw Hill; 1970.
11. Nuhr M, Crevenna R, Gohlsch B, et al. Functional and biochemical properties of chronically stimulated human skeletal muscle. *Eur J Appl Physiol*. 2003;89:202-208.
12. Radda GK, Gadian DG, Ross BD. Energy metabolism and cellular pH in normal and pathological conditions. A new look through 31phosphorus nuclear magnetic resonance. *Ciba Found Symp*. 1982;87:36-57.
13. Taunton JE, Maron H, Wilkinson JG. Anaerobic performance in middle and long distance runners. *Can J Appl Sport Sci*. 1981;6:109-113.
14. Rusko H, Rahkila P, Karvinen E. Anaerobic threshold, skeletal muscle enzymes and fiber composition in young female cross-country skiers. *Acta Physiol Scand*. 1980;108:263-268.
15. Carrithers JA, Tesch PA, Trieschmann J, et al. Skeletal muscle protein composition following 5 weeks of ULLS and resistance exercise countermeasures. *J Gravit Physiol*. 2002;9: P155-P156.
16. Langfort J, Viese M, Ploug T, Dela F. Time course of GLUT4 and AMPK protein expression in human skeletal muscle during one month of physical training. *Scand J Med Sci Sports*. 2003;13:169-174.
17. Scheinowitz M, Kessler-Icekson G, Freimann S, et al. Short- and long-term swimming exercise training increases myocardial insulin-like growth factor-I gene expression. *Growth Horm IGF Res*. 2003;13:19-25.
18. Nicklas BJ, Ambrosius W, Messier SP, et al. Diet-induced weight loss, exercise, and chronic inflammation in older, obese adults: a randomized controlled clinical trial. *Am J Clin Nutr*. 2004;79:544-551.
19. Fujiwara T, Hara Y, Chino N. Expiratory function in complete tetraplegics: study of spirometry, maximal expiratory pressure, and muscle activity of pectoralis major and latissimus dorsi muscles. *Am J Phys Med Rehabil*. 1999;78:464-469.
20. Seelen HA, Potten YJ, Drukker J, et al. Development of new muscle synergies in postural control in spinal cord injured subjects. *J Electromyogr Kinesiol*. 1998;8:23-34.

21. Chen CL, Yeung KT, Bih LI, et al. The relationship between sitting stability and functional performance in patients with paraplegia. *Arch Phys Med Rehabil*. 2003;84:1276-1281.

22. Ryerson S. Hemiplegia resulting from vascular insult. In Umphred D, ed. *Neurological Rehabilitation*. St. Louis, MO: Mosby Inc.; 1995;619-658.

23. Ostelo RW, Goossens ME, de Vet HC, van den Brandt PA. Economic evaluation of a behavioral-graded activity program compared to physical therapy for patients following lumbar disc surgery. *Spine*. 2004;29:615-622.

24. Petrofsky JS, Morris A, Bonacci J, et al. Aerobic training on a portable abdominal machine. *J Appl Res.* 2003;3:402-415.

25. Petrofsky JS, Morris A, Bonacci J, et al. Comparison between an abdominal curl with times curls on a portable abdominal machine. *J Appl Res.* 2003;3:394-401.

26. Petrofsky JS, Lee S, Cuneo M. Effects of aging and type 2 diabetes on resting and post occlusive hyperemia of the forearm; impact of rosiglitazone. *BMC Endocr Disord.* 2005;5:4-16.