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Disclosures:

Supported by NIH grants R01AG12561 and P50AG11669, and by the Arthritis Foundation.

0894-9115/07/8602-0093/0
American Journal of Physical Medicine & Rehabilitation
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DOI: 10.1097/PHM.0b013e31802ede64

RESEARCH ARTICLE

Functional *vs.* Strength Training in Disabled Elderly Outpatients

ABSTRACT

Krebs DE, Scarborough DM, McGibbon CA: Functional *vs.* strength training in disabled elderly outpatients. Am J Phys Med Rehabil 2007;86:93–103.

Objective: To determine whether high-intensity functional training (FT) or strength training (ST) better enables impairment, disability, and functional gains among disabled community-dwelling elders.

Design: Randomized, blinded, prospective clinical trial in a large, tertiary care outpatient rehabilitation department. Fifteen elders (62–85 yrs old) referred for physical therapy with one or more impairments, including lower-limb arthritis, participated in 6 wks of FT (weekly outpatient and three to five times per week of home practice in rapid and correct execution of locomotor activities of daily living, including gait, stepping, and sit to stand) or progressive resistive ST using elastic bands with intensity, therapist contact, and home practice similar to those of FT.

Results: Both groups significantly improved their combined lower-extremity strength (hip abduction, ankle dorsiflexion, knee flexion, ankle plantarflexion, and knee extension) ($P = 0.003$), but no statistical difference between the ST and FT group gains ($P = 0.203$) was found. Subjects in both interventions improved their gait speed, but the FT group improved more than the ST group ($P = 0.001$). During chair rise, the FT group improved their maximum knee torque more than the ST group ($P = 0.033$), indicating that they employed a more controlled and efficient movement strategy.

Conclusions: These data suggest that an intensive FT intervention results in strength improvements of comparable magnitude as those attained from ST and that FT also confers greater improvements in dynamic balance control and coordination while performing daily life tasks.

Key Words: Elders, Strengthening, Functional Training, Exercises, Functional Limitations, Disability, Intervention Study

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Scant data exist on the effects of functional training (FT) or strength training (ST) among older persons,[1–8] and even fewer studies address elders with disabilities.[9–16] The dominant paradigm in rehabilitation has been to treat the impairment (e.g., weakness) under the assumption that functional limitations will improve as well.[17] According to Hopp, "Although training increases force-generating capacity, little is known about its effects on functional performance. Unless investigations are conducted in which different measures of functional performance are made before and following resistance training, the validity of this approach to improving the quality of life of older persons cannot be established."[18]

We and others have recently demonstrated that among community-dwelling elders, both strength and functional performance improves after even modest strength gains.[1] Fiatarone et al.[19] showed that frail, institutionalized subjects aged 90 ± 1 yrs old experienced highly significant strength gains (174 ± 31%) after an 8-wk high-resistance exercise training program. Fiatarone et al.[20] did not report functional locomotor benefits nor the real-life role changes (if any) that resulted, except that mean tandem gait velocity improved 48% from baseline measures, two subjects no longer used canes to ambulate, and one of three subjects who was initially unable to rise from a chair without arm use became able to do so after the ST. Lord et al.[21] and Chandler et al.[22] separately reported that 10 wks of general activity and strengthening exercise improved the functional capacity of elders. Chandler et al.[22] specifically noted that, among 100 disabled community-dwelling elders, gait, chair rise, and stair climbing, but not balance or disability, were positively impacted by strengthening exercise. Tinetti et al.[23] combined home-based strengthening and FT (median length 12 wks) for 104 elders and found significant locomotor activities of daily living improvements. However, no reports differentiate locomotor functional changes resulting from FT compared with conventional ST, or the compensatory mechanisms that could be engendered by impairment (organ level) or functional (whole-person level) training.

We[24] and others suggest that late-stance ankle plantarflexion power is a critical determinant of dysfunctional gait; impaired elders have dramatically reduced ankle-power peak magnitude compared with healthy elders of the same age and stature. Furthermore, there is some evidence that decreased knee-flexion power and, in particular, increased hip-flexion power in mid to late stance phase are, in part, a compensatory response to diminished ankle-muscle power output,[25] which seems to be only moderately related to muscle strength.[26] Practicing lifting, gait, and other locomotor activities may confer similar benefits as high-intensity ergometry for elders.[27] Thus, a high-intensity FT program focused on improving ankle power during locomotion should decrease the functional limitations of impaired elders.

We studied ankle-power flow resulting from 6 wks of FT (weekly outpatient and three to five times per week of home practice in rapid and correct execution of locomotor activities of daily living, including gait, stepping, and sit to stand) or progressive resistive ST using elastic bands with intensity, therapist contact, and home practice similar to those of FT. We hypothesized that both ST and FT groups would increase their muscle strength, but that those in the FT group would obtain greater functional gains.

METHODS

Subjects

Fifteen elders (62–85 yrs of age) consented to participate and signed the institution's approved human research consent form (Table 1). Eligibility

TABLE 1 Subject characteristics

Treatment Group	Height, m	Weight, kg	BMI	Age, yrs	Sex	Presenting Diagnosis
Strength training	1.7 (0.1)	72.3 (11.7)	26.9 (5.1)	70.4 (6.5)	M = 2	O = 4
					F = 4	N = 2
					N = 6	A = 0
Functional training	1.7 (0.8)	73.8 (9.5)	26.5 (4.1)	78.1 (4.6)	M = 3	O = 5
					F = 6	N = 2
					N = 9	A = 2
Total sample	1.7 (0.1)	73.6 (10.1)	26.7 (4.3)	75.0 (6.5)	M = 5	O = 9
					F = 10	N = 4
					N = 15	A = 2

For diagnostic classification, the presenting complaints from the patient's "reason for physical therapy visit" were used. BMI, body mass index (kg/m^2); O, orthopedic, chiefly osteoarthritis; N, neurologic, including stroke, peripheral neuropathy; A, all others, including diffuse balance problems, cardiovascular, etc. Values are means (SD) for continuous data.

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criteria included age 60 yrs or older, cognitive intactness, and ability to ambulate independently for at least 15 feet. Each subject had at least one lower-limb impairment, and each had at least one functional limitation on the Short Form 36 (SF-36) nine-item physical function inventory (excluding the vigorous-activity item).[1] All had complaints of pain and symptomatic lower-limb arthritis (Kellgren 2 or 3) for which they were referred to physical therapy. Table 1 provides demographic characteristics of the participants. Subjects were excluded because of terminal illness, progressive neurological disease, major loss of vision (legally blind), acute pain, and nonambulatory status. Subjects were recruited through weekly screening of the outpatient physical therapy appointments for subjects 60 yrs or older who received permission from their physical therapist and/or primary care physician. All 15 subjects were consecutively (without excluding any one who met eligibility criteria) entered until 15 subjects were entered; there were no dropouts. Each subject underwent detailed biomechanical analysis of locomotor activities and lower-extremity strength testing. This assessment occurred at the initial visit and 6 wks after participation in one of two exercise programs. Additional questionnaires regarding self-perceived functional ability were administered, including a modified version of the SF-36, at the initial and final visits. Laboratory staff was blind to treatment-group membership, as were patients, who were told that they had been assigned to one of two different kinds of exercise. Each patient signed an institutional review board–approved informed consent.

Intervention

Patients were randomly assigned via a computer-generated table to 6 wks of ST or FT. Each exercise session begins with a warm-up period (10 min) followed by an exercise period (30 min) and a 10-min cool-down/activity period. The ST intervention exercise program is a validated program for elders, has been proven to generate both strength and functional benefits,[1,2] and is based on resisted proprioceptive neuromuscular facilitation exercise patterns using a series of graded resistance elastic bands prescribed by the therapist to permit 10-repetition maximum, at which point the resistance is increased to permit only 6-repetition maximum, and then it is increased again.[1] The FT program is a novel movement-control program that has not been previously described; the program's details are described in Table 2. This program consists of exercises simulating locomotor activities of daily living performed at three different speeds (self-selected, fast, and slow speeds) with progressive levels of difficulty. Task difficulty was gradated by, for instance, having subjects hold objects during gait, increase speed and number of repetitions of each task, changing environment (including the floor surface and step height), or combining tasks to challenge balance and motor control (Table 2). Two physical therapists instructed the subjects in either FT or ST; neither therapist was involved in testing (testers were blinded to treatment group, but training therapists could not be). Both interventions were individualized to the needs of each subject in accordance with the planned algorithm to promote consistency in application of the interventions. Both exercise interventions were designed with a four-level normal progression and four additional advanced levels to obviate ceiling effects. Subjects were encouraged to exercise 3–5 days/wk, and all subjects submitted weekly exercise adherence logs, which the therapist checked at the weekly outpatient visit.

Lower-Extremity Strength

Bilateral lower-extremity isometric muscle-strength testing was performed immediately before the gait trials, using a handheld Compufet dynamometer (Hoggan Health Industries model # 5025.) Knee extension and hip abduction muscle-strength testing were performed with the subjects sitting. During hip abduction, the subject pressed both knees outward while abduction was blocked by the Compufet being pressed against a rigid, upright surface. Knee flexion muscle strength was tested in prone position, and plantarflexion muscle strength was tested in long sitting (sitting with the knees in full extension). Our pilot studies showed that disabled elders required these modified testing positions to prevent undue discomfort and to permit maximum muscle performance.[1,2] One practice trial was performed, and the average of two recorded trials was used for data analysis; we have previously reported the reliability of these strength measures among similarly disabled elders to be $r = 0.87$.[1]

Locomotor Activities of Daily Living

Full-body analyses were performed at the motion laboratory, including kinematics (linear and angular motions) and kinetics (forces and moments that cause these motions) during standing and locomotor activities. The instrumentation includes two Kistler piezoelectric force plates, four Selspot II optoelectronic cameras, and 64 infrared light-emitting diodes (irLEDs), attached securely to 11 body segments (right and left feet, shanks, thighs and arms, pelvis, trunk, and head). This data-acquisition system yields 6-*df* kinematics of the 11 body segments.[28,29] Instrumentation and processing of raw kinematic data yields resolutions of <1 degree orientation and <1 mm position.[30] All tasks were performed barefoot, with close guarding by at least two assistants to prevent falling. Data from two trials

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TABLE 2 Description of the exercise intervention programs

Warm-Up/Cool-Down Exercises*	Strength-Training Exercises	Functional Training Exercises
Sitting 1. Deep breaths (five reps) 2. Terminal knee extension with ankle dorsiflexion and plantarflexion (five reps for each leg) 3. Bilateral shoulder flexion (five reps) 4. Shoulder shrugs (six reps) Sitting 5. Forward lunges (five reps for each leg) 6. Lateral lunges (five reps for each leg)	All exercises were instructed with the goal of attaining 10 repetitions. Sitting 1. Hip flexion and resisted hip extension. 2. Hip flexion with external rotation and resisted hip abduction and internal rotation. 3. Ankle dorsiflexion with resisted plantarflexion. Sitting 4. Toe raises 5. Hip flexion with resisted hip extension and abduction. 6. Hip flexion and with horizontal adduction of opposite shoulder and resisted hip abduction/extension with shoulder abduction/flexion. Sitting 7. Resisted terminal knee extensions 8. Resisted knee flexion 9. Resisted hip abduction 10. Shoulder protraction and resisted retraction Mode of progression 1. Four levels of difficulty. Each designed for the individual exercise using increasing number of repetitions and changes to the exercise task (e.g., forward walking progressing to stop; start walking; walking while turning head). 2. Used resistive elastic bands. *Advanced Levels* 1–4: Resistive band colors were doubled up with the level 4 band.	All exercise activities were performed at three speeds (self preferred, fast as possible, and as slow as possible). Sitting 1. Chair rise 2. Forward reach to opposite foot Sitting 3. Forward walking 4. Side step walking 5. Combined forward and backward walking patterns 6. Step up/step forward and down 7. Marching 8. Stooping/squatting 9. Forward and upward reach Sitting 10. Head/upper-body rotation reach Mode of progression 1. Four levels of difficulty. When 10 repetitions were performed (for at least 8 of 10 exercises) for 1 wk of exercise successfully, then the next level of difficulty band was introduced. 2. Depending on the specific exercise, various items from the home were used to add difficulty (e.g., plastic bottle and laundry basket). *Advanced levels* 1–4: Continued progression of task-dependent difficulty and increased emphasis on combined activities, motor control, and balance (e.g., picking up laundry basket and carrying it while walking over an obstacle).

* Warm-up/cool-down exercises were identical for both functional training and strength-training exercise interventions.

were collected in a given session. The tasks included gait, chair rise, and quiet standing balance tests. Below, each task is described, and the variables obtained for each activity are defined.

Gait

All subjects walked approximately 10 m without an assistive device, first at their preferred speed and then paced (120 bpm) by a metronome, to provide cadence-controlled between- and within-subject comparisons. Data collection began when each subject entered the 2 × 2 × 2 m viewing volume, approximately 3 m beyond the starting point. Each individual was asked to walk at their preferred pace "in as straight a line as possible as if you were taking a brisk walk through the park." The instructions for 120-bpm metronome-paced gait were identical except that the subjects were asked to walk at a specified pace. All subjects performed one practice gait trial before data collection.

Average gait velocity is determined from change in whole-body center of gravity (CG) displacement relative to change in time during a complete gait cycle (time elapsed between consecutive ipsilateral heel strikes). Double-support duration is obtained from one of the two periods during which the body is supported by both limbs, expressed as percent gait cycle. Maximum moment arm is the Pythagorean

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horizontal distance between the whole-body CG and center of pressure (CP) in the anteroposterior (AP) and mediolateral directions during single-limb stance.[1,28] Range of whole-body CG AP linear momentum (the absolute difference between the maximum and minimum AP linear momentum values during a gait cycle), and range of whole-body CG lateral linear momentum (the absolute difference of the maximum right and left lateral momentum values during a gait cycle) were obtained from the gait analysis. All gait variables were analyzed based on the average of the two gait trials. Kinetic and torque analyses were performed using methods described in detail elsewhere.[21,25,26,31]

Chair Rise

For each chair-rise trial, the participant was seated with the greater trochanters approximately 4 cm from the front edge of an armless, backless chair, adjusted to 100% knee height (the distance from the right medial tibial plateau to the floor). Two chair-rise trials were recorded for each subject, after performing one practice trial. Participants placed their feet 10 cm apart, at 18-degree ankle dorsiflexion. Arm and foot position constraints were used to improve the consistency of the body position during chair-rise testing.[32–34] When participants kept their arms folded in a constrained position in front of their abdomen with their feet remaining in the same position throughout the chair-rise trial, the trial was considered successful and was used for analysis. Each participant was asked to "arise from the chair as you normally do" beginning on "go" after the cue "one, two, ready, go." Chair-rise trials were performed first with eyes open then eyes closed.

Maximum trunk flexion (relative to global/room coordinates) and maximum knee torque were recorded between the start of movement and the end of chair-rise time (EOR).[1,25] The start of movement is defined as the time at which anterior upper-body linear momentum is positive, and EOR is the time at which whole-body CG reaches it first peak vertical position.[34] Chair-rise cycle time was calculated as the time elapsed from the start of movement through EOR. Time of lift-off, as a percentage of chair-rise cycle time, is defined as the instant the thigh segment is displaced sagittally 2 degrees.[34] The maximum range of AP linear momentum was recorded between EOR and the end of data collection, approximately 5 secs.

Quiet Standing Balance Tests

Standing-still test positions were gradated to be progressively more difficult (levels 1–6), as validated by Lord et al.[35] Base of support was varied by controlling foot placement into one of three positions; subjects were tested both in light (eyes open) and in darkness (eyes closed). For the feet-together position, subjects' feet were side by side, with the malleoli 1 cm apart. For semitandem standing, the feet were also 1 cm apart, but the heel of the forward (dominant) foot was even with the toe tip of the hind foot. Foot dominance was the subjects' swing foot when pantomime-kicking a ball. In all cases, the feet were parallel to each other and were aligned with the sagittal plane. If subjects successfully completed the semitandem standing eyes-open trials, they were asked to perform increasingly more challenging standing tasks such as semitandem standing with eyes closed, and tandem (one foot in front of the other) with eyes open and with eyes closed, until they were unable to stand without taking a protective step.[35] Subjects were told to stand as still as possible during the trials. Two quiet standing trials were recorded for each subject, after performing one practice trial. The subject stood for 10 secs, after which 7 secs of data were collected. The phase-plane combined stability parameter[28] was calculated to quantify standing balance control. The stability parameter is the root mean square variance of the position and velocity in horizontal (AP and mediolateral) planes.[29]

SF-36

Subjects completed the SF-36 in interview format. These interviews were carried out initially within 1 wk of the first test session and again after the 6-wk intervention exercise program. Within a week of completion, all subjects received (via mail) a study survey that was designed to obtain subjective reactions to the exercise programs.

Data Analysis

Descriptive statistics and repeated-measures multivariate analysis of variance with honestly significant difference–corrected paired comparisons were calculated on the outcome variables after determining the independent variables were free of multicolinearity. Although one could argue that multivariate analysis of variance on a small sample such as ours might lead to type II errors, we found statistical significance; thus, it must be concluded that the multivariate analysis of variance, combined with the conservative honestly significant difference–corrected paired comparisons, prevented potential type I errors on the multiple comparisons. The independent variable was type of intervention: ST or FT. The average of trials 1 and 2 for each muscle group was taken across both the right and left sides at both the 0- and 6-wk visits. We used an intention-to-treat analysis for overall hypothesis testing and one-tailed testing because the hypotheses are unidirectional. Pearson correlation analysis determined the relationship between right and left muscle strength and between

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the subject characteristics and percent changes in strength between the 0- and 6-wk visits. A Mann–Whitney nonparametric one-tailed comparison was used for the SF-36 data analysis. SPSS version 10 (Chicago, IL) and SAS version 6.04 (Cary, NC) statistical packages were used for all analyses.

RESULTS

Subjects performed the exercise program 4.99 ± 1.07 days/wk in the ST group and 5.39 ± 1.27 days/wk in the FT group ($P = 0.29$). On average, the maximum exercise-level changes from baseline did not differ between the ST group (3.60 ± 1.52) and the FT group (4.38 ± 0.74; $P = 0.10$); each group had a four-level normal progression and four additional advanced levels, for eight total possible advancement levels.

Strength

The total sample improved their combined lower-limb strength (sum of the five muscle groups) by 19% relative to initial values (Table 3, $P = 0.003$). The most significant muscle-group strength gains were for hip abductors ($P = 0.02$) and ankle dorsiflexors ($P = 0.006$). There also were gains in hamstring ($P = 0.038$) and ankle plantarflexors ($P = 0.039$) across all subjects. Though not statistically significant, there were modest gains in knee-extension strength across all subjects ($P = 0.052$). There were no differences between the FT and ST groups in strength gains, but, on average, the FT group improved by 25.6%, and the ST group improved 15.6% after the 6-wk intervention. The left and right baseline lower-extremity strength values strongly correlated to each other (hamstrings $r = 0.88$, $P < 0.001$; quadriceps $r = 0.81$, $P < 0.001$; $P = 0.007$; ankle dorsiflexion $r = 0.87$, $P < 0.001$; ankle plantarflexion $r = 0.90$, $P < 0.001$). The percent change of the combined strength variable did not correlate with age, weight, height, or BMI ($r = 0.51$ to -0.029, $P = 0.051–0.917$), thus supporting the generalizability of these results and obviating concerns about these potentially confounding variables in this sample.

Gait

Preferred Gait

All subjects significantly improved maximum and average CG velocity ($P < 0.003$). Overall, the FT group, compared with the ST group, had a greater improvement in maximum and average gait velocity ($P = 0.024$ and $P = 0.023$, respectively, Fig. 1). Indeed, the FT group had threefold gait-velocity improvements compared with the ST group. The FT group had significantly ($P = 0.037$) greater improvement (decreased percent cycle time) in double support after the intervention (FT group, −2.48% ± 2.09; ST group, −0.629% ± 1.19; Fig. 2).

Paced Gait

Three subjects (two subjects in FT and one in the ST group) were unable to walk at the ideal paced time of 120 bpm (±0.01 bpm) and were therefore eliminated from the paced-gait analysis. The 12 subjects able to perform paced gait demonstrated improved maximum moment arm and stance duration ($P = 0.044$ and 0.045, respectively). After the exercise intervention, the ST group showed statistically greater ($P = 0.045$) mean change in maximum moment arm (2.76 ± 2.64) than the FT group (0.32 ± 1.92) (Fig. 2). The ST group also statistically ($P = 0.023$) improved lateral linear momentum (−2.43 ± 5.94) compared with the FT group (5.11 ± 5.38) (Fig. 2).

Chair Rise

Eleven subjects were able to rise independently, without taking a step or unfolding their arms, at 100% knee height at the initial visit. Two subjects were only able to rise from a chair at 120% knee height, and two others required manual assistance to rise. Data analysis for the 11 subjects revealed a trend toward improved chair-rise (eyes closed) maximum range of AP linear momentum after the end of rise, with a decrease from 9.18 to 6.05 kg-m/sec ($P = 0.045$). The FT group changes in momentum did not differ from the ST pre- *vs.* postintervention changes ($P = 0.113$). The FT group used less peak knee torque than the ST

TABLE 3 Percent differences in strength between baseline and postexercise values for the strength-training (ST) and functional training (FT) exercise groups

Muscle Action	Functional Training Group	Strength-Training Group	FT–ST difference significance, *P*
Hip abduction	16.4 (22.8)	13.7 (12.9)	0.40
Knee flexion	9.5 (15.0)	19.8 (41.1)	0.25
Knee extension	33.6 (49.4)	3.7 (30.4)	0.11
Plantarflexion	20.2 (32.5)	12.6 (14.9)	0.30
Dorsiflexion	48.1 (66.6)	28.3 (34.5)	0.26

Note that FT, on average, gain 26%, and the ST group gain an average of 16%.

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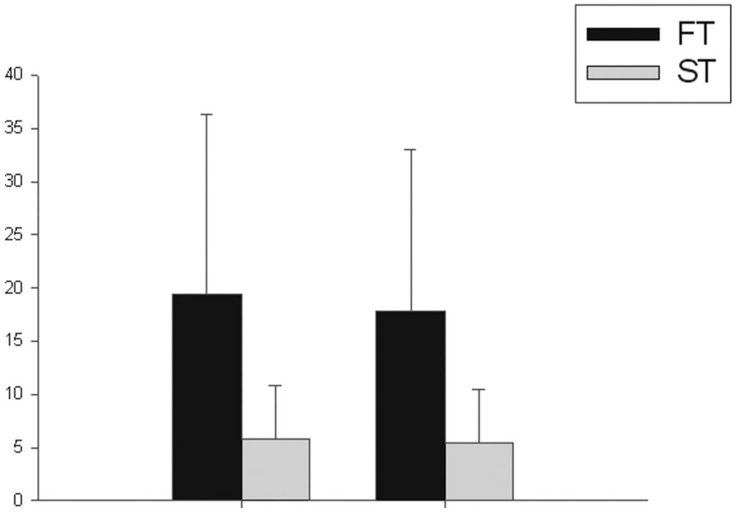

FIGURE 1 *Maximum within gait-cycle (*left bars*) and average (*right bars*) preferred walking speed in the functional training (FT) and the strengthening (ST) groups: absolute changes (cm/sec) before and after exercise intervention. Larger values indicate improvement. Note that the improvement in the FT group is threefold that of the ST.*

group during chair rise with eyes open ($P = 0.033$) and the chair rise with eyes closed ($P = 0.031$) (Fig. 3). There were no significant differences ($P > 0.05$) in change scores for all subjects combined or between intervention groups for chair-rise cycle time and maximum trunk-flexion angle.

Quiet Standing Balance

Eight subjects showed improved ability in quiet standing balance, progressing one or more position level(s) of difficulty (Table 4), irrespective of group. Phase-plane analysis demonstrated an overall improvement in the CP stability parameter across the 10 subjects who performed with feet together and eyes closed during both visits ($P = 0.007$). The ST group performed better than the FT group ($P = 0.038$) in standing still, decreasing their average CP phase-plane stability parameter (-0.22 ± 0.31) compared with the FT group (1.03 ± 1.54). There were no significant changes noted

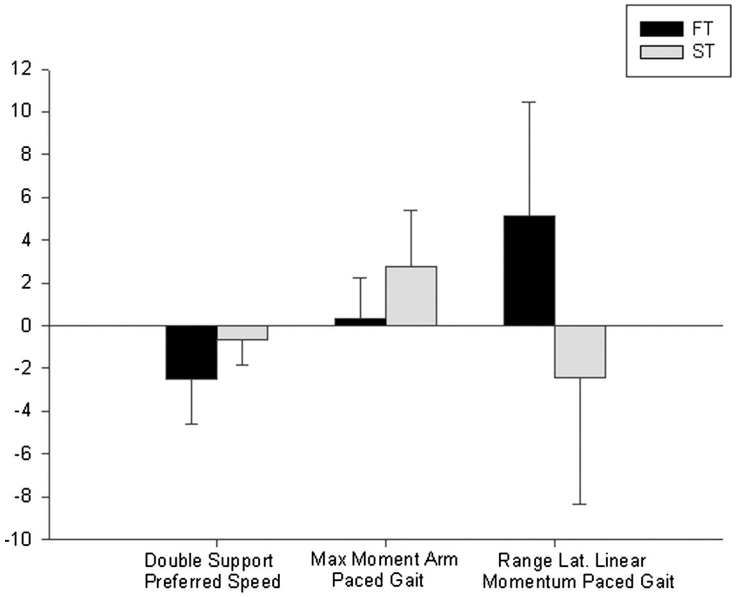

FIGURE 2 *Percent change in preferred gait-speed double-support time, paced-gait maximum moment arm, and range of lateral linear momentum between FT and ST groups. Smaller double-support time and lateral linear momentum, but larger maximum moment-arm values, respectively, indicate improvement. Note that the FT group had a threefold improvement in double-support time, but the ST group improved their maximum moment arm (CG–CP Pythagorean distance of separation) nearly fourfold that of the FT group.*

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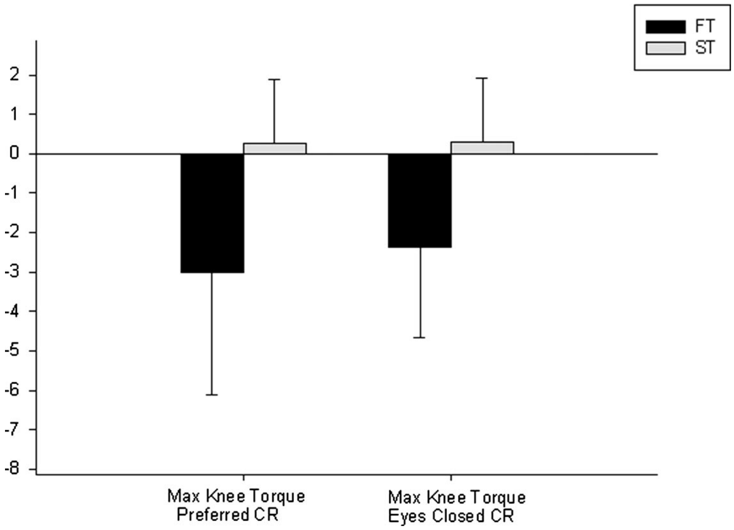

FIGURE 3 *Change in normalized (height in meters · percent body weight; M-%BW) knee torque during preferred chair rise with eyes open and eyes closed between the FT and ST group. Note that more negative values indicate improvement; the FT group clearly decreased their knee stress, an important predecessor to decreased knee pain.*

in CG stability parameters during feet together with eyes closed or CG and CP stability parameters during semitandem with eyes open.

Questionnaires

One subject in the ST group sustained an unrelated fall halfway through the 6-wk intervention, resulting in injury of her dominant shoulder. Although she continued to participate in the intervention, we modified the exercises to use only the other arm. All subjects, with the exception of the person who sustained the shoulder injury, completed the SF-36 physical functioning subscale questionnaire initially and on completion of the exercise program. Seven subjects reported improvement in the SF-36 items. Five of these subjects were in the FT group, and two were in the ST group. The remaining seven (three in the FT and four in the ST group) showed no changes from their baseline scores. There was significant improvement among all subjects ($P = 0.013$) after the intervention. There was a statistically insignificant trend ($P = 0.068$) toward greater improvement in the FT group compared with the ST group.

TABLE 4 Quiet standing balance outcome across all subjects before and after the exercise programs

	FT	ST
Visit 1	3.2 (1.1)	3.5 (1.1)
Visit 2	4.2 (1.5)	4.0 (1.2)
Change	1.0 (1.2)	0.50 (1.1)

Median change scores, that is, the difference before and after the intervention and (quartiles) are summarized below. One point is given for each successfully completed standing trial, according to level of challenge. Level 1 = feet together, eyes open; level 2 = feet together, eyes closed; level 3 = semitandem, eyes open; level 4 = semitandem, eyes closed; level 5 = tandem, eyes open; level 6 = tandem, eyes closed. FT, functional training group; ST, strength-training group.

DISCUSSION

Rehabilitation medicine in general and physical therapy in particular have long stated they treat the whole person, but, in fact, treatments are primarily directed at the impairment- or organ-system (here, the muscular system) level of dysfunction.[36] Our data suggest that a paradigm shift may be needed: our FT group obtained both functional benefits *and* strength impairment improvements by progressively performing more vigorous functional activities.[17] The ST subjects' data, although preliminary, demonstrate similar strength gains from 6 wks of a similar program, as did our prior sample of 132 community-dwelling elders, performing ST for 6 mos,[1] in contrast to prior reports[37] suggesting that only long-term exercise confers significant impairment gains. Although prior research has shown that functionally directed interventions improve activities of daily living outcomes,[38,39] we are not aware of other work directly comparing impairment-level (ST) with functional-level (FT) outcomes in disabled elders.

All subjects demonstrated improved maximum and average gait velocity during preferred gait (Fig. 1). However, the subjects in the FT group demonstrated significantly greater gait-velocity improvements, apparently because they practiced faster walking as their intervention. Subjects improved in some

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gait parameters irrespective of the intervention group, partly because they had impairments that PT could be expected to help them improve, such as lower-limb arthritis. Because they are older, however, they also had several comorbidities for which they were referred to PT, thus enhancing the generalizability of these findings. The FT group also improved (decreased) their double-support time and increased their balance factor—the maximum moment arm—during preferred gait (Fig. 2). One might argue that the percent changes are small, but Judge[38] reported similar balance and disability-score improvements from an explicit balance-training program for elders, and King[39,40] reported that general physical conditioning yields more modest performance improvements, and yet both programs were judged worthy of incorporation into elders' exercise regimes. During cadence-controlled paced gait, our ST group was significantly better than the FT group in increased moment arm and decreased lateral linear momentum. Further exploration of the functional merits of these ST outcomes, especially of the decreased lateral momentum, should be the subject of future investigations. The training effect in the FT group allowed gains in gait velocity that may result from a more efficient distribution of power during gait, as we have suggested elsewhere.[41]

These changes are consistent with specificity of exercise theories: training for peak performance of an activity is quite task specific. Training for peak performance, through repetition and practice, achieved better outcomes than the indirect method of strengthening muscles in a non–task-related manner.[42] Those who received the ST showed effects related to the mechanics of gait pattern, increasing their velocity, decreasing their double-support time, and increasing their moment arm.

Increases in gait velocity can occur by increasing ankle plantarflexor power, essentially advancing the leg into stance phase faster and delivering more AP power to the CG.[43] Using ankle power to advance the leg will result in higher knee-power absorption, which is accompanied by greater angular excursions of the ankle and knee, thus allowing the pelvis and trunk a more fluid translation. The increased walking speed, but greater angular excursions, may result in small or no changes in double-support time (cf. the −2.48% decrease for FT and −0.63% double-support decrease for ST, which could be a statistical type I error). The FT group probably walked faster by using a more efficient distribution of power, but the ST group did not walk faster by decreasing double support and increasing moment arm—rather, they walked faster because they got stronger, but without improving their gait style. We believe that these findings resulted from the ST intervention addressing only impairments and not functional limitations. Figure 4 proposes one model that may account for the FT and ST relationships to impairments and functional limitations observed in this study.

We found improved stability across all subjects during the time directly after EOR during chair rise with eyes closed. Performing chair rises with eyes closed increases the level of difficulty for the chair-rise task, because one cannot rely on visual feedback, and therefore, the patient is more dependent on information from proprioceptive and vestibular sources. The additional challenge from performing the task with eyes closed improved our ability to detect AP stability changes. The significantly decreased knee torque (Fig. 3) after treatment among the FT group suggests that these individuals are showing a learning effect of transitioning their anterior momentum into vertical mo-

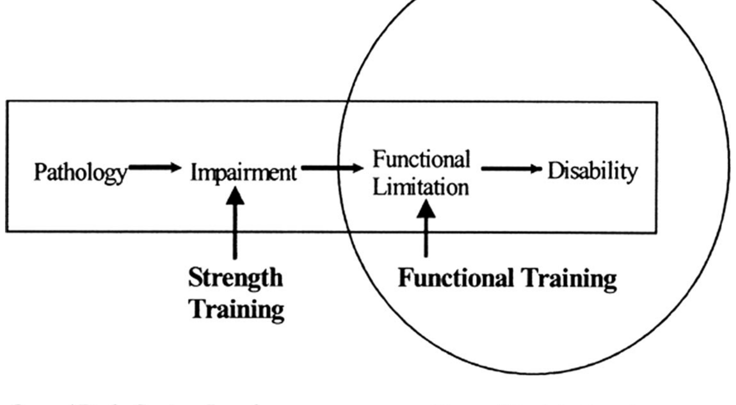

FIGURE 4 *Proposed relationships among impairments, functional limitations, and disability, and the interventions targeted at impairments and functional limitations. Our data suggest that this model correctly accounts for the relationships depicted.*

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mentum—the explicit goal of FT. Thus, the more healthy chair-rise strategy is referred to as the momentum-transfer strategy.[32,34,44,45] We have previously shown (with a separate sample of impaired elders) that there is less knee and hip torque required when performing the efficient momentum-transfer movement strategy during chair rise.[34] For our subjects with knee osteoarthritis, decreased knee torque probably translates to decreased pain.[46] Several individuals in our study reported substantial improvements in their ability and ease in rising from a chair. More positive changes in functional capacity were expressed by those in the FT group than in the ST group. It is probable that a larger sample size will yield greater changes in chair-rise outcomes with increased statistical power.

Of interest is the finding that ST engendered better standing-still balance than FT but that FT better improved dynamic balance during gait and chair rise. Recent evidence demonstrates clearly that standing still requires primarily muscle stiffening[47]—hardly a functional requisite for locomotor dynamics. Apparently, the ST group learned to better stiffen their muscles and thus stand still, but these benefits did not enhance the ST group's preferred locomotor dynamics. The latter is obviously more relevant to patients and clinicians than standing still.

The strong correlation between left and right lower-extremity strength supports the common clinical contention that to decrease strength testing time and subject fatigue, one should test muscle strength only on one side.[48] This conclusion is especially relevant to the disabled elderly patient.

Limitations

Both interventions engendered strength gains in this sample of elders. Although a longer intervention duration might yield greater strength changes for both groups, it would also result in several problems, including dropouts from unrelated morbidity acquired during the longer trial. Future investigations should also employ larger samples; the fact that statistical significance was found in this smaller sample, however, underscores the clinical importance of these data. The insignificant quadriceps-strength change and questionnaire data probably resulted from several factors. This small-sample pilot study, with limited representation of the elderly population, had greater quadriceps baseline strength than originally anticipated, and previous studies have shown that the greatest strength changes occur in elders with the lowest baseline strength.[17] Additionally, test–retest reliability for handheld dynamometry decreases as knee strength increases.[48] Finally, we examined only the physical functioning subscale of the SF-36; prior studies have also shown changes in mental health among older subjects after exercise.[49–51] Clearly, a larger sample would enhance the statistical power of these findings.

Although it would be informative to compare FT to a more vigorous ST, such as high-intensity weight lifting,[19] two factors may confound this comparison. For an intervention to be home based (obviously important to community-dwelling elders such as these), it cannot require the purchase of exotic or expensive equipment. In addition, these elders were referred to, and expected to obtain, physical therapy to ameliorate their lower-limb weakness and other impairments, but exposing them to the side effects of weight lifting (e.g., initial sprains and strains) may have decreased the voluntary enrollment in and subsequent adherence to this study. Moreover, the key issue is functional benefit—and these data demonstrate that to obtain a functional benefit, specific, tailored FT is more advantageous than ST.

CONCLUSIONS

These data suggest that an intensive FT intervention results in strength improvements of a magnitude comparable with those attained from ST, and that FT also confers greater improvements in dynamic balance control and coordination during daily life tasks. Intense FT can offer a direct, valuable mode of improving daily life activities and functional performance, but definitive conclusions must await a larger sample with more generalizable study populations. These data demonstrate the potential importance of intervening at the whole-person functional-performance level rather than simply addressing impairments such as weakness.

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