Name of Assessment Tool: FUNCTIONAL REACH (FR)

Type of test:

- ***Time to administer:*** This test takes a few minutes and is very reliable
- ***Clinical Comments:*** There are some recent discussions whether this test examines limits of stability. This test may predict falling in some community dwelling populations better than patient populations.

Purpose/population for which tool was developed: Developed as a clinically feasible measure of the margin of stability (in balance assessment) in adults. The forward reach was chosen as the test task because it is a common functional movement and because it is similar to the leaning movements used to measure the excursion of the center of pressure on a force platform (an accepted dynamic balance measure). [1] A recent article challenges that FR and limits of stability should not be used interchangeably. [2]

When appropriate to use: 1) to document change over time in patients with balance problems, 2) to assess likelihood that patient will fall , 3) to complete a balance assessment.

Scaling: Results in the literature have been reported in **inches** and centimeters. The functional reach score equals the difference (in inches or centimeters) between the 'end' and the 'start' hand positions. (2.54 cm = 1 inch)

Equipment needed:

- Yardstick and/or large paper, tape. Mackenzie (1999) suggests a modified form of the measuring device using a self-recording tape measure connected to a handle. [3]

Directions: Subject must be able to stand 1 minute without support in order to have this test administered

Set-up/Instructions:
Tape a level yardstick to wall at patient's acromion height. Patient stands perpendicular to yardstick, with arm flexed to 90 degrees and hand in a fist. Record position of 3rd metacarpal head on the yardstick. Instruct pt. to reach as far forward as possible without losing his/her balance,, lifting his heels, or taking a step. Record position of 3rd metacarpal head on the yardstick. [*Note: pt. needs to keep hand at level of yardstick when reaching forward but cannot be allowed to touch the wall. Beyond these restrictions, DO NOT control the method of reach]*. A large piece of paper could be taped to the wall for marking the start & end positions. Allow 2 practice trials then average the next 3 trials to obtain the score for the session. A paper by Billek-Sawhney (2005) found the reliability between 2 trials to be r=.975 meaning one can use 2 trials. [4]

Arnadottir and Mercer (2000) [5] found 35 women age 65 to 93 performed better on FR when they were barefoot or wore walking shoes than when subjects wore dress shoes regardless of whether they performed the test on carpet or linoleum. There was no difference between barefoot walking shoe conditions on either floor surface.

The foot placement is the typical stance of the client. No studies were found that compared foot placement for FR. An article by Mcllroy and Maki (1996) [6] suggests the wide range of preferred foot placements highlights the need for standardization during foot placement. Functional reach increases significantly with additional sensory information from the fifth metacarpal surface of the dominant hand [7] and if a target is given. [8]

Contraindications: Blurred vision has less of an effect on FR than the Tinetti or TUG. [9]

Learning Effect: Clients who have a target reach further than those who do not. [8]

Reliability:

Reference	***N =***	***Sample description***	***Reliability statistic***
***Intrarater reliability*:** same rater within one session (or one day)			
Mecagni, 2000[10]	8	2 trials	ICC =.96
Franchignoni, 1998[11]	45	healthy women 55-71	$ICC_{(2,1)}$ = .97
Rockwood, 2000 [12]	1161	3 trials: persons with cognitive impairment	ICC=.92

Interrater Reliability			
Duncan, 1990 [1]	17	normal subjects, age 20-87	ICC = .98
Franchignoni, 1998 [11]	45	healthy women 55-71	$ICC_{(2,1)}$ = .86
Light, 1995 [13]	30	5 trials each for 2 subjects, in community-dwelling elderly	r = .98
Wolf, 1999 [14]	56	For 4 raters observing the same test,	ICC = .99
Kileff, 2005 [15]	8	(2 raters) people with MS	Friedman Test Mean difference; .5 on FR left arm and .25 FR right arm
Giorgetti, 1998 [16]	21	Mean age = 73, without disability	ICC = .73
	21	(2 examiners) Mean age = 75, with disability	ICC = .79
Holbein-Jenny, 2005 [17]	26	Community-dwelling	$ICC_{(1,1)}$ Forward = .98; Backward = .96 Right = .94; Left = .91
Schenkman, 1997 [18]	15	patients with early to middle stages of PD.	ICC = .90
Frzovic, 2000 [19]	28	(N=14) people with MS ; (N=14) Control	ICC=.89

Test-retest reliability

Reference	***Population***	***Time Btw. Testing***	***Mean (cm)***	***SD (cm)***	***Test-retest Reliability***	***MDC (cm)***
Duncan, 1990 [1]	Community-dwelling elderly (n=128)	1 week			Forward ICC= 0.92	Unable to calculate-no X or SD given
Franchignoni, 1998 [11]	(n=45) Females, ages 55-75	24 hrs.			Forward ICC= 0.87	Unable to calculate—no X or SD given
Hageman, 1995 [20]	Community-dwelling healthy adults (n=12)	1 week			Forward ICC= 0.92	Unable to calculate—no X or SD given
Holbein-Jenny, 2005 [17]	Elderly (n=21), ages 74-92	1-2 weeks	14.22, 7.37, 8.38, 9.40	6.54, 5.59, 6.35, 7.87	Forward ICC= 0.75 Backward ICC= 0.71 Right ICC= 0.66 Left ICC= 0.83	Forward= 10.54 Backward= 8.33 Right= 10.26 Left= 8.99
Lim, 2005 [21]	Idiopathic Parkinson's Disease (n=26)	1 week			Forward ICC= 0.74	SDD= 11.5
Marsh, 2005 [22]	Community-dwelling elderly (n=44)	2 weeks			Lateral ICC= 0.86	unable to calculate-X and SD not given for subset
Schenkman, 1998 [23]	Parkinson's Disease, (n=14) 74.5 yrs (mean age)	1 day	32.3		Forward ICC= 0.84	Unable to calculate-no SD given for initial measurement
Sherrington, 2005 [24]	Hopital inpatients and community dwelling elderly, fallers and previous fallers (n=30)	1 day	14	9.6	Forward ICC= 0.89	8.83

Based on a review of 9 articles, test-retest reliability on functional reach has been shown to vary from low to high, with intraclass correlation coefficients (ICC) ranging from .42-.93. The time between testing varying greatly from 1 day to 1 month.[1, 11, 17, 18, 20, 21, 24-26] Only 3 studies examining test-retest reliability had a sample size over 30.[1, 11, 22] Nine studies examined forward reach[1, 11, 17, 18, 20, 21, 24-26] and 1 examined backward reach.[17] 3 studies reported test-retest reliability in subjects with PD.[18, 21, 25] One study of 26 subjects with idiopathic PD reported an ICC of .74 for forward reach with a testing interval of one week,[21] while a second study of 14 subjects with PD reported an ICC of .84 for forward reach with a testing interval of one day.[18] Another study of 10 elderly and 20 subjects with PD subjects, using a testing interval of one week, reported an $ICC_{2,1}$ of .62 in the elderly, .93 for subjects with PD who had a history of falls, and .42 for subjects with PD with no history of falls.[25]

Of the current studies examining test-retest reliability, Four provided data to calculate MDC_{95}, which ranged from 4 to 11 cm.[17, 24-26] Two studies reporting test-retest reliability of forward functional reach, one week apart, in 20 people with PD found MDC_{95} of 4 cm of people who had fallen and 8 cm for people who had not fallen and 12 cm for 26 people with a diagnosis of idiopathic PD.[21, 25]

Validity:

Construct / Concurrent Validity: It is difficult to always differentiate between these 2 types of validity. Evaluating this property requires a "gold standard" measure with which to compare the tests results. Such a "gold standard" is often not available.		
Population	***N =***	***Support for Validity***
Concurrent validity:		
Adult volunteers (ages 21-87)	128	FR correlated with: force plate measures of the excursion of the center of pressure (.71). [1]
Community-dwelling elderly	45	FR correlated with: gait speed (.71); the hierarchical mobility skills protocol (.65); IADL scores (.66). (n=45) [26] These authors concluded that FR correlates with physical frailty more than with age.
	34	FR correlated with: dorsiflexion ROM with knee extended (.47) and plantarflexion (.16). Women, age 64-87 [10]
	45	Change in FR after rehabilitation correlated with: change in the Mobility Skills Score (.37); change in FIM (.38); change in walking speed (r = -.20). [27]
	50	FR was not significantly associated with strength gains in frail elderly (mean age 78) who underwent home strengthening exercise 3 times/week for 10 weeks [28]
Older adults with c/o disequilibrium	30	Clinical (yardstick) recording of FR correlated with: videotape analysis of FR (.98) (n=15 with c/o disequilibrium; 15 without c/o disequilibrium. [13]
	28	FR correlated with: single leg stance (.65) (in people with peripheral vestibular disease). [29]
s/p LE amputation	30	FR correlated with: PPT (.66) (in people with diabetes and transmetatarsal amputation). [30]
Rural, aged Japanese	383	No significant association between anterior FR or lateral FR and falls. [31]; mean age = 79
Osteoarthritis	130	No significant association between knee pain and FR [31]; mean age = 80
Osteoporosis or Osteopenia	16	Spearman rank correlation coefficients of kyphosis index and FR (-.60). [32]
Geriatric Rehabilitation	52	The FR did not discriminate between levels of ambulation by ambulatory aid or on the FIM [33]
Balance Deficits	20	FR and TUG (.56), BBS and FR no significance. [34]
Osteoarthritis of the knee	50	Community-dwelling women (mean age = 69) -.52 FR and age, -.35 FR and self report function, .48 FR and self efficacy. [35]
Parkinson's Disease	35	FR correlated .44 - .51 with balance master items [36]
***Predictive Validity*:**		
Population	***N =***	***Support for Validity***
LTC residents	303	Thapa (1996) found FR did not predict falls. [37]
Dx/o Parkinson's Disease	37	12 of 37 subjects (mean age = 68) had a FR of less than 11.8 inches; these 12 subjects were referred to physical therapy as they were deemed at risk for falling. Four of those twelve subjects did subsequently fall. The falls were generally related to noncompliance with the physical therapy recommendations and use of an assistive device. [38]

Fallers	217	Duncan, 1992 [39] found FR to have predictive validity in identifying recurrent fallers (i.e., 2 or more falls during the 6-month follow up period); n= 217 community-dwelling male veterans (age 70-104). Logistic regression shows that: • If FR = 0 inches: 8 times more likely to have 2 falls in 6 mos than person with FR=10" • If FR < or equal to 6 inches: 4 times more likely to have 2 falls • If FR > 6 inches but < 10 inches: 2 times more likely to have 2 falls	
	16	Cho & Kamen (1998) [40] found no group differences on FR for 8 healthy older subjects compared to 8 age-matched idiopathic fallers.	
	705	Having a long functional reach (≥ 35 cm) and being able to perform a full tandem stand with eyes closed for at least 10 seconds were associated with decreased rates of falls. [41]	
	67	Any improvement in FR during PT Rx in a geriatric day hospital can predict subsequent decrease in falling [42]	
Older adults	436	FR did not predict disability in a large cohort study of women. [43]	
	705	FR was positively associated with quadriceps and grip strength; [44] as well as BMI in studies of 705 elderly Japanese women in Hawaii. [41]	
Community-dwelling	402	FR was not associated with falls [45] which averaged 24 cm	
Fallers	15	Mean age = 73 [46]	No difference on FR between 2 groups
Non-Fallers	10	Mean age = 75 [46]	
Community-dwelling elderly	99	Duncan (1990) found that only 3/99 male veterans who could ascend/descend stairs foot over foot had FR of 6 inches or less. [1]	
	45	No subject with FR less than 7 inches: was able to complete more than 6/11 items on the mobility skills protocol; could balance for greater than 1 second during SLS; was able to tandem walk; or was able to leave his/her neighborhood without help. [26]	
Women community-dwelling	99	Mean age = 71 [47] Non-fallers (N=65): FFR= 30(1) Right FR = 20(1) Fallers (N=35): FFR= 29(1) Right FR= 20(1) Frequent Fallers (N=16): FFR= 29(2) Right FR= 19(1) Recurrent Fallers (N=19): FFR= 29(2) Right FR= 20(1)	No significant differences between groups
Community-dwelling	15	Steady patients	No statistical differences between 2 groups
	23	Unsteady patients [48]	

Sensitivity/specificity:

Population	***N =***	***Cutoff Score and Description***	***Results***
Fallers	54	Cutoff of 25 cm: (identifying multiple fallers vs nonmultiple fallers (N=54; outpatients over the age of 65 attending community rehab) [49]	Sensitivity of 63% Specificity of 59%
Dx/o Parkinson's Disease	58	Cutoff of 25.4 cm: (identifying fallers) [50]	Sensitivity of 30% Specificity of 92%.
Day Hospital	30	Using cut off of 18.5 to predict fall; Mean score fallers (N=18) 15.5(6.5); non-fallers (N=12) 19.4(4.2); Mean age = 80-81 [51]	Sensitivity of 75% Specificity of 67% OR 5.28, p < .08
Community dwelling elderly	203	Using a cutoff of 30 for able vs. not able [52]	Sensitivity 86% Specificity 38%
		Using a cutoff of 24 for decreased disability vs. disabled [52]	Sensitivity 81% Specificity 52%
NOTE: Clinicians need to choose a cut-off score based on the specific purpose for which the test is used			

Responsiveness/sensitivity to change				
Population Descriptor	***N =***	***Reference and Intervention***	***Responsive*** *Yes/No*	***Data Supporting Responsiveness***
Community-dwelling elderly	42	***Okumiya, 1996*** [53] Healthy Japanese elderly; mean age = 79 *Experimental group*: Exercisers *Control group*: Non-exercising Length / frequency of intervention	Yes	Exercisers improved significantly greater than controls
Community-dwelling elderly	12	***Rogers, 2001*** [54] Balance intervention program; mean age=70 Length / frequency of intervention 10 weeks	Yes	Significant Improvement from 33 cm initial to 40 cm
	20	***Barrett, 2002*** [55] Healthy elderly persons Progressive resistive exercise program Flexibility training; 2x per wk; 10 weeks	Yes	Progressive Initial: 34 (5) cm Final: 38 (3) cm; $p < .003$ Flexibility Initial 33(5) to 33(6); NS Significant change between groups
Community-dwelling elderly (Continued)	14	***Shigematsu, 2001*** [56] Exercise program Length / frequency of intervention 60 min, 3x/week for 3 months	Yes	Initial: 23 (5) to 27(3); $p<.05$ Control 26(8) to 25(7); NS
	19	***Dennis, 1999*** [57] Health ambulatory women over 65 Intervention: Alexander Technique Instruction Length / frequency of intervention 1 hr, 2x/week, 4 weeks	Yes	Initial: 7 (3) inches Final: 8(2) inches; $p <.025$ Control: FR decreased by .74 inches; $p<.005$
	134	***Morey, 1999*** [58] Group 1: spinal flexibility plus aerobic exercise Group 2: aerobic only exercise	No	Both with baseline measure of 13"; No significant gains in either group
Community-dwelling elderly (Continued)	52	***Simmons, 1996*** [59] Subjects mean age=80, with a fear of falling 4 groups: water exercisers, land exercisers, water sitters, land sitters	Yes	Significant improvement in water exercisers ($p<.001$), land exercisers ($p<.03$) No change in other 2 groups
	94	***Hakim, 2004*** [60] Healthy older adults Control group: no exercise Group 1: structured exercise Group 2: Tai Chi intervention	Yes	Group 1: Better FR ($p<.01$) Group 2: Better at Forward ($p<.01$), Backward ($p<.001$) and Left FR ($p<.001$)
	38	***Mak, 2003*** [64] Regular exercisers vs. Tai Chi practitioners	Yes	Exercisers: 27(4) Tai Chi: 30(3) $p<.04$ difference between 2 groups

Community-dwelling elderly (Continued)	256	***Li, 2004*** [61] *Control (N=131):* Exercise stretching *Exp (N=125):* Tai Chi grp Length / frequency of intervention 60 min sessions, 3x/wk for 6 months	Yes	Ave. change after intervention Control showed no change in score; Tai Chi grp showed increase (p<.001) 6 mo follow-up: Tai Chi grp showed less decline (p=.02) Group differences significant? Tai Chi grp showed greater change in FR scores (p<.001)
	108	***Li, 2005*** [65] Mean age = 78 N=54 Coble stone mat walking N=54 Regular walking 60 min, 3x/week for 16 weeks	Yes	Cobble stone mat walking: 11(3) to 13(3) inches Regular walking: 11(3) to 11(3) inches Regular group x time interaction (p<.01)
	175	***Li, 2004*** [61] Mean age = 77 26 week Tai Chi 40-50 min 26 week stretching Each group attend mean of 61 sessions	Yes (Randomized)	p < .001 between groups Does not give data points
Community-dwelling elderly (Continued)	40	***Sousa, 2005*** [62] Mean age =73; strengthening 3x/week for 14 weeks Mean age = 75; control (N=20)	Yes	9.4% increase strength group No change control group
Community-dwelling elderly (Continued)	22	***Robinson, 2004*** [63] *Control (N=5)*: No intervention *Exercise grp (N=10 fallers, N=7 non-fallers):* 6 week falls prevention program addressing strength, balance, flexibility and education Length / frequency of intervention 50 min 2x/wk for 6 wks plus daily exercise at their home	Yes	Control: Pre: 10.56” Post: 13.89” (p<.01) Fallers: Pre: 6.66” Post: 7.3”, NS Non-fallers: Pre: 10.34” Post: 10.17”, NS Group differences significant? Fallers and nonfallers differed sign from controls (p<.05)
HIV/AIDS	38	***Galantino, 2005*** [66] Tai Chi (N=13) Aerobic Exercise (N=13) Control (N=12) 2x/week for 8 weeks	Yes	No difference between 2 exercise groups but significant difference over time in both groups (p<.000) and between controls (p<.003).
Chronic TBI	20	***Brown, 2005*** [67] BWSTT vs overground ambulation 30 minutes 2x/week	No	BWSTT 14(9) to 16(11) Overground 11(11) to 13(13)
PD	8	***Campbell, 2003*** [68] FR remains stable over the cycle of medication and over days		17.7cm = mean score of all tests on all participants
Older Women Age 65-89	19	***Gajdosik, 2005*** [69] Stretch (N=10) Control (N=9) 8 wks; 3x/wk	No	34(5) to 35(4) Control: 32(5) to 33(4)

Healthy	11	***Bellew, 2005*** [70] Mean age =76 15 minutes balance training for 5 wks	Yes/No	Significant change in lateral reaches (p<.017) <u>not</u> FFR.
	10	Control (Mean age = 71)		
Community-dwelling fallers	73	***Nitz, 2004*** [71] Mean age = 76 Balance group: 1x/week for 10 weeks Control group: 1x/week for 10 weeks	No	No Change in FFR
			Yes	Right Lateral Reach 15(1) to 17(1); p<.03 Control 16(1) to 16(1); NS
TBI	13	***Wade, 1997*** [75] In patient rehabilitation	No	28(12) to 33(9)cm
Frail elderly	34	***Shimada, 2003*** [73] Control (N=9)	Yes	19(6) to 19(7); NS
		Exercise with balance (N=12)		19(6) to 23(4); p<.05
		Exercise with gait reduction (N=11)		16(6) to 15(7); NS
		40 minutes 2-3x/week, 12 weeks; both exercise groups		p<.022 significant difference between balance and gait exercise groups
Healthy Women	20	***Skelton, 1995*** [74] Training 1x/week for 12 weeks	No	Data appears to be reported incorrectly
	20	Control		
Community-Living Stroke	44	***Duncan, 2003*** [76] Intervention group	No	.53(.69)cm change
	48	Usual care group		.63(.76)cm change
Dx/o peripheral neuropathy	10	***Richardson, 2001*** [77] Exercise regimen Length / frequency of intervention 3 weeks	No	FR did not change
s/p CVA	29	***Bernhardt, 1998*** [78] In-patient rehabilitation measured at 4 weeks and 8 weeks (Protocol used a target)	Yes	Improved significantly from 18.3 (10.6)cm to 23.1(9.1)cm; (p<.004)
s/p vertebral compression fx	10	***Lyles, 1993***[79] Control (women without hx/o fx) vs. women with fx	Yes	c/fx: 26.9 (5.8) cm s/fx: 34.5 (5.3) cm Significant differences between groups
s/p LE amputation	30	***Mueller and Salsich, 1997*** [80] Footwear changes in people with diabetes (DM) and transmetatarsal (TMA) amputation (N=15)	Yes	DM-TMA: 19.1(8.6) cm Controls: 31.5(9.1) cm <u>Group differences significant?</u> DM-TMA group significantly lower than control (p <.001)
	30	***Mueller and Strube, 1997*** [80] Six types of footwear tried on people with diabetes and transmetatarsal amputation	No	No differences in FR
Dx/o Parkinson Disease	46	***Schenkman, 1998*** [23] Mean age=71 Exercise group run by PT vs. control group 10 weeks (30 sessions)	Yes	<u>Ave. change after intervention</u> Exercise group: Improved by .62 (1.75) inches Control group: Declined by: -.11(1.64) inches <u>Group differences significant?</u> (p<.05)

Older adults in in-patient rehab	28	***Weiner, 1993*** [27] Male veterans *Experimental group (N=15)*: Receiving daily in-patient PT *Control group (N=13)*	Yes	Improved significantly over rehab duration; no improvement in controls
LTC Residents	47	***McMurdo, 2000*** [81] Seated balance exercises 2 times per week for 6 months	No	No change in FR
	15	***Taylor, 2003*** [82] Walking program Women in assistive living residence 9 weeks (frequency decided by resident)	Yes	Significant improvement from 4" to 5.7" (p<.001)
s/p hip fx	21	***Sherrington, 1997*** [83] Stepping exercises 5-50 reps; 1x/day at home for 1 month	No	No change in FR
Dx/o intellectual disability	17	***Carmeli, 2003*** [84] (Mean age =57); Ball exercises and treadmill training for 6 months	No	No change in FR
Community-dwelling elderly (Continued)	22	***Robinson, 2004*** [63] *Control (N=5)*: No intervention *Exercise grp (N=10 fallers, N=7 non-fallers):* 6 week falls prevention program addressing strength, balance, flexibility and education Length / frequency of intervention 50 min 2x/wk for 6 wks plus daily exercise at their home	Yes	Control: Pre: 10.56" Post: 13.89" (p<.01) Fallers: Pre: 6.66" Post: 7.3", NS Non-fallers: Pre: 10.34" Post: 10.17", NS Group differences significant? Fallers and nonfallers differed sign from controls (p<.05)
Other	12	***Richardson, 2000*** [85] Halo vests on young adults vs. without it on	Yes	Limit FR from 15.1 (2.1) inches to 12.9 (1.4) inches; (p<.01)
	193	***Cummings, 1997*** [86] Older women with foot binding in China	Yes	24 cm (N=105) Normal 21cm (N=55) Bound p<.05
Drug Studies		Drug studies that used FR as an outcome measure: • diazepam effect on balance of older adults [87] • levodopa effect in pts with progressive supranuclear palsy.[88]		

Ceiling or floor effect: There is no ceiling or floor effect on this test.

Reference data: ***All studies that reported inches were converted to centimeters (cm)***

Resource	***N =***	***Subjects***	***FR Scores***
Weiner, 1992 [26]	45	Community-dwelling elderly; male & female; mean age = 78 (8.4)	mean (SD) = 27.68cm (7.87)
Newton, 1997 [89]	251	Seniors; average age 74	mean (SD)= 22.60 (8.38) cm
Fried, 2000 [43]	436	Community-dwelling women, 70-80 years; not cognitively impaired	mean=29.1 cm

Duncan, 1990 [1]	131	volunteers; age 21-87; male and female	**Males**: means (SD) • 20-40 = 42.49cm (4.93) • 41-69 = 38.05cm (5.61) • 70-87 = 33.43cm (3.94)
			Females: means (SD) • 20-40 = 37.49cm (5.54) • 41-69 = 35.10cm (5.59) • 70-87 = 26.60cm (8.97)
Shigematsu, 2000 [90]	373	Japanese women	mean(SD)= 28.8 (7.4) cm
Mecagni, 2000 [10]	34	Women, age 64-87	mean(SD) = 22.1 cm (7.1) or 8.7 inches (2.8)
Rockwood, 2000 [12]	1301	Mean age 78.1 years (range 69-104; in Canadian Study of Healthy Aging; nationwide representative sample) The farthest reach score was used.	Median: With cognitive impairment: 25 cm
			Median**:** Without cognitive impairment: 29 cm
Wolf, 1999 [14]	28	Subjects with stroke compared to 28 subjects without impairment. This study used the average of 3 trials.	s/p stroke: mean (SD) = 21.92 cm (6.57)
			without impairment: mean(SD) = 32.11 cm (5.88)
Grill, 1999 [38]	37	Persons with PD, mean age of 68	initial visit: mean (SD) = 34.04cm (6.86)
			one-year follow-up: mean (SD) =33.53cm (SD 8.13)
Smithson, 1998 [25]	30	Persons with PD, mean age of 71 This study compared persons with a history of falls to those with no history of falls.	with a history of falls: mean (SD) = 24.39cm (5.84) for the first test and 25.40cm (6.35) for the second test
			without a history of falls: mean(SD) = 29.97cm (3.81) for the first test and 32.00 cm (5.59) for the second test.
Schenkman, 2000 [91]	251	Community dwelling adults (mean age = 71) This study assessed spinal flexibility and balance. n=56 with PD n=195 without PD	subjects with PD: mean (SD) = 31.50cm (7.62)
			subjects without PD: mean(SD) =34.29cm (5.84)
Aoyagi, 2000 [92]	447	Community-dwelling Japanese persons (mean age =66). This was a study of bone mineral density (BMD).	Exercisers: Women = 29.6 (.5) cm Men= 29.5 (1.0) cm
			Non-exercisers: Women = 28.6 (.4) cm Men= 29.2 (.8) cm
Purser, 1999 [93]	185	Older women with osteoporosis and vertebral fractures.	Women with osteoporosis and vertebral fractures 28.96cm (5.84)

Lehmann, 2006 [94]	50	Persons with late effects of polio, mean age = 60		Men: 21.3(9.5)cm (N=21) Women: 25.2(8.9)cm (N=29) All: 23.5(9.3)cm (N=50)
Frzovic, 2000 [19]	14	Subjects with MS and 14 controls		in AM: 39.19 (5.88) cm
				in PM: 39.92 (6.66) cm
Davis, 1999 [41]	705	Japanese women in Hawaii (mean age = 74)		Mean (SD) =30.9 (6.1) cm
Stack, 2005 [95]	51	(N=33) Grade III, PD (N=18) Grade IV, PD		18cm (13-23) 15cm (7-21)
Marsh, 2005 [22]	140	Community dwelling; Mean age = 75		30.5(6.6)cm
Cim biz, 2005 [96]	30	Diabetic neuropathic; Mean age = 58		34(13)cm
	30	Control; Mean age = 67		44(14)cm
Chow, 2004 [32]	16	Females with osteoporosis/Osteopenia; Mean age=67		30(9)cm
Hageman, 1995 [20]	24	(N=12) Younger adults; Mean age = 25 (N=12) Older adults; Mean age = 65		43(4)cm 37(6)cm
Smith, 2004 [97]	75	Stroke		23(9)cm
Stankovic, 2004 [98]	30	PD	Mean age = 68	Without Falls: 30(6)cm
			Mean age = 72	With Falls: 21(6)cm
	20	Control	Mean age = 70	32(6)cm
Teri, 1998 [99]	30	Alzheimer's		25(15)cm
Wolf, 2003 [100]	145	Tai Chi participants; Mean age = 81		30(8)cm
	141	Wellness Class; Mean age = 81		27(8)cm
Goldberg, 2005 [101]	8	Young; Mean age = 24		34.80cm (2.29)
	7	Balance unimpaired; Mean age = 74		26.16cm (1.52)
	8	Balance impaired; Mean age = 80		26.92cm (2.03)
Huang, 1996 [102]	569	Post-menopausal Japanese American women; ages 55-93; s/p vertebral compression fracture		Predicted performance on FR; average FR was 33.1 (6.1) cm
NOTE: FR declines with age in both genders. [1, 20, 92]				

Interpreting results:

It measures a subject's forward limit of stability, which is considered one part of postural control (or balance) assessment. Duncan (1990) [1] concludes that FR is a good clinical measure of the margin of stability and is "conceptually related" to the excursion of the center of pressure. Others are suggesting that FR is a weak measure of stability limits (low correlation with FR and displacement of center of pressure, .38). Movement of the trunk seems to influence the test more than displacement of center of pressure. [103]

When the Functional Reach [104] test and platform measures of postural sway were used with clients with hemiparesis, they appeared to be evaluating comparable standing-balance abilities. In a kinematic study of 34 young subjects (20-36) and 33 older subjects (60-76 years), spinal motion during forward FR was characterized by forward and lateral trunk flexion, thoracolumbar and lower body rotation. Young subjects displaced their center of pressure further forward (45.2 cm) and through a greater percentage of their initial base of support than older subjects (37.1 cm). The younger group had more forward trunk flexion and thoracolumbar rotation. [105] O'Brien, et al (1997) found a weak correlation between inclination of the upper thoracic spine and functional reach. [106] Wernick-Robinson (1999) found FR does not measure dynamic balance because people with vestibular hypofunction did as well. [107]

Daubney and Culham (1999) [108] found that ankle plantar-flexion force accounted for 13% of the score on the FR. Correlations were found between FR and hip extensor strength (.45) and hip flexor strength (.47). [30] Eight hundred thirty three community dwelling elderly 64-79 years old (457 were Mexican American) participated in a home assessment. For each degree increase in shoulder ROM, the likelihood of having a short reach was reduced by 3% and for each degree increase in elbow ROM, the likelihood of having a short reach was reduced by 2%. [109]

In a very large study (N=303) of people in community nursing homes significant difference in FR were found in height, age, and lower extremity weakness but not in assistive device, upper extremity weakness, ADL's, weight, MMSE, Depression, gender, hearing, vision or B.P. [110]

Other:

Reach in Four Directions:

In 1997, the first "reach in four directions" (RFDT) results were published. This study included a large minority population. (N=204-250) The mean forward reach was 8.9 inches, right 6.8 inches and left 6.6 inches. [89] A small study (N=7) found a .43 -.65 correlation between BFR and ankle dorsiflexion (df). Improvements in df improved BFR. [111]

Lateral Reach measurements were published in 1999. Validity of lateral reach results showed a significant correlation with COPE (r=0.33) measurements and laboratory measure of reach (r=.65). Test-retest reliability (r=0.94) was also found. [112] Lateral reaches to the right and left were not significantly different between the sides. For their analysis, right side measurements were used. Age was negatively correlated with Lateral Reach results. Results were not separated into cohorts. This study included 60 females (mean age=72.5). Lateral Reach in 22 community dwelling females (average age 81) was 14.3 (4.5) cm left and 14.9 (4.6) cm right. [113] Lateral reach in 383 Japanese (mean age = 79) 19(12)cm [31] Lateral reach in sitting of 18 elderly persons showed a -.63 correlation between rising time and lateral reach in sitting. [114]

Results of reach in four directions of 87community dwelling adults is reported in Table 5-1.

Functional Reach used for persons in wheelchairs:

Functional reach has been used to test the utility of different wheelchair belting techniques in people with spinal cord injuries [115] and to determine whether the test could be used to measure differences among levels of SCI injury. [116]

Forward, right and left functional reach on 53 seniors who sat in a wheelchair were compared for people sitting on a cushion vs a sling. [117] Forward and lateral reach for 31 healthy and 31 subjects with hemiparesis in a sitting position are published by Hsu (2005). [118]

Table 5-1

Means (X), Standard Deviations (SD) and 95% Confidence Intervals (CI) of the **Multi-Directional Reach Test** by Age and Gender Cohorts (in centimeters).

			Forward (cm)			**Backward (cm)**			**Left (cm)**			**Right (cm)**		
Age (yrs)	**Gender**	**N**	**X**	**SD**	**CI**	**X**	**SD**	**CI**	**X**	**SD**	**CI**	**X**	**SD**	**CI**
50-59	Male	9	37	6	32-41	28	6	24-32	22	4	19-26	22	4	19-25
	Female	15	32	6	28-35	20	6	16-23	18	4	16-20	18	4	16-20
60-69	Male	9	30	5	27-34	25	9	17-32	19	3	17-21	20	3	19-23
	Female	10	30	5	24-30	20	8	14-25	17	5	13-20	15	5	13-18
70-79	Male	10	29	5	26-32	19	7	14-24	18	4	15-21	17	4	15-19
	Female	14	29	7	25-33	15	7	11-19	15	7	11-19	16	7	12-19
80+	Male	4	27	9	13-40	16	4	9-23	17	7	6-28	16	7	8-23
	Female	12	22	6	18-26	11	4	8-13	12	3	10-14	13	3	11-15
TOTAL SAMPLE		83	29	7	28-29	19	8	17-20	17	5	16-18	17	5	16-18

Steffen, TM, Mollinger, LA (2005). Age-and gender-related test performance in community-dwelling adults: multi-directional reach test, berg balance scale, sharpened Romberg tests, activities-specific balance confidence scale, and physical performance test. Journal of Neurological Physical Therapy 29(4): 181-188.

References:

1. Duncan P, Weiner D, Chandler J, Studenski S. Functional Reach: A new clinical measure of balance. *J Gerontol Med Sci.* 1990;45:M192-197.

2. Clark S, Iltis PW, Anthony Cj, Toews A. Comparison of older adult performance during the functional-reach and limits-of-stability tests. *J Aging Phys Act.* 2005;13:p. 266-275.

3. Mackenzie M. A simplified measure of balance by functional reach. *Physiother Res Int.* 1999;4(3):233-236.

4. Billek-sawhney B, Gay J. The functional reach test. Are 3 trials necessary? *Top Geriat Rehabil.* 2005;vol 21:144-148.

5. Arnadottir S, Mercer V. Effects of footwear on measurements of balance and gait in women between the ages of 65 and 93 years. *Phys Ther.* 2000;80(1):17-27.

6. Mcllroy W, Maki B. Prefered placement of the feet during quiet stance: development of standardized foot placement for balance testing. *Clin Biomech.* 1997;12(1):66-70.

7. Rugelj D. The relationship between innervation density and dynamic balance function. *Cell Mol Biol Lett.* 2002;7(1):149-150.

8. Chevan J, Atherton H, Hart M, Holland C, Larue B, Kaufman R. Nontarget-and target-oriented functional reach among older adults at risk for falls. *J Geriatr Phys Ther.* 2003;26(2):22-25.

9. Huang M, Burgess R, Weber M, Greenwald N. Performance of balance impaired elders on three balance tests under two visual conditions. *J Geriatr Phys Ther.* 2006;29(1):3-7.

10. Mecagni C, Smith JP, Roberts K, O'Sullivan S. Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: A correlational study. *Phys Ther.* 2000;80:1004-1011.

11. Franchignoni F, Tesio L, Martino M, Ricupero C. Reliability of four simple, quantitative tests of balance and mobility in healthy elderly females. *Aging Clin Exp Res.* 1998;10:26-31.

12. Rockwood K, Awalt E, Carver D, MacKnight C. Feasibility and mesurement properties of the functional reach and the timed up and go tests in the Canadian study of health and aging. *J Gerontol Med Sci.* 2000;55A:M70-M73.

13. Light K, Purser J, Rose D. The functional reach test for balance: criterion-related validity of clinical observations. *Issues on Ageing.* 1995;18:5-9.

14. Wolf S, Catlin P, Gage K, Gurucharri K, Robertson R, Stephen K. Establishing the reliability and validity of measurements of walking time using the emory functional ambulation profile. *Phys Ther.* 1999;79:1122-1133.

15. Kileff J, Ashburn A. A pilot study of the effect of aerobic exercise on people with moderate disability multiple sclerosis. *Clin Rehabil.* 2005;19:165-169.

16. Giorgetti M, Harris B, Jette A. Reliability of clinical balance outcome measures in the elderly. *Physiother Res Intl.* 1998;3(4):274-283.

17. Holbein-Jenny M, Billek-sawhney B, Beckman E, Smith T. Balance in personal care home residents: a comparison of the berg balance scale, the multi-directional reach test, and the activities-specific balance confidence scale. *J Geriatr Phys Ther.* 2005;28(2):48-53.

18. Schenkman M, Cutson TM, Kuchibhatla M, Chandler J, Pieper C. Reliabilty of impairment and physical performance measures for person's with Parkinson's disease. *Phys Ther.* 1997;77:19-26.

19. Frzovic D, Morris M, Vowels L. Clinical tests of standing balance: Performance of persons with multiple sclerosis. *Arch Phys Med Rehabil.* 2000;81:215-221.

20. Hageman P. Gait characteristics of healthy elderly: A literature review. *Issues on Aging.* 1995;18:14-18.

21. Lim L, van Wegen E, de Goede C, et al. Measuring gait and gait-related activities in parkinson's patients own home environment: a reliability, responsiveness and feasibility study. *Parkinsonism Relat D.* 2005;11:19-24.

22. Marsh AP, Rejeski JW, Hutton SL, Brown CL, Ip E, Guralnik JM. Development of a lateral mobility task to identify individuals at risk for mobility disability and functional decline. *J Aging Phys Act.* 2005;vol. 13:p. 363-381.

23. Schenkman M, Cutson TM, Kuchibhatla M, et al. Exercise to improve spinal flexibility and function for people with Parkinson's disease: A randomized, controlled study. *J Am Geriatr Soc.* 1998;46:1207-1216.

24. Sherrington C, Lord S. Reliability of simple protable tests of physical performance in older people after hip fracture. *Clin Rehabil.* 2005;19:496-504.

25. Smithson F, Morris M, Iansek R. Performance on clinical tests of balance in Parkinson's disease. *Phys Ther.* 1998;78(6):577-592.

26. Weiner D, Duncan P, Chandler J, Studenski S. Functional reach: A marker of physical frailty. *J Am Geriatr Soc.* 1992;40(3):203-207.

27. Weiner D, Bongiorni D, Studenski S, Duncan P, Kochersberger G. Does functional reach improve with rehabilitation? *Arch Phys Med Rehabil.* 1993;74:796-800.

28. Chandler J, Duncan P, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? *Arch Phys Med Rehabil.* 1998;79:24-30.

29. Mann G, Whitney S, Redfern M, Borello-France D, Furman J. Functional reach and single leg stance in patients with peripheral vestibular disorders. *J Vestib Res.* 1996;6(5):343-353.

30. Salsich G, Mueller M. Relationship between measures of function, strength and walking speed in patients with diabetes and transmetatarsal amputation. *Clin Rehabil.* 1997;11:60-67.

31. Takahashi T, Ishida K, Yamamoto H, et al. Modifications of the functional reach test: analysis of lateral and anterior functional each in community-dwelling older people. *Arch Gerontol Geriatr.* 2006;vol. 42:p.167-173.

32. Chow S, Moffat M. Relationship of thoracic kyphosis to functional reach and lower-extremity joint range of motion and muscle length in women with osteoporosis or osteopenia: a pilot study. *Top Geriatr Rehabil.* 2004;20(4):297-306.

33. Brooks D, Davis A, Naglie G. Validity of 3 physical performance measures in inpatient geriatric rehabilitation. *Arch Phys Med Rehabil.* 2006;87:105-110.

34. Bennie S, Bruner K, Dizon A, Fritz H, goodman B, Peteson S. Measurements of balance: Comparison of the timed "Up and Go" test and Functional Reach with the Berg Balance Scale. *J Phys Ther Sci.* 2003;15:93-97.

35. Harrison A. The influence of pathology, pain, balance, and self-efficacy on function in women with osteoarthritis of the knee. *Phys Ther.* 2004;84:822-831.

36. Thomas M, Jankovic J, Suteerawattananon M, et al. Clinical gait and balance scale (GABS): validation and utilization. *J Neurol Sci.* 2004;217:89-99.

37. Thapa P, Gideon P, Brockman K, Fought R, Ray W. Clinical and biomechanical measure of balance as fall predictors in ambulatory nursing home residents. *J Gerontol Med Sci.* 1996;51A(5):M239-M246.

38. Grill S. Postural instabilty in Parkinson's disease. *Md Med J.* 1999;48(4):179-181.

39. Duncan P, Studenski S, Chandler J, Prescott B. Functional Reach: Predicitive validity in a sample of elderly male veterans. *J Gerontol Med Sci.* 1992;47(3):M93-98.

40. Cho C, Kamen G. Detecting balance deficits in frequent fallers using clinical and quantitative evaluation tools. *J Am Geriatr Soc.* 1998;46:426-430.

41. Davis J, Ross P, Nevitt M, Wasnich R. Risk factors for falls and for serious injuries on falling among older Japanese women in Hawaii. *J Am Geriatr Soc.* 1999;47:792-798.

42. Spilg E, Martin B, Mitchel S, Aitchison T. Falls risk following discharge from a geriatric day hospital. *Clin Rehabil.* 2003;17:334-340.

43. Fried L, Bandeen-Roche K, Chaves P, Johnson B. Preclinical mobility disability predicts incident mobility disability in older women. *J Gernotol.* 2000;55A(1):M43-M52.

44. Davis J, Ross P, Preston S, Nevitt M, Wasnich R. Strength, physical activity, and body mass index: relationship to performance-based measures and activities of daily living among older japanese women in Hawaii. *J Am Geriatr Soc.*1998;46:274-279.

45. Morita M, Takamura N, Kusano Y, et al. Relationship between falls and physical performance measures among community-dwelling elderly women in Japan. *Aging Clin Exp Res.* 2005;17:211-216.

46. Wallmann H. Comparison of elderly nonfallers and fallers on performance measures of functional reach, sensory organization, and limits of stability. *J Gerontol Med Sci.* 2001;56A(9):M580-M583.

47. Brauer S, Burns Y, Galley P. A prospective study of laboratory and clinical measures of postural stability to predict community-dwelling fallers. *Gerontology.* 2000;55A(8):M469-M476.

48. Lin S, Tsai T, Lee I, Wu Y. Perception of unsteadiness in patients with dizziness: Association with handicap and imbalance. *J Biomed Sci.* 2002;9:428-435.

49. Dite W, Temple V. A clinical test of stepping and change of direction to identify multiple falling older adults. *Arch Phys Med Rehabil.* 2002;83:1566-1571.

50. Behrman A, Light K, Flynn S, Thigpen M. Is the functional reach test useful for identifying falls risk among individuals with Parkinson's Disease? *Arch Phys Med Rehabil.* 2002;83:538-542.

51. Thomas JI, Lane JV. A pilot study to explore the predictive validity of 4 measures of falls risk in frail elderly patients. *Arch Phys Med Rehabil.* 2005;vol 86:p 1636-1640.

52. Wang C, Olson S, Protas E. Physical-performance tests to evaluate mobility disability in community-dwelling elders. *J Aging Phys Act.* 2005;13:184-197.

53. Okumiya K, Matsubayashi K, Wada T, Kimura S, Doi Y, Ozawa T. Effects of exercise on neurobehavioral functional in community-dwelling older people more than 75 years of age. J Am Geriatr Soc. 1996;44(5):569-572.

54. Rogers ME, Fernandez J, Bohlken R. Training to reduce postural sway and increase functional rearch in the elderly. *J Occup Rehabil.* 2001;11(4):291-298.

55. Barrett C, Smerdely P. A comparison of community-based resistance exercise and flexibility exercise for seniors. *Aust J Physiother.* 2002;48:215-219.

56. Shigematsu R, Tanaka K, Holland G, et al. Validation of the functional fitness age (FFA) index in older Japanese women. *Aging Clin. Exp. Res.* 2001;13:385-390.

57. Dennis R. Functional reach improvement in normal older women after alexander technique instruction. *J Gerontol Med Sci.* 1999;54A(1):M8-M11.

58. Morey M, Schenkman M, Studenski S, et al. Spinal-flexibility-plus-aerobic-only training: effects of a randomized clinical trial on function in at-risk older adults. *J Gerontol Med Sci.* 1999;54A(7):M335-M342.

59. Simmons V, Hansen P. Effectiveness of water exericse on postural mobility in the well elderly: an experimental study on balance enhancement. *J Gerontol Med Sci.* 1996;51A(5):M233-M238.

60. Hakim R, DiCicco J, Burke J, Hoy T, Roberts E. Differences in balance related measures among older adults participating in Tai Chi, structured exercise, or no exercise. *J Geriatr Phys Ther.* 2004;27(1):11-15.

61. Li F, Harmer P, Fisher K, Mcauley E. Tai Chi: improving functional balance and predicting subsequent falls in older persons. *Med Sci Sports Exerc.* 2004;36(12):2046-2052.

62. Sousa N, Sampaio J. Effects of progressive strength training on the performance of the functional reach test and the timed get-up-and-go test in an elderly population from the rural north of portugal. *Am J Hum Biol.* 2005;vol 17:p. 746-751.

63. Robinson B, Gordon J, Wallentine S, Visio M. Relationship between lower-extremity joint torque and the risk for falls in a group of community dwelling older adults. *Physiother Theor Pract.* 2004;20:155-173.

64. Mak M, Ng P. Mediolateral sway in single-leg stance is the best discriminator of balance performance for Tai-Chi practitioners. *Arch Phys Med Rehabil.* 2003;84:683-686.

65. Li F, Fisher KJ, Harmer P. Improving physical function and blood pressure in older adults through cobblestone mat walking: a randomized trial. *J Am Geriatr Soc.* 2005;vol. 53:p. 1305-1312.

66. Galantino ML, Shepard K, Krafft L, et al. The effect of group aerobic exercise and t'ai chi on functional outcomes and quality of life for persons living with acquired immunodeficiency syndrome. *J Altern Complement Med.* 2005;11(6):1085-1092.

67. Brown T, Mount J, Rouland B, Kautz K, Barnes R, Kim J. Body weight-supported treadmill training versus conventional gait training for people with chronic traumatic brain injury. *J Head Trauma Rehabil.* 2005;20(5):402-415.

68. Campbell F, Ashburn A, Thomas P. An exploratory study of the consistency of balance control and the mobility of people with Parkinson's disease (PD) between medication doses. *Clin Rehabil.* 2003;17:318-324.

69. Gajdosik RL, Vander Linden DW, McNair PJ, Williams AK, Riggin TJ. Effects of an eight-week stretching program on the passive-elastic properties and function of the calf muscles of older women. *Clin Biomech.* 2005 2005;20:973-983.

70. Bellew J, Fenter P, Chelette B, Moore R, Loreno D. Effects of a short-term dynamic balance training program in healthy older women. *J Geriatr Phys Ther.* 2005;28(1):4-8.

71. Nitz J, Choy N. The efficacy of a specific balance-strategy training programme for preventing falls among older people: a pilot randomised controlled trial. *Age Ageing.* 2004;33:52-58.

72. Ramsbottom R, Ambler A, Potter J, Jordan B, Nevill A, Williams C. The effect of 6 months training on leg power, balance, and functional mobility of independently living adults over 70 years old. *J Aging Phys Act.* 2004;12:497-510.

73. Shimada H, Uchiyama Y, Kakurai S. Specific effects of balance and gait exercises on physical function among the frail elderly. *Clin Rehabil.* 2003;17:472-479.

74. Skelton D, Young A, Greig C, Malbut K. Effects of resistance training on strength, power, and selected functional abiliteis of women aged 75 and older. *J Am Geriatr Soc.* 1995;43:1081-1087.

75. Wade L, Canning C, Fowler V, Felmingham K, Baguley I. Changes in postural sway and performance of functional tasks during rehabilitation after traumatic brain injury. *Arch Phys Med Rehabil.* 1997;78:1107-1111.

76. Duncan P, Studenski S, Richard L, et al. Randomized clinical trial of therapeutic exercise in subacute stroke. *Stroke.* 2003;34:2173-2180.

77. Richardson J, Sandman D, Vella S. A Focused Exercise Regimen Improves Clinical Measures of Balance in Patients With Peripheral Neuropathy. *Arch Phys Med Rehabil.* 2001;82(February):205-209.

78. Bernhardt J, Ellis P, S. D, Hill K. Changes in balance and locomotion measures during rehabilitation following stroke. *Physiother Res Int.* 1998;3(2):109-122.

79. Lyles K, Gold D, Shipp K, Pieper C, S M, Mulhausen P. Association of osteoporotic vertebral compression fractures with impaired functional status. *Am J Med.* 1993;94(6):595-601.

80. Mueller M, Salsich G, Strube M. Functional limitations in patients with diabetes and transmetatarsal amputations. *Phys Ther.* 1997;77:937-943.

81. McMurdo M, Millar A, Daly F. A randomized controlled trial of fall prevention strategies in old peoples' homes. *Gerontology.* 2000;46:83-87.

82. Taylor L, Whittington F, Hollingsworth C, et al. Assessing the effectiveness of a walking program on physical function of residents living in an assisted living facility. *J Community Health Nurs.* 2003;20(1):15-26.

83. Sherrington C, Lord S. Home exercise to improve strength and walking velocity after hip fracture: A randomized controlled trial. *Arch Phys Med Rehabil.* 1997;78:208-212.

84. Carmeli E, Bar-Chad S, Lotan M. Five clinical tests to assess balance following ball exercises and treadmill training in adult persons with intellectual disability. *J Gerontol.* 2003;58A:M767-M772.

85. Richardson J, Ross A, Riley B, Rhodes R. Halo vest effect on balance. *Arch Phys Med Rehabil.* 2000;81:255-257.

86. Cummings S, Ling X, Stone K. Consequences of foot binding among older women in beijing, china. *Am J Public Health.* 1997;87(10):1677-1679.

87. Cutson T, Gray S, Hughes M, Carson S, Hanlon J. Effect of a single dose of diazepam on balance measures in older people. *J Am Geriatr Soc.*1997;45:435-440.

88. Ondo W, Warrior D, Overby A, et al. Computerized posturography analysis of progressive supranuclear palsy. *Arch Neurol.* 2000;57(10):1464-1469.

89. Newton R. Balance screening of an inner city older adult population. *Arch Phys Med Rehabil.* 1997;78:587-591.

90. Shigematsu R, Tanaka K. Age scale for assessing functional fitness in older Japanese ambulatory women. *Aging Clin Exp Res.* 2000;12:256-263.

91. Schenkman M, Morey M, Kuchibhatla M. Spinal flexibility and balance control among community-dwelling adults with an without Parkinson's disease. *J Gerontol.* 2000;55(8):M441-M445.

92. Aoyagi K, Ross PD, Hayashi T, et al. Calcaneus Bone Mineral Density is Lower Among Men and Women with Lower Physical Performance. *Calcified Tissue Int.* 2000;67:106-110.

93. Purser J, Pieper C, Branch L, Shipp K, Gold D, Lyles K. Spinal deformity andmobility self-confidence among women with osteoporosis and vertebral fractures. *Aging Clin Exp Res.* 1999;11(4):235-245.

94. Lehmann K, Sunnerhagen KS, Willen C. Postural control in persons with late effects of polio. *Acta Neurol Scand.* 2006;vol 113:p.55-61.

95. Stack E, Ashburn A, Jupp K. Postural instability during reaching tasks in parkinson's disease. *Physio Res Int.* 2005;10(3):146-153.

96. Cimbiz A, Cakir O. Evaluation of balance and physical fitness in diabetic neuropathic patients. *J Diabetes Complications.* 2005;19:160-164.

97. Smith P, Hembree J, Thompson M. Berg balance scale and functional reach: determining the best clinical tool for individuals post acute stroke. *Clin Rehabil.* 2004;18:811-818.

98. Stankovic I. The effect of physical therapy on balance of patients with Parkinson's disease. *Int J Rehab Res.* 2004;27(1):53-57.

99. Teri L, McCurry S, Buchner D, et al. Exercise and activity level in alzheimer's disease: a potential treatment focus. *J Rehabil Res Dev.* 1998;35(4):411-419.

100. Wolf S, Sattin R, Kutner M, O'Grady M, Greenspan A, Gregor R. Intense Tai Chi exercise training and fall occurrences in older, transitionally frail adults: a ramdomized, controller trial. *J Am Geriatr Soc.* 2003;51:1693-1701.

101. Goldberg A, Hernandez M, Alexander N. Trunk repositioning errors are increased in balance-impaired older adults. *J Gerontol.* 2005;60A(10):1310-1314.

102. Huang C, Ross P, Wasnich R. Vertebral fracture and other predictors of physical impairment and health care utilization. *Arch Intern Med.* 1996;156:2469-2475.

103. Jonsson E, Henriksson M, Hirschfeld H. Does the functional reach test reflect stability limits in elderly people? *J Rehabil Med.* 2002;35:26-30.

104. Fishman M, Colby L, Sachs L, Nichols D. Comparison of upper-extremity balance tasks and force platform testing in persons with hemiparesis. *Phys Ther.* 1997;77(10):1052-1062.

105. Cavanaugh J, Shinberg M, Ray L, Shipp K, Kuchibhatla M, Schenkman M. Kinematic characterization of standing reach: comparison of younger vs. older subjects. *Clin Biomech.* 1999;14:271-279.

106. O'Brien K, Culham E, Pickles B. Balance and skeletal alignment in a group of elderly female fallers and nonfallers. *J Gerontol Biol Sci.* 1997;52A(4):B221-B226.

107. Wernick-Robinson M, Krebs D, Giorgetti M. Functional reach: Does it really measure dynamic balance? *Arch Phys Med Rehabil.* 1999;80(March):262-269.

108. Daubney M, Culham E. Lower-extremity muscle force and balance performance in adults aged 65 years and older. *Phys Ther.* 1999;79(12):1177-1185.

109. Escalante A, Lichtenstein M, Hazuda H. Determinats of shoulder and elbow flexion range: results from the San Antonio Longitudinal Study of Aging. *Arthritis Care Res.* 1999;12(4):277-286.

110. Thapa P, Gideon P, Fought R, Kromicki M, Ray W. Comparison of clinical and biomechanical measures of balance and mobility in elderly nursing home residents. *J Am Geriatric Soc.* 1994;42:493-500.

111. Petty J, Mercer V, Gross M, Riegger-Krugh C. Relationship between maximum ankle dorsiflexion range of motion and maximal posterior horizontal excursion in standing. *Issues on Ageing.* 2000;23(3):7-14.

112. Brauer S, Burns Y, Galley P. Lateral reach: A clinical measure of medio-lateral postural stability. *Physiother Res Intl.* 1999;4:81-85.

113. DeWaard B, Bentrup B, Hollman J, Brasseur J. Relationship of the functional reach and lateral reach tests in elderly females. *J Geriatr Phys Ther.* 2002;25:4-9.

114. Kaneko J, Morala D, Kurosawa K, et al. Relationship between movement patterns and physical fitness elements during rising from the supine to sitting postion in community-dwelling elderly persons. *J Phys Ther Sci.* 2003;15:87-91.

115. Curtis K, Kindlin C, Reich K, White D. Functional reach in wheelchair users: The effects of trunk and lower extremity stabilization. *Arch Phys Med Rehabil.* 1995;76:360-367.

116. Lynch S, Leahy P, Barker S. Reliability of measurements obtained with a modified functional reach test in subjects with spinal cord injury. *Phys Ther.* 1998;78(2):128-133.

117. Amos L, Brimner A, Dierckman H, et al. Effects of positioning on functional reach. *Phys Occup Ther Geriatr.* 2001;20(1):59-72.

118. Hsu W-L, Yang Y-R, Hong C-T, Wang RY. Ankle muscle activation during functional reach in hemiparetic and healthy subjects. *Am J Phys Med Rehabil.* 2005;84(10):p. 749-755.