

Multi-directional Reach Test: An Investigation of the Limits of Stability of People Aged between 20–79 Years

ANONG TANTISUWAT, PhD^{1)*}, DANNAOVARAT CHAMONCHANT, MSc¹⁾, SUJITRA BOONYONG, PhD¹⁾

¹⁾ Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University: 154 Rama I road, Wangmai, Pathumwan, Bangkok 10330, Thailand

Abstract. [Purpose] The multi-directional reach test (MDRT) is a simple, inexpensive, reliable and valid screening tool for assessing the limits of stability in the anteroposterior and mediolateral directions. The aim of this study was to quantify the limits of stability of people aged between 20 and 79 years using the MDRT. [Subjects] One hundred and eighty subjects were divided into the following 6 age groups: 20–29, 30–39, 40–49, 50–59, 60–69 and 70–79 years (n=30 per group). [Methods] The MDRT was used to measure the limits of stability in four directions: forward, backward, leftward and rightward. Subjects performed maximal outstretched arm reach in each direction with their feet flat on the floor. [Results] All age groups performed the greatest values of the limit of stability in the forward direction. The 60–79 year group demonstrated significantly lower limits of stability in the forward, leftward and rightward directions compared to the 20–39 year group. [Conclusion] The limits of stability declined with age mainly in the forward, leftward and rightward directions. The MDRT appears to be a useful assessment tool for postural control and balance of those aged 60 years and over.

Key words: Age, Balance, Functional reach test

(This article was submitted Nov. 21, 2013, and was accepted Jan. 7, 2014)

INTRODUCTION

Falls are a major health problem for the elderly and cause injuries which may lead to disability or death¹⁾. Shumway-Cook and colleagues²⁾ found that the risk of falling increases with age. The incidence of falls of individuals aged 65 and over increases by approximately 25–35 percent compared to puberty. The fall rate of elderly females is higher than that of males³⁾. Moreover, falls by the elderly have been found to occur inside and outside the home at incidence rates of 33–64 percent and 22–76 percent, respectively⁴⁾. The areas inside the home where falls most frequently occur are the living room, dining room, and bedroom.

A variety of clinical measures are used to determine dynamic balance. Clinical measures include the timed up and go (TUG) test⁵⁾, the step test⁶⁾, the Berg balance scale (BBS)⁷⁾, and the functional reach test⁸⁾. The functional reach test is a frequently used tool to assess dynamic balance and indirectly measure the limits of stability (LOS). It investigates the maximum distance a subject can reach beyond the subject's arm length while maintaining a fixed base of support (BOS) in the forward direction⁸⁾ and lateral directions⁹⁾. Previous studies have found that the functional

reach test (forward and lateral) is a good assessment tool for assessing the balance of the elderly in clinical settings^{10–12)}. Moreover, the functional reach test is also used to evaluate the success of balance training¹³⁾.

In response to findings of the elderly accidentally falling backwards and laterally¹⁴⁾, Newton¹⁵⁾ developed the multi-directional reach test (MDRT). It can be used to measure the extent of balance in the four directions of forward (FR), backward (BR), rightward (RR), and leftward (LR). The mean±SD values of each direction of 254 elderly people were reported by Newton as being 8.89±3.4, 4.64±3.07, 6.15±2.99, and 6.61±2.88 inches for FR, BR, RR, and LR, respectively. The MDRT is considered a simple, reliable (ICC=0.942) and valid (concurrent validities of MDRT with TUG and BBS are r=0.26–0.44 and r=0.36–0.48, respectively) screening tool for assessing dynamic balance and LOS in the anteroposterior and mediolateral directions¹⁵⁾. However, the standard values reported by Newton are derived from measurement of the elderly in the United States of America and may not be representative of the elderly in Asia who have different anthropometrics and balance performance. Since differences in balance performance may arise from differences in lifestyle, and social and cultural life, it might not be appropriate to use such values for evaluating individuals in Asia. Therefore, the aim of this study was to quantify the LOS of Thai individuals aged between 20 and 79 years using the MDRT.

*Corresponding author. Anong Tantisuwa (E-mail: anong.ta@chula.ac.th)

Table 1. Subject characteristics (n = 180)

Characteristic	Age groups (years)					
	20–29 (n = 30)	30–39 (n = 30)	40–49 (n = 30)	50–59 (n = 30)	60–69 (n = 30)	70–79 (n = 30)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Age (years)	21.6 ±1.8	34.3±2.8	44.6±3.1	54.5±2.4	64.1±2.9	74.0±2.9
Weight (kg)	55.3±6.3	59.5±8.5	56.3±11.8	59.1±6.9	55.8±7.6	57.7±10.7
Height (cm)	160.1±5.2	162.3±7.7	157.3±8.9	157.8±8.6	157.2±6.8	158.4±9.1
BMI (kg/m ²)	21.6±2.0	22.7±3.3	22.7±3.7	23.8±2.2	22.6±2.4	22.9±2.9

Table 2. Scores on the multi-directional reach test

MDRT (cm)	Age groups (years)					
	20–29	30–39	40–49	50–59	60–69	70–79
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
FR	28.3±8.1	28.3±7.7	27.5±7.1	27.6±6.6	22.8±4.7	24.5±7.3
BR	18.8±5.9	17.9±6.4	14.8±6.6	15.4±5.4	14.9±5.8	14.6±7.1
LR	17.9±5.2	21.0±5.4	17.7±6.3	18.4±4.7	15.6±4.9	15.6±4.9
RR	18.9±6.5	20.5±5.3	18.0±5.7	17.9±4.8	14.8±3.3	14.6±6.2

MDRT = Multi-directional Reach Test; FR = forward reach; BR = backward reach; LR = leftward reach; RR = rightward reach

SUBJECTS AND METHODS

One hundred and eighty healthy subjects (male = 67, female = 113) aged between 20 and 79 years were divided into 6 age groups according to decade, 20–29, 30–39, 40–49, 50–59, 60–69, and 70–79, as each age group would have undergone changes in physical structure and biomechanics. All subjects had a body mass index (BMI) in the range of 18.5–22.9 kg/m². Subjects led an active lifestyle and could stand independently without assistive devices. Subjects were excluded if they were unable to understand and follow verbal instructions, or could not raise both arms up to 90° in the forward and lateral directions. They were also excluded if they had musculoskeletal or neurological or sensory disorders, abnormal motor function or muscular weakness, a history of back or lower extremity surgery, joint arthritis affecting standing or walking, or taking medication which affects postural control. Prior to participation in the study, each subject signed an informed consent form which complied with the ethical guidelines approved by The Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group Chulalongkorn University, Thailand.

The present study used the MDRT¹⁵⁾ to measure dynamic balance and LOS in the forward, backward, leftward, and rightward directions. The MDRT was performed by affixing a yardstick (100 cm) to a tripod which was set parallel to the floor at the height of the subject's acromion process. The MDRT was measured in four directions: FR, BR, RR, and LR. The subjects were asked to stand on their bare feet and raise an outstretched arm to shoulder height, and the length at the fingertips was recorded as the initial reach data. Then, the subjects were instructed to "reach as far (direction given) as you can and try to keep your hand along the yardstick, without moving your feet or taking a step from floor." For

the backward direction the subject was instructed to "lean back as far as you can." The subjects used their preferred arm for FR and BR, and used the left and the right arms for LR and RR, respectively. The subjects were given no specific instructions regarding their behavior during measurement apart from trying to reach as far as they could. Three successful trials were recorded for each direction.

The MDRT data were compared among the 6 age groups using one-way analysis of variance (ANOVA). Differences among groups were considered statistically significant at values of $p < 0.05$. The Bonferroni correction was used as a post-hoc test for identifying age group pairs with statistically significant differences.

RESULTS

The subjects' characteristics are shown in Table 1. Mean and standard deviations of the MDRT in centimeters are shown in Table 2. The comparison revealed there were significant differences in FR, LR, and RR among all the age groups ($p < 0.05$). Statistically significant differences between the pairs of groups in each direction are shown in Table 3. The 20–29 and 30–39 groups demonstrated significantly higher LOS in FR than the 60–69 group ($p = 0.038$ and $p = 0.042$, respectively). The 30–39 group demonstrated significantly higher LOS in LR than the 60–69 ($p = 0.001$) and 70–79 ($p = 0.002$) groups, respectively. The 20–29 group demonstrated significantly higher LOS in RR than the 60–69 ($p = 0.049$) and 70–79 ($p = 0.034$) groups, respectively. The 30–39 group demonstrated significantly higher LOS in RR than the 60–69 ($p = 0.001$) and 70–79 ($p = 0.001$) groups, respectively. There were no significant differences in the BR among the age groups. All age groups showed the greatest values of LOS in the forward direction.

Table 3. Comparison of the MDRT among age groups

MDRT (cm)	Mean difference (cm)						
	Age Groups (years)	20–29	30–39	40–49	50–59	60–69	70–79
FR	20–29		0.06	0.78	0.74	5.55*	3.83
	30–39			0.72	0.68	5.49*	3.77
	40–49				0.04	4.78	3.06
	50–59					4.82	3.10
	60–69						1.72
BR	20–29		0.82	3.99	3.43	3.93	4.22
	30–39			3.17	2.61	3.11	3.40
	40–49				0.57	0.07	0.22
	50–59					0.50	0.79
	60–69						0.29
LR	20–29		3.06	0.23	0.44	2.41	2.28
	30–39			3.28	2.61	5.46**	5.34*
	40–49				0.67	2.18	2.05
	50–59					2.85	2.73
	60–69						0.12
RR	20–29		1.58	0.93	1.06	4.16*	4.31*
	30–39			2.51	2.63	5.73**	5.89**
	40–49				0.13	3.23	3.38
	50–59					3.10	3.26
	60–69						0.16

Abbreviations as in Table 2

* = significant difference at p-value < 0.05

** = significant difference at p-value < 0.001

DISCUSSION

This is the first study to investigate the MDRT in different age ranges in Asia. All factors^{16–18)} that can affect balance were controlled. Therefore, we are confident that the differences found in this study are related to age. The results reveal that the MDRT value tends to decrease with age.

The present study is consistent with the findings for 106 men aged 30–80¹²⁾, for whom a decline in the reaching distance in both forward and lateral directions with increasing age was reported. The greatest reaching distance was found in the 30s. The distance of the MDRT in all directions was greatest in the 20s and 30s in the current study. The reduction of MDRT with age may be related to the deterioration of various systems in the body. A decrease in LOS^{12, 19)}, muscle strength²⁰⁾, and foot sensation²¹⁾ have all been documented with age. It is known that the ability to maintain balance during activities relies on interrelationship among the visual and peripheral nervous systems, reaction time, and foot and ankle movement²²⁾. The muscles frequently found to be weak in the elderly with poor balance are the quadriceps, ankle dorsiflexor and plantar flexor^{23, 24)}. In particular, the weakness of the plantar flexor muscle is not only crucial to the reduction of anteroposterior LOS, but it also causes failure in the lateral direction²²⁾. Additionally, trunk extensor and flexor strength are important factors that

correlate with balance performance²⁵⁾. Hence, exercises to strengthen the plantar flexor muscles and trunk stabilization exercises are important for the reduction of the risk of falls by the elderly.

Subjects in all age groups showed the greatest value of MDRT in the forward direction, whereas the lowest value was found in the backward direction. This may be due to the biomechanical arrangement of the ankle and foot, which allows greater capacity for forward excursion than for backward excursion¹⁵⁾. Moreover, familiarity with the majority of the activities of daily living that are commonly performed in front of the body²⁶⁾, may also have helped the subjects to be better at controlling balance in the forward direction. In contrast, great efforts are required to shift the body weight towards the rear as the subjects are unable to exert visual control over the feet during movement²⁷⁾. Consequently, there is less opportunity for the subjects to correct for instability²⁸⁾ in order to maintain the COG within the BOS.

In this study, significant decreases in MDRT values with age were most apparent among the subjects aged over 60 years (Table 3). The minimally significant value is deemed to be more than 5 centimeters in all directions except backward reach. No significant differences in the MDRT were found among the young and middle-aged subjects. These findings indicate that the MDRT is suitable for use as a screening tool for assessing balance performance.

The assessment should, in particular, be implemented for people aged 60 years and over. However, the relationship between this value and the risk of falls poses interesting issues for further study.

In conclusion, LOS declined with age mainly in the forward, leftward and rightward directions. The MDRT appears to be a useful assessment tool for postural control and balance for those aged 60 years and over.

ACKNOWLEDGEMENT

This study was supported by the Research fund project 54005, Faculty of Allied Health Sciences, Chulalong Korn University, Thailand.

REFERENCES

- 1) Prudham D, Evans JG: Factors associated with falls in the elderly: a community study. *Age Ageing*, 1981, 10: 141–146. [[Medline](#)] [[CrossRef](#)]
- 2) Shumway-Cook A, Woolacott M, Kerns KA, et al.: The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *J Gerontol A Biol Sci Med Sci*, 1997, 52: M232–M240. [[Medline](#)] [[CrossRef](#)]
- 3) Fuller GF: Falls in the elderly. *Am Fam Physician*, 2000, 61: 2159–2168, 2173–2174. [[Medline](#)]
- 4) Kwan MM, Close JC, Wong AK, et al.: Falls incidence, risk factors, and consequences in Chinese older people: a systematic review. *J Am Geriatr Soc*, 2011, 59: 536–543. [[Medline](#)] [[CrossRef](#)]
- 5) Podsiadlo D, Richardson S: The timed “Up & Go”: a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*, 1991, 39: 142–148. [[Medline](#)]
- 6) Hill K, Bernhardt J, McGann A, et al.: A new test of dynamic standing balance for stroke patients: reliability, validity and comparison with healthy elderly. *Physiother Can*, 1996, 48: 257–262. [[CrossRef](#)]
- 7) Berg KO, Wood-Dauphinee SL, Williams JI, et al.: Measuring balance in the elderly: validation of an instrument. *Can J Public Health*, 1992, 83: S7–S11. [[Medline](#)]
- 8) Duncan PW, Weiner DK, Chandler J, et al.: Functional reach: a new clinical measure of balance. *J Gerontol*, 1990, 45: M192–M197. [[Medline](#)] [[CrossRef](#)]
- 9) Brauer S, Burns Y, Galley P: Lateral reach: a clinical measure of medio-lateral postural stability. *Physiother Res Int*, 1999, 4: 81–88. [[Medline](#)] [[CrossRef](#)]
- 10) Takahashi T, Ishida K, Yamamoto H, et al.: Modification of the functional reach test: analysis of lateral and anterior functional reach in community-dwelling older people. *Arch Gerontol Geriatr*, 2006, 42: 167–173. [[Medline](#)] [[CrossRef](#)]
- 11) Bellew JW, Panwitz BL, Peterson L, et al.: Effect of acute fatigue of the hip abductors on control of balance in young and older women. *Arch Phys Med Rehabil*, 2009, 90: 1170–1175. [[Medline](#)] [[CrossRef](#)]
- 12) Nolan M, Nitz J, Choy NL, et al.: Age-related changes in musculoskeletal function, balance and mobility measures in men aged 30–80 years. *Aging Male*, 2010, 13: 194–201. [[Medline](#)] [[CrossRef](#)]
- 13) Freeman J, Fox E, Gear M, et al.: Pilates based core stability training in ambulant individuals with multiple sclerosis: protocol for a multi-centre randomised controlled trial. *BMC Neurol*, 2012, 12: 19. [[Medline](#)] [[CrossRef](#)]
- 14) Cummings SR, Nevitt MC, Study of Osteoporotic Fractures Research Group: Non-skeletal determinants of fractures: the potential importance of the mechanics of falls. *Osteoporos Int*, 1994, 4: 67–70. [[Medline](#)] [[CrossRef](#)]
- 15) Newton RA: Validity of the multi-directional reach test: a practical measure for limits of stability in older adults. *J Gerontol A Biol Sci Med Sci*, 2001, 56: M248–M252. [[Medline](#)] [[CrossRef](#)]
- 16) Corbeil P, Simoneau M, Rancourt D, et al.: Increased risk for falling associated with obesity: mathematical modeling of postural control. *IEEE Trans Neural Syst Rehabil Eng*, 2001, 9: 126–136. [[Medline](#)] [[CrossRef](#)]
- 17) Berger W, Trippel M, Discher M, et al.: Influence of subjects’ height on the stabilization of posture. *Acta Otolaryngol*, 1992, 112: 22–30. [[Medline](#)] [[CrossRef](#)]
- 18) Tinetti ME, Doucette J, Claus E, et al.: Risk factors for serious injury during falls by older persons in the community. *J Am Geriatr Soc*, 1995, 43: 1214–1221. [[Medline](#)]
- 19) Clark S, Rose DJ: Evaluation of dynamic balance among community-dwelling older adult fallers: a generalizability study of the limits of stability test. *Arch Phys Med Rehabil*, 2001, 82: 468–474. [[Medline](#)] [[CrossRef](#)]
- 20) Porter MM, Vandervoort AA, Lexell J: Aging of human muscle: structure, function and adaptability. *Scand J Med Sci Sports*, 1995, 5: 129–142. [[Medline](#)] [[CrossRef](#)]
- 21) Melzer I, Benjuya N, Kaplanski J: Postural stability in the elderly: a comparison between fallers and non-fallers. *Age Ageing*, 2004, 33: 602–607. [[Medline](#)] [[CrossRef](#)]
- 22) Melzer I, Benjuya N, Kaplanski J, et al.: Association between ankle muscle strength and limit of stability in older adults. *Age Ageing*, 2009, 38: 119–123. [[Medline](#)] [[CrossRef](#)]
- 23) Hughes MA, Duncan PW, Rose DK, et al.: The relationship of postural sway to sensorimotor function, functional performance, and disability in the elderly. *Arch Phys Med Rehabil*, 1996, 77: 567–572. [[Medline](#)] [[CrossRef](#)]
- 24) Lord SR, Clark RD, Webster IW: Postural stability and associated physiological factors in a population of aged persons. *J Gerontol*, 1991, 46: M69–M76. [[Medline](#)] [[CrossRef](#)]
- 25) Granacher U, Gollhofer A, Hortobágyi T, et al.: The importance of trunk muscle strength for balance, functional performance, and fall prevention in seniors: a systematic review. *Sports Med*, 2013, 43: 627–641. [[Medline](#)] [[CrossRef](#)]
- 26) Lin SI, Lin RM: Sensorimotor and balance function in older adults with lumbar nerve root compression. *Clin Orthop Relat Res*, 2002, (394): 146–153. [[Medline](#)] [[CrossRef](#)]
- 27) Pai YC, Iqbal K: Simulated movement termination for balance recovery: can movement strategies be sought to maintain stability in the presence of slipping or forced sliding? *J Biomech*, 1999, 32: 779–786. [[Medline](#)] [[CrossRef](#)]
- 28) Luchies CW, Alexander NB, Schultz AB, et al.: Stepping responses of young and old adults to postural disturbances: kinematics. *J Am Geriatr Soc*, 1994, 42: 506–512. [[Medline](#)]