ORIGINAL ARTICLE

Measuring Methods for Functional Reach Test: Comparison of 1-Arm Reach and 2-Arm Reach

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ABSTRACT. Kage H, Okuda M, Nakamura I, Kunitsugu I, Sugiyama S, Hobara T. Measuring methods for functional reach test: comparison of 1-arm reach and 2-arm reach. Arch Phys Med Rehabil 2009;90:2103-7.

Objectives: To investigate which functional reach test better reflects the center of pressure excursion, a 1-arm reach or a 2-arm reach, and to investigate the effect of trunk rotation on the reach distance in a 1-arm reach. In addition, we considered the influence of the individual variation at the starting position.

Design: Descriptive study using a force platform and a 3-dimensional (3D) motion capture system.

Setting: Motion analysis laboratory in a college setting.

Participants: Elderly volunteers (N=41; 15 men, 26 women; 71.8±5.2y).

Interventions: Not applicable.

Main Outcome Measures: 3D coordinate data and the movement of the center of pressure.

Results: The correlation between the reach distance and the center of pressure excursion was significantly higher ($P<.05$) for the 1-arm reach ($r=.60, .72$) compared with a 2-arm reach ($r=.41, .55$). In the case of the 1-arm reach, center of pressure excursion was a significant factor affecting reach distance ($\beta=.319, .470$) in multivariate regression analysis, but trunk rotation was not ($\beta=.162, .095$). When the reach distance was measured using the heel as a reference, the correlation was stronger.

Conclusions: To evaluate dynamic balance, a 1-arm reach, which better reflects center of pressure excursion, is more valid. It is meaningful to reduce the individual variation of the acromion at the starting position.

Key Word: Rehabilitation.

THE FUNCTIONAL REACH TEST developed by Duncan et al[1] in 1990 is a popular method of measuring the dynamic balance of the elderly. FR is measured as the maximal distance one can reach forward beyond arm length at shoulder height while maintaining a fixed base of support in the standing position.[1,2] The FR test was originally designed as a measure of the margin of stability, similar to COP excursion, an indicator of dynamic balance, which is recorded on a force platform. Duncan[1] reported that FR was highly correlated with COP excursion ($r=.71$). Moreover, FR is inversely associated with recurrent falls, physical frailty, and physical changes,[2-4] as is COP excursion.[5,6]

Although the original method is defined as reaching forward with 1 arm, recently reach distance using 2 arms has been used to examine dynamic balance,[7-13] because those researchers considered that a 2-arm reach could exclude the influence of trunk rotatory flexibility on reach distance, thus indicating dynamic balance more effectively and accurately. Volkman et al[7] report higher reproducibility of the 2-arm reach than the 1-arm reach. Tsushima et al[8] report a slightly smaller variation in the 2-arm reach. However, to our knowledge, there are no reports that show the relationship between 1-arm reach distance and trunk rotation. Also, there is no evidence that the 2-arm reach distance is more highly associated with dynamic balance than the 1-arm reach distance. The FR test is often used in studies of elderly people, because there are many reports suggesting that the FR test is useful as a predictor of the risk of falling and a decline in function of the elderly.[14-19] Improving the accuracy of the FR test is useful to increase its predictive value.

The purpose of this study was to investigate which method was more valid for evaluating dynamic balance, a 1-arm reach or a 2-arm reach, by comparing the correlation between reach distance and COP excursion. We also explored the relationship between reach distance and trunk rotation in the case of a 1-arm reach.

METHODS

Subjects

Forty-one community-dwelling elderly volunteers (15 men, 26 women) between the ages of 65 and 86 years (mean ± SD, 71.8 ± 5.2y) participated in the study. They were able to walk without assistive devices, were independent in daily activities, and lived at home. We made sure that they could reach forward without pain or staggering and could raise their arms to 90° when they performed the FR test. This study was approved by the institutional review board, and written informed consent was obtained from all subjects.

Functional Reach Test

The subjects stood barefooted comfortably with their feet shoulder-width apart and their toes at a baseline marked on the forceplate. Then they were instructed to raise their arms until they were parallel to the floor. The finger location at the starting position of the first trial was recorded and recreated in each trial. After the subjects took the starting position, they

List of Abbreviations

ASIS	anterior superior iliac spine
COP	center of pressure
3D	three-dimensional
FR	functional reach

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were instructed to begin a reaching movement on a cue from the examiner, to reach their maximal distance, at their own speed, and come back to the standing position. To keep their arms level with their acromions, they reached forward while pushing a horizontal sliding bar with their fingers instead of their fists because a marker was attached to the proximal interphalangeal joint. The subjects performed a forward reaching movement under 2 conditions:

1. One-arm reach. Subjects took the starting position with their right arm horizontal and their left arm at their side. They were instructed to extend their right arm and reach as far forward as they could.
2. Two-arm reach. Subjects took the starting position with both of their arms horizontal.

They were instructed to extend both arms and reach as far forward as they could.

The subjects were not instructed on a reaching strategy. If subjects raised a heel or took a step during testing, the trial was repeated. To minimize order effects, the order of the 2 conditions was randomized. Measurement was duplicated in each condition. Of these 2 trials for each condition, the trial that showed the farther reach was selected for statistical analysis.

3-Dimensional Kinematics and Center of Pressure Excursion Analysis

Three-dimensional kinematic data and COP excursion data were synchronously acquired during each trial. The Peak 3D motion analysis system[a] was used for collecting 3D kinematic data during the forward reach. Five infrared reflective markers were placed on both acromions, both ASIS points, and the proximal interphalangeal joint of the right index finger. The finger marker simulated the frontal end of the forward reaching fist used in the original method. The motion of each marker was captured with 6 cameras around the subject, and the locations of the markers were indicated against the most posterior point of the heel, serving as the origin. An AMTI force platform[b] was used to record the ground reaction force. Kinematic data and ground reaction force were sampled by a computer at a frequency of 60Hz. The Peak Motus software version 7.0[a] was used to calculate the 3D coordinates of each marker and the COP. Values of marker displacement and COP excursion were rounded to the nearest 0.1cm.

Anthropometry

Body height was measured to the nearest 0.1cm using a height measuring stadiometer.[c] Foot lengths (distance between the most posterior point of the heel and the tip of the frontmost toe) were measured to the nearest 0.1 cm using an anthropometer[d] while the subject was standing.

Data Analysis

Before the reach trials, shoulder location at the starting position was measured as the horizontal distance from the most posterior point of the heel to the right acromion. The reach distance was obtained in 2 ways using the index finger: (1) finger-to-finger, using the marker location on the finger at the starting position as a reference point; and (2) heel-to-finger, using the most posterior point of the heel as a reference point (fig 1A). The location of ASIS at their maximum reach was obtained using the most posterior point of the heel as a reference point (see fig 1A). The reference heel points were calculated as each foot length behind the baseline on which the toes were aligned. These were all calculated as anteroposterior distances projected on a horizontal plane.

COP excursion is commonly determined as the distance from the COP at the starting position to the COP at the maximal reach. In our research, however, COP excursion was determined as the distance from the most posterior point of the heel as the origin, because the starting position was not the same between the 2 types of reach.

The trunk rotation angle and shoulder protraction at the maximal reach of the 1-arm reach was also calculated (fig 1B).

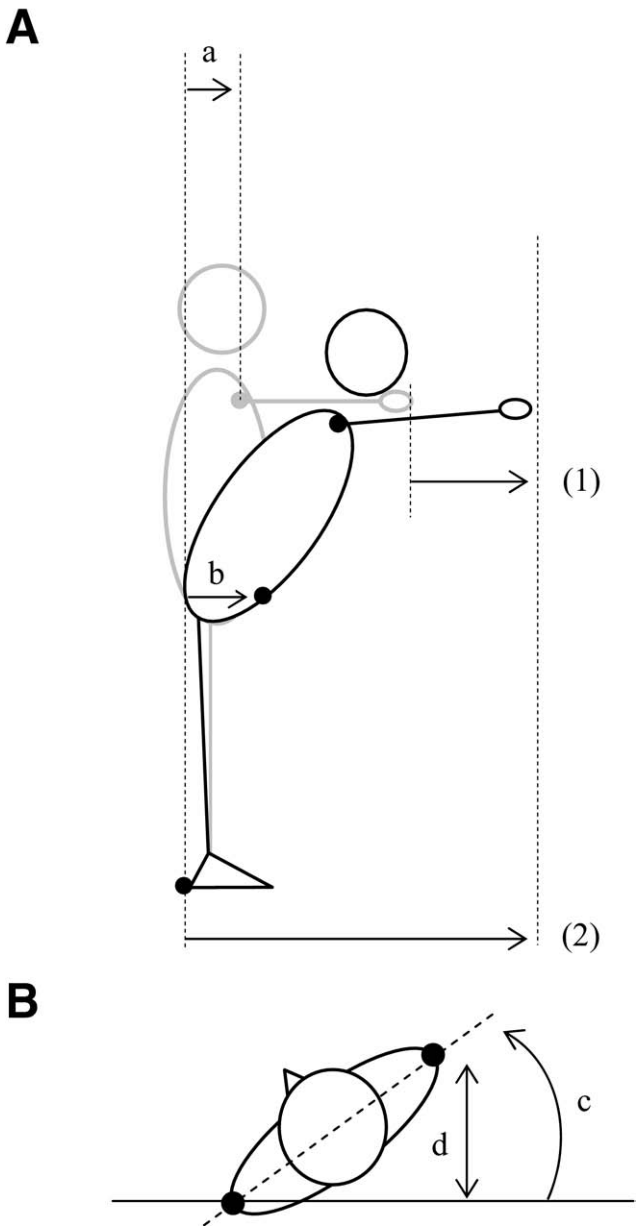

Fig 1. Functional reach test measuring scheme. (A) Lateral view at the starting position (gray line) and at maximal reach (black line). Two definitions of reach distances (cm) were used: (1) finger-to-finger, reach distance from the finger location at a starting position; (2) heel-to-finger, reach distance from the most posterior point of the heel. (a) Shoulder location; horizontal distances from most posterior point of heel to right acromion at starting position. (b) ASIS location; horizontal distances from most posterior point of heel to ASIS at the maximum reach. (B) Overhead view at the maximal reach when reaching with 1 arm. (c) Trunk rotation angle (degrees) is formed by a line connecting the right and left acromions and the frontal plane. (d) shoulder protraction (cm) is anteroposterior distance between right and left acromions.