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Original article

Determination of the reference value and systematic bias of the functional reach test in Japanese elderly people by meta-analysis

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ABSTRACT

Background/Purpose: The functional reach test (FRT), which was developed as a clinical balance assessment tool, has been widely used as a fall risk assessment tool in elderly people. The aim of the present study was to investigate the reference value and the presence of systematic bias in the FRT using the methodology of meta-analysis in community-dwelling elderly people.
Methods: Relevant research articles were sought from electronic databases: MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Igakucyuouzasshi. The search was conducted from January 1990 to August 2011, and the terms "functional reach" and "elderly" were used in combination in the search. The searches were limited to peer-reviewed research articles involving Japanese elderly people with good functioning, aged 60 years and older. Weighted means were calculated for the reference value of FRT by a fixed effect model and a random effect model. Furthermore, weighted least squares regression was performed to determine the presence of systematic bias in the reference value of FRT.
Results: A total of 19 articles fulfilled the inclusion criteria, including 4274 participants whose mean age ranged from 69.0 to 81.4 years. The reference value of FRT was 29.44 cm (95% confidence interval: 27.60–31.27 cm) using the random-effect model, since the reference value using the fixed-effect model was found to have significant heterogeneity. Furthermore, multivariate weighted least squares regression was performed, and sex, age, height, and measurement method (one-arm or two-arm reach) were all independently associated with the FRT value (multiple $R^2 = 0.295$, $\chi^2 = 76.6$, $p < 0.001$).
Conclusions: Since participants' characteristics (sex, age, and height) and measurement method are probably related to systematic error in the FRT, judgment of physical function in elderly people using only the reference value determined in this study may have limitations.
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1. Introduction

The functional reach test (FRT), a clinical balance assessment tool developed by Duncan et al,[1] has been used to assess fall risk in elderly people.[2] The FRT is considered to be a useful and feasible index to assess balance and fall risk in elderly people in community settings. However, previous studies have reported that the FRT has been affected by the age and height of individuals,[3] trunk mobility,[4] and the measurement method.[5] If these factors work as systematic biases, the validity of the FRT as a balance and fall risk assessment tool may need to be re-considered. Furthermore, the interpretation of FRT results is difficult because there is no reference value on which to base interpretation. In our previous study,[6] we determined the reference values of the timed up and go test, which has been widely used as a fall risk assessment tool,[2,7] and provided clinically useful information to health care professionals. Therefore, the reference value and the presence of systematic bias in the FRT need to be investigated in order to use the FRT as a balance and fall risk assessment tool for elderly people. The aim of the present study was to investigate the reference value for the FRT, as well as the presence of systematic bias, using the methodology of meta-analysis in community-dwelling elderly people.

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2. Method

2.1. Databases searched

Relevant research articles were sought from electronic databases: MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Igakucyuouzasshi (Japanese electronic database for medical research articles). The search was conducted from January 1990 to August 2011, and the terms “functional reach” and “elderly” were used in combination in the search.

2.2. Search strategy

The searches were limited to peer-reviewed research articles published in English or Japanese. Retrieved articles were examined by two reviewers (NK and KT-N) based on the following inclusion criteria: (1) the articles involved Japanese people; (2) the articles involved community-dwelling people who were aged 60 years and older; (3) the articles involved elderly people with good functioning, defined as those with independent activities of daily living (ADL), independent instrumental ADL (IADL), and participation in social activities; (4) the articles did not involve frail elderly people and patients who had specific diseases, such as neuromuscular diseases and hip fractures; (5) sample size and the mean and standard deviations of the FRT were all described in the text; and (6) information about the FRT measurement method was described. The above inclusion criteria were adopted to minimize data variation among the studies. In particular, articles involving elderly people who were functioning well were retrieved, because the functional status of participants is likely to influence physical performance on tests such as the FRT.[8] Functional status was judged from information about participants’ ADL, IADL, or social activities that were reported in each retrieved article. When that information was not reported, that article was excluded from further analysis. In addition, the reference value was estimated for Japanese people, because ethnic differences need to be considered for physical performance tests.[6]

2.3. Summary of data

The articles fulfilling the above criteria were summarized to obtain the participants’ information (age, sex, height, and functioning), FRT measurement method (one-arm or two-arm reach), sample size, and mean and standard deviation of the FRT. All information was tabulated and input into a computer database to perform further statistical analysis. When multiple FRT values were reported in the article (e.g., data was reported by sex and age group), the data of each group were entered into the database.

2.4. Statistical analysis

Weighted means were calculated for the FRT reference value using a published general methodology[9] as in the previous study.[6] Weighted means were estimated using a fixed-effect model, and a test of homogeneity was performed. If heterogeneity was found, weighted means were re-estimated using a random-effect model. Furthermore, weighted least squares regression was performed to determine the presence of systematic bias in the reference value for the FRT; the dependent variable was the FRT value reported in each study, while the independent variables were the sex, mean age, and mean height of the participants of each study and the measurement method (two- or one-arm reach) in each study. The 95% confidence interval (CI) for the weighted mean of the FRT was also estimated. The significance level was set at 5%. Statistical analysis was performed using the R programming language and environment (R version 2.14.0).[10]

3. Results

A total of 19 articles and 34 groups that fulfilled the inclusion criteria were analyzed in this study.[5,11–28] The selection flow chart of the retrieved articles is shown in Fig. 1. The forest plot to summarize the results in each study’s group for the meta-analysis is shown in Fig. 2. The total number of participants was 4274: 1008 men, 2235 women, and 1031 of unreported gender. The mean age of the participants in each study ranged from 69.0 to 81.4 years. For FRT measurement, the participants were instructed to perform maximum forward reaching with the feet fixed and one or two arms raised in most studies. With regard to arm raising, it was confirmed that reaching with one-arm raised was used in 13 of 19 studies (68.4%). In addition, trunk rotation during FRT measurement was not mentioned in 18 of 19 studies. The forward reach distance was measured using a tape measure or a yardstick.

The FRT reference value calculated using the fixed effect model was 30.51 cm (95% CI: 30.33–30.69 cm), but significant heterogeneity was found on the test of homogeneity ($Q = 3117.8$, $p < 0.001$). Therefore, the FRT reference value was re-calculated using a random-effect model, and the value was 29.44 cm (95% CI: 27.60–31.27 cm) (Table 1). Furthermore, the relationships between the FRT value and sex, age, height, and measurement method (two- or one-arm reach) were investigated by univariate weighted least squares regression, since heterogeneity was found in the FRT reference value. There were significant relationships between the FRT value and all factors (sex, age, height, and measurement method). Variations in the FRT value estimated using univariate weighted least squares regression is shown in Table 1. In summary, older age and female sex were negatively associated, and height and two-arm reach were positively associated with the FRT value. Furthermore, on the multivariate weighted least squares regression, sex, age, height, and measurement method were all independently associated with the FRT value (multiple $R^2 = 0.295$, $\chi^2 = 76.6$, $p < 0.001$).

4. Discussion

The FRT reference value in community-dwelling elderly people with good functioning was estimated using the methodology of meta-analysis in the present study. Using the random-effect model, the reference value was 29.44 cm. In the random-effect model, both participant-level error and study-level error are included in the calculation. Therefore, the difference between the reference value estimated by the fixed-effect model and that estimated by the random-effect model is represented by the between-study variance . Heterogeneity was found in the meta-analysis conducted in

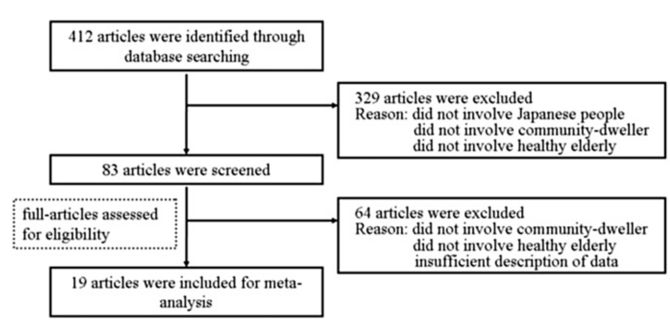

Fig. 1. Selection flow of retrieved articles for meta-analysis.

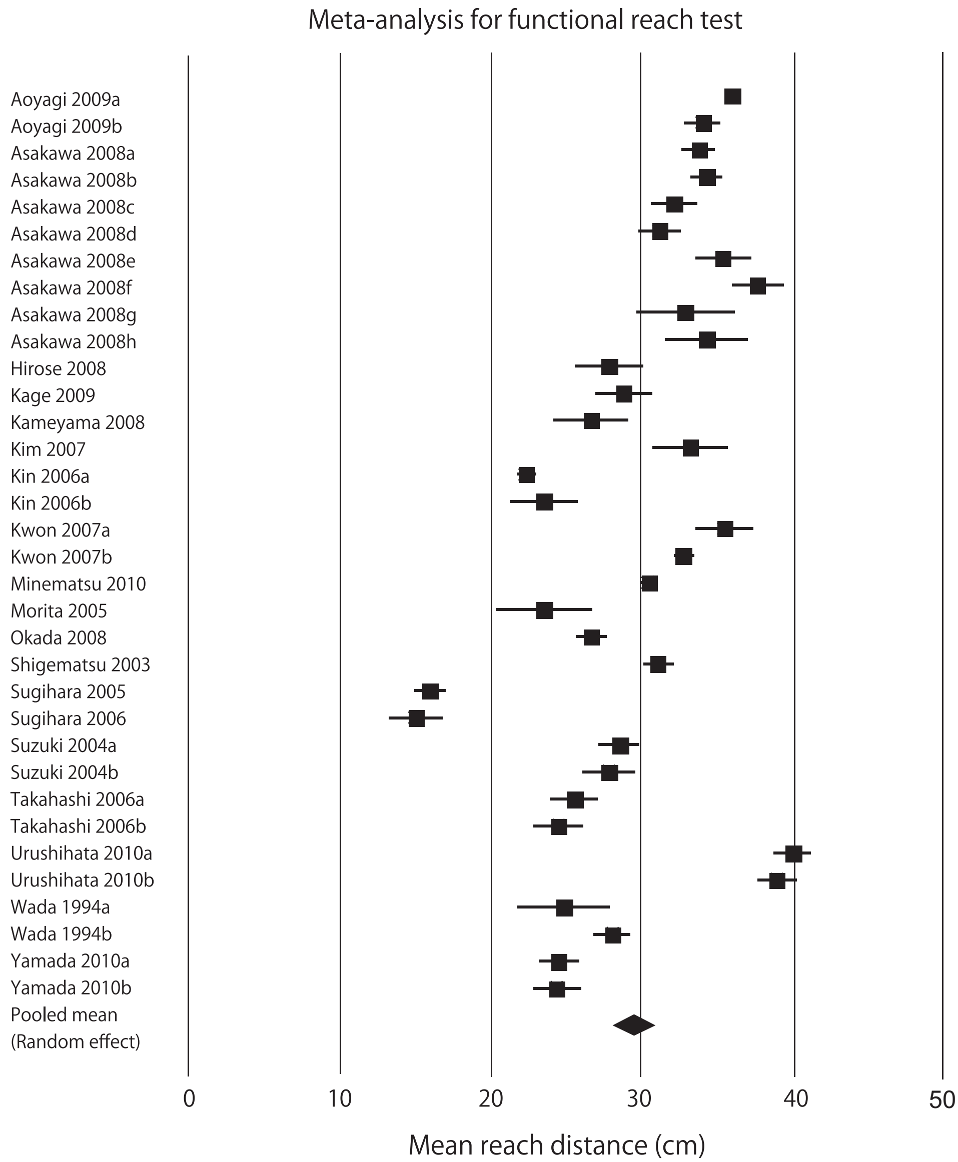

Fig. 2. Summary of results in each study's group used in the meta-analysis.

the present study, but the difference between the reference value estimated by the fixed effect model and that estimated by the random-effect model was small (30.51 cm vs. 29.44 cm, respectively, a difference of about 3.6%). Therefore, between-study variance appears to have been small in this study. If between-study variance is large, reliability in the reference value estimated by meta-analysis is thought to be doubtful,[6] however, the reference value estimated by the present study appears reliable.

By contrast, the FRT value fluctuated significantly by sex, age, height, and measurement method (one- or two-arm reach), and these factors were shown to be systematic biases on the FRT. Approximately 30% of the FRT value was explained by sex, age, height, and measurement method, for which variation was large. Furthermore, the variation in FRT presented in Table 1 indicates the degree of fluctuation in the FRT results by sex, age, height, and measurement method. For example, when individuals who have the same balance ability are assessed using FRT, the FRT result is likely to be lower by an average of 3.15 cm in women than in men. Other variables can also be interpreted similarly. Thus, it appears that the degree of fluctuation by sex, age, height, and measurement method cannot be ignored. Therefore, when the FRT is performed to assess balance and fall risk in elderly people, raters must consider the effect of measurement method and characteristics such as sex, age, and height.

Considering the variability of the FRT value, use of the FRT as a fall risk assessment tool may be limited. In the previous study,

Table 1
Estimates of the weighted mean and variations in the functional reach test.

Variables	Estimates
Weighted mean of the functional reach test	
Fixed-effect model[a]	30.51 cm (95% CI: 30.33 ; 30.69)
Random-effect model	29.44 cm (95% CI: 27.60 ; 31.27)
Variations in the functional reach test	
Sex (women)	−3.15 cm (95% CI: −2.70 ; −3.60)*
Age (increase 10 y)	−1.99 cm (95% CI: −2.48 ; −1.50)*
Height (increase 10 cm)	3.22 cm (95% CI: 2.66 ; 3.79)*
Measuring method (two-arm reach)	1.32 cm (95% CI: 0.78 ; 1.86)*

*$p < 0.001$.
[a] Test of homogeneity was significant.

elderly fallers and non-fallers could not be discriminated by the FRT, and the FRT was not correlated with anterior displacement of the center of gravity, which indicates balance function.[29] Moreover, it has been reported that the FRT is not associated with the timed up and go test and gait velocity, which are also useful fall risk assessment tools.[2,30–34] From the results of these previous studies, the FRT may be associated with not only balance but also with other physical functions such as mobility of the trunk and ankle joints.[4,35] In addition, regarding the measurement method, Kage et al[5] reported that the FRT value differed between one- and two-arm reach, which agrees with the present findings. Therefore, raters should be careful when adopting the FRT to judge balance function and fall risk in community-dwelling elderly people. That is to say, when the FRT is performed to assess fall risk, combined use with other assessment tools such as the timed up and go test and gait velocity is recommended.

This study had several limitations. Firstly, in addition to sex, age, height, and measurement method, other factors that work as systematic biases may exist. In particular, most studies did not mention trunk rotation during FRT measurement. In addition, postural abnormality of the trunk may affect the FRT result.[36] Therefore, trunk functions, such as trunk rotation and posture, may be potential biases affecting the FRT. However, the data of the present study was insufficient to investigate these factors. Secondly, since systematic bias affects the FRT, judging the physical function of community-dwelling elderly people using only the reference value estimated in the present study may have limitations.

In conclusion, the FRT is widely used to assess balance function and fall risk in elderly people. The reference value and systematic bias of the FRT determined in this study are clinically useful when interpreting FRT results in elderly people.

Authors contributions

Dr Kamide contributed to the study concept, article retrieval, article review, statistical analysis, data interpretation, and manuscript drafting and revision. Dr Takahashi-Narita contributed to article retrieval, article review, data interpretation, and manuscript revision. Ms Kawamura, Mr Mizuno, and Dr Shiba contributed to the study concept, data interpretation, and manuscript revision. All authors approved the final version of the submitted manuscript.

Disclosure of conflict of interest

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author or upon any organization with which the author is associated.

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