Physical functioning measures and risk of falling in older people living in residential aged care facilities

Nicholas Wilson, Sarah Hilmer, Lyn March, Ian Cameron, Stephen Lord, Rebecca Mason and Philip Sambrook

Abstract:

Background: Frail older individuals living in residential aged care facilities (RACFs) have impaired physical function compared with to older people living in the community. In residents of RACFs, we aimed to produce sex-specific means and empirical norms of objective physical function measures to ascertain whether these measures are predictors of falls.

Methods: Data were extracted from a large cohort study investigating fall and fracture rates in RACFs in the Northern Sydney Health Area, Australia.

Results: Study participants ($n = 602$, 70.9% female) were recruited from 51 RACFs. Cohort means ($\pm$ standard deviation) for females were for grip strength (GS) 16.8 ± 5.3 kg, simple reaction time (RT) 384 ± 154 ms, walking speed (WS) 0.56 ± 0.20 ms⁻¹, balance category (B) 3.8 ± 1.1 and sit to stand category (STS) 3.6 ± 0.5 . For males, means were for GS 28.8 ± 7.8 kg, RT 335 ± 150 ms, WS 0.62 ± 0.22 ms⁻¹, B 4.1 ± 1.1 and STS 3.7 ± 0.5 . Means of B and STS decreased significantly over the 1-year study period for males and females ($p < 0.001$). Individual multivariate negative binomial regression models for each functional outcome showed having a WS < 0.6 ms⁻¹ (IRR = 1.37, 95% CI = 1.03–1.84), a STS score of 3 (IRR = 1.39, 95% CI = 1.09–1.79) and B category of 3 or 5 (IRR = 1.69, 95% CI = 1.29–2.22) were significantly associated with an increased fall rate.

Conclusions: This study establishes normative values for physical function tests in mobile residents of RACFs and demonstrates that walking speed, balance and sit to stand impairments are associated with falls in this group.

Keywords: functional measures, falls, older people, medication, aged care facilities

Introduction

Frequently, individuals move into residential aged care facilities (RACFs) because physical or mental impairments prevent them from living a safe, mobile and independent life in the community [The Royal Australian College of General Practitioners, 2005]. Impairments of objective measures of physical function are associated with nursing home placement, disability, frailty and falls in community dwelling older people [Tinetti and Kumar, 2010; Kannus *et al.* 2005; Klein *et al.* 2005; Guralnik *et al.* 1995; Tinetti and Speechley, 1989]. The importance of physical function testing as part of a multidisciplinary health assessment upon admission to a RACF is well documented [Australian Commission on Safety and Quality in Health Care, 2009].

As older frail individuals have only recently been included in epidemiological studies it is now of interest to document and analyse possible changes in functional measures over time and to ascertain whether they exhibit consistent relationships with falls. In a previous study, we failed to find any strong associations between sedative and anticholinergic drug exposure and impairments in physical function within residents of RACFs, in contrast to those seen in community dwelling older people [Wilson *et al.* 2010]. Floor effects of the functional tests are present in many residents of aged care facilities who are often severely physically or cognitively impaired. We aimed to establish empirical norms of objective physical functional measures for this frail older population and to determine whether

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functional status predicts falls within residents of RACFs, as seen in community dwelling older people.

Methods

Participants

Data were obtained from a multicentre cluster-randomized controlled trial designed to determine the effect of sunlight exposure and increased calcium intake on fall and fracture rates in older people living in RACFs in the Northern Sydney Central Coast Health (NSCCH) area, Australia [March *et al.* 2009]. Individuals were eligible if they were ambulant, aged over 70 years, and likely to survive for 12 months as informed by facility staff. Exclusion criteria were skin cancer within the last 3 years and taking vitamin D or calcium supplements in the last 6 months. Verbal and written consents were obtained and in cases of cognitive impairment, sought from the appropriate person as defined by legislation. The project was approved by the NSCCH Human Research Ethics Committee and registered on the Australian New Zealand Clinical Trials Registry (ACTR number: ACTRN12607000089437).

Comorbidities, medication, cognition and functional status

Medical conditions were noted from nursing administration records, face-to-face interview and RACF staff interviews. A comorbidity score was calculated by summation of the following diseases: stroke, diabetes, osteoporosis, Parkinson's disease and arthritis, allowing for the limited medical information available and modified from the Functional Comorbidity Index [Groll *et al.* 2005]. Medication was noted from signed nursing administration records and in the case of self-medication, prescription of medication containers sighted by research team and cross checked with administrative records. Cognitive impairment and depression were assessed using the Mimi-Mental State Exam (MMSE) and Geriatric Depression Scale (GDS), respectively [Okimoto *et al.* 1982; Yesavage *et al.* 1982; Folstein *et al.* 1975].

Objective measures of physical function were performed by the research team at baseline and 12 months. Grip strength (GS, kg) was measured using a North Coast Medicals hand dynamometer (Sportstek Physical Therapy Supplies Pty Ltd, Victoria, Australia). The maximum reading

from two trials on each hand was used [Bandinelli *et al.* 1999]. Walking speed (WS, ms^{-1}) was assessed by a timed walk over 8 feet (2.44 m), and calculated as the average over two timed trials to the nearest 0.1 second. Participants were encouraged to walk without a walking aid [Guralnik *et al.* 1994]. A standing balance test (B) was undertaken by grading the participant's ability to stand on a block of foam. Balance was graded into five categories ranging from 1 (unable to stand on the floor for 30 seconds) to 5 (being able to stand on the foam unaided for 30 seconds) [Delbaere *et al.* 2008]. A sit to stand test (STS) was conducted with participants seated in a standard chair (43 cm high) and asked to stand up without using their hands if they felt it was possible. If not, participants were asked to stand using arm support. Number of attempts, technique and a score ranging from 4 (stood with no help), 3 (used arms), 2 (needed human help) to 1 (unable) were noted [Seaby and Torrance, 1989]. Reaction time (RT, ms) was ascertained using a reaction time device (Neuroscience Research Australia, NSW, Australia) with a light stimulus and a finger press as the response. Five practice trials were followed by 10 test trials from which an average was taken [Lord *et al.* 2003].

All residents were followed for 12 months ($n = 526$). Sixty-three subjects died during the observation period and 13 withdrew from the study. Falls were defined as 'events that resulted in a person coming to rest unintentionally on the ground or other lower level, not as a result of a major intrinsic event or an overwhelming hazard' [Gibson *et al.* 1987]. Fall data recording was undertaken by a team of three trained researchers and involved monthly reading of nursing notes and incident reports, randomly cross checked for accuracy [Lord *et al.* 2003].

Statistical analysis

Intraclass correlation coefficients (ICCs) were used to evaluate the test/retest reliability of WS and GS. Receiver operating characteristics (ROCs) curves were examined for each test to determine the Youden Index, or optimal cutoff point that best differentiate fallers and nonfallers [Schisterman *et al.* 2005]. Univariate and subsequent multivariate negative binomial regression models were constructed to ascertain risk factors for falls within this population [Ullah *et al.* 2010]. Incident rate ratios (IRRs) were also calculated for a range of potential confounders.

Variables significantly associated ($p < 0.05$) with falls were included in a multivariate model, after conducting backward stepwise elimination of potential confounders. Analyses were performed using SAS 9.1 (SAS Institute, Cary, NC, USA) and SPSS 16.0 (SPSS Inc. Chicago, IL, USA).

Results

At baseline, there were 602 participants in the cohort, with mean age ($\pm$ standard deviation) of 85.7 ± 6.4 years (range 70–107), and 70.9% were female (Table 1). The mean number of medications taken was 6.0 ± 3.0 . Baseline and 12-month physical function test means and quintiles are also shown in Table 1. High WS reliability was

confirmed as indicated by an ICC of 0.99 ($p < 0.001$) at baseline. GS was similarly reliable (ICC 0.96, $p < 0.001$). Cohort means at baseline were for males: GS, $28.8 (\pm 7.8 \text{ kg})$; RT, $335 (\pm 150 \text{ ms})$; WS, $0.62 (\pm 0.22 \text{ ms}^{-1})$; B $4.1 (\pm 1.1)$; and STS, $3.7 (\pm 0.5)$; and females: GS, $16.8 (\pm 5.3 \text{ kg})$; RT, $384 (\pm 154 \text{ ms})$; WS, $0.56 (\pm 0.20 \text{ ms}^{-1})$; B $3.8 (\pm 1.1)$; and STS, $3.6 (\pm 0.5)$. For those who had test measures at both baseline and 12 months, means statistically decreased for males in B, $0.6 (\pm 1.2)$ ($p < 0.001$), and STS, $0.4 (\pm 0.84)$ ($p < 0.001$). In females similar declines in mean function were seen in B, $0.6 (\pm 1.1)$ and STS, $0.3 (\pm 0.7)$ (both $p < 0.001$). Conversely the mean GS for women increased by 1.0 kg (± 3.9)

Table 1. Characteristics of the 602 FREEDOM study participants.

Characteristic	Males $n = 175$ (29.1%)				Females $n = 427$ (70.9%)			
	Baseline	12 month	Change	p -value	Baseline	12 month	Change	p -value
Age (years $\pm$ SD)	83.5 ± 6.6				86.4 ± 6.2			
Mean comorbidity score* ($\pm$ SD)	0.9 ± 0.8				1.0 ± 0.9			
Mean MMSE score (/30 $\pm$ SD)	24.6 ± 4.6	22.9 ± 6.4	-1.6 ± 3.9	<0.001	23.9 ± 5.2	22.4 ± 6.2	-1.5 ± 3.6	<0.001
Mean GDS score (/15 $\pm$ SD)	4.7 ± 3.3	5.0 ± 3.4	0.3 ± 3.0	0.3	3.7 ± 2.8	4.0 ± 3.0	0.3 ± 2.4	<0.05
Mean GS (kg $\pm$ SD)	28.8 ± 7.8	29.1 ± 7.3	0.3 ± 5.4	0.51	16.8 ± 5.3	17.8 ± 5.0	1.0 ± 3.9	<0.001
Percentile 20	22	22			12	14		
40	26	28			15	16		
60	31	31			18	19		
80	36	36			21	22		
Mean RT (ms $\pm$ SD)	335 ± 150	317 ± 131	-19 ± 150	0.42	384 ± 154	388 ± 187	4 ± 171	0.78
Percentile 20	229	211			260	252		
40	270	237			317	294		
60	303	307			378	366		
80	416	466			463	477		
Mean WS (ms^{-1} $\pm$ SD)	0.62 ± 0.22	0.60 ± 0.21	-0.01 ± 0.15	0.35	0.56 ± 0.20	0.56 ± 0.21	-0.01 ± 0.16	0.49
Percentile 20	0.42	0.40			0.37	0.37		
40	0.52	0.53			0.50	0.47		
60	0.65	0.65			0.60	0.58		
80	0.77	0.75			0.72	0.73		
Mean B (scale 1–5 $\pm$ SD)	4.1 ± 1.1	3.5 ± 1.4	-0.6 ± 1.2	<0.001	3.8 ± 1.1	3.3 ± 1.3	-0.6 ± 1.1	<0.001
Percentile 20	3	2			3	2		
40	4	3			4	3		
60	5	4			4	4		
80	5	5			5	5		
Mean STS (grade 1–4 $\pm$ SD)	3.7 ± 0.5	3.3 ± 1.0	-0.4 ± 0.84	<0.001	3.6 ± 0.5	3.3 ± 0.9	-0.3 ± 0.7	<0.001
Percentile 20	3	3			3	3		
40	4	3			4	3		
60	4	4			4	4		
80	4	4			4	4		

*Comorbidity score includes: stroke, arthritis, osteoporosis, Parkinson's disease and diabetes. Low scores in the reaction time (RT) and in the Geriatric Depression Scale (GDS) and high scores in the Mini Mental State Examination (MMSE), grip strength (GS), walking speed (WS), balance (B) and sit to stand (STS) indicated better performance. Number of subjects who could undertake the physical test at baseline and 12 months are: for men, GS = 134, RT = 44, WS = 118, B = 112 and STS = 138; and women, GS = 352, RT = 135, WS = 329, B = 331 and STS = 357.

($p < 0.001$). No significant changes in RT and WS were observed.

The cut points that best differentiated fallers from nonfallers were rounded for feasibility. They were 0.6 ms^{-1} for WS, 19 kg for GS and 250 ms for RT. The risk factors that were significantly associated with increased rate of falling in univariate negative binomial regression analyses remained significant in subsequent multivariate negative binomial models. The multivariate model showed that fall rate increased if the individual, was of male sex (IRR = 1.35, 95% CI = 1.04–1.75), was cognitively impaired (IRR = 1.62, 95% CI = 1.28–2.07), had depressive symptoms (IRR = 1.41, 95% CI = 1.06–1.88), had a history of falls in the past year (IRR = 2.15, 95% CI = 1.69–2.74), used a walking stick or walker (IRR = 1.56, 95% CI = 1.36–1.78), suffered from incontinence (IRR = 1.24 per category increase, 95% CI = 1.07–1.45), had a WS less than 0.6 ms^{-1} (IRR = 1.37, 95% CI = 1.03–1.84), had a STS score of 3 (IRR = 1.39, 95% CI = 1.09–1.79) and B category of 3 or 5 (IRR = 1.69, 95% CI = 1.29–2.22) (Table 2).

Strong nonlinear relationships with falls rates were observed with B and STS ability. Fall rates were highest in those with intermediate balance

(category 3) and lowest in those with poor and good balance (categories 1 and 5; $X^2 = 33.48$, 4df, $p < 0.001$). Similarly, fall rate was highest in those who could stand using their arms (category 3) and lowest in those who could stand without the use of arms and in those who required help to stand (categories 2 and 4; $X^2 = 35.02$, 2df, $p < 0.001$). GS and RT were significantly, but weak-moderately correlated with all other functional measures ($r = 0.14$ – 0.45 , all $p < 0.01$) whilst B and STS were moderately correlated with each other ($r = 0.55$, $p < 0.001$) but not with RT.

Discussion

The study findings indicate that low levels of physical function were very common in frail older people living in RACFs. It provides robust measurements of physical function that could serve as reference values for both males and females when undertaking future studies in this older population.

Both B and STS tests show rapid deterioration over 1 year. The WS, RT and GS appear to have reached an impaired level that does not decrease by any discernable amount over a 1-year period. In 2005, Cesari and colleagues showed older people with a mean age of 74.2 ± 2.9 , had a greater risk of falls, hospitalisation disability and

Table 2. Univariate and multivariate risk factors for falling.

Risk factor; unit for IRR change	IRR [95% CI] Univariate	IRR [95% CI] Multivariate
Age; 1 year	1.01 [0.98, 1.03]	
Sex; male	1.33 [1.01, 1.75] [‡]	1.35 [1.04, 1.75] [‡]
Cognitive impairment; MMSE <23	1.37 [1.06, 1.77] [‡]	1.62 [1.28, 2.07] [‡]
Depressive symptoms; GDS ≥ 7	1.94 [1.44, 2.61] [‡]	1.41 [1.06, 1.88] [‡]
History of falls in past 12 months; yes/no	2.51 [1.95, 3.22] [‡]	2.15 [1.69, 2.74] [‡]
Walking aid; none/stick/walker	1.69 [1.47, 1.93] [‡]	1.56 [1.36, 1.78] [‡]
Incontinence; none/sometimes/all the time	1.34 [1.14, 1.57] [‡]	1.24 [1.07, 1.45] [‡]
More than six medications; yes/no	1.11 [0.86, 1.43]	
Comorbidities; one point*	1.08 [0.94, 1.25]	
WS; $<0.6 \text{ ms}^{-1}$	2.39 [1.84, 3.10] [‡]	1.37 [1.03, 1.84] ^{§‡}
GS; $\leq 19 \text{ kg}$	1.03 [0.80, 1.34]	1.00 [0.75, 1.34] [§]
RT; $>250 \text{ ms}$	1.61 [0.99, 2.64]	1.04 [0.65, 1.67] [§]
STS; category 3; yes	2.04 [1.59, 2.56] [‡]	1.39 [1.09, 1.79] ^{§‡}
B; category 3; yes	2.48 [1.90, 3.23]	1.69 [1.29, 2.22] ^{§‡}

Low scores in the reaction time (RT) and in the Geriatric Depression Scale (GDS) and high scores in the Mini Mental State Examination (MMSE), grip strength (GS), walking speed (WS), balance (B) and sit to stand (STS) indicated better performance.

*Comorbidity score includes: stroke, arthritis, osteoporosis, Parkinson's disease and diabetes. Incidence Rate Ratio (IRR) shown with 95% confidence intervals [CI].

§IRR from independent negative binomial model than other physical function tests all including sex, cognitive impairment, depressive symptoms, use of walking aid and incontinence as confounders. More than six medications, comorbidities and age excluded from multivariate analysis.

[‡] $p < 0.05$.

death when WS was less than 1 ms^{-1} [Cesari *et al.* 2005]. In this cohort, only 14 individuals (2.4%) had a WS of greater than 1 ms^{-1} , highlighting the underlying poor level of physical function in the group. This highlights the need for more appropriate cut points with regard to clinical assessment within this population. In this case 0.6 ms^{-1} , as used by Gallucci and colleagues is more useful to divide the population [Gallucci *et al.* 2009].

Further illustrative of these poor functional measures is the weak GS of the cohort. GS has been highlighted as an important tool in the screening for sarcopenia in a wide cross section of community dwelling older people, with cut points of 30.3 kg for men and 19.3 kg for women predicting poor mobility [Lauretani *et al.* 2003]. In our population, 61.2% of men and 69.8% of women fell into this high-risk category. Age- and sex-specific equations were used to estimate height from lower leg length [Chumlea and Guo, 1992] and BMI was calculated to ascertain whether the individual was considered frail as per predefined criteria using GS as an indicator [Fried *et al.* 2001]. In our population the prevalence of weak GS that is consistent with the frailty syndrome at baseline was 61% for male and 64% for female.

The high frailty rate can make testing problematic as floor effects are common with physical function scores so low that any further impairment may be difficult to detect. Similarly, small meaningful improvements may also be imperceptible. Females showed a statistically significant increase in GS mean of 1 kg, however it would be hazardous to give this too much importance alone. Despite the low values, large variation in baseline and follow up GS were apparent whereupon individuals improved/worsened sufficiently to reclassify their frailty status. The clinical significance of the change in GS cohort mean over 1 year is unclear, however when viewed as individual improvements/deteriorations, the sometimes large changes seen reinforce why GS is such an important tool in classifying functional status [Lauretani *et al.* 2003].

The strong nonlinear relationships seen with fall rate and B and STS ability are similar to those observed previously [Lord *et al.* 2003; Studenski *et al.* 1994; Tinetti, 1987]. Our results mirror these studies, reinforcing that those who can stand with the use of the arms and have

intermediate balance have the highest fall rate and those with the best and worst standing ability and balance have the lowest. The B, STS ability and WS were the three physical function tests that proved to be significantly associated with fall rate when investigated using multivariate models. These three simple tests are an important component of fall screening. Surprisingly, we found no associations of impairments in RT and GS with increased fall rate. RT testing in this population proved to be problematic with a significant number of individuals not being able to undertake the testing due to mental or physical impairments, thus both reducing statistical power for falls analysis and giving data that reflects the better-performing individuals. Poor GS has been shown to be a risk factor for falling in community dwellers, however we failed to find any association in RACF residents [American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001; Tinetti *et al.* 1995].

Other risk factors for falling in this population were being male, having cognitive impairment, showing depressive symptoms, having a history of falls in the past year, use of walking aid and suffering from incontinence, all of which have been identified as risk factors in community dwelling older people [Kannus *et al.* 2005; Tinetti and Speechley, 1989]. In contrast to community dwelling older people we found no significant association with increase fall rate and age, polypharmacy (six or more medications) and comorbidity score [Tinetti and Kumar, 2010; Neutel *et al.* 2002; Tinetti and Williams, 1998; Tinetti *et al.* 1988].

Data reliability is a strength of this study as all of the data collection and functional testing was undertaken by a team of three trained researchers. This team performed objective and clinically validated tests thus reducing researcher-induced variation whilst establishing workable references of physical function. The ICCs seen indicate the testing was very precise. Negative binomial regression models are preferred when analysing falls as they have recently been proven to give a superior statistical fit than other models [Ullah *et al.* 2010]. The use of negative binomial modelling in our population can be justified as the dispersion is significantly different from zero in all models. Furthermore, the assessment of the goodness of fit of the final models using

chi-squared tests on the difference of log likelihood proved these models fit the data significantly better than null model (all $p < 0.001$).

This study has limitations. The exclusion criteria limit this being a true representation of the population in RACFs [Sanchez Riera *et al.* 2008]. This study focused on ambulatory fallers, and therefore did not include wheelchair-bound or immobile residents of the RACFs. Our measures give accurate references of physical function measures of mobile residents which may be higher than that RACF population as a whole. Despite a team of trained researchers undertaking all of the interviews and functional analysis tests, the high prevalence of cognitive impairment and depressive symptoms can potentially weaken the quality of the data [The Royal Australian College of General Practitioners, 2005]. Tests that require an individual to exert maximal effort are the most affected which could be reasoning for the observed increase in GS over the 1-year follow-up period. However, interestingly, there was no statistically significant difference ($p < 0.05$) in the change in all physical function tests over the 12-month study when comparing individuals who are cognitively impaired or have depressive symptoms with those who do not.

This study establishes reference values for physical function tests in mobile residents of RACFs. We confirmed the notion that fall rate has a non-linear relationship with B and STS. Furthermore, we found that not all physical function parameters are related to falls, and that the risk factors are different to those in older individuals who live in the community. Further work is required to elucidate the physiological changes which may be associated with functional status decline and falls in this elderly population.

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Conflict of interest statement

None declared.

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