Using Timed Up-and-Go to Identify Frail Members of the Older Population

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Background. Fried's definition of frailty is widely used but its measurement is problematic. Timed up-and-go (TUG) is a simple measure of mobility that may be a useful proxy for frailty. Here, we describe the distribution of frailty and TUG in the older population of Ireland and discuss the extent to which TUG identifies the frail and prefrail populations.

Methods. A total of 1,814 participants of The Irish Longitudinal Study on Ageing aged 65 and older completed a comprehensive health assessment. Frailty was defined by having three or more of low gait speed, low grip strength, unintentional weight loss, self-reported exhaustion, and low physical activity. ROC curves were used to identify how well TUG discriminates the frail and prefrail populations and whether TUG improves on gait speed as a single objective measure of frailty.

Results. Among the Irish population aged 65 and older, 7.7% were frail and 44.0% were prefrail. TUG identifies frail members of the population well (AUC = 0.87) but is less able to discriminate the nonfrail from the prefrail or frail populations (AUC = 0.73). TUG captures the components of frailty that become more common with age but does not discriminate the components that do not, for example, unintended weight loss or exhaustion. There is no advantage in using TUG instead of gait speed with respect to identifying frailty.

Conclusions. TUG is a sensitive and specific measure of frailty that offers advantages in its measurement where the full application or interpretation of Fried's criteria is impracticable; however, TUG cannot be used to reliably identify prefrail individuals.

FRAILTY is the state of vulnerability to stressors that is independent of any specific disease or disability but that is common in older people and predisposes them to various adverse health outcomes (1). Identifying frail individuals and developing interventions to reduce frailty is a research priority. Frailty is an increasingly common target of epidemiological studies and more recently of intervention trials (2–4) and is an important factor for other investigations of the efficacy of treatments in older people (5) but difficulties in its measurement prevent its widespread use.

There are many definitions of frailty (6–12). One that has gained widespread acceptance is the "phenotypic" definition of Fried and colleagues (9). This multidomain measure incorporates measures of weakness, slowness, low physical activity, weight loss, and exhaustion, which reflect aspects of the cycle of decline that is hypothesized to underlie the frailty syndrome (1).

Timed up-and-go (TUG) is a well-known test of functional mobility (13). Individuals rise from a chair of standardized height, walk a fixed distance of 3 m, turn, return to the chair, and sit down again. The task requires a transfer from standing to sitting and vice versa, walking and turning, and so is influenced by walking speed, strength, and balance as well as having a substantial cognitive involvement. TUG is linked to regular physical activity (14), global health decline (15), disability in activities of daily living (15–17), and falls (15,17–19). Since TUG captures many aspects of age-related physiological decline and predicts adverse outcomes without being specific to any particular disease, we hypothesize that TUG could be a useful marker for the phenotypic definition of frailty in the general older population.

TUG offers a number of advantages if it could be used as a measure of frailty. TUG is an objective single continuous measure that is quick and simple to apply in all settings and requires no specialized equipment. This makes it attractive for epidemiological surveys where the subjective components of frailty are difficult to compare across subpopulations and in settings where assessment of each of the frailty criteria can be impracticable.

Measures of gait speed are also simple and powerful tests but vary with respect to the time or distance travelled, whether turns are included, and whether the patient is standing or moving at the start of the test (20). On the other hand, TUG is well standardized across settings in which it has been used. Therefore, individual TUG times can be compared easily with published reference values, within individuals to measure change, and between populations for comparative studies.

Here, we describe the operationalization of the phenotypic definition of frailty in The Irish Longitudinal Study on Ageing (TILDA). We describe the distribution of frailty and TUG performance among 1,814 participants aged 65 and older who underwent a comprehensive health assessment, and we explore the extent to which TUG identifies the "frail" and "prefrail" members of the older population. Finally, we examine whether TUG is a better discriminator of the four "non-gait" components of frailty than is gait speed.

METHODS

Sample

TILDA includes 8,175 participants representative of the community-living population aged 50 and older in Ireland. Households were selected in geographic clusters from a list of all Irish residential addresses. Each household was visited by an interviewer and any resident aged 50 or older as well as their spouse or partner was invited to participate. The household response rate was 62.0%. Ethical approval was obtained from the Trinity College Dublin Research Ethics Committee and all participants provided written informed consent. Those with cognitive impairment that prevented consent being given were not included in the study. Participants were interviewed in their homes and answered questions on many aspects of health, social interactions, and financial circumstances. Each participant was invited to travel to a health centre for a comprehensive health assessment. The sampling procedure, the home interview, and the health assessment have all been described in detail previously (21). Those aged 65 and older who also attended the health centre assessment ($N = 1,814$) were included in this analysis.

Measures of Frailty and Chronic Disease

Frailty was operationalized as closely as possible to the phenotypic definition of Fried and colleagues (9). It was decided to follow the methods of Fried to produce population-specific cut-points and not to use the absolute values reported. This was done primarily because measures were not directly comparable, in particular, differences in the assessments of handgrip strength (using a Baseline dynamometer), physical activity (based on the short form of the International Physical Activity Questionnaire), and walking speed (using a GAITRite portable walkway instead

of a timed walk from a standing start) that made using the absolute cut-points reported by Fried and colleagues inappropriate.

Two measures of handgrip strength were taken from the dominant hand, and the mean of these readings was calculated. The 20th percentile of handgrip strength was found, adjusted for sex and body mass index (BMI), and any individual scoring below this value was deemed to have low grip strength. BMI was divided into sex-specific quartiles but cutoffs were found to be similar within many of the groups. Therefore, the cutoffs applied were 20.5 kg for men with BMI less than 24, 21.5 kg for men with BMI of 24–26, and 23 kg for men with BMI greater than 26. For women, the cutoff was 11.5 kg for those with BMI less than 23 and 13 kg for those with BMI greater than 23.

Gait speed was measured using the GAITRite portable electronic walkway system (CIR Systems Inc, Havertown, PA). Participants performed two walks at their usual pace along the 4.88 m (16 ft) walkway. They started and finished walking 2.5 m before and 2 m after the walkway to allow for acceleration and deceleration. The two walks were combined and average gait speed was calculated. Participants who completed the walk slower than the 20th percentile (sex and height specific) of the population older than 65 years were considered to have low gait speed. The cutoffs used were 109.7 cm/s for men less than 173 cm, 116.7 cm/s for men taller than 173 cm. For women, the cutoff was 100.7 cm/s for those less than 159 cm and 108.4 cm/s for those taller than 159 cm.

Two items from the 20-item Centre for Epidemiological Studies Depression scale (22) were combined to make the measure of exhaustion, following the approach of Fried and colleagues (9). Participants were asked how often they felt that "I could not get going" and "I felt that everything I did was an effort" with four possible responses to each question: never, rarely, sometimes, or often. A response of "sometimes" or "often" to either question is considered "exhaustion."

Physical activity was measured using the short form of the International Physical Activity Questionnaire (23). The time spent walking and in vigorous and moderate physical activity was recorded, weighted, and combined with the participant's weight in kilograms to provide estimates of energy expenditure kilocalories (kcal) per week. Participants who reported less activity than the sex-specific 20th percentile of the population (<868 kcal/wk for men, <309 kcal/wk for women) were considered to have low physical activity.

Weight loss was ascertained by the question "In the past year, have you lost 10 pounds (4.5 kg) or more in weight when you were not trying to?"

Chronic diseases were ascertained by a self-report of a doctor's diagnosis of heart disease, cataracts, hypertension, high cholesterol, stroke, diabetes, lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson's disease, peptic ulcer, or hip fracture. The number of chronic diseases was classified as 0, 1, 2, or "3 or more."

Timed-Up-and-Go

Each participant performed the TUG test. Participants were asked to stand from a seated position, walk 3 m at their usual pace, turn around, walk back to the chair, and sit down. The chair had armrests and the seat was 46 cm high. TUG was only performed once. Walking aids were allowed and no instructions were given about the use of arms. The time taken from the command "Go" to when the participant was sitting with their back resting against the back of the chair was recorded using a stopwatch. Participants were instructed to walk at their usual pace.

Analysis

Each frailty component was operationalized as described earlier, and the number of components present was added. Those with one or two components were prefrail. Those with three, four, or five components were classified as frail.

Prevalences were estimated by applying inverse probability weights, corresponding to the probability that a member of the community-living older population of Ireland selected at random underwent the TILDA health assessment. Among those who underwent a health centre assessment, missing data are rare. Those with missing data on some components of frailty but with enough data to be certain of a classification of frailty (ie, those with three or more positive components) were classified as frail.

To assess how TUG could be used as a measure of frailty, the distribution of TUG times was described within subpopulations defined by the number of frailty components. The ability of TUG to discriminate those with each frailty component was measured using area under the Receiver Operating Characteristic (ROC) curve (Area Under the Curve [AUC]).

Two dichotomizations of the sample were considered, first the frail versus prefrail and nonfrail and second the frail and prefrail versus nonfrail. The sensitivity, specificity, and positive predictive value (PPV) of TUG to discriminate each group was found at integer second cutoffs. Logistic regression was used to determine whether the relationship between TUG and frailty was confounded by age, sex, and chronic disease and the extent to which TUG captures the relationship between frailty and age. Finally, we compared TUG with a continuous measure of gait speed with respect to identifying those with any of the four "non-gait" frailty components.

All analysis was conducted using Stata Version 12.0.

Results

Characteristics of the Sample

Of the 3,507 participants aged 65 and older recruited to TILDA, 1,814 underwent the health centre assessment. Of these, 51% were women and the median age was 70 (inter-quartile range: 67–75, range: 65–93). TUG was successfully completed by 1,793 (99%) participants and 1,752 (97%) had sufficient data for each component of the frailty score to be calculated.

Prevalence of Frailty Components

The prevalence of each frailty component is shown in Table 1. Slowness and weakness become more common with age for both sexes. Low physical activity is around twice as common among those aged 75 and older as it is among the 65–74 age group; however, the proportion of those reporting exhaustion or weight loss does not increase with age. Exhaustion is more common in women in both age groups, but there is little sex difference in the prevalence of other frailty components, primarily due to the sex stratification of cutoff scores. In total, 81 participants are frail and 716 are prefrail, corresponding to prevalence estimates of 7.7% and 44.0% of the population aged 65 and older, respectively. No participants met all five frailty criteria. Among those aged 75 and older, 13.5% are frail and 53.8% are prefrail.

Relationship Between TUG and Frailty

TUG times within groups defined by the number of frailty components are shown in Figure 1. Conversely, the distribution of frailty by TUG time is shown in Figure 2. This illustrates that while there is a clear increase in TUG time with increasing frailty and that the frail and nonfrail populations are distinct, overlap does occur between the nonfrail and prefrail and between the prefrail and frail groups.

Table 1. Prevalence of Frailty Components and the Proportion of the Older Irish Population Considered Prefrail and Frail by Age and Sex

| Age	65–74				75+			
Sex	Men		Women		Men		Women	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Exhaustion	7.8	5.7,10.5	10.0	7.7,12.9	6.2	3.3,11.4	10.4	5.9,17.6
Weight loss	5.9	4.0,8.6	7.8	5.7,10.7	7.0	3.4,13.8	8.2	4.6,14.0
Low activity	15.4	12.3,19.0	17.1	14.1,20.7	35.7	28.1,44.1	29.9	22.6,38.3
Slowness	14.7	11.8,18.3	13.7	11.0,17.0	38.4	31.0,46.4	39.5	31.4,48.3
Low grip	10.7	8.2,13.9	14.2	11.3,17.6	33.2	25.5,42.1	30.9	23.5,39.3
Prefrail	36.4	32.3,40.8	43.1	38.9,47.5	69.1	61.7,75.7	66.2	58.0,73.6
Frail	2.9	1.7,5.0	3.5	2.1,5.7	12.5	7.5,19.9	14.3	9.0,22.2
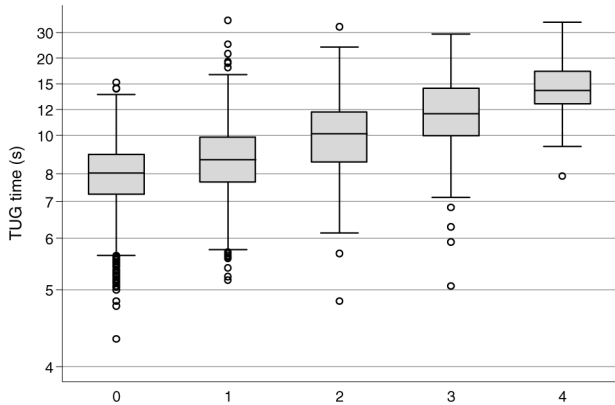
Figure 1. Distribution of timed up-and-go (TUG; seconds) by number of frailty components. No participants had all five components.
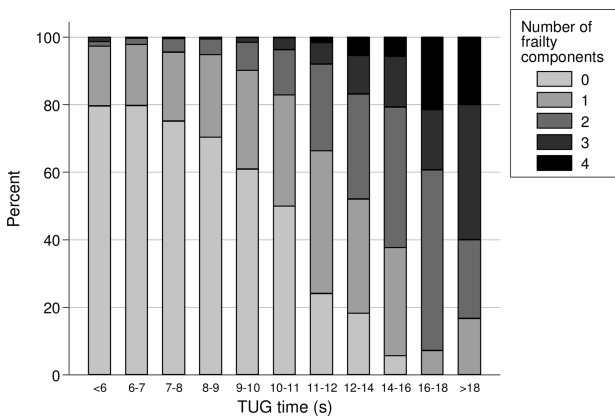

Figure 2. Distribution of the number of frailty components by timed up-and-go (TUG) time. Those with 0 components are "nonfrail," those with 1 or 2 are "prefrail," and those with 3 or 4 are "frail."

Univariate logistic regression models showed that both age (odds ratio [OR] = 1.15/y, 95% CI: 1.11–1.19) and TUG (OR = 1.61/s, 95% CI: 1.49–1.74) have strong associations with frailty (Table 2). After adjusting for sex and chronic disease, the effect of age is largely unchanged (OR = 1.14, CI: 1.10–1.18). However, after adding TUG to the model, there is no longer a significant effect of age (OR = 1.04, 95% CI: 0.99–1.09), although the effect of TUG is largely unchanged from the univariate analysis (OR = 1.57, 95% CI: 1.44–1.72). This suggests that TUG captures most of the age-related contribution to frailty and that an assessment of frailty based on TUG does not need to take age into account. Chronic disease remains an independent predictor of being classified as frail in the final model.

Using TUG to Identify Frail Older People

TUG can identify frail members of the population well (AUC = 0.87) but is less able to discriminate the nonfrail from the prefrail or frail populations (AUC = 0.73). Table 3 shows the sensitivity, specificity, and PPV of TUG when used to identify the frail and prefrail populations at different cutoffs.

Table 2. Logistic Regression Models Showing the Effects of Timed Up-and-Go (TUG) and Age on the Odds of Being Classified as Frail (Odds Ratios [ORs] and 95% Confidence Intervals [CI] Shown)

	Model 1	Model 2	Model 3	Model 4
Age (y)	1.15***		1.14***	1.04
	[1.11,1.19]		[1.10,1.18]	[0.99,1.09]
TUG time (s)		1.61***		1.57***
		[1.49,1.74]		[1.44,1.72]
Sex			0.99	0.84
			[0.62,1.58]	[0.49,1.44]
No chronic disease			Ref.	Ref.
One chronic disease			1.78	1.31
			[0.36,8.70]	[0.24,7.04]
Two chronic diseases			3.38	3.5
			[0.76,15.13]	[0.71,17.13]
Three or more chronic diseases			7.96**	4.82*
			[1.91,33.2]	[1.06,21.89]

Notes. Models 1 and 2 show the univariate effect of age and TUG. Model 3 shows that the age effect is not explained by adjusting for sex or chronic disease. Model 4 shows that after adding TUG to the model, the age effect is greatly reduced but the effect of chronic disease remains.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3. Sensitivity and Specificity and Positive Predictive Value (PPV) of Timed Up-and-Go (TUG) for Identifying Frail and Prefrail Members of the Older Population at Integer Second Cutoffs

TUG greater than (s)	Frail			Prefrail or frail		
	Sensitivity (%)	Specificity (%)	PPV (%)	Sensitivity (%)	Specificity (%)	PPV (%)
5	100	0	7	100	0	51
6	100	1	7	100	1	51
7	100	6	7	98	9	53
8	97	18	8	92	26	57
9	95	42	11	77	55	64
10	93	62	16	60	77	74
11	80	78	22	44	93	86
12	72	86	29	31	96	90
13	52	92	33	20	99	95
14	42	94	36	15	99	95
15	36	96	43	12	100	100
16	29	98	52	8	100	100
17	21	99	54	5	100	100
18	14	99	63	3	100	100
19	7	100	52	2	100	100
20	6	100	52	2	100	100

With respect to identifying the frail population, a relatively high cutoff (TUG >16 s) is required to achieve a PPV of more than 50%, at which 29% of the frail population are identified (specificity 98%). Using a lower cutoff of 10 seconds would identify 93% of the frail population but with a PPV of only 16%. Nevertheless, when using this cutoff, 62% of the not frail (ie, nonfrail or prefrail) population would be excluded, suggesting that TUG using this cutoff would have value as a screening test able to exclude a large proportion of the population while capturing a substantial majority of frail individuals.

Every individual who took 15 seconds or longer to complete TUG was prefrail or frail. However, the sensitivity to identify prefrail individuals at this cutoff is poor, with only

12% of the frail or prefrail population taking 15 seconds or more. Using a lower cutoff of 12 seconds identifies a subgroup that includes 31% of the prefrail/frail population and excludes 96% of the nonfrail population, leading to a PPV of 90%, however, there is no cutoff that identifies a substantial proportion of the prefrail population with a PPV significantly higher than the population prevalence of prefrailty.

Comparing TUG and Gait Speed

TUG time and gait speed are highly correlated (Spearman's rank correlation = −0.75). Gait speed is generally a marginally better discriminator of the four nongait components of the frailty measure than TUG. Gait speed identifies those reporting exhaustion (AUC = 0.61 vs. 0.58, $p = .063$) and low physical activity (AUC = 0.66 vs. 0.64, $p = .046$) slightly better than TUG, whereas the ability to discriminate those reporting weight loss (AUC = 0.59 vs. 0.60, $p = .575$) and poor grip strength (AUC = 0.67 vs. 0.66, $p = .397$) is equal. The fact that TUG does not discriminate those with exhaustion, low activity, and weight loss mirrors the finding above that while TUG captures the age-related component of frailty, it does not appear to capture at all the aspects of frailty that do not increase in prevalence with age.

Discussion

We have examined the relationship between frailty as defined using Fried's criteria and the TUG test in a large sample representative of the community-living population of Ireland aged 65 years and older and shown the power of TUG to identify the frail population.

Our estimates of the prevalence of frailty and prefrailty are similar to those previously seen in other European and North American populations (6,9,24,25). However, international comparability is limited by the subjective aspects of the frailty assessment and the use of sample specific cut-points for other components, a problem that highlights the need for objective comparable frailty measures. Further, our sample did not include those living in long-term care institutions and excluded those with cognitive impairment that prevented them personally consenting to the study.

TUG is closely linked to gait speed, and somewhat reflects grip strength and physical activity, however, neither TUG nor gait speed identify those with unintended weight loss or more surprisingly those who report exhaustion. TUG does not therefore capture all of the components of frailty; nevertheless, we have shown that TUG discriminates the frail from the nonfrail and prefrail populations. Using a cutoff of 10 seconds, TUG is a useful screening tool for frailty; a group is identified including 93% of the frail population, excluding 62% of the not frail population. Using a cutoff of 16 seconds, TUG is highly specific for frailty, with 98% of the not frail population performing the task faster than this. On the other hand, although high-TUG cutoff around 15 seconds is 100% specific for prefrailty, there is no cutoff that is useful as a sensitive test for prefrailty.

After adjusting for TUG, there was no effect of age on the probability of being considered frail, although chronic disease remained a significant predictor. This suggests that TUG captures all of the age-related aspects of frailty, and that the other components of frailty, specifically exhaustion and unintended weight loss may represent another dimension of frailty that is not directly age related. To our knowledge no previous studies have compared TUG with Fried's definition of frailty, however, a previous case–control study comparing mobility measures across 337 older Japanese women also found that TUG had good power to discriminate between those with a "high risk" or "low risk" of frailty that was not diminished after adjusting for age (26).

Despite the additional complexity of TUG, there appears to be no advantage in using TUG as opposed to a test of gait speed when assessing frailty, indeed walking speed is slightly more closely related to two of the other components of the frailty definition. Previous studies have shown similar ability of TUG and walking speed to predict impairments in activities of daily living, falls, and decline in global health (15). However, despite the added complexity of the task, TUG is more standardized across studies and is often easier to conduct in restricted settings, where it is easier to identify a suitable chair and 3 m walkway than the longer space usually required for walking speed tests.

The main strengths of this study are its large population-representative sample and comprehensive health assessment. The main limitation is the lack of gold standard for frailty. We calculated the ability of TUG to identify frail members of the population using the phenotypic definition as a gold standard and assumed that this was measured without error. We also conducted our analysis using different operationalizations of Fried's criteria with no substantial change to our results. We did not include the population aged less than 65 in our analysis, since frailty as defined by Fried's criteria in this age group is likely to represent a different underlying etiology than in the population aged 65 and older.

Previous estimates of the usefulness of TUG to predict adverse outcomes have been mixed. TUG has been shown to be sensitive but not specific when used to discriminate fallers from nonfallers in clinical or nursing home samples, but in one population-representative study, the power of TUG to discriminate previous fallers was limited (27). TUG correlates well with activities of daily living (15–17). However, within-subject variation of TUG can be high (28). Finally, TUG has been reported to be infeasible for many cognitively impaired participants (29); however, in our sample, which excluded those too cognitively impaired to personally consent to the study, fewer than 1% failed to complete the task. In a separate group who opted to be assessed in their own homes and were not included in this analysis, this figure rises to 3%.

In summary, this analysis suggests that TUG can be used as a sensitive and specific proxy for frailty and a specific proxy for prefrailty that can be applied where application of Fried's criteria is not practicable. Although there is no advantage in terms of discrimination ability when using TUG instead of a simple test of gait speed, the high degree of standardization of TUG across studies and the small area required to conduct the test makes it potentially more attractive for clinical and epidemiological use. Future waves of TILDA will be used to explore the relative ability of frailty measures including TUG to predict health outcomes including falls, health care utilization, transition to long-term care, incident disability, and death.

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