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Gobbens, R.; van Assen, M.A.L.M.; Luijkx, K.G.; Schols, J.M.G.A.

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The Predictive Validity of the Tilburg Frailty Indicator: Disability, Health Care Utilization, and Quality of Life in a Population at Risk

Robbert J. J. Gobbens, RN, MScN, PhD,*[,1,2] Marcel A. L. M. van Assen, PhD,[3] Katrien G. Luijkx, PhD,[2] and Jos M. G. A. Schols, MD, PhD[2,4]

[1]Rotterdam University of Applied Sciences, The Netherlands.
[2]Tranzo Academic Centre for Transformation in Care and Welfare, Tilburg University, The Netherlands.
[3]Department of Methodology and Statistics, Tilburg School of Social and Behavioral Sciences, Tilburg University, The Netherlands.
[4]Caphri Department of General Practice, Maastricht University, The Netherlands.

*Address correspondence to Robbert Gobbens, RN, MScN, PhD, Rotterdam University of Applied Sciences, Museumpark 40, 3015 CX Rotterdam, The Netherlands. E-mail: gobrj@hr.nl

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Purpose: To assess the predictive validity of frailty and its domains (physical, psychological, and social), as measured by the Tilburg Frailty Indicator (TFI), for the adverse outcomes disability, health care utilization, and quality of life. ***Design and Methods:*** The predictive validity of the TFI was tested in a representative sample of 484 community-dwelling persons aged 75 years and older in 2008 (response rate 42%). A subset of all respondents participated 1 year later (N = 336, 69%) and again 2 years later (N = 266, 55%). We used the TFI, the Groningen Activity Restriction Scale assessing disability, seven indicators of health care utilization, and a brief version of the World Health Organization Quality of Life questionnaire (WHOQOL-BREF). The WHOQOL-BREF was assessed in 2008 and 2010; all others were assessed in 2008, 2009, and 2010. ***Results:*** The predictive validity of the TFI assessed in 2008 for disability, health care utilization, and quality of life was corroborated by (a) medium to very large associations of frailty with adverse outcomes 1 or 2 years later; (b) mostly good to excellent area under the curve of total frailty; and (c) an increase in predictive accuracy of most adverse outcomes, even after controlling for that same adverse outcome in 2008, and life-course determinants and multimorbidity. Physical frailty was mostly responsible for the predictive validity of the TFI. ***Implications:*** This study showed that the TFI is a valid instrument to predict disability, many indicators of health care utilization, and quality of life of older people, 1 and 2 years later.

Key Words: Frailty, Predictive validity, Disability, Health care utilization, Quality of life

Frailty is a relatively new concept. Since 1978, when the Federal Council on Aging introduced the term "frail elderly" (Hogan, MacKnight, & Bergman, 2003), frailty has emerged as an important concept in research on aging and the care of older people (Bergman et al., 2004). Frailty is defined as a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological, and social), which is caused by the influence of a range of variables and which increases the risk of adverse outcomes (Gobbens, Luijkx, Wijnen-Sponselee, & Schols, 2010a). This definition expresses the multidimensional nature of frailty, and more and more researchers are becoming convinced of the importance of this (Levers, Estabrooks, & Ross Kerr,

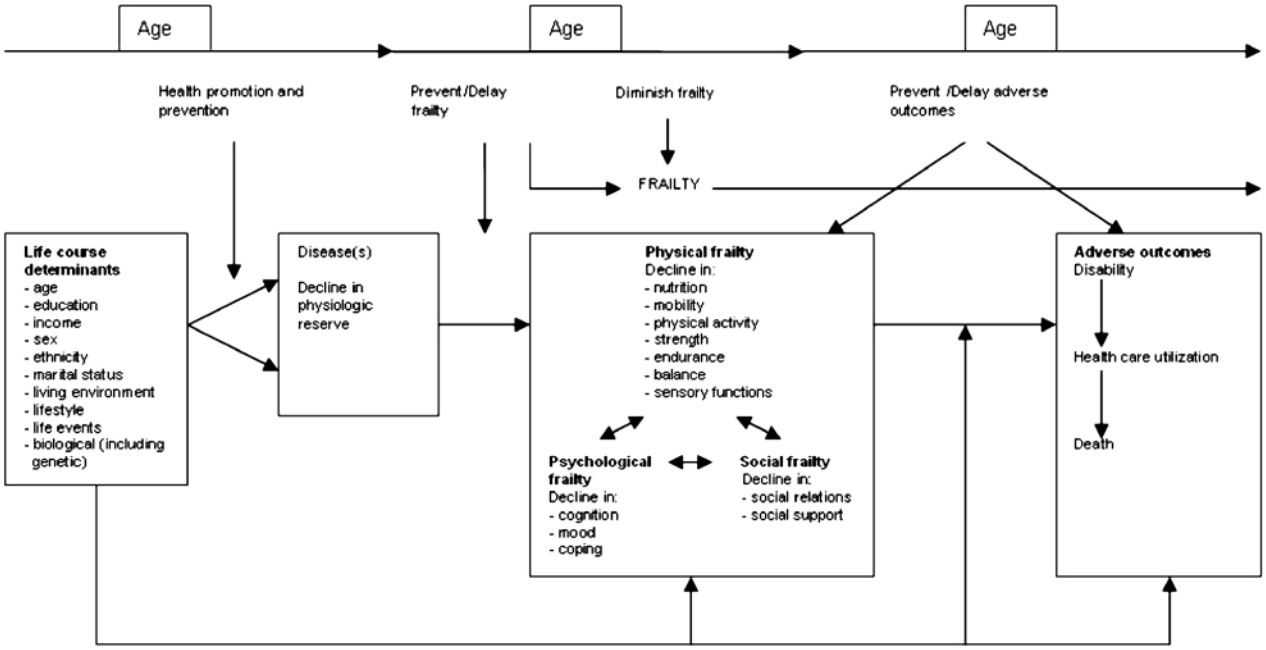

Figure 1. An integral conceptual model of frailty (Gobbens, Luijkx, et al., 2010b).

2006; Markle-Reid & Browne, 2003; Puts, Lips, & Deeg, 2005; Ravaglia et al., 2008; Rockwood et al., 1999; Sourial et al., 2010).

Based on this definition of frailty, an integral conceptual model of frailty was developed (Gobbens, Luijkx, Wijnen-Sponselee, & Schols, 2010b). The model, depicted in Figure 1, is a refinement of the model developed by a group of Canadian researchers (Bergman et al., 2004) and expresses the relationships between life-course determinants, disease or diseases (multimorbidity), frailty, and adverse outcomes (Gobbens, Luijkx, et al., 2010b; Gobbens, van Assen, Luijkx, Wijnen-Sponselee, & Schols, 2010a). The adverse outcomes in the model, which are all health-related outcomes, are disability (Boyd, Xue, Simpson, Guralnik, & Fried, 2005; Fried et al., 2001; Puts et al., 2005), health care utilization (Fried et al., 2001; Jones, Song, & Rockwood, 2004; Kiely, Cupples, & Lipsitz, 2009; Rochat et al., 2010; Rockwood et al., 2005), and death (Fried et al., 2001; Hubbard, Andrew, Fallah, & Rockwood, 2010; Jones et al., 2004; Mitnitski, Graham, Mogilner, & Rockwood, 2002; Rockwood et al., 2005; Song, Mitnitski, & Rockwood, 2010).

The Tilburg Frailty Indicator (TFI) was developed in line with this integral conceptual model of frailty (Gobbens, van Assen, Luijkx, Wijnen-Sponselee, & Schols, 2010b). Several other multidimensional instruments are currently available for measuring frailty in older persons, such as the Edmonton Frail Scale (Rolfson, Majumdar, Tsuyuki, Tahir, & Rockwood, 2006), the Frailty Index (Jones et al., 2004), and the Groningen Frailty Indicator (Schuurmans, Steverink, Lindenberg, Frieswijk, & Slaets, 2004). The TFI differs from these instruments in that the score on the TFI results entirely from self-reports and contains no questions on disability. Research has shown that frailty should be distinguished from disability (Fried, Ferrucci, Darer, Williamson, & Anderson, 2004). Frailty, in fact, is regarded as a predisability state (Abellan van Kan et al., 2008; Morley, Haren, Rolland, & Kim, 2006).

A recent cross-sectional study has shown that the TFI is easy to administer and also a reliable and valid measure for assessing frailty (Gobbens, van Assen, et al., 2010b). The TFI has a good test–retest reliability, a good construct validity, and a good to excellent criterion-oriented concurrent validity for predicting the adverse outcomes disability, receiving personal care, receiving nursing and informal care, and mediocre for hospitalization and general practitioner visits. The concurrent validity of the TFI was also demonstrated by strong correlations with quality of life and relations among life-course determinants, disease(s), and frailty were also confirmed (Gobbens, van Assen, et al., 2010a).

The cross-sectional nature of the study regarding the psychometric properties of the TFI (Gobbens, van Assen et al., 2010b) did not allow strict cause–effect interpretations of the associations between frailty and the adverse outcomes. Consequently, the predictive validity of the TFI for adverse outcomes in

the long term has not yet been established. Therefore, the aim of this study was to assess the predictive validity of frailty and its three domains (physical, psychological, and social) for the adverse outcomes disability, health care utilization, and quality of life.

Methods

Study Population and Data Collection

In 2008, a sample of 1,154 community-dwelling individuals aged 75 years and older was randomly drawn from a register of the municipality in Roosendaal (The Netherlands), a town of 78,000 inhabitants. A total of 484 persons participated in the study (42% response rate; Gobbens, van Assen, et al., 2010a). In June 2008, the participants completed the TFI and answered the questions on adverse outcomes of frailty (disability and health care utilization) and quality of life. A subset of all 484 respondents completed the questionnaire containing the TFI and questions on adverse outcomes again 1 year later, in June 2009 (N = 336, 69% response rate), and once more, a year later, in June 2010 (N = 266, 55% response rate). At the last date, quality of life was also assessed.

The review board of the Tilburg School of Social and Behavioral Sciences approved the study, and informed consent for the collection and use of the information was obtained from all respondents.

Measures

Life-course Determinants and Multimorbidity.—Life-course determinants and multimorbidity were assessed using questions in part A of the TFI (Gobbens, van Assen, et al., 2010a, 2010b). The nine life-course determinants assessed were sex, age, marital status, ethnicity, level of education, income, lifestyle, life events, and living environment. Multimorbidity was determined by asking "Do you have two or more diseases and/or chronic disorders?"

Frailty.—Frailty and the domains of frailty (physical, psychological, and social) were assessed using the TFI, part B (Gobbens, van Assen, et al., 2010a, 2010b). Part B contains 15 questions on components of frailty. Physical frailty (range 0–8) consists of eight components: unexplained weight loss, physical health, difficulty in walking, balance, vision problems, hearing problems, strength in hands, and physical tiredness. Psychological frailty (range 0–4) includes cognition, depressive symptoms, anxiety, and coping. Social frailty (range 0–3) consists of three components: living alone, social relations, and social support. Total frailty has a range of 0–15. High scores on the (sub) scales indicate a greater degree of frailty. Eleven items from the TFI have two response categories *yes* and *no*, whereas four items (cognition, depressive symptoms, anxiety, and social relations) have three response categories *yes*, *sometimes*, and *no*. The item cognition was dichotomized into *yes* and *sometimes or no*, and the other three items were dichotomized into *yes or sometimes* and *no*. The score for frailty and the three domains of frailty were determined by adding the responses to the components belonging to each scale.

Adverse Outcomes.—Disability. Disability was assessed using the Groningen Activity Restriction Scale (GARS; Kempen & Suurmeijer, 1990; Suurmeijer et al., 1994). The GARS was developed for measuring disability with respect to activities of daily living and instrumental activities of daily living. The GARS consists of 18 items with 4 response categories (1 = *yes*, *I can do that easily and without help*; 2 = *yes*, *I can do that without help but it takes some effort*; 3 = *yes, I can do that without help but it takes a lot of effort*; and 4 = *no, I cannot do that without help*). The sum score was used, resulting in GARS scores ranging from 18 (no disability) to 72 (maximum disability). The GARS is easy to administer and a reliable and valid measure for assessing disability (Suurmeijer et al., 1994).

Health care utilization. Seven indicators of health care utilization were used: visit to a general practitioner, contacts with health care professionals, hospital admission, receiving personal care, receiving nursing care, receiving informal care, and use of facilities in care home/nursing home/rehabilitation center. Visit to a general practitioner was measured using the question "How frequently have you visited or been visited by a general practitioner during the last year?," using five categories from *never* to *seven times or more*.

Contacts with health care professionals (namely medical specialist, dentist, worker in home care, physiotherapist, occupational therapist, speech therapist, alternative healer, dietician, chiropodist, psychologist/psychiatrist, and social worker) were assessed by asking "Will you put a cross by the persons if you, for yourself, have had contact with

them during the last year?," *yes* or *no*. A score for contacts was obtained by adding the scores on the 11 questions, yielding a score with range 0–10.

Hospital admission was measured using the question "Were you admitted to a hospital in the last year?," receiving personal care with "Have you used professional support for your personal care in the last year? With personal care we mean washing yourself, taking a bath or taking a shower, dressing yourself, getting in and out of bed et cetera," receiving nursing care with "Have you used professional nursing support in the last year, for example to care for wounds or give injections?" and receiving informal care with "Have you received informal care during the past twelve months because of your health status?" Answering categories for these questions were *yes* or *no*.

Finally, use of facilities in residential care was assessed by asking the participants "Please mark with a cross the facilities you used in the past year; day care in a care home, night care in a care home, temporary residence in a care home, day care in a nursing home, night care in a nursing home, temporary residence in a nursing home, rehabilitation centre." Use of facilities in residential care was dichotomized so that "0" corresponds to *no use of facilities* and "1" *otherwise*.

Quality of life. Four domains of quality of life were assessed using a brief version of the World Health Organization Quality of Life questionnaire (WHOQOL-BREF): physical health (seven items), psychological (six items), social relationships (three items), and environmental (eight items; Skevington, Lotfy, & O'Connell, 2004; WHOQOL Group, 1998). All items were rated on a 5-point scale with a higher score indicating a higher quality of life. Domain scores were calculated by multiplying the mean score by a factor of 4 and thus resulted in a range from 4 to 20 for each domain. Many studies have shown that the WHOQOL-BREF has adequate psychometric properties among different populations, including elderly people (Hwang, Liang, Chiu, & Lin, 2003; Kalfoss, Low, & Molzahn, 2008; Skevington et al., 2004; WHOQOL Group, 1998).

Analysis Strategies

After determining the characteristics of participants using descriptive statistics, variables were coded for analysis. The determinants "ethnicity," "satisfaction with residence," and the three life events "end of important relationship," "traffic accident," and "crime" were excluded because of their low frequency of occurrence. Because frailty for participants who were divorced, unmarried, or widowed was equal, $F(2, 221) = 2.33$, $p = .10$, $R^2 = .021$, but different from those who were cohabiting or married, a dummy variable "cohabit" was created ("1" *married or cohabiting* and "0" *rest*). The life event "serious illness" was excluded because it overlaps multimorbidity. The two life events "death of a loved one" and "serious illness of a loved one" were combined into one dummy "life events" ("1" *if at least one of these two life events had occurred* and "0" *rest*). Finally, a variable "sex" was created ("1" *for women* and "0" *for men*).

Associations of frailty and its three domains with adverse outcomes were assessed and tested as a first step to assess the predictive validity of the TFI. Correlations were used for continuous adverse outcomes and eta for dichotomous outcomes. We expected positive associations between the frailty domains and the adverse outcomes assessed 1 or 2 years later. The statistical power is .8 to detect a population correlation equal to .16 with $N = 250$ and .12 with $N = 450$. Because correlations of .1 and .3 represent small and medium effects respectively, we had high power to detect medium to strong effects.

Sequential and logistic regression analyses were carried out to control for the effect of other variables. The focus of these analyses was to determine whether the frailty domains assessed in 2008 predicted adverse outcomes assessed 1 year later (in 2009) or 2 years later (in 2010), after controlling for the same adverse outcome, life-course determinants, and multimorbidity, all assessed at 2008. The sequential analyses consisted of three blocks. In the first block, the effect of the adverse outcome assessed in 2008 was estimated. The second block was added to the model the life-course determinants and multimorbidity assessed in 2008. Finally, in the third block, the three domains of frailty assessed in 2008 were added to the model. We tested whether each block increased the prediction of each adverse outcome 1 and 2 years later, using the change in R^2 for continuous and the χ^2 likelihood ratio test for dichotomous adverse outcomes. In addition, we tested the effect of each individual predictor in the model including all predictors simultaneously. Power analyses revealed that the sequential regression analyses had a power of .8 to

detect an effect of frailty in the third block for effect sizes Cohen's f^2 = .044 at N = 250 and f^2 = .032 at N = 350. Because f^2 equal to .02 and .15 represent small and medium effects respectively, we had high power to detect medium to strong effects.

One relevant aspect of the predictive validity is whether frailty assessed in 2009 further improved the predictive accuracy of adverse outcomes in 2010, after controlling for frailty and the adverse outcome in 2008. To examine this issue, we added frailty in 2009 as the fourth block in the sequential analyses to predict the adverse outcome in 2010.

Finally, the predictive validity of total frailty was also assessed using receiver operating characteristics analyses. In these analyses, the total score of frailty in 2008 was the independent variable, and disability (0 if score on GARS <29 and 1 otherwise; Ormel, Rijsdijk, Sullivan, van Sonderen, & Kempen, 2002), visits to a general practitioner (0 for no visits and 1 otherwise), contacts with health care professionals (0 for no contacts and 1 otherwise), and the dichotomous adverse outcomes in 2009 and 2010 were the dependent variables. Quality-of-life domains were not included because they have no generally accepted cutoff score. The area under the curve (AUC) with 95% CI was reported. Sensitivity and specificity of frailty were assessed using cutoff score 5 (Gobbens, van Assen, et al., 2010b).

All tests were two-tailed. Power analyses were conducted using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) and other analyses using SPSS 18.0 (SPSS, IBM Corp., Somers, NY).

Results

Participant Characteristics

The data of five participants were left out of the analyses as they had many omissions. Table 1 presents the descriptive statistics of the remaining 479 participants. The mean age of the participants was 80.3 years, and 56.8% was women in 2008 and 37.7% and 42.6% was widowed in 2008 and 2010, respectively. For all the predictors of adverse outcomes (life-course determinants, multimorbidity, and frailty), we tested if there were differences at baseline between participants who dropped out after the first measurement in 2008, after the second measurement in 2009, and those who did not dropout. Tests of independence revealed that participant dropout was associated with an unhealthier lifestyle, $\chi^2(4)$ = 17.92, p = .001, Cramer's V = .14, and less satisfaction with their residence, $\chi^2(2)$ = 9.31, p = .010, Cramer's V = .14. Analysis of variances showed that dropout was associated with more total, $F(2, 442)$ = 6.16, p = .002, R^2 = .027, physical ($F(2, 454)$ = 5.83, p = .003, R^2 = .025, and psychological frailty, $F(2,466)$ = 5.85, p = .003, R^2 = .025.

Associations between frailty and adverse outcomes and their significance are presented in Table 2. With the exception of the prediction of hospitalization in 2010 by total frailty in 2009, total frailty predicted all adverse outcomes assessed 1 or 2 years later. Effect sizes were mostly medium (r = .3, eta = .25) to large (r = .5, eta = .4) or larger (Cohen, 1988). Physical frailty predicted all adverse outcomes, with medium and large effect sizes. Psychological frailty predicted all adverse outcomes except hospitalization in 2010, and effect sizes were medium to large for quality of life, but small to medium for the other adverse outcomes. The effects of social frailty were either absent, small (r = eta = .1), or small to medium. That is, social frailty affected disability, the quality of life domains, and receiving personal care for both the 1- and 2-year intervals, no effect on visits to a general practitioner and hospitalization, and had effects that lasted only 1 year on the four remaining adverse outcomes.

Table 3 presents the results of the regression analyses on the continuous adverse outcomes. Explained variances vary from 26% for visits to a general practitioner in 2010 to 71% for disability in 2009 (last row). Not surprisingly, most of the variance was explained by the adverse outcome assessed in 2008. For instance, disability in 2008 explained 66% of the same variable in 2010 (second row). The combined effects of determinants and multimorbidity added 2.1% (for disability 2010) to 5% (for contacts with [health] care professionals 2010) to the explained variance (row R^2 of second block). These effects were only statistically significant for 3 out of 10 adverse outcomes. Controlled for the adverse outcome, determinants, and multimorbidity in 2008, the combined effects of the frailty domains were significant for seven adverse outcomes but not for visits to a general practitioner and contacts with health care professionals 2010 (penultimate row). All effect sizes were small to medium (f^2 between .02 and .15). Although most of the time physical frailty was responsible for the effect of frailty, psychological frailty had an effect on contacts with health care professionals 2009 and social frailty had an effect

Table 1. Participant Characteristics (2008, *N* = 479; 2009, *N* = 336; 2010, *N* = 266)

Characteristics	2008, *n* (%)	2009, *n* (%)	2010, *n* (%)
Age, mean ± *SD*	80.3 ± 3.8	81.1 ± 3.8	81.9 ± 3.7
Sex, % of women	272 (56.8)	185 (55.1)	147 (55.3)
Marital status			
Married or cohabiting	238 (49.8)	157 (46.7)	116 (43.8)
Not married	45 (9.4)	34 (10.1)	25 (9.4)
Divorced	15 (3.1)	13 (3.9)	11 (4.2)
Widowed	180 (37.7)	132 (39.3)	113 (42.6)
Ethnicity			
Dutch	461 (96.6)	328 (97.6)	259 (97.4)
Other	16 (3.4)	8 (2.4)	7 (2.6)
Education			
None or primary	181 (38.1)	123 (36.7)	88 (33.1)
Secondary	221 (46.5)	157 (46.9)	129 (48.5)
Higher	73 (15.4)	55 (16.4)	49 (18.4)
Income			
€600 or less	12 (2.7)	4 (1.3)	2 (0.8)
€601–900	71 (16.2)	31 (10.2)	12 (4.9)
€901–1,200	106 (24.2)	67 (22.0)	63 (25.8)
€1,201–1,500	57 (11.9)	39 (12.8)	38 (15.6)
€1,501–1,800	67 (14.0)	53 (17.4)	34 (13.9)
€1,801–2,100	48 (10.0)	43 (14.1)	29 (11.9)
€2101 or more	77 (16.1)	68 (22.3)	66 (27.0)
Lifestyle			
Healthy	351 (73.6)	264 (78.8)	199 (75.4)
Not healthy, not unhealthy	114 (23.9)	66 (19.7)	57 (21.6)
Unhealthy	12 (2.5)	5 (1.5)	8 (3.0)
Multimorbidity, % yes	230 (48.5)	134 (41.9)	133 (50.6)
Life events, % yes			
Death loved one	157 (33.0)	97 (30.0)	91 (34.2)
Serious illness	67 (14.2)	38 (11.8)	39 (14.7)
Serious illness loved one	149 (31.3)	71 (22.0)	81 (30.6)
End of important relationship	23 (4.8)	11 (3.4)	14 (5.3)
Traffic accident	9 (1.9)	7 (2.2)	3 (1.1)
Crime	3 (0.6)	4 (1.2)	4 (1.5)
Satisfaction residence, % yes	458 (96.4)	324 (97.0)	255 (96.2)
Frailty, mean ± *SD*	4.7 ± 3.0	4.3 ± 3.1	4.6 ± 3.1
Physical, mean ± *SD*	2.5 ± 2.1	2.3 ± 2.1	2.5 ± 2.1
Psychological, mean ± *SD*	0.9 ± 1.1	0.8 ± 1.0	0.9 ± 1.1
Social, mean ± *SD*	1.2 ± 0.9	1.1 ± 0.9	1.3 ± 0.9
Disability, mean ± *SD*	26.7 ± 9.6	27.3 ± 10.1	28.3 ± 10.7
Health care utilization			
Visits GP			
0	50 (10.6)	40 (12.0)	21 (7.9)
1–2	131 (27.8)	105 (31.6)	101 (38.0)
3–4	165 (35.0)	109 (32.8)	85 (32.0)
5–6	69 (14.6)	50 (15.1)	38 (14.3)
≥7	57 (12.1)	28 (8.4)	21 (7.9)
Contacts with health care professionals, mean ± *SD*	2.3 ± 1.4	2.1 ± 1.4	2.3 ± 1.5
Hospitalization	101 (21.4)	57 (17.1)	51 (19.2)
Receiving personal care	63 (13.5)	38 (11.4)	38 (14.4)
Receiving nursing	44 (9.5)	40 (12.1)	33 (12.5)
Receiving informal care	133 (30.6)	74 (24.7)	70 (26.9)
Facilities in residential care	27 (5.7)	15 (4.5)	16 (6.0)
Quality of life			
Physical, mean ± *SD*	15.1 ± 2.9		15.2 ± 2.9
Psychological, mean ± *SD*	15.0 ± 2.2		15.0 ± 2.3
Social, mean ± *SD*	15.9 ± 2.7		15.4 ± 2.9
Environmental, mean ± *SD*	15.6 ± 2.2		15.7 ± 2.3

Note: SD = standard deviation; GP = general practitioner.

Table 2. Associations Between TFI, Domains of the TFI, and Adverse Outcomes of Frailty

	TFI total			TFI physical			TFI psychological			TFI social		
	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Disability 2008	.56***			.62***			.29***			.12**		
Disability 2009	.60***	.62***		.64***	.64***		.33***	.39***		.16**	.18**	
Disability 2010	.64***	.65***	.67***	.69***	.66***	.72***	.34***	.42***	.39***	.18**	.20**	.17**
Visits GP 2008	.34***			.38***			.22***			−.01		
Visits GP 2009	.26***	.34***		.28***	.34***		.21***	.29***		.02	.05	
Visits GP 2010	.23***	.27***	.38***	.30***	.27***	.39***	.14*	.24***	.30***	−.09	.01	.05
Contacts with HCP 2008	.35***			.37***			.15**			.17***		
Contacts with HCP 2009	.35***	.40***		.36***	.39***		.24***	.27***		.10	.18**	
Contacts with HCP 2010	.33***	.39***	.36***	.36***	.38***	.37***	.19**	.28***	.21**	.07	.14*	.14*
Quality of life												
Physical 2008	−.72***			−.71***			−.47***			−.21***		
Physical 2010	−.68***	−.67***	−.75***	−.68***	−.68***	−.76***	−.45***	−.48***	−.49***	−.20**	−.19**	−.24***
Psychological 2008	−.68***			−.60***			−.58***			−.20***		
Psychological 2010	−.59***	−.62***	−.69***	−.58***	−.59***	−.64***	−.43***	−.51***	−.58***	−.16**	−.18**	−.21**
Social 2008	−.39***			−.29***			−.33***			−.21***		
Social 2010	−.37***	−.34***	−.43***	−.31***	−.30***	−.34***	−.33***	−.33***	−.43***	−.13*	−.11	−.18**
Environmental 2008	−.54***			−.45***			−.43***			−.28***		
Environmental 2010	−.45***	−.45***	−.55***	−.41***	−.42***	−.50***	−.31***	−.32***	−.41***	−.21**	−.22***	−.25***
Hospitalization 2008	.08			.13**			.03			.04		
Hospitalization 2009	.20***	.21***		.21***	.26***		.15**	.10		.02	.01	
Hospitalization 2010	.15*	.11	.18**	.19*	.14*	.14*	.06	.03	.17**	.01	.01	.08
Receiving personal care 2008	.36***			.33***			.23***			.21***		
Receiving personal care 2009	.38***	.35***		.35***	.31***		.27***	.27***		.19**	.18**	
Receiving personal care 2010	.41***	.39***	.41***	.45***	.38***	.44***	.17**	.29***	.21**	.14*	.14*	.16*
Receiving nursing 2008	.26***			.27***			.17***			.04		
Receiving nursing 2009	.28***	.25***		.25***	.25***		.14*	.11*		.17**	.17**	
Receiving nursing 2010	.27***	.28***	.31***	.30***	.24***	.29***	.15*	.23***	.25***	.04	.14*	.11
Receiving informal care 2008	.31***			.34***			.18***			.09		
Receiving informal care 2009	.34***	.38***		.36***	.39***		.17**	.20**		.18**	.17**	
Receiving informal care 2010	.38***	.36***	.41***	.40***	.35***	.40***	.21**	.27***	.32***	.10	.12	.10
Facilities residential care 2008	.26***			.25***			.19***			.09*		
Facilities residential care 2009	.23***	.21***		.20***	.18**		.20***	.15**		.12*	.15**	
Facilities residential care 2010	.23***	.26***	.26***	.26***	.28***	.25***	.15*	.20**	.25***	.01	.01	.02

Notes: Correlations are presented for continuous and eta for dichotomous adverse outcomes. TFI = Tilburg Frailty Indicator; GP = general practitioner; HCP = health care professionals.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 3. Effect of Adverse Outcome 2008, Life-course Determinants 2008, and Frailty Domains 2008 on Adverse Outcomes 2009 and 2010: Results of Sequential Regression Analysis

	Disability 2009	Disability 2010	Visits GP 2009	Visits GP 2010	Contacts HCP 2009	Contacts HCP 2010	QoL Ph 2010	QoL Ps 2010	Qol So 2010	QoL En 2010
2008										
Adv outcome	0.74***	0.69***	0.51***	0.33***	0.57***	0.54***	0.55***	0.56***	0.47***	0.66***
R^2	.66***	.59***	.34***	.20***	.42***	.37***	.58***	.49***	.33***	.50***
2008										
Sex (women)	−0.010	−1.53	0.026	−0.22	0.22	0.30	0.68*	0.40	0.73*	0.71**
Age	0.30**	0.14	−0.010	0.005	0.017	0.018	0.022	−0.005	0.046	0.027
Marital status	0.25	−01.26	0.028	−0.037	−0.42*	−0.26	0.66	0.63*	0.33	0.87**
Education	0.20	−0.17	−0.023	−0.016	0.19	0.40**	0.35	0.37*	0.26	0.31
Income	−0.34	−0.038	−0.010	0.000	0.004	0.17	−0.05	−0.11	−0.10	−0.061
Lifestyle	1.94*	0.25	0.062	−0.16	0.063	0.17	0.16	−0.24	−0.26	−0.25
Life events	0.63	−1.09	0.033	0.13	0.19	0.028	−0.086	−0.097	−0.51	−0.34
Multimorbidity	0.83	−0.15	0.34**	0.31*	0.17	0.21	0.13	0.27	0.045	−0.013
R^2	.037***	.021	.025	.041	.027	.050*	.025	.025	.043	.042*
2008										
Ph frailty	0.79**	1.73***	−0.002	0.079	0.039	0.058	−0.37***	−0.31***	−0.28**	−0.079
Ps frailty	0.53	0.40	0.032	−0.003	0.20**	0.099	−0.22	−0.097	−0.33	−0.21
So frailty	−0.058	0.060	−0.012	−0.094	−0.28**	−0.26*	0.024	0.25	0.092	0.300
R^2	.019**	.056***	.001	.016	.034***	.020	.037***	.044***	.046**	.018*
R^2 total	.71***	.66***	.37***	.26***	.48***	.44***	.64***	.56***	.42***	.56***

Notes: GP = general practitioner; HCP = health care professionals; QoL = quality of life; Ph = physical health; Ps = psychological; So = social relationships; En = environmental; Adv outcome = adverse outcome; Ph frailty = physical frailty; Ps frailty = psychological frailty; So frailty = social frailty.

*$p < .05$. **$p < .01$. ***$p < .001$.

on the same adverse outcome and on contacts with health care professionals 2010.

To determine whether frailty assessed in 2009 improved the predictive accuracy of adverse outcomes in 2010, after controlling for frailty in 2008, we ran additional regression analyses. In these three analyses, we added the frailty domains in 2009 to the models in Table 3 where the outcome in 2010 is predicted using the assessment in 2008. The frailty domains assessed in 2009 improved the prediction of disability with 1.9% ($p = .016$), of visits to a general practitioner with 4% ($p = .012$), and of contacts with health care professionals with 0.9% ($p = .38$). A positive effect of physical frailty in 2009 on disability was found ($b = 1.18$, $p = .005$), whereas there were no significant effects of the individual domains on visits to a general practitioner and contacts with health care professionals.

The results of the logistic regression analyses on dichotomous adverse outcomes are reported in Table 4. The model predicted adverse outcomes in 2009 and 2010 (last row). The adverse outcome in 2008 always had an effect on the same outcome 1 or 2 years later (second row). The determinants and multimorbidity added to the explanation for 5 out of 10 adverse outcomes (χ^2 second block). The combined effects of the frailty domains were significant for 8 out of 10 adverse outcomes (penultimate row); no effects were found on nursing 2009 and informal care 2009. Physical, psychological, and social frailty had an effect on five, one, and one of the outcomes, respectively.

Additional analyses were carried out to assess whether the frailty domains assessed at 2009 improved predictive accuracy of adverse outcomes in 2010, after controlling for these frailty domains in 2008. In these five analyses, the frailty domains in 2009 were added to the models in Table 4 where the outcome in 2010 is predicted using the assessment in 2009. Adding the frailty domains in 2009 did not improve significantly the prediction of hospitalization, $\chi^2(3) = 2.11$, $p = .55$, personal care, $\chi^2(3) = 5.87$, $p = .12$, nursing, $\chi^2(3) = 3.46$, $p = .33$, and informal care, $\chi^2(3) = 3.52$, $p = .32$. However, prediction of facilities in residential care was improved significantly, $\chi^2(3) = 8.48$, $p = .04$, with psychological frailty having a positive effect, $b = 1.58$, $p = .041$.

The AUC with 95% CIs and sensitivity and specificity of total frailty for the adverse outcomes, except the quality-of-life domains, are presented in Table 5. The predictive validity of total frailty with respect to disability and receiving personal care was excellent (AUC > .8), whereas it was good

Table 4. Effect of Adverse Outcome 2008, Life-course Determinants 2008, and Frailty Domains 2008 on Adverse Outcomes 2009 and 2010: Results of Sequential Logistic Regression Analysis

	Hospitalization 2009	Hospitalization 2010	Personal care 2009	Personal care 2010	Nursing 2009	Nursing 2010	Informal care 2009	Informal care 2010	Facilities RC 2009	Facilities RC 2010
2008										
Adv outcome	0.54	0.71	3.41***	1.89**	1.81**	2.92***	2.05***	2.38***	2.57**	4.60**
$\chi^2(1)$	6.99**	6.76**	64.19***	29.60***	15.65***	16.62***	41.06***	40.95***	11.77***	12.51***
2008										
Sex (women)	−0.69	−0.081	0.30	0.59	−0.36	1.15	0.68	0.20	1.13	0.88
Age	−0.094	−0.054	0.026	0.13*	0.14*	0.065	0.096	0.000	0.10	−0.11
Marital status	−0.089	0.037	−0.063	−1.38	−1.26	−3.16***	0.36	0.25	−0.60	0.76
Education	−0.15	−0.10	0.21	0.27	−0.10	0.092	−0.30	0.12	−0.16	0.64
Income	0.11	0.080	−0.20	−0.042	−0.021	0.010	−0.049	−0.25	0.30	0.000
Lifestyle	−0.37	−0.087	0.77	0.189	0.39	1.04*	0.14	−0.30	−0.083	−3.06*
Life events	0.22	0.73	−0.81	−0.15	−0.071	0.16	0.20	0.75	1.33	−0.53
Multimorbidity	0.18	0.058	−0.22	0.058	0.23	1.21	1.32**	0.24	−0.049	−1.19
$\chi^2(8)$	10.14	7.21	13.34	22.12**	24.71**	29.77***	33.16***	17.48*	9.01	4.35
2008										
Ph frailty	0.31**	0.34**	0.45*	0.63***	0.13	−0.038	0.14	0.23	0.11	1.26**
Ps frailty	0.17	−0.14	0.27	−0.022	0.12	0.098	0.043	0.33	0.78*	0.88
So frailty	−0.059	−0.051	−0.095	−0.63	0.29	−1.34**	0.42	0.19	−0.065	−1.39
$\chi^2(3)$	12.27**	8.37*	8.97*	18.71***	2.74	11.35**	5.05	11.96**	7.96*	27.00***
$\chi^2(12)$	29.40**	22.337*	86.50***	70.42***	43.10***	57.74***	79.27***	70.38***	28.74**	43.85***

Notes: Facilities RC = facilities residential care; Adv outcome = adverse outcome; Ph = physical; Ps = psychological; So = social.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 5. Predictive Validity of the TFI: Disability and Health Care Utilization

	Adverse outcomes	Sensitivity	Specificity	AUC (95% CI)
TFI 2008	Disability 2009	0.75	0.73	0.80 (0.75–0.86)
	Disability 2010	0.73	0.75	0.81 (0.75–0.87)
TFI 2009	Disability 2010	0.78	0.77	0.83 (0.77–0.88)
TFI 2008	Visit general practitioner 2009	0.43	0.61	0.57 (0.48–0.66)
	Visit general practitioner 2010	0.42	0.72	0.58 (0.47–0.70)
TFI 2009	Visit general practitioner 2010	0.41	0.62	0.54 (0.43–0.66)
TFI 2008	Contacts with HCP 2009	0.46	0.81	0.66 (0.57–0.75)
	Contacts with HCP 2010	0.43	0.82	0.63 (0.52–0.74)
TFI 2009	Contacts with HCP 2010	0.42	0.75	0.64 (0.54–0.75)
TFI 2008	Hospitalization 2009	0.57	0.60	0.65 (0.58–0.73)
	Hospitalization 2010	0.53	0.62	0.60 (0.51–0.69)
TFI 2009	Hospitalization 2010	0.47	0.61	0.59 (0.51–0.68)
TFI 2008	Receiving personal care 2009	0.86	0.62	0.82 (0.76–0.89)
	Receiving personal care 2010	0.86	0.66	0.81 (0.74–0.88)
TFI 2009	Receiving personal care 2010	0.80	0.65	0.80 (0.72–0.88)
TFI 2008	Receiving nursing 2009	0.65	0.60	0.73 (0.65–0.81)
	Receiving nursing 2010	0.70	0.63	0.71 (0.61–0.82)
TFI 2009	Receiving nursing 2010	0.73	0.64	0.73 (0.63–0.83)
TFI 2008	Receiving informal care 2009	0.71	0.66	0.73 (0.67–0.80)
	Receiving informal care 2010	0.69	0.69	0.75 (0.68–0.82)
TFI 2009	Receiving informal care 2010	0.71	0.69	0.73 (0.66–0.80)
TFI 2008	Facilities residential care 2009	0.86	0.59	0.81 (0.72–0.90)
	Facilities residential care 2010	0.86	0.62	0.78 (0.66–0.89)
TFI 2009	Facilities residential care 2010	0.81	0.62	0.79 (0.68–0.89)

Note: AUC = area under the curve; HCP = health care professionals; TFI = Tilburg Frailty Indicator.

(AUC >.7) for receiving nursing, receiving informal care, and facilities in residential care. The AUC was mediocre for contacts with health care professionals and hospitalization and mediocre and not significant for visits to a general practitioner. Noteworthy is that the predictive validity for a 2-year interval was about equal to that for a 1-year interval.

Discussion

Based on an integral conceptual model of frailty, the TFI, an instrument for identifying frail community-dwelling older people, was developed. The aim of the present longitudinal study was to examine the predictive validity of frailty and its domains (physical, psychological, and social), measured with the TFI, for the adverse outcomes disability, health care utilization, and quality of life, assessed 1 or 2 years later. Because no gold standard for measuring frailty exists, evaluating an operational definition of frailty for predicting adverse outcomes is likely to be the most persuasive test (Rockwood, 2005).

The predictive validity of the TFI for the adverse outcomes disability, health care utilization, and quality of life was corroborated by (a) medium to very large associations of total frailty with adverse outcomes 1 or 2 years later; (b) mediocre to excellent AUCs of total frailty; and (c) increase in predictive accuracy of most adverse outcomes, even after controlling for that same adverse outcome in 2008, and life-course determinants and multimorbidity. That is, for example, knowing a person's disability in 2008, assessing the TFI in 2008 improved the prediction of that person's disability in 2009 and 2010, compared with the prediction that uses only that person's disability in 2008. Of the three domains, physical frailty had the largest and social frailty had the weakest effects on adverse outcomes and social frailty did not predict all adverse outcomes 2 years later.

Although frailty and its domains can predict most adverse outcomes, the results were mixed on hospitalization. The only nonsignificant correlation between total frailty and adverse outcomes that we found was with hospitalization. However, the sequential regression analysis revealed that the frailty domains do increase the predictive accuracy of hospitalization, after controlling for the variables assessed at 2008. Hospitalization is frequently examined in frailty studies (Fried et al., 2001; Hastings, Purser, Johnson, Sloane, & Whitson, 2008; Landi et al., 2004), and the finding that a

broad definition of frailty can predict hospitalization is also supported in another study (Landi et al., 2004). No effects of frailty were observed on visits to a general practitioner (2009 and 2010) and contacts with health care professionals (2010). We do not interpret this as evidence against the predictive validity of the TFI because these two outcomes can also be seen as outcomes that are not adverse. In fact, much preventive and restorative care can occur in the contacts with a general practitioner and other professional primary caregivers.

The present study showed that physical frailty was mostly responsible for the significant effect of frailty on the adverse outcomes, and social frailty did not predict some adverse outcomes 2 years later. The importance of physical frailty is consistent with findings that examined the predictive validity of the phenotype of frailty (Fried et al., 2001). The high correlations between physical frailty and psychological adverse outcomes (e.g., psychological quality of life) and social adverse outcomes (e.g., social quality of life), even relative to their correlations with psychological and social frailty, suggest that physical frailty is the most important frailty predictor of adverse outcomes. We suggest two explanations for the finding that social frailty did not predict some adverse outcomes 2 years later. First, frail older people tend to apply for and use health care if they have physical problems. Most indicators of health care utilization employed in the present study are directed at these problems. An adverse outcome such as use of an organization concerned with the welfare of the aged seems more relevant to examine the effect of social frailty. Second, part of the explanation might also be that the scale of social frailty is less reliable than the other scales, which attenuates its associations with other variables. However, both psychological frailty and social frailty had a significant effect on two adverse outcomes after controlling for physical frailty. The finding that not only physical frailty but also psychological frailty and social frailty predicted adverse outcomes is supported by a previous study (Gobbens, van Assen, et al., 2010b) and corroborates the multidimensional nature of frailty consisting of three domains.

Some limitations of this study must be noted. First, dropout in 2009 and 2010 was associated with more frailty. Many older people might have dropped out because they were institutionalized or had died because of the high mean age of the sample (80.3 years). The dropout of the most frail older people probably led to an underestimation of the predictive accuracy of the frailty domains. The fact that we were unable to assess the adverse outcomes institutionalization in long-term care (Jones et al., 2004; Rockwood et al., 1999, 2005) and death (Fried et al., 2001; Hubbard et al., 2010; Jones et al., 2004; Mitnitski et al., 2002; Rockwood et al., 2005; Song et al., 2010) is a second limitation. Third, although we did not exclude persons with cognitive impairment in our study, people who are suffering from problems with cognitive functioning were probably less likely to participate because the TFI is a self-report instrument. A final limitation is that we used a self-report questionnaire and we did not include performance-based tests for measuring frailty. However, previous findings validated the TFI as an instrument for frailty and its domains (Gobbens, van Assen, et al., 2010b), showing expected correlations between frailty as measured with the TFI and related measures of frailty such as the Timed Up & Go test (Podsiadlo & Richardson, 1991), the four-test Balance scale (Gardner, Buchner, Robertson, & Campbell, 2001), and the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975).

We suggest several directions for future research. The association between frailty and disability has been examined in many studies (Boyd et al., 2005; Fried et al., 2004; Wong et al., 2010). Although previous studies suggest frailty, specifically physical frailty, as a predisability state (Abellan van Kan et al., 2008; Morley et al., 2006), future research will need to demonstrate which part of the physical domain of frailty best predicts disability. There is also a lack of knowledge concerning the mechanism underlying the relationship between frailty and quality of life (Bilotta et al., 2010). Because both concepts are related to mortality (Graham et al., 2009; Tsai, Chi, Lee, & Chou, 2007), research on their relationship is warranted. Despite the fact that the TFI has not been validated for settings other than the community, the TFI may nevertheless have potential applications in hospital or primary care settings. Hence, we propose to examine its validity in these settings too. In addition, future research needs to validate the TFI for the adverse outcomes institutionalization and death, for younger elderly persons (60–70 years), and in other countries using other languages.

An important question is how often the TFI must be assessed for identifying frail older people. Completing the TFI takes less than 15 min, and costs are low for care workers as well, because the TFI is a self-report instrument. In this study, we

found that the frailty domains assessed in 2009 led to a small to medium increase in prediction of three of eight adverse outcomes in 2010, in comparison with the prediction by the frailty domains assessed in 2008. Because costs of completion of the TFI are low and prediction is increased for some adverse outcomes, we recommend measuring frailty with the TFI once a year.

Professional primary caregivers (e.g., general practitioners, nurses, and nurse practitioners) have a major task in identifying frail older people at an early stage. This is important in order to avoid unnecessary loss of quality of life and to make timely preventive or curative interventions possible. Developing and implementing interventions is an essential next step in decreasing adverse outcomes in frail older people (Espinoza & Walston, 2005). A recent review suggested that interventions for frail community-dwelling older people should be directed toward tailor-made, multidimensional interventions, preceded by an individualized assessment, and conducted by a primary care team, involving case management and long-term follow-up (Daniels, Metzelthin, van Rossum, de Witte, & van den Heuvel, 2010). The challenge is to maintain and improve health services for the growing number of frail older people, and at the same time limiting the growth in health care expenditure. Considering the costs and the mixture of adverse outcomes associated with frailty, developing and implementing (preventive) interventions is crucial for society as a whole. The TFI can be used to identify frail older people, then followed by interventions that aim to prevent or reduce adverse outcomes of frailty. The findings of our study suggest focusing mainly on developing interventions to diminish physical frailty and its adverse outcomes.

Conclusions

This study showed that the TFI, being a multidimensional assessment of frailty, is a valid instrument to predict disability, many indicators of health care utilization, and quality of life of older people 1 and 2 years later. The TFI can be used as a preliminary screening tool by workers in community care to determine the need for more detailed assessments, and then tailor-made interventions may be performed with the aim to increase the quality of life of frail older people.

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