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Measuring frailty in Dutch community-dwelling older people: Reference values of the Tilburg Frailty Indicator (TFI)

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ABSTRACT

Objectives: The objectives of this study were to provide reference values of the Tilburg Frailty Indicator (TFI) for community-dwelling older people by age, sex, marital status, ethnicity, education, income, and residence, and examine the effects of these seven socio-demographic variables on frailty.
Methods: 47,768 individuals aged 65 years and older living in the Netherlands completed a health questionnaire (58.5% response rate), including the TFI. The TFI is a self-report questionnaire for measuring frailty, developed from an integral approach of frailty, including physical, psychological, and social domains.
Results: Reference values were provided for men and women separately, as a function of age. We found associations of all socio-demographic variables with frailty, also after controlling for the effects of age. These associations held for both sexes and for big cities as wells as more rural areas. For instance, the effect of age was large for total and physical frailty, women were more frail than men, and some very large average frailty differences between the ethnic groups were found, with autochthon people having the lowest frailty score.
Conclusions: In conclusion, this study offers reference values of the TFI by socio-demographic characteristics and explains frailty using these characteristics. This information will support researchers, policymakers and health care professionals in interpreting scores of the TFI, which may guide their efforts to reduce frailty and its adverse outcomes.

1. Introduction

Due to declining fertility rates and increasing longevity, population ageing is accelerating rapidly worldwide. In the more developed countries the population aged 60 years or older is expected to increase by 45% by the middle of the century, rising from 287 million in 2013–417 million in 2050 (United Nations Department of Economic and Social Affairs, 2013). Population ageing has major consequences and implications for the planning and delivery of health and social care (Clegg, Young, Iliffe, Rikkert, & Rockwood, 2013). One of these consequences is an expected increase in the number of frail older people, because frailty is associated with greater age.

Currently, there is still no consensus on how to define frailty (Abellan van Kan et al., 2008; Gobbens, Luijkx, & Wijnen-Sponselee, & Schols, 2010a). Two conceptual frailty approaches have been adopted. One of the approaches focuses only on the physical functioning of older persons (Fried et al., 2001), so-called physical frailty. By placing the emphasis on biomedical indicators of frailty, the attention for the whole older person may be jeopardized, possibly leading to fragmentation of care (Gobbens, Luijkx, Wijnen-Sponselee, & Schols, 2007; Markle-Reid & Browne, 2003). The other conceptual frailty approach also includes psychological and social functioning (Gobbens et al., 2010a; Schuurmans, Steverink, Lindenberg, Frieswijk, & Slaets, 2004). The following definition of frailty suits this latter approach: "Frailty is a dynamic state affecting an individual who experiences losses in

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one or more domains of human functioning (physical, psychological, social), which is caused by the influence of a range of variables and which increases the risk of adverse outcomes" (Gobbens et al., 2010a; Gobbens, Luijkx, Wijnen-Sponselee, & Schols, 2010b). Well-known adverse outcomes of frailty are disability (Fried et al., 2001; Puts, Lips, & Deeg, 2005), hospitalization (Fried et al., 2001), institutional placement (Rockwood et al., 2005), lower quality of life (Gobbens and van Assen, 2014), and mortality (Shamliyan, Talley, Ramakrishnan, & Kane, 2013). Thus early interventions aimed at preventing frailty or the progression of frailty in older people is critical. The identification of frail people is the key to early prevention and intervention techniques, aiming to avert the aforementioned adverse outcomes.

Numerous instruments have been developed to measure frailty, but most only cover the physical domain of frailty, and not the psychological and social domains. For instance, the phenotype of frailty (Fried et al., 2001), the Study of Osteoporotic Fractures (SOF) scale (Ensrud et al., 2008) and the FRAIL scale (Morley, Malmstrom, & Miller, 2012) address only physical frailty. In addition, some frailty instruments cover all domains, but these instruments also include items referring to disability, such as the Groningen Frailty Indicator (GFI) (Schuurmans et al., 2004), the Frailty Index (FI) (Rockwood & Mitnitski, 2007) and the EASY-Care Two-step Older persons Screening (EASY-Care TOS) (van Kempen, Schers, Melis, & Olde Rikkert, 2014). The Cardiovascular Health Study recommended distinguishing frailty from disability, but recognized there is some overlap between the two concepts (Fried, Ferrucci, Darer, Williamson, & Anderson, 2004). Today frailty is largely recognized as a pre-disability condition suitable to be targeted by preventive interventions against disability (Cesari, 2012; Morley, Haren, Rolland, & Kim, 2006).

The Tilburg Frailty Indicator (TFI) is an instrument for measuring frailty developed from an integral approach of frailty, including physical, psychological, and social domains, and excluding disability (Gobbens, van Assen, Luijkx, Wijnen-Sponselee, & Schols, 2010a). The TFI is a self-report user-friendly questionnaire, which takes less than 15 min to complete (Gobbens, van Assen et al., 2010a). The TFI has good test-retest reliability, a good construct validity (Gobbens, van Assen et al., 2010a), and a good predictive validity for adverse outcomes disability and indicators of health care utilization (Gobbens, van Assen, Luijkx, & Schols, 2012). Moreover, the prediction of indicators of health care utilization by the TFI was not improved by adding interview and physical measures of frailty (Gobbens & van Assen, 2012). A recent systematic review concluded that the TFI has the most robust evidence of reliability and validity of 38 frailty assessment instruments (Sutton et al., 2016). The original Tilburg Frailty Indicator was developed and validated primarily in the Netherlands (Gobbens, van Assen et al., 2010a). Subsequently, the TFI has been translated into seven other languages including English, Danish (Andreasen, Sorensen, Gobbens, Lund, & Aadahl, 2014), Brazilian Portuguese (Santiago, Luz, Mattos, Gobbens, & van Assen, 2013), Portuguese (Coelho, Santos, Paul, Gobbens, & Fernandes, 2014), Polish (Uchmanowicz et al., 2014), Italian (Mulasso, Roppolo, Gobbens, & Rabaglietti, 2015) and German (Freitag, Schmidt, & Gobbens, 2015).

Current use of the TFI in clinical practice and research is somewhat limited by the absence of general population norms or reference scores. Information on frailty and its distribution among different subgroups will assist interpreting assessments of the TFI. Moreover, norms will provide valuable information for policy-makers on trends in frailty, both in time and in subgroups of the population, allowing them to anticipate future developments, and which may guide their efforts to reduce frailty and its adverse outcomes. Hence, the main aim of this study was to provide reference values of the TFI for the Dutch community-dwelling older population by age, sex, marital status, ethnicity, education level, income, and residence, in urban or in the rural areas. An additional aim was to examine the effects of these seven socio-demographic variables on frailty.

Many studies have demonstrated that the prevalence of frailty increases with age (Fried et al., 2001; Gale, Cooper, & Sayer, 2015; Moreira & Lourenco, 2013; Runzer-Colmenares et al., 2014; Song, Mitnitski, & Rockwood, 2010; Sanchez-Garcia et al., 2014). A systematic review found that with 5-year intervals from age 65 the prevalence figures, based on measurements with the phenotype of frailty (Fried et al., 2001) and the Strawbridge questionnaire (Strawbridge, Shema, Balfour, Higby, & Kaplan, 1998), were: 65–69 years 4%, 70–74 years 7%, 75–79 years 9%, 80–84 years 16%, ≥85 years 26% (Collard, Boter, Schoevers, & Oude Voshaar, 2012). In a Canadian National Population Health Survey the prevalence of frailty, in relation to accumulation of deficits, increased exponentially with age during the adult lifespan, not just after age 65 (Rockwood, Song, & Mitnitski, 2011).

Frailty was shown to be associated to the other demographic characteristics as well: in eleven studies of community-dwelling older persons aged 65 and over it was shown that frailty was more prevalent in women (9.6%, 95% CI = 9.2–10.0%) than in men (5.2%, 95% CI = 4.9–5.5%) (Collard et al., 2012). With regard to marital status, a lower level of frailty was found among married people (Runzer-Colmenares et al., 2014); widowers and singles were more commonly frail (Moreira & Lourenco, 2013; Sanchez-Garcia et al., 2014). Several studies have shown associations between frailty and ethnicity. Cross-sectional analysis of 16,584 randomly selected community-dwelling individuals 50 years of age and older, enrolled in the Survey of Health, Aging and Retirement in Europe (SHARE), established that the proportion of frailty, according to the frailty phenotype, was higher in southern than in northern Europe (Santos-Eggimann, Cuenoud, Spagnoli, & Junod, 2009). It may also be higher in older Mexican-American than in European-American persons (Espinoza & Hazuda, 2008). Cardiovascular Health Study data demonstrated that African-American persons have fourfold greater odds of frailty than their White counterparts (Hirsch et al., 2006).

Frailty was also found to be associated with having a lower level of education. The Longitudinal Aging Study Amsterdam provided evidence for persisting educational differences in frailty among older persons over a period of thirteen years (Hoogendijk et al., 2014). Frailty was also associated with lower income (Fried et al., 2001; Herr, Robine, Aegerter, Arvieu, & Ankri, 2015; Moreira & Lourenco, 2013; Romero-Ortuno, 2014; Szanton, Seplaki, Thorpe Jr., Allen, & Fried, 2010). Multivariate analysis in a recent study demonstrated that a poor level of financial security in old age was the socioeconomic position indicator that was most strongly associated with frailty (Herr et al., 2015). In another study the negative association between income and frailty persisted after controlling for major potential confounders including age, gender, nationality, smoking, cardiovascular risk factors, chronic diseases, and education (Guessous et al., 2014). Differences in frailty between older people living in rural and urban areas have been demonstrated in developed countries (Yu et al., 2012), e.g. in Canada rural people, particularly the oldest (≥80 years), were more frail than urban people (Song, MacKnight, Latta, Mitnitski, & Rockwood, 2007). A study conducted in China also showed that urban dwellers were less frail than rural dwelling older adults (Yu et al., 2012). It is concluded that urban-rural differences in health can vary between studies (Song et al., 2007).

In the present study, normative data is derived from a large sample of older persons aged 65 years or older. This large sample completed the survey of the Dutch Public Health Services of the city of Amsterdam and the provinces Zeeland and Brabant (Zeebra) to measure health status of community-dwelling older people, which in 2012 for the first time included the TFI in the survey.

2. Methods

2.1. Study population and data collection

The data in this study was collected in 2012 as part of a general health questionnaire of the Public Health Services in the Netherlands. Samples of community-dwelling individuals aged 65 years and older were randomly drawn by Statistics Netherlands from the registers of the municipalities in the city of Amsterdam (large city), 800,000 inhabitants, and the provinces Zeeland and Noord-Brabant (small cities and more rural areas; organization Zeebra), around 381,000 and 2,470,000 inhabitants, respectively. The following exclusion criteria were used: older persons in institutions (assisted living facilities, nursing homes), prisoners, older persons staying in refugee asylum centers, participation in other research by Statistics Netherlands. Furthermore, at most one older person per household was included in the sample.

In total 81,644 individuals (Amsterdam 4,542, Zeebra 77,102) were invited by letter to complete a questionnaire on the internet or on paper; twice they received a reminder. In Amsterdam, non-respondents from the three major ethnic minority groups (Moroccans, Turks, and Surinamese) were also approached by visiting the respondent's address. The interviews were conducted by a trained interviewer in the respondent's preferred language. The interviewers most often belonged to the same ethnic groups as the respondents. 47,768 individuals completed this questionnaire – 2,432 subjects living in Amsterdam and 45,336 living in Zeebra (58.5% response rate). Medical-ethics approval was not necessary as particular treatments or interventions were not offered or withheld from respondents, and integrity of respondents was not encroached upon as a consequence of participating in the study, which is the main criterion in medical-ethical procedures in the Netherlands (Central Committee on Research Inv Human Subjects, 2010). Informed consent, in terms of information-giving and maintaining confidentially, was respected.

2.2. Measurements

The questionnaire contained the TFI, as well as questions with respect to socio-demographic characteristics, physical and psychological health, health care utilization, diseases, falls, lifestyle factors, and well-being. Socio-demographic and health indicators were measured in accordance with standardized questions of the Local and National Monitor Public Health in the Netherlands (RIVM).

2.2.1. Frailty

Frailty was assessed using part B of the TFI. This part contains fifteen questions on components of frailty, with eight, four, and three components referring to the physical, psychological, and social domain, respectively (Gobbens, van Assen et al., 2010a). The score '1' was given per component if participants reported a problem; the score '0' was given if participants reported no problem. The maximum score for total frailty is fifteen, and the maximum scores for the physical, psychological and social domains of frailty are eight, four, and three, respectively; scores ≥ 5 indicate that the assessed individual is frail (Gobbens, van Assen et al., 2010a).

2.2.2. Socio-demographic characteristics

The socio-demographic characteristics considered were: age (in years), sex, marital status (four categories), ethnicity (autochthon, Moroccan, Turkish, Surinamese, other non-western, other western), highest education attained (four categories), household income per year (five categories) and location (Amsterdam, Zeebra). See Table 1 for a detailed description of the answering categories.

2.3. Data analysis

We first analyzed the descriptives and missing values of the demographic and dependent variables, and compared the age-sex distributions of our samples to their populations. The missing value analyses included an analysis of the association between each of the demographic variables on the one hand, and the number of items of the TFI with a missing value on the other hand, using Cramer's V.

The bivariate analyses consisted of two parts. Because of the importance of age as a predictor of frailty, we first analyzed the association between age and the frailty variables (total frailty and the dichotomous frail variable, and the three frailty domains physical, psychological, and social), for men and women separately. We used linear and quadratic regression, and ANOVA to establish the effect of age. To facilitate interpretation of the quadratic effects of age, we ran our regression analyses on a transformed centered age variable, $\text{age}^* = (\text{age} - \text{average age})/5$. We also constructed a reference or norm table of total frailty, physical frailty, and frail, as a function of age, for men and women separately. In the second part associations between other demographic variables and the continuous frailty variables were established. We excluded frail from these analyses because it is derived from total frailty and contains less information than total frailty. Again, we used linear and quadratic regression and ANOVA to establish effects of age. The strengths of associations were determined using R^2, i.e. the proportion of explained variance of frailty, and Cohen's *d*. The outcomes of the bivariate analyses were used to decide how to incorporate the demographics in the multiple (logistic) regression analyses; as a factor, or continuous with a linear or quadratic effect.

The multiple (linear and logistic) regression analyses consisted of three parts. First, because of the relevance of age as predictor, we analyzed whether bivariate associations between demographics and frailty were preserved after controlling for age. Second, the multiple regression analyses were run, and explained variance (R^2) of total frailty and the frailty domains was assessed. The model in this second part already included the sex $\times$ age interaction. Finally, we assessed whether the associations between the demographic variables and frailty were different for men and women (interactions with sex), and large city and rural area (interactions with location). These effects were assessed by adding these interactions to the multiple variables model in the second part. Only interactions resulting in an increase of at least explained variance larger than 0.005, which corresponds to a (very) small effect size (Cohen, 1988), were added to the multiple variable analyses.

All analyses were carried out using SPSS Version 22. Because of the very large sample size in our study, almost all tests and differences were statistically significant, also the very small and practically irrelevant effect sizes. Therefore, we focused on effect size in our analyses, and not on statistical significance.

3. Results

3.1. Descriptive and missing value statistics

Column 1 of Table 1 contains the demographic variables with their frequencies in round brackets and number of missing values in square brackets. 47.6% of the participants were men, the majority was married or cohabited (65.6%), 89.8% was autochthon, and almost half of the participants had a lower middle education (46.5%). Average age of men and women was 72.86 (*SD* = 6.31) and

Table 1
Bivariate associations of frailty (total and domain scores) with socio-demographic variables.[1] Associations are assessed with explained variance (R^2), without controlling for age (before slash), and after controlling for age (linear and quadratic effect).

Variables	Frailty (N)				
Levels (N)	Total [25.7%] (35,484)	Physical [17.8%] (39,275)	Psychological [9%] (43,488)	Social [13.6%] (41,255)	Frail [25.7%] (35,484)
Location [0.0%]	0.006/0.005	0.003/0.002	0.001/0.000	0.022/0.020	
Amsterdam (2,432)	3.66 (3.25)	1.79 (2.09)	0.92 (1.13)	1.11 (0.95)	0.26
Zeebra (45,336)	2.62 (2.82)	1.35 (1.82)	0.81 (1.06)	0.58 (0.80)	0.16
Marital status [3.1%]		0.039/0.008	0.026/0.013		
Married/Cohabiting (31,337)		1.13 (1.65)	0.69 (1.01)		0.12
Not married (1,735)		1.60 (1.93)	0.88 (1.07)		0.17
Divorced (2,595)		1.70 (2.04)	1.03 (1.14)		0.26
Widowed (10,633)		2.00 (2.15)	1.08 (1.13)		0.28
Education [5.9%]	0.056/0.023	0.049/0.018	0.024/0.013	0.019/0.005	
Linear	0.045	0.038	0.022	0.016	
Linear + Quadratic	0.054/0.026	0.047/0.021	0.024/0.016	0.019/0.008	
Low (8,362)	4.06 (3.45)	2.21 (2.22)	1.10 (1.21)	0.82 (0.88)	0.25
Middle-low (20,909)	2.65 (2.77)	1.32 (1.78)	0.83 (1.06)	0.60 (0.80)	0.16
Middle-high (7,846)	2.28 (2.58)	1.16 (1.68)	0.67 (0.95)	0.54 (0.78)	0.14
High (7,818)	1.89 (2.28)	0.90 (1.46)	0.60 (0.91)	0.46 (0.72)	0.11
Sex [0.0%]	0.034/0.026	0.014/0.009	0.025/0.022	0.036/0.030	
Man (22,761)	2.16 (2.56)	1.15 (1.66)	0.64 (0.98)	0.45 (0.74)	0.13
Woman (25,007)	3.21 (3.04)	1.59 (1.98)	0.98 (1.11)	0.76 (0.85)	0.20
Income [0.2%]	0.051	0.040	0.019	0.040	
Linear	0.049/0.028	0.038/0.020	0.019/0.013	0.038/0.025	
Linear + Quadratic	0.050	0.038	0.019	0.040	
0–20% (to 15.2)[2] (4,395)	3.68 (3.24)	1.84 (2.08)	1.03 (1.14)	0.94 (0.90)	0.23
20–40% (15.2–19.4) (13,768)	3.41 (3.18)	1.81 (2.07)	0.97 (1.14)	0.76 (0.87)	0.21
40–60% (19.4–24.2) (11,306)	2.59 (2.75)	1.34 (1.79)	0.79 (1.04)	0.57 (0.80)	0.16
60–80% (24.2–31.0) (9,670)	2.23 (2.51)	1.10 (1.60)	0.71 (0.99)	0.50 (0.75)	0.14
80–100% (>31.0) (8,542)	1.82 (2.27)	0.87 (1.46)	0.60 (0.92)	0.40 (0.69)	0.10
Ethnicity [0.0%]	0.009/0.011	0.009/0.011	0.003/0.004	0.005/0.006	
Autochthon (42,902)	2.62 (2.82)	1.34 (1.82)	0.80 (1.06)	0.59 (0.81)	0.16
Morocco (137)	5.04 (3.77)	3.05 (2.50)	1.31 (1.29)	0.61 (0.76)	0.37
Turkey (136)	6.12 (4.08)	3.68 (2.59)	1.66 (1.33)	0.93 (0.89)	0.47
Surinam (226)	4.58 (3.90)	2.36 (2.44)	1.18 (1.28)	1.22 (1.00)	0.29
Other non-west (181)	3.54 (3.27)	1.84 (2.08)	0.99 (1.15)	0.88 (0.94)	0.23
Other west (4,116)	2.83 (2.94)	1.43 (1.87)	0.83 (1.07)	0.68 (0.86)	0.18
Age [0.9%]	0.134	0.133	0.025	0.071	
Linear	0.125	0.125	0.024	0.068	
Linear + Quadratic	0.132	0.132	0.024	0.070	
Age b (SE)	0.69 (0.013)	0.44 (0.008)	0.11 (0.004)	0.15 (0.003)	
Age^2 b (SE)	0.12 (0.007)	0.076 (0.004)	0.012 (0.002)	0.019 (0.002)	

[1] Percentage of missings is presented in square brackets for each variable. For each variable and each of its levels, the number of observations (in round brackets) and mean and standard deviation (in round brackets) are presented.
[2] In multiples of € 1,000.

73.83 (SD = 6.85) years, respectively. Compared to the populations, men were overrepresented in the samples (populations had 45.1% men in Zeebra and 43.6% in Amsterdam) (Statistics Netherlands, 2016). Persons of 80 years and older were also underrepresented for both men and women at Zeebra, and for women in Amsterdam; more precisely, for these three groups the percentage of participants in year groups 65–70, 70–75, 75–80 was higher in the sample than in the population, whereas it was smaller for the older age groups (Statistics Netherlands, 2016).

Percentage of missing values was less than 1% on the demographic variables, with the exception of marital status (3.1%) and education (5.9%). The percentage of missing values on frailty was considerable, from 9.0% on psychological frailty to 25.7% on total frailty, with 10.5% of having a missing value on only one TFI item. 40.8% of participants had at least one missing value on the TFI. The number of missing values on the TFI was (very) weakly associated to the demographic variables, with Cramer's V equal to 0.072 (marital status), 0.025 (ethnicity), 0.099 (education), 0.067 (location), 0.074 (income), and 0.130 (sex). The association of having at least one missing value on the TFI with age was small to medium (R^2 = 0.035), with those having at least one missing value being 2.85 years older on average.

3.2. Bivariate analyses

We first focused on the bivariate analyses of frailty with age. The results of these analyses are summarized in the last row of Table 1. The first, second, and third line correspond to the explained variance of frailty by ANOVA (age treated as nominal factor), linear regression, quadratic regression, respectively. Important results are that the fit of the quadratic model was scarcely improved by the factor model (increase of R^2 never larger than 0.002), but that the quadratic model yielded particularly better predictions of total and physical frailty than the linear model (.007 increase of R^2). Hence

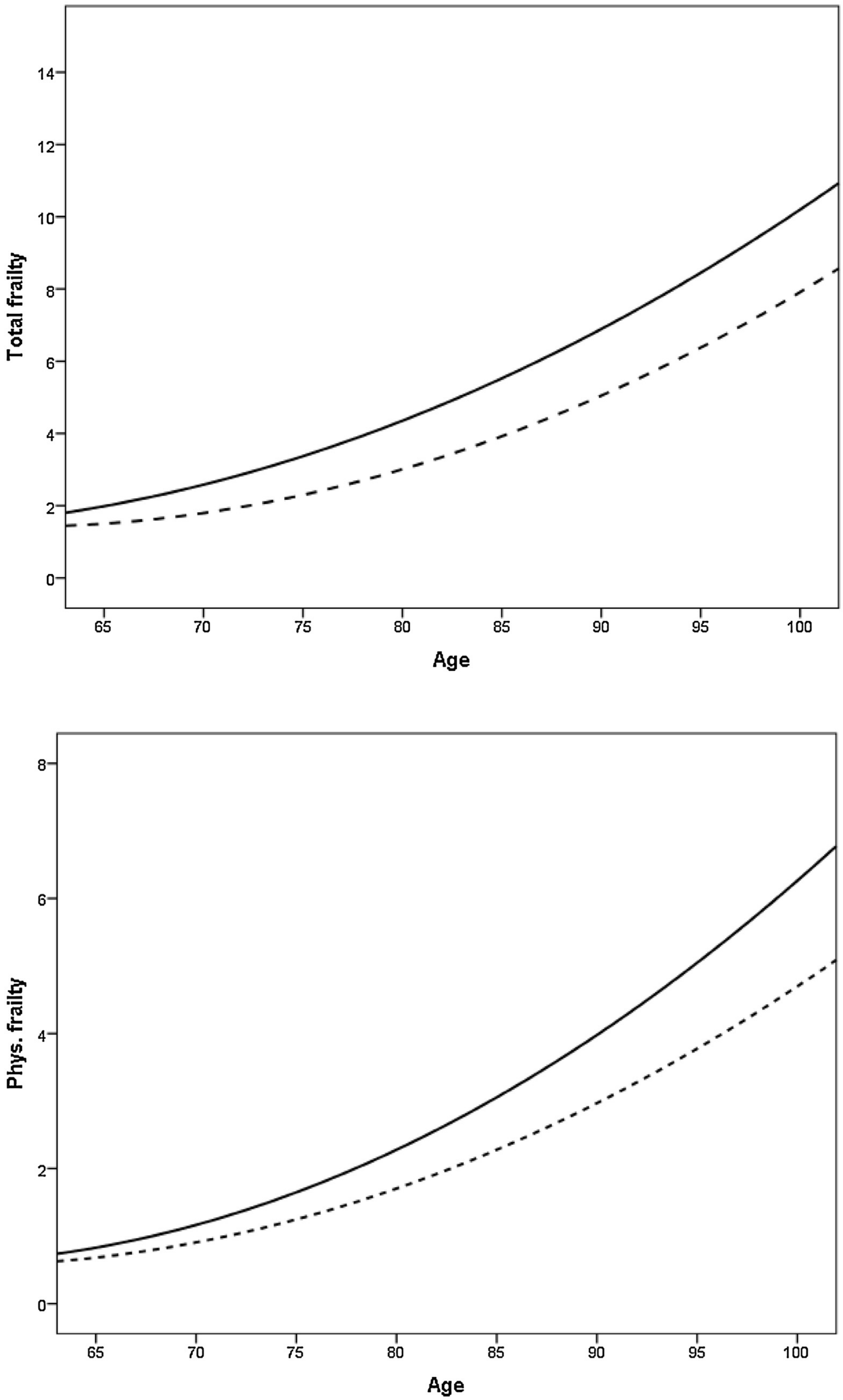

Fig. 1. Total frailty (top) and physical frailty (bottom) as a function of age according to a quadratic model, for men (broken line) and women (full line) separately. Estimated equations for total frailty were (standard errors between brackets):
2.11 (.025) + .54 (.016) Age* + .10 (+ * +.010) Age^{*2} for men.
3.09 (.028) + .82 (.019) Age* + .096 (+ * +.010) Age^{*2} for women.
The equations for physical frailty were:
1.11 (.015) + .36 (.010) Age* + .058 (+ * +.0063) Age^{*2} for men.
1.48 (.017) + .51 (.012) Age* + .073 (+ * +.0061) Age^{*2} for women.

the association of age with frailty is well captured by a quadratic trend. The effect of age was strong on total and physical frailty ($R^2 = 0.13$), medium on social frailty ($R^2 = 0.071$), and weak to medium on psychological frailty ($R^2 = 0.025$). The last two lines of Table 1 show the coefficients and standard errors of the linear and quadratic effects of age, showing that the detrimental effect of age on frailty increased with age. Fig. 1 shows the quadratic trends of age on total (1A) and physical (1B) frailty, for men and women separately. Because the quadratic model fitted well, we included both a linear and quadratic effect of age in the multiple (logistic) regression analysis.

Table 2 presents a reference or norm table of total frailty, physical frailty, and frail, as a function of age, for men and women separately. Data on two successive years was combined until age 86; from 87 years and older, all data was grouped together because from this age onwards data was relatively sparse (e.g., 192 men of age 87–88 years). For group comparisons, 95% confidence intervals are reported between brackets. The nonlinear (quadratic) trend is observed from Table 2, where confidence intervals of total and physical frailty of two successive age groups frequently do not overlap. Moreover, note the larger average frailty of women, with women showing the same average frailty as men of 6–10 years older.

The bivariate analyses of frailty and the other demographic variables are summarized in Table 1, with effect sizes presented before the '/'. Location generally had a small effect on frailty, with the exception of social frailty, with participants living in Amsterdam having higher average social frailty. Marital status had a weak to medium effect on physical and psychological frailty, with widowed persons showing the highest and married and cohabiting persons showing the lowest average frailty. Education had medium effects on total and physical frailty, and small to medium effects on psychological and social frailty. Higher education was associated with less frailty. Although the quadratic model of education fitted almost as well as the factor model, we decided to continue with the factor model because we consider education to be an ordinal variable; in the multiple variables analyses a high level of education was our reference category. The effect of sex was small on physical frailty, and small to medium on the other frailty variables. The effect of income was medium to large. Because the linear model fitted almost as well as the factor model (at most 0.002 difference in R^2), we decided to incorporate a linear effect of income in later analyses.

The effect of ethnicity on frailty seems small; however, these small explained variances (<0.01) are deceiving because the large percentage of autochthones (almost 90%), the R^2 does not adequately reflect group differences. Table 1 shows some very large average frailty differences between ethnic groups, with autochthon people having the lowest frailty. Physical and total frailty were much higher for Moroccans ($d = 0.86$ and $d = 0.94$, respectively) and Turks ($d = 1.24$ and $d = 1.28$, respectively), whereas effect size was medium to large for Surinam people ($d = 0.69$ and $d = 0.56$), and lower for other non-western ($d = 0.33$ and $d = 0.27$) and western people ($d = 0.07$ and $d = 0.05$). On psychological frailty, the effect was again large for Turks ($d = 0.81$), and medium for Moroccans ($d = 0.47$), and smaller for Surinamese ($d = 0.36$), other non-western ($d = 0.18$), and western ($d = 0.03$) people. With respect to social frailty, effect size was large for Surinam people ($d = 0.77$), small to medium for other non-westerns ($d = 0.36$) and Turks ($d = 0.41$), and very small for westerns ($d = 0.11$) and Moroccans ($d = 0.02$).

3.3. Multiple variable analyses

Table 1 shows the results of the association between the demographic variables and frailty after controlling for the effect of age, following the '/'. The results indicate that most of the effects of ethnicity, income, sex, and location on frailty persisted after controlling for age. That is, of people of the same age, women were more frail than men (which is confirmed by Table 2 and Fig. 1); Turks were more frail than autochthones, etc. Effect sizes of marital status and education were more than halved after controlling for age, which means that most of the differences in frailty between widowed and married/cohabiting, and between low and high levels of education, was explained by age.

Table 3 summarizes the results of the multiple (linear and logistic) regression analyses on all frailty variables. The 'R^2/Chi2' indicates that a considerable part of the variance of total, physical, and social frailty was explained by the demographic variables, but less of psychological frailty. The associations between demographic and frailty variables were the same with respect to sign as in the bivariate analyses (see again Table 1). The quadratic interaction effect of age (Quad × man) was omitted from the model for most frailty variables, since it was not statistically significant. For the same reason, the linear interaction effect of age (Lin × man) was omitted in the equation of frail.

The last two rows of Table 3 reveal that adding interactions with either location or sex did not improve the prediction of frailty; all explained variances hardly improved, with a maximum improvement of 0.003 for social frailty when adding interactions of frailty with location, income, education, and ethnicity to the model. That is, the associations reported in Table 3 hold for both sexes and both for Amsterdam and the more rural areas (Zeebra).

4. Discussion

The goal of this study was twofold – first, to provide reference or norm scores for the Tilburg Frailty Indicator (TFI) by socio-demographic characteristics and second, to provide a definite answer on the effects of age, sex, marital status, ethnicity, education level, income, and residence on five dependent variables – total frailty, physical frailty, psychological frailty, social frailty and frailty. We conducted our study with a sample of community-dwelling older people aged 65 years and over in Amsterdam (2432) and Zeeland and Noord-Brabant (Zeebra) (45,336).

Our results on associations between socio-demographic variables and frailty largely confirmed those found in previous studies. The effect of age was large for total and physical frailty, and this effect was medium and small to medium for psychological and social frailty, respectively. Many studies have shown that higher age is associated with more physical frailty (Gale et al., 2015; Moreira & Lourenco, 2013; Runzer-Colmenares et al., 2014; Sanchez-Garcia et al., 2014), mostly determined by using the phenotype of frailty (Fried et al., 2001). As yet there are few studies considering the effect of age on both psychological and social frailty. In a Dutch sample of 484 community-dwelling people (≥75 years), using the TFI for measuring frailty, age did not predict psychological and social frailty, but only physical frailty (Gobbens, van Assen, Luijkx, Wijnen-Sponselee, & Schols, 2010b). Another Dutch study also found no effect of age on psychological frailty (Comijs, 2011), however from age 75 onwards, social frailty was relatively common and increased sharply with age (Broese van Groenou, 2011). The difference in findings is explained by the lower statistical power to detect the effect of age on psychological frailty in the smaller samples of the previous studies.

In our study frailty prevalence for men ranged from 7.5% (65–66 years) to 32% (≥87 years), and for women from 13% (65–66 years) to 44% (≥87 years). These percentages are much higher than the overall weighted average prevalence of frailty found in a systematic review (10.7%), in which 21 community-based studies were included (Collard et al., 2012). However, the phenotype of frailty was used in fourteen of these studies, and it is well known

Table 2
Average total and physical frailty, and percentage of frail older people, for men and women separately, as a function of age. 95% confidence intervals are presented in brackets.

	Total						Physical						Frail			
	Men			Women			Men			Women			Men		Women	
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	%	N	%	N
65–66	1.46	2.04	3,423	2.11	2.40	3,180	0.66	1.23	3,599	0.91	1.49	3,425	7.5	3,887	12.6	3,879
	(1.394, 1.531)			(2.028, 2.195)			(0.622, 0.703)			(0.865, 0.964)			(6.6, 8.3)		(11.5, 13.6)	
67–68	1.74	2.32	2,766	2.26	2.47	2,417	0.85	1.41	2,932	0.96	1.54	2,641	10.6	3,189	13.3	3,056
	(1.658, 1.831)			(2.166, 2.363)			(0.803, 0.905)			(0.917, 1.034)			(9.6, 11.7)		(12.1, 14.5)	
69–70	1.79	2.25	2,334	2.42	2.55	2,097	0.90	1.45	2,498	1.06	1.59	2,331	10.8	2,756	13.9	2,729
	(1.703, 1.886)			(2.313, 2.532)			(0.843, 0.956)			(0.995, 1.124)			(9.6, 11.9)		(12.6, 15.2)	
71–72	1.89	2.34	2,035	2.74	2.71	1,767	0.98	1.52	2,203	1.26	1.75	1,998	11.0	2,468	15.6	2,485
	(1.786, 1.990)			(2.609, 2.862)			(0.915, 1.042)			(1.181, 1.335)			(9.8, 12.3)		(14.2, 17.0)	
73–74	2.02	2.39	1,808	3.06	2.77	1,637	1.04	1.54	1,980	1.43	1.82	1,871	11.4	2,271	17.9	2,375
	(1.906, 2.127)			(2.926, 3.195)			(0.976, 1.112)			(1.349, 1.514)			(10.1, 12.7)		(16.4, 19.5)	
75–76	2.31	2.49	1,517	3.38	2.97	1,419	1.28	1.65	1,676	1.71	1.98	1,632	14.5	1,921	20.2	2,138
	(2.186, 2.437)			(3.228, 3.538)			(1.202, 1.360)			(1.611, 1.804)			(13.0, 16.1)		(18.5, 21.9)	
77–78	2.67	2.83	1,223	3.84	3.07	1,225	1.47	1.85	1,360	1.93	2.03	1,423	16.6	1,620	22.1	1,987
	(2.511, 2.828)			(3.671, 4.016)			(1.376, 1.573)			(1.828, 2.039)			(14.8, 18.4)		(20.3, 24.0)	
79–80	3.07	2.93	979	4.2	3.18	1,004	1.74	1.92	1,113	2.15	2.11	1,175	17.9	1,373	24.2	1,647
	(2.888, 3.256)			(4.002, 4.396)			(1.626, 1.853)			(2.033, 2.274)			(15.9, 20.0)		(22.1, 26.2)	
81–82	3.23	2.95	714	4.86	3.17	814	1.84	2.01	822	2.58	2.15	977	19.8	1,028	28.4	1,392
	(3.017, 3.451)			(4.640, 5.076)			(1.702, 1.977)			(2.440, 2.710)			(17.3, 22.2)		(26.0, 30.8)	
83–84	3.49	3.07	548	5.25	3.31	606	2.06	2.07	622	2.88	2.24	714	23.4	773	31.6	1,046
	(3.237, 3.752)			(4.990, 5.518)			(1.895, 2.221)			(2.713, 3.043)			(20.4, 26.4)		(28.7, 34.4)	
85–86	4.18	2.97	352	5.78	3.20	428	2.38	2.03	409	3.28	2.17	493	28.1	537	34.8	771
	(3.867, 4.491)			(5.472, 6.079)			(2.184, 2.579)			(3.086, 3.470)			(24.3, 31.9)		(31.4, 38.1)	
≥87	4.86	3.15	439	6.89	3.19	752	2.87	2.15	508	3.96	2.18	873	31.2	709	43.7	1,284
	(4.566, 5.157)			(6.660, 7.117)			(2.685, 3.059)			(3.813, 4.102)			(27.8, 34.6)		(41.0, 46.4)	

Table 3
Results of multiple linear regression analyses (for total, physical, psychological, and social frailty) and logistic regression analyses (for frailty).[1] Coefficients and their standard errors are presented for the model including all predictors simultaneously. Explained variances (R^2) and increases therein (ΔR^2) are presented in the last rows.

	Total		Physical		Psychological		Social		Frail	
	B	SE	B	SE	B	SE	B	SE	B	SE
Location (Amsterdam)	0.730	0.062	0.217	0.040	0.019	0.023	0.444	0.017	0.463	0.052
Sex (man)	−0.853	0.028	−0.294	0.018	−0.256	0.010	−0.310	0.010	−0.341	0.027
Age										
Linear	0.718	0.016	0.450	0.011	0.078	0.006	0.168	0.005	0.288	0.012
Linear × man	−0.239	0.022	−0.132	0.013	−0.003	0.008	−0.091	0.007		
Quadratic	0.103	0.007	0.069	0.004	0.009	0.002	0.005	0.002	0.023	0.006
Quadratic × man							0.023	0.004		
Marital status										
Alone			0.124	0.046	0.082	0.027				
Divorced			0.410	0.039	0.250	0.022				
Widowed			0.096	0.024	0.146	0.014				
Education										
Low	0.692	0.005	0.470	0.031	0.194	0.018	−0.003	0.013	0.469	0.044
Middle-low	0.084	0.037	0.081	0.023	0.045	0.014	−0.062	0.010	0.245	0.038
Middle-high	0.038	0.043	0.051	0.027	−0.022	0.016	−0.019	0.012	0.193	0.045
Income	−0.284	0.012	−0.139	0.008	−0.057	0.004	−0.092	0.003	−0.131	0.011
Ethnicity										
Morocco	1.719	0.261	1.439	0.162	0.440	0.095	−0.168	0.071	0.951	0.186
Turkey	2.730	0.253	1.978	0.158	0.700	0.095	0.155	0.068	1.350	0.178
Surinam	1.433	0.212	0.771	0.134	0.261	0.074	0.350	0.055	0.519	0.156
Other non-west	0.788	0.192	0.445	0.120	0.139	0.069	0.199	0.052	0.485	0.157
Other west	0.195	0.048	0.081	0.030	0.023	0.008	0.069	0.013	0.169	0.044
R^2		0.202		0.179		0.067		0.144		
ΔR^2 location		0.002		0.001		0.001		0.001		
ΔR^2 sex without age		0.001		0.001		0.001		0.003		

[1] Reference categories are Zeebra (location), married/cohabiting (marital status), high educational level, and autochthon.

that studies measuring multidimensional frailty show a higher prevalence of frailty (Collard et al., 2012).

The effect of sex persisted after controlling for age; women were more frail than men. The finding that scores on physical frailty are higher among women might be explained by lower levels of activity and lower average caloric intake (due to living alone more often) of women, compared to men (Fried et al., 2001; Walston & Fried, 1999). Researchers also suggest that men have higher baseline levels of muscle mass and higher levels of neuroendocrine and hormonal factors that may protect them from reaching physical frailty (Walston & Fried, 1999). The finding that women are also more psychological frail, after controlling for age, is not supported by other Dutch studies, using the four components of the TFI (problems with memory, depression, anxiety, problems with coping) (Gobbens, van Assen et al., 2010b; Comijs, 2011). These other studies however, contained fewer participants, and did not control for the same variables in their analyses. Finally, our study supported other studies' findings that women are more socially frail than men (Andrew, Mitnitski, & Rockwood, 2008; Broese van Groenou, 2011; Gobbens, van Assen et al., 2010b). These sex differences should be interpreted in the light of the fact that women are living alone more often, because women lose a partner due to death more often than men.

The effects of marital status on the five dependent frailty variables were more than halved after controlling for age. People who cohabited or were married demonstrated lower physical and psychological frailty scores. In all likelihood, most of the people belonging to the other marital status categories (not married, divorced, widowed) were living alone. Living alone is associated with more physical frailty (Fried et al., 2001) as well as social frailty (Bilotta, Case et al., 2010). In addition, living alone is a risk factor for depression (Bilotta, Case et al., 2010; Cheng, Fung, & Chan, 2008), social isolation, and loneliness (Routasalo, Savikko, Tilvis, Strandberg, & Pitkala, 2006) and these factors are associated with poor quality of life and mortality (Arslantas, Adana, Abacigil Ergin, Kayar, & Acar, 2015; Bilotta, Bowling et al., 2010; Steptoe, Shankar, Demakakos, & Wardle, 2013).

Our study revealed some very large average frailty differences between ethnic groups, with autochthon people having the lowest frailty scores. Turks had the highest frailty score, followed by Moroccans and Surinamese. However, social frailty was much higher in Surinamese, compared to Moroccans, which may indicate that Moroccans have a better social network. We recommend additional research on the association of ethnicity and frailty. Additional research is particularly relevant since the total disease burden (as measured with, for instance the Disability-Adjusted Life Years) of ethnic minorities is likely to increase more than that of native Dutch (Ikram, Kunst, Lamkaddem, & Stronks, 2014). Moreover, ethnic minorities had an increased risk of unplanned hospital readmission within 30 days and excess length of stay of at least three days during hospitalization (de Bruijne et al., 2013). We recommend that interventions by health care professionals should be aimed at addressing specific frailty problems of ethnic groups, such as physical and psychological frailty of Turkish and Moroccan people, and social frailty of Surinamese people. Culturally sensitive communication programs may be necessary to provide ethnic groups with the health information they need (Verhagen, Ros, Steunenberg, & de Wit, 2014).

Lower educational levels were associated with frailty. In another Dutch study the effect of educational level on frailty was reduced by 76% by factors such as mental (e.g. depression, mastery), biomedical (e.g. chronic diseases), social (e.g. network size), behavioral factors (e.g. smoking, alcohol use), and material resources (Hoogendijk et al., 2014). These findings highlight the need of a multidimensional approach in developing and carrying out interventions aimed at reducing frailty, especially in people with a low level of education.

Income had a negative linear association with frailty, which remained after controlling for age. Financial resources may provide a partial buffer against the detrimental psychological effects of frailty (Hubbard, Goodwin, Llewellyn, Warmoth, & Lang, 2014). These resources may mitigate frailty and adverse outcomes of frailty, such as disability, by having the means for technical adjustments in the home, making remaining independent more possible. The effect of income on social frailty was large, which is supported by a study that argued that those with lower income are likely to have less established networks of social support (Hubbard et al., 2014), one of TFIs social frailty components. A lack of social support may lead to less practical and emotional support to compensate their poor frailty status.

Location had a generally small effect on frailty, with participants living in the big city (Amsterdam) having higher average total and social frailty than participants living in the provinces Zeeland and Noord-Brabant. Higher frailty in big cities than in more rural areas is confirmed by other Dutch studies (Cramm & Nieboer, 2013; Metzelthin et al., 2010). In contrasting, two other non-Dutch studies found higher frailty in rural than urban areas (Song et al., 2007; Yu et al., 2012). An explanation for these different findings is that countries differ with respect to people (e.g., ethnicity), living conditions, and services in rural areas. Whereas proximity to services in rural areas is high in the Netherlands, this may not be the case in China or Canada. Moreover, living standards in the Netherlands are at least as high outside as inside big cities. More research is needed to investigate the relationship between location and frailty, and more specifically effects of environmental factors (housing, facilities, nuisance, neighborhood).

Finally, an important result is that the observed associations between socio-demographic variables and frailty seem to hold for both sexes and for big cities as wells as more rural areas (at least in the Netherlands). The absence of interactions with location supports the external validity of our findings for application to older persons in (at least Dutch) areas that were not included in our study. Hence the estimates reported in Table 3 may be used to compute reference values of the TFI for community-dwelling older people by age, sex, marital status, ethnicity, education, income, and residence in the Netherlands.

Some limitations should be noted in interpreting the results of this study. First, older persons than 80 years old are underrepresented in our sample. This may affect our conclusions if this is explained by frail persons being less likely to participate in our research. In that case, the reference scores reported for the older age groups (older than 80) may be a bit too positive, i.e. average frailty of older persons may be higher than reported in Table 3, particularly for the very old.

Second, there were many missing values with regard to frailty; around a quarter of respondents had missing values on total frailty. This rate is much higher than in other studies that used the TFI for measuring frailty (Coelho et al., 2014; Freitag et al., 2015; Gobbens, van Assen et al., 2010a). An explanation for this finding is that the TFI was positioned at the end of a long questionnaire for Zeebra. However, analyses revealed that the number of missing values on frailty was (very) weakly associated to the seven demographic variables, from which we conclude that this had no or a negligible effect on our findings.

Third, the procedure was different for autochthons and ethnic groups; only ethnic minorities were visited at home after not responding, which may have caused differences between ethnic groups in characteristics of participants, and participants' answers. Fourth, the TFI was completed by inhabitants of a big city (Amsterdam) and the provinces Zeeland and Noord-Brabant in the

Netherlands, and not by people in other Dutch areas or countries. Although the absence of an interaction with location suggests external validity of our results for other Dutch areas, we cannot be sure our findings also apply to community-dwelling older people in other Dutch areas, and particularly other countries. We suggest the development of reference values for the TFI in countries where the TFI was validated, e.g. Portugal (Coelho et al., 2014), Brazil (Santiago et al., 2013), Germany (Freitag et al., 2015), Poland (Uchmanowicz et al., 2014), Italy (Mulasso et al., 2015) and Denmark (Andreasen et al., 2014).

In conclusion, we explain frailty using socio-demographic characteristics and offer reference values of the TFI by socio-demographic characteristics age, sex, marital status, education, income, ethnicity, and location. This information will support researchers, policymakers and health care professionals (e.g. general practitioners, nurses, physical therapists, social workers) when interpreting scores of the TFI and its domains (physical, psychological, social), which may guide their efforts to reduce frailty and its adverse outcomes disability, health care utilization, lower quality of life and premature death.

Conflict of interest

The authors declare that they have no conflict of interest.

Author contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, and (3) final approval of the submitted version.

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