Towards tailored elderly care

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Predictive validity of a frailty measure (GFI) and a case complexity measure (IM-E-SA) on healthcare costs in an elderly population

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ABSTRACT

Objectives Measures of frailty (Groningen Frailty Indicator, GFI) and case complexity (INTERMED for the Elderly, IM-E-SA) may assist healthcare professionals to allocate healthcare resources. Both instruments have been evaluated with good psychometric properties. Limited evidence has been published about their predictive validity. Thus, our aim is to evaluate the predictive validity of both instruments on healthcare costs.

Participants Community-dwelling and institutionalized living elderly persons

Measurements Multivariate linear regression models were developed to estimate associations between the predictors frailty (GFI) and/or case complexity (IM-E-SA) and the healthcare costs (in € log transformed) in the following year. All models were adjusted for demographics and the presence of morbidity.

Results In the multivariate regression analyses the continuous scores of the GFI and IM-E-SA remained significant predictors for total healthcare costs. Adjusted βs for GFI and IM-E-SA were respectively 0.14 (95%CI 0.10-0.18) and 0.06 (95%CI 0.04-0.07). The corresponding explained variances for both models were similarly R^2 0.40. Frailty remained a significant predictor of long-term care costs (adjusted β 0.13 [95%CI 0.09-0.16]), while case complexity was a significant predictor of curative care costs (adjusted β 0.03 [95% CI 0.02-0.05]).

Conclusions
The GFI and IM-E-SA both accurately predict total healthcare costs in the following year.

6.1 INTRODUCTION

While life expectancy is increasing worldwide, healthy life expectancy is not, which contributes considerably to the burden of chronic diseases. The majority of elderly people will even suffer from several chronic diseases[1]. Almost 40 percent of the Dutch elderly persons aged between 65-74 year were diagnosed with two or more chronic conditions, and almost 60 percent of the elderly persons aged of 75 years and over reported multimorbidity[2]. Thus the demographic transition is a challenge for both the healthcare system and society at large[3,4]. For example, in Europe the old-age dependency ratio (people aged 65 or above relative to the working-age population) will decrease from 1:4 in 2003 to 1:2 by 2050[5]. Furthermore, by 2020 the estimated shortage of European health workers will be about one million professionals[6].

Selection of older persons at high risk for poor health outcomes (e.g. acute illnesses and hospital admissions) based on chronological age only disregards the fact that the pace of ageing shows considerable inter-individual variation[7-9]. Therefore, identification of older people by measuring frailty may yield better indicators of imminent poor outcome. Frailty indicates a state of vulnerability regarding the future occurrence of poor health outcomes, such as mortality, hospitalization, institutionalization, chronic conditions, and loss of function in one or more domains (i.e., physical, psychological, cognitive, and social domains)[9-13]. Personalized and more efficient prevention programs for high-risk elderly people require accurate instruments to identify these frail older persons. A self-assessment instrument with good psychometric properties like the Groningen Frailty Indicator (GFI) may be suitable[10,14]. Clinical and longitudinal studies showed that the GFI predicts mortality, quality of life, functional decline, and postoperative delirium[9,15-20]. However, up till now it is unknown if the GFI has the ability to predict healthcare costs.

An alternative approach could be the self-assessment of case complexity by the INTERMED for the Elderly Self Assessment (IM-E-SA), which assesses foreseen needs in bio-psycho-social healthcare domains. This measure aims to identify elderly persons with complex care needs who are in need for more intensive (tailored) interdisciplinary care[21-24]. The IM-E-SA has shown good psychometric properties in a cross sectional study[22]. However, the predictive validity for future healthcare costs is unknown.

Some studies even combine the scores of the GFI and IM-E-SA to identify elderly subgroups who are, e.g. robust, having physical and mobility complaints, feeling (extremely) frail[25,26]. In epidemiological studies the total score of the instruments are frequently reported to reflect the level of frailty and/or case complexity in elderly populations. However, in daily practice dichotomous scores on the instruments are sometimes preferred to differentiate elderly people into non-frail versus frail or non-case complex versus case complex groups. Subsequently different care arrangements may be offered per subgroup. Up till now, elaborate comparisons between elderly subgroups that differ in frailty and/or case complexity levels regarding healthcare costs have not been reported.

The primary objective of the present study is to evaluate the predictive validity of the self-assessment versions of the GFI and INTERMED for the Elderly on total healthcare costs, long-term care costs, and curative care costs in one year follow-up. The associations may provide information about specific care usage of frail or case complex elderly persons. Such insights are essential for the development of effective care interventions tailored for frail or case complex elderly persons to prevent an increase in their healthcare costs in the future.

6.2 METHODS

From March till December 2010 a longitudinal population-based study was conducted among elderly persons residing in urban and rural areas in the Northern provinces of the Netherlands. The elderly persons were identified with the assistance of in total 25 healthcare organizations (e.g. hospitals, welfare organizations, homes for the elderly) and associations for the elderly. Trained research nurses contacted eligible elderly persons who lived independently, in living-assisted residences or in nursing homes. Next, the research nurses with professional experience in geriatric care, assessed if candidate participants had to be excluded for severe cognitive decline or terminal illnesses. Elderly persons were included if they were 65 years of age and over, and were able to complete a questionnaire. The data on healthcare costs were obtained for the year 2011. Elderly persons were included in the present study if the total healthcare costs were provided (i.e. costs for long-term and curative care).

The ethics review board of our institution provided a waiver for this non-intrusive longitudinal observational study as it was not a study with test subjects as meant in the Medical Research Involving Human Subjects Act. Written informed consent was obtained from all participants. In particular, participants consented with collecting healthcare costs data from their insurance company and the Care Indication Determination Centre.

6.2.1 Baseline

At baseline, all participants received a questionnaire comprising items about demographics (i.e. age, gender, marital status, living situation, and education level) and morbidity (presence of 17 diseases/disorders: e.g. cancer, cardiovascular disease, and diabetes mellitus). Moreover, the participants completed measures on frailty and case complexity. The full versions of both instruments are available in previous published papers[10,22].

Frailty was assessed with the internally consistent and valid self-assessment version of the GFI[10,14]. It comprises 15 items and measures the loss of functions and resources in four domains: physical, cognitive, social, and psychological[10,14]. All answer categories were dichotomized and a score of 1 indicates a problem or dependency. The range of the GFI score is 0 to 15. Geriatric experts agreed that a score of 4 or higher represents moderate to severe frailty. In daily practice this cut-off score can be important for clinical decision making as healthcare professionals look to differentiate between non-frail and frail individuals, and organize different care pathways accordingly.

Case complexity and healthcare needs were assessed with the IM-E-SA[22]. This is a valid and reliable measure which provides a bio-psychosocial description of the elderly person based on clinically relevant variables[22]. This measure comprises the following domains: biological, psychological, social, and healthcare[22,27,28]. All domains comprise five questions, with each domain being assessed in a context of time (history, current state, and prognosis). In total, the instrument consists of 20 items and the scores are summed (range 0-60), with a total score of 18 or higher identifying participants as case complex[22].

6.2.2 Healthcare cost outcomes

Data on healthcare costs – comprising both costs for long-term care and curative care – in 2011 were provided for two out of the three compartments of the healthcare insurance system in the Netherlands.

The first compartment included 'costs for long-term care': costs mainly for intramural care, and covered by a state controlled mandatory insurance (General Act on Exceptional Healthcare Costs, in Dutch: Algemene Wet Bijzondere Ziektekosten)[29]. Long-term care can be provided at the individual's home, a residential care home or a nursing home that an individual is residing[29,30]. The long-term care involves personal care (e.g. help with showering and dressing), nursing care (e.g. wound dressing), assistance (e.g. help with organizing day-do-day practical matters), and treatment (help with recovering from illnesses or injuries or improving skills or behavior)[29,30]. Every request for long-term care must be assessed by the Care Indication Determination Centre (in Dutch: Centrum Indicatiestelling Zorg). This independent organization decides on the intensity and duration of the care to be provided and estimates these costs[29]. In the present study, actual costs incurred for 2011 were provided.

The second compartment incorporates costs for curative care, which are financed by health insurance companies (Health Insurance Act, in Dutch: Zorgverzekeringswet)[29]. All Dutch citizens are obliged to have a basic health insurance package for curative care with an individually chosen private healthcare insurer[30]. The specific content of the basic package is established by the Dutch government. The corresponding fees differ between health insurers, but a fixed compulsory deductible is also set by the government[30]. Examples of cost that are covered in the basic health insurance are hospital costs (e.g. inpatient and outpatient specialist care, medical treatments, diagnostic assessments), general practice care, paramedical care, pharmaceutical care, psychological care, and aids and assistive devices (e.g. incontinence material, diabetes test strips)[29]. In addition to the statutory basic health insurance, a supplemental health insurance package can be purchased. These packages vary in reimbursement and premiums per health insurance company and compensate for costs that are not or only partly covered under the basic insurance[30]. Those additional packages reimburse for example additional treatments (psychological care, movement therapy), offer a higher compensation for glasses and hearing aids, and alternative medicine[29,30]. In the present study, elderly persons could select from four optional packages of supplementary health insurance denoted by a number between one and four. Higher numbered packages were more expensive, but also reimbursed a higher percentage of cost related to care.

The third component comprises costs not available for the present study. These costs, covered by municipal authorities, include those for instrumental assistance (e.g. housekeeping) and provision of adaptations to the home (e.g. stair lift or a bathroom adaptation)[29].

Data on mortality before December 31st 2011 were obtained from the municipal registry. All collected data were merged by a third party to ensure the anonymity of the participants.

6.2.3 Statistical analysis

Baseline characteristics were analyzed using descriptive statistics. Differences between participating and excluded elderly persons were evaluated with the Mann-Whitney U test and Pearson Chi-Square tests, where appropriate. Since the data were not normally distributed, median scores and interquartile ranges (IQR) were calculated for all costs. Differences in healthcare costs between elderly subgroups, i.e. by differences in frailty or case complexity, were assessed using Mann-Whitney U tests.

Univariate and multivariate linear regression models were used to estimate the associations between the predictors frailty and/or case complexity versus healthcare costs during one-year follow-up. Except for the GFI-score, IM-E-SA-score, and age, all variables were entered as dichotomous variables. Furthermore, the data of the supplemental healthcare insurance packages were entered as dummy variables, with the statutory basic health insurance as the reference group. Before the GFI and IM-E-SA were simultaneously added to the model, multicollinearity was tested with a variance inflation factor (VIF) as both concepts are moderately correlated[10]. A VIF above 10 indicates multicollinearity[31]. The associations were expressed as unstandardized β coefficients with corresponding 95% confidence intervals (95% CI). The prediction models were developed with log-transformed cost data from the elderly persons who were alive December 31, 2011. The multivariate linear regression models were developed with a backward stepwise selection method. Potential predictors were included in the multivariate model if their p-value was ≤0.15 in the univariate analyses. Alpha values greater than 0.05

are frequently used in prediction modeling to limit bias in the predictor coefficients[32]. In the final multivariate regression model, predictors were included if their p-value was ≤0.05. For all prediction models we checked whether the assumptions for the multivariate linear regression analyses were valid.

All prediction models were re-run by including the data of participants who died in 2011. Furthermore, the prediction models were extended with a time at risk variable that reflected the period that a person was alive in 2011. For example, persons who remained alive throughout the whole study follow-up had a time at risk of 1, whereas persons who died at April 1st 2011 had a time at risk of 0.25.

All multivariate regression models were evaluated for goodness of model fit by calculating the proportion of explained variance (R^2). The final prediction models (including either GFI or IM-E-SA) for total healthcare costs were checked for calibration. Calibration is the extent of agreement between the predicted healthcare costs and observed healthcare costs. This evaluation was performed graphically by plotting the log-transformed predicted healthcare costs against the log-transformed observed healthcare costs[33]. Ideally, the plot shows a 45° gradient[34].

6.2.4 Post-hoc analyses

Since time at risk appeared a significant predictor for all healthcare costs in the multivariate analyses, post-hoc analyses were performed to assess if the monthly incurred healthcare costs differed between persons who died in 2011 and those who remained alive during the follow-up period. Statistical differences between both groups were calculated with Mann-Whitney U tests.

All statistical analyses were performed by using SPSS Statistics 22.0 (SPSS inc. Chicago, Illinois).

6.3 RESULTS

In total, 2,016 elderly participants completed the questionnaires. However, 1,212 older persons were excluded because they were not insured by the insurance company that covered the costs related to curative care. Furthermore, 28 persons passed away in 2010 and 63 persons declined further participation. Therefore the present study includes 713 subjects. Compared with the excluded persons, the participants in the present study were more likely to be single (p=0.03), and had a lower level of education (p≤0.001). No further differences were found between participants and excluded elderly persons on demographic characteristics, morbidity and measurement scores.

Table 1 shows the demographic and clinical characteristics of the elderly participants. The mean age of the participants was 80 years and 64% lived independently (*n*=455). At baseline, 51% (*n*=361) of the elderly persons were identified as frail, 26% (*n*=184) as case complex and 23% (*n*=163) were identified as both frail and case complex. Almost all participants (93%) had a supplementary healthcare insurance package in addition to the statutory basic health insurance, respectively 217, 91, 355, and 4 participants had package 1, 2, 3, and 4. Because of the low number of participants with package 4, in the statistical analyses these were combined with those who had package number 3. In total 84 persons died in 2011.

Table 1 Baseline characteristics of the included elderly population (*n*=713)

	n (%)
Age (mean, SD)	80 (8)
Gender female	447 (63)
Marital Status (partner/spouse)	303 (43)
Living situation	
Home-dwelling elderly	455 (64)
Living in homes for the elderly or nursing homes	258 (36)
Education level	
Primary school or lower	381 (53)
Secondary school or higher	323 (45)
Unknown	9 (1)
Morbidity	
0-1 disease	199 (28)
≥2 diseases	514 (72)
MEASURES (median scores [interquartile range])	
Frailty (Groningen Frailty Indicator)	4 [2-6]
Case Complexity (INTERMED for the Elderly Self Assessment)	13 [8-18]

Table 2 Median total healthcare costs, costs for long-term care and costs for curative care during one year follow-up (2011) for elderly populations who were (non) frail or (non) case complex and for the total population

	Non-Frail[1] *n*=352		Frail[1] *n*=361		
	€ median (IQR[3])	€ mean	€ median (IQR[3])	€ mean	p-value[4]
Total healthcare costs	7,697 (2,215-23,903)	15,611	29,438 (13,349-45,814)	30,792	≤0.001
Total costs for long-term care	0 (0-15,536)	8,834	19,547 (6,050-31,147)	22,604	≤0.001
Costs for institutional care[5]	0 (0-11,876)	7,025	14,197 (0-32,595)	17,655	≤0.001
Costs for home care	0 (0-218)	1,809	0 (0 – 4,915)	4,948	≤0.001
Total cost for curative care	3,543 (1,616-7,859)	6,777	4,926 (2,513-10,483)	8,189	≤0.001
Costs for hospital treatments/admissions	987 (231-4,185)	4,000	860 (212-4,950)	3,764	0.63
Costs for pharmaceutical care	780 (260-1,572)	1,237	1,120 (323-1,932)	1,573	0.01
Costs for general practitioners	277 (170-506)	374	349 (181-634)	450	0.02
Costs for aids and devices	96 (0-498)	528	374 (18-1,368)	1,016	≤0.001

[1] Groningen Frailty Indicator: non-frail (total score 0-3) or frail (total score 4-15)

[2] INTERMED for the Elderly Self Assessment: non-case complex (total score 0-17) or case complex (total score 18-60)

[3] Interquartile range

[4] Differences on median healthcare costs, calculated with Mann-Whitney tests

[5] Care in nursing home or home for the elderly

6.3.1 Healthcare costs in the population

The median total healthcare costs per person in 2011 were € 18,773 (IQR € 4,317 - € 37,950, Table 2). The minimum incurred total healthcare costs in 2011 was € 38 per person while the maximum incurred costs was € 103,651. One third of the elderly population (*n*=242) did not have any costs related to long-term care, while all participants had expenses for curative care.

Elderly persons who were identified as case complex had the highest total healthcare costs, cost for long-term care and cost for curative care (Table 2). Compared with non-frail elderly persons, frail elderly persons sustained statistically significantly higher costs on all healthcare costs, but hospital costs were (not statistically significantly) lower (p=0.63). Compared with non-case complex elderly, case complex elderly persons also reported statistically significantly higher costs on all healthcare costs, except for pharmaceutical care (p=0.41) and cost for primary care (p=0.20).

Non- case complex[2] *n*=529		Case complex[2] *n*=184			Total population *n*=713	
€ median (IQR[3])	€ mean	€ median (IQR[3])	€ mean	p-value[4]	€ median (IQR[3])	€ mean
14,760 (3,009-32,531)	19,623	33,221 (15,854-47,687)	33,860	≤0.001	18,773 (4,317 -37,950)	23,297
5,919 (0-21,737)	12,917	21,795 (5,315-41,341)	24,110	≤0.001	10,689 (0 - 28,185)	15,806
0 (0-17,467)	9,930	17,365 (0-36,186)	19,530	≤0.001	0 (0 - 23,386)	12,407
0 (0-1,018)	2,987	0 (0-4,603)	4,580	0.05	0 (0 – 1,731)	3,398
3,805 (1,788-7,933)	6,706	5,753 (3,027-13,108)	9,751	≤0.001	4,232 (1,962 - 9,420)	7,492
850 (216-4,013)	3,524	1,113 (263-6,554)	4,905	0.04	924 (224 – 4,649)	3,880
872 (305-1,708)	1,310	1,127 (214-1,896)	1,686	0.41	906 (283 - 1,781)	1,407
297 (178-543)	396	376 (166-674)	458	0.20	309 (175 - 567)	412
156 (0-692)	671	460 (0-1,520)	1,074	≤0.001	199 (0 - 973)	775

6.3.2 Prediction models

In both the univariate and multivariate linear regression analyses, frailty (GFI) and case complexity (IM-E-SA) remained significant predictors for log-transformed total healthcare costs (Table 3). In the univariate linear regression analyses, crude βs for the GFI and IM-E-SA were respectively 0.24 (95%CI 0.20-0.28) and 0.08 (95%CI 0.07- 0.09). The corresponding proportions of explained variances for the univariate predictors GFI and IM-E-SA were 0.18 and 0.17 respectively. Both models were adjusted with the significant predictors gender, living situation and morbidity. The adjusted βs for the GFI and IM-E-SA were respectively 0.14 (95% CI 0.10 to 0.18) and 0.06 (0.04 to 0.07). Due to the log-transformed healthcare costs data, those βs can be interpreted as follows: one unit increase in GFI score or IM-E-SA score is associated with a 15% ($e^{0.14}$) or 6% ($e^{0.06}$) increase in healthcare costs in the follow-up year, respectively. The explained variances of both models were almost equal with a R^2 of 0.40. Combining both concepts in the prediction model for total healthcare costs, we found no evidence for multicollinearity (VIF=1.83). The corresponding adjusted βs for GFI and IM-E-SA in this extended model, were respectively: 0.06 (95%CI 0.02-0.11) and 0.04 (95%CI 0.03-0.06).

By adding both GFI and IM-E-SA to the multivariate model for predicting long-term care costs or costs for curative care, it showed that frailty remained a significant predictor of long-term care costs (adjusted β 0.13 [95%CI 0.09-0.16]), while case complexity was a significant predictor of curative care costs (adjusted β 0.03 [95%CI 0.03 (0.02-0.05]), Table 4).

Repeating all final prediction models for total healthcare costs, long-term healthcare costs and curative care costs including older adults who died in 2011 and a time at risk variable did not change the above mentioned results. However, this extension showed that the time at risk was a significant predictor for total healthcare costs (adjusted β 0.63 [95%CI 0.13-1.14], p=0.02), long-term care costs (adjusted β 0.88 [95%CI 0.33-1.43], p=0.002) and curative care costs (adjusted β 1.53 [95%CI 1.09-1.98], p≤0.001).

Next, the final multivariate prediction models for total healthcare costs with either the GFI or IM-E-SA as a predictor adjusted for gender, living situation and morbidity were well calibrated. The calibration plots showed agreement between the predicted and observed total healthcare costs (Figures 1 and 2). Moreover, both plots showed that the predictions of higher healthcare costs were less accurate compared to the lowest healthcare costs. The confidence intervals appeared to be wider as the costs increased.

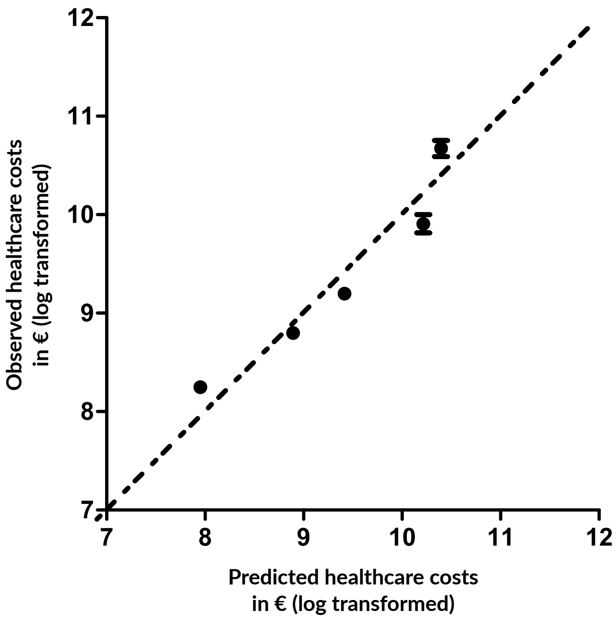

Figure 1 Calibration plot of the predicted and observed total healthcare costs in € (log-transformed) with corresponding 95% confidence intervals. The multivariate linear prediction model included Groningen Frailty Indicator, gender, living situation, and morbidity as predictors.

6.3.3 Post-hoc analyses

Post-hoc analyses revealed that persons who died in 2011 incurred statistically significantly higher healthcare costs, compared with persons alive the entire follow-up period. These costs were €3,920 (IQR €2,787-5,201) versus €1,475 (IQR €305-3,170, p≤0.001) per month for total healthcare costs, €2,444 (IQR €1,397-3,686) versus 776 (IQR: 0-2,349, p≤0.001) per month for long-term care costs, and €940 (IQR €430-2,420) versus €345 (IQR €163-758, p≤0.001) per month for curative care costs.

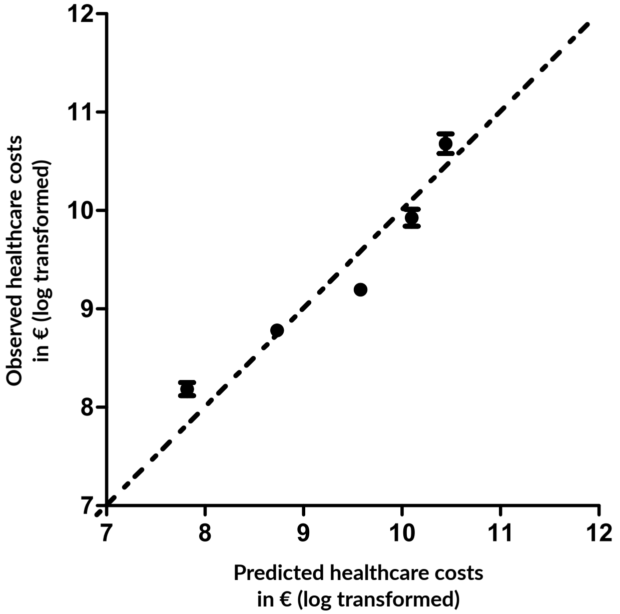

Figure 2 Calibration plot of the predicted and observed total healthcare costs in € (log-transformed) with corresponding 95% confidence intervals. The multivariate linear prediction model included INTERMED for the Elderly Self Assessment, gender, living situation, and morbidity as predictors.

Table 3 Univariate and multivariate linear regression models to predict total healthcare costs in € log-transformed with predictors frailty and/or case complexity, demographic characteristics, morbidity, and health insurance in a 1 year follow-up period

	Total healthcare costs in € (log-transformed)			
	Univariate linear regression models		Multivariate linear regression model including frailty[1]	
PREDICTORS	β (95% CI)	p-value	β (95% CI)	p-value
Measures				
Frailty (GFI)[2]	0.24 (0.20 to 0.28)	≤0.001	0.14 (0.10 to 0.18)	≤0.001
Case complexity (IM-E-SA)[3]	0.08 (0.07 to 0.09)	≤0.001	NA	NA
Demographic characteristics				
Age	0.06 (0.05 to 0.07)	≤0.001	-	-
Gender[5]	0.22 (-0.01 to 0.44)	0.06	-0.29 (-0.49 to -0.08)	0.01
Marital Status[6]	-0.74 (-0.95 to -0.52)	≤0.001	-	-
Living situation[7]	1.57 (1.37 to 1.76)	≤0.001	1.35 (1.13 to 1.56)	≤0.001
Education level[8]	-0.32 (-0.54 to -0.10)	0.01	-	-
Morbidity				
Morbidity[9]	1.10 (0.87 to 1.33)	≤0.001	0.74 (0.52 to 0.96)	≤0.001
Health insurance[10]				
Supplementary package 1	0.23 (-0.24 to 0.70)	0.20	-	-
Supplementary package 2	0.12 (-0.41 to 0.64)		-	-
Supplementary package 3/4	0.38 (-0.07 to -0.84)		-	-
Constant of the multivariate model			7.95	
PERFORMANCE OF THE MODEL				
R^2	-		0.40	

[1] If the variable had a p-value ≤0.15 in the univariate analysis, it was considered in the multivariable model and maintained in the final multivariate model if p-value was 0.05

[2] Groningen Frailty Indicator

[3] INTERMED for the Elderly Self Assessment

[4] Not applicable

[5]Gender: 0 is male and 1 is female

[6]Marital Status: 0 is no partner/spouse; 1 is partner/spouse

[7] Living situation: 0 is living independently or in assisted living residences; 1 is living in homes for the elderly or nursing homes

[8] Education level: 0 is primary school or lower; 1 is secondary school or higher.

[9] Morbidity: 0 is 0-1 diseases; 1 is 2 or more diseases

[10] The supplementary health insurance packages were coded as dummy variables, where the basic insurance alone (no supplementary package) is the reference group

Total healthcare costs in € (log-transformed)			
Multivariate linear regression model including case complexity[1]		Final multivariate linear regression model including frailty and case complexity[1]	
β (95% CI)	p-value	β (95% CI)	p-value
NA[4]	NA	0.06 (0.02 to 0.11)	0.01
0.06 (0.04 to 0.07)	≤0.001	0.04 (0.03 to 0.06)	≤0.001
-	-		
-0.24 (-0.44 to -0.04)	≤0.001	-0.28 (-0.48 to -0.08)	0.01
-	-		
1.48 (1.27 to 1.68)	≤0.001	1.40 (1.19 to 1.61)	≤0.001
-	-		
0.57 (0.35 to 0.80)	≤0.001	0.58 (0.36 to 0.81)	≤0.001
-	-	-	-
-	-	-	-
-	-	-	-
7.75		7.75	
0.41		0.41	

Chapter 6

Table 4 Univariate and multivariate linear regression models to predict costs related to care and cure with predictors frailty or case complexity, demographic characteristics, morbidity, and health insurance in a 1 year follow-up period

	Costs for long term care in €(log-transformed)			
	Univariate linear regression models		Final multivariate linear regression model[1]	
PREDICTORS	β (95% CI)	p-value	β(95% CI)	p-value
Measures				
Frailty (GFI)[2]	0.16 (0.12 to 0.19)	≤0.001	0.13 (0.09 to 0.16)	≤0.001
Case complexity (IM-E-SA)[3]	0.03 (0.01 to 0.04)	≤0.001	-	-
Demographic characteristics				
Age	0.04 (0.02 to 0.05)	≤0.001	-	-
Gender[4]	-0.31 (-0.57 to -0.04)	0.02	-	-
Marital Status[5]	-0.37 (-0.62 to -0.12)	0.004	-	-
Living situation[6]	1.05 (0.85 to 1.25)	≤0.001	0.95 (0.75 to 1.14)	≤0.001
Education level[7]	-0.12 (-0.35 to 0.12)	0.32	-	-
Morbidity				
Morbidity[8]	0.18 (-0.12 to 0.47)	0.24	-	-
Health insurance[9]				
Supplementary package 1	-0.13 (-0.64 to 0.38)	0.73	-	-
Supplementary package 2	-0.05 (-0.63 to 0.53)		-	
Supplementary package 3/4	-0.21 (-0.70 to 0.28)		-	
Constant of the model			8.65	
PERFORMANCE OF THE MODEL				
R^2	-		0.30	

[1] If the variable had a p-value ≤0.15 in the univariate analysis, it was considered in the multivariable model and maintained in the final multivariate model if p-value was 0.05

[2] Groningen Frailty Indicator

[3] INTERMED for the Elderly Self Assessment

[4] Gender: 0 is male and 1 is female

[5] Marital Status: 0 is no partner/spouse; 1 is partner/spouse

[6] Living situation: 0 is living independently or in assisted living residences; 1 is living in homes for the elderly or nursing homes

[7] Education level: 0 primary school or lower; 1 is secondary school or higher.

[8] Morbidity: 0 is 0-1 diseases; 1 is 2 or more diseases

[9] The supplementary health insurance packages were coded as dummy variables, where the basic insurance alone (no supplementary package) is the reference group

Costs for curative care in € (log-transformed)			
Univariate linear regression model		Final multivariate linear regression model[1]	
β (95% CI)	p-value	β (95% CI)	p-value
0.05 (0.02 to 0.09)	0.01	-	-
0.05 (0.03 to 0.06)	≤0.001	0.03 (0.02 to 0.05)	≤0.001
0 (-0.02 to 0.01)	0.65	-	-
-0.29 (-0.50 to -0.08)	0.01	-0.41 (-0.60 to -0.21)	≤0.001
0.08 (-0.13 to 0.28)	0.47	-	-
0.13 (-0.08 to 0.35)	0.23	-	-
-0.10 (-0.30 to 0.11)	0.34	-	-
0.89 (0.68 to 1.1)	≤0.001	0.73 (0.50 to 0.96)	≤0.001
0.41 (-0.03 to 0.85)	0.06	-	-
0.46 (-0.03 to 0.95)		-	-
0.57 (0.14 to 1.00)		-	-
		7.55	
-		0.14	

6.4 DISCUSSION

The present study supports the predictive validity of the GFI and IM-E-SA in older adults on total healthcare costs during a one year follow-up period. Gender, living situation and morbidity were also significant predictors of total healthcare costs. An intriguing result was that in the multivariate regression models the GFI remained a significant predictor of long-term care cost, while case complexity was a significant predictor of curative care cost. These results corroborate the concepts of frailty and case complexity as measured with the GFI and IM-E-SA. Frailty reflects dependence in daily activities due to losses in physical functions, cognitive impairment, psychological distress and social dysfunctions. To assist elderly persons to stay in their own homes for as long as possible, or to maintain dignity and sufficient levels of quality of life in a nursing home, the needs of these older adults with different levels of frailty are met by the provision of long-term care. In contrast, case complexity reflects the biopsychosocial risks and needs based on the history, the present state and an estimation of the future by the elderly themselves[35]. Consequently, older adults with increased biopsychosocial risks and needs incurred higher curative care costs, as these were related to hospital treatments and hospital admissions.

Other studies evaluated the predictive validity of the GFI on poor outcomes (i.e. mortality, hospitalization and functional decline), and showed the potential of the instrument to identify elderly persons at risk[15,36-39]. However, the predictive power and test accuracy for individual risk-assessment were not found to be sufficient in those studies, although predictive power of the GFI was concordant with other frailty instruments, irrespective of whether these measures included either a physical domain or multiple domains[15,36-39]. The present study was the first study to evaluate the predictive validity of the IM-E-SA on healthcare costs however an evaluation on its ability to predict poor outcomes has not been done to date.

A strong point of the present study is the development of prediction models with a new perspective as the models included predictors of measurement scores, demographic characteristics and morbidity. The final prediction models of total healthcare costs showed similar proportions of explained variances (R^2 0.40). Our innovative approach by adding a frailty instrument to a prediction model showed a higher explained variance for long-term costs (R^2 0.30) in comparison with a model including other significant predictors, i.e., gender, age and living situation (R^2 0.23)[40]. Furthermore, this previous study showed that adding past long-term care increased the R^2 to 0.73[40]. However, caution is needed with this model as it may only be suitable for elderly persons who remain living institutionalized since the majority of them will not leave the intramural setting. Consequently, this model cannot be used in home-dwelling older people.

A possible limitation of the present study is that the respondent's healthcare costs were available from a single Health Insurance Company. However, we are convinced that the provided data on curative healthcare costs have not compromised our findings as all health insurance companies provide similar basic health insurance coverage as this is obligatory in the Netherlands. Differences in covered costs may be observed in the supplemental health insurance packages, however in the present study these packages did not remain significant predictors in all multivariate models. Moreover, due to the lacking data of curative care costs, data were analyzed of 35% (*n*=713) of the original sample size. A comparison on baseline characteristics elderly persons included versus excluded did not show major differences between both groups. Furthermore, the generalizability of the results were supported by the similarity in frailty and case complexity scores in the present study compared with previously published studies[10,22]. However, compared with the Dutch general elderly population the present study included a substantial sample of institutionalized living elderly persons, 3% versus 36%, respectively[41,42]. The latter may also explain the high mortality rate of the present study compared with the mortality rate of Statistics Netherlands[43]. A second limitation of the study was that no data were available on informal care or domestic home care that both can affect the use of healthcare services and therefore costs[40,44]. Possibly, some of these non-medical costs are concentrated among elderly groups with specific characteristics, which could not be assessed in the present study. Therefore the presented models seem relevant for healthcare policy makers, clinicians and researchers to predict medical healthcare costs and not the overall costs for society.

A major strength of the study was the detailed specification of costs related to long-term care and curative care for persons who were living independently or institutionalized. These data were also merged with questionnaires and mortality providing relevant characteristics of a Dutch elderly population. Besides the development of the prediction models, the present study also provided an insight in healthcare costs concentrated in the last year of life. Persons who died in 2011 had monthly costs which were up to three times higher for total healthcare, long-term care and curative care, as compared with elderly persons who remained alive.

Firstly we recommend future studies to develop new prediction models on healthcare costs as globally, healthcare demands will increase exponentially due to the ageing society[45]. To select those persons at risk for an increase in healthcare costs a prediction model including a measurement score like the GFI or IM-E-SA is recommended as these scores contributed to almost half of the explained variances.

In the present study we used the continuous scores of the GFI and IM-E-SA as those scores are preferred in multivariate regression models as dichotomous scores reduce the power of the analyses[46]. However, in clinical settings the use of a dichotomous score is beneficial in daily practice to differentiate persons into useful categories and apply different care pathways accordingly[10,22]. The commonly used cut-off score of the GFI and IM-E-SA are based upon consensus of a panel of geriatric experts and/or established with statistical analyses with cross sectional data[8,10,22]. Therefore, our second recommendation is to assess the optimal cut-off points of both measures in longitudinal studies. Possibly, optimal cut-off values vary according to elderly populations and adverse health outcomes evaluated[10,22].

6.4.1 Conclusion

in conclusion, our study showed that models including GFI or IM-E-SA accurately predict total healthcare costs in the follow-up year. Frailty (GFI) remained a significant predictor for long-term care costs, while case complexity (IM-E-SA) predicted curative care cost in the follow-up year.

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