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Development and validation of a fall risk Questionnaire in Greek community-dwelling individuals over 60 years old

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Abstract

Objectives: The purpose of this study was to develop a questionnaire that can reliably recognize Greek individuals over the age of 60 with increased risk of falls. **Methods**: An 11-item self-reported Questionnaire (LRMS) was developed and delivered to 200 individuals. Collected data were compared to Timed Up and Go (TUG), Falls Efficacy Scale-International (FES-I), Tinetti Assessment Tool, Geriatric Depression Scale-15 (GDS-15) and Morse fall scale. The results were statistically analyzed. **Results**: Correlation between LRMS and the examined tools was high TUG (r=0.831), FES-I (r=−0.820), Tinetti balance (r=−0.812), Tinetti gait (r=−0.789), GDS-15 (r=−0.562), and Morse fall scale (r=0.795). Cronbach's alpha for LRMS total score was 0.807. ICC of the LRMS total score was 0.991. The area under the curve of LRMS was 0.930 (cut-off point 10.5, 95% C.I. 0.88 - 0.98, p<0.001, sensitivity=86%, specificity=98%) with TUG as gold standard, 0.919 (cut-off point 11.5, 95% C.I. 0.88 - 0.96, p<0.001, sensitivity=85%, specificity=89%) with FES-I and 0.947 (cut-off point 10.5, 95% C.I. 0.91 - 0.98, p<0.001, sensitivity=93%, specificity=91%) with Tinetti. **Conclusions**: The LRMS Questionnaire showed sufficient internal consistency, excellent test–retest reliability and high correlation with the already established tools for fall risk assessment. It is short and easy to use without assistance from specially trained personnel.

Keywords: Community-dwelling adults, Elderly, Older adults, Questionnaire, Risk of falls

Introduction

Falls among the elderly are a common cause of morbidity and mortality worldwide. This is particularly important as there has recently been a rapid increase in the aging of the population. According to World Health Organization (WHO) the number of individuals over 60 years of age will increase from 900 million to 2 billion people by 2050, which will comprise 22% of the total population[1]. It is estimated that falls are of concern for 32% of individuals 65–74 years of age and for 51% of elderly over 85 years of age[2]. It is also important to note that falls are responsible for 87% of fractures in the elderly[3], while 5% of them require admission to the hospital. It is also estimated that 6% of medical expenses for people over 65 years old are for fall-related trauma[4].

To properly prevent falls and related complications, the need to recognize people at a higher fall risk becomes evident. Many factors have been associated with an increased fall risk[3,5,6]. Among them are advanced age (over 65 years of age), female gender, history of falls, fear of

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falls, need for walking assistive devices, vision impairment, neuromuscular disorders, cardiopulmonary disorders, frailty, polypharmacy, depression, dementia and a number of extrinsic factors such as uneven surfaces, inadequate lightning and unsafe footwear[5,7,8]. Apart from the proper identification of individual predisposing factors, it is equally important to examine the presence of multiple factors, as it has been shown that the fall risk increases dramatically when more than one risk factors are present[9].

Until now, no single instrument has been developed that can reliably recognize high-risk individuals by addressing all predisposing factors simultaneously[10]. The difficulties arise primarily from the multifactorial nature of fall risk, which makes the development of a simple and efficient tool very challenging. Therefore, a combination of questionnaires and clinical examination is used to maximize the possibility of identifying high-risk individuals[10]. The most widely used performance-based measures that assess gait and balance are the Timed Up and Go Test (TUG)[11], the Tinetti Assessment Tool[12], and the Berg Balance Scale[13]. Fear of falls can be measured with the Short Falls Efficacy Scale International (FES-I)[14], which has been validated for the Greek population[15]. Cognitive impairment is usually measured with the Mini-Mental State Examination (MMSE)[16]. Moreover, the Geriatric Depression Scale (GDS-15) is a reliable tool to identify depression in the elderly and has also been validated for use in the Greek population[17,18]. The use of these tools can be helpful in the identification of some of the most important risk factors for falls. However, each tool investigates a single risk factor and most of them are administered by trained personnel, limiting their routine administration in the community and highlighting the need for self-administered tools. A recent systematic review of the last 10 years literature identified only six self-rated fall risk questionnaires for community-dwelling individuals from various countries[19].

The purpose of the present study is to develop a self-reported questionnaire, that could also be delivered by phone that can reliably and accurately recognize community-dwelling individuals over the age of 60 in the Greek population that have an increased fall risk. The questionnaire presented by the authors is designed as a screening tool for use in primary care to identify at-risk individuals who require more in-depth evaluation for their fall risk.

Materials and Methods

Study Participants

All participants signed a written informed consent form for their participation in the study. Ethical approval was procured from the KAT Attica General Hospital's Ethical Committee. Eligibility criteria were ≥60 years old, Greek community-dwelling individuals, and normal cognition status (MMSE >24). Cognitive status was evaluated for all participants who met the first two criteria. All participants filled out the Questionnaire under study and underwent further evaluation with the TUG, short FES-I, Tinetti Assessment Tool, GDS-15 and Morse fall scale[20]. Data regarding past medical history and fracture history were also recorded. The collection of data was performed in adult day care facilities.

Development of the LRMS Questionnaire

An initial not validated Greek questionnaire that addresses risk factors associated with falls was created by the second author (Y.D.) in the past[21]. This questionnaire was modified according to suggestions from the authors' team and the revised questionnaire is presented in the Appendix (Appendix, Questionnaire 1). After meticulous study of the current literature, factors that were included were history of falls within the previous year, visual and hearing impairment, gait and balance impairment as perceived by the respondents, frequency of urination, fear of falls, ease of getting up after a fall, use of walking assistive devices, polypharmacy and extrinsic factors. An effort was made to include most of the risk factors for falls[22-24]. Each question was scored on a 3-point scale according to its relevance to the fall risk (0= no association with falls, 5= weak association, 10= high association). Additionally, the first 4 questions were linked, as only those who answered "yes" to the first question ("Did you experience any fall during the past year?") could answer questions 1-3 which were related to a respondent's past fall.

Questionnaire 1 was filled out by 10 experts in the field and 10 Greek community-dwelling individuals over 60 years of age to assess the content, structure, and clarity of the questions. A revision was needed for most of the questions, and in most of them, a clarification comment was added. After the revision, Questionnaire 2 (Appendix, Questionnaire 2) was formed and was distributed to 20 community-dwelling individuals. Initial statistical analysis showed unacceptably low internal reliability (Cronbach's alpha coefficient= 0.266).

In Questionnaires 1 and 2, Questions 2–4 were answered only by those who gave a positive answer in Question 1 ("Did you have a fall during the past year?"). It was, then, decided to disconnect the first 4 questions, so that all participants could answer every question (Appendix, Questionnaire 3). It was also decided to use a 4-point scale to score each question (0, 1, 2, 3), which is still simple to use but provides more options for the participants to choose the answer closer to the reality. Additionally, the total number of questions was increased to 14, as it was decided to assess each risk factor with a different question rather than include them as possible answers to one question (Question 4 in Questionnaire 2 was replaced by Questions 2–6 in Questionnaire 3). This revised Questionnaire (Questionnaire 3) was repeated in the previous 20 participants in order to assess these changes in the same sample, and the internal reliability was improved to a lower acceptable level (Cronbach's alpha coefficient= 0.65).

After further review of the participants' answers in Questionnaire 3, Questions 2 ("How often do you feel dizziness?") and 3 ("How often do you feel unsteadiness?") were merged to create Question 2 ("How often do you feel

dizziness or unsteadiness?") in the LRMS Questionnaire, as most participants gave similar answers to them and could not differentiate easily between dizziness and unsteadiness. Questions 5 ("How often does your hearing difficulty affect your gait?") and 11 ("Are your shoes safe (sport shoes, special walking shoes)?") of Questionnaire 3 were deleted, as only 2 participants answered that they had gait difficulties due to hearing problems or that their shoes were not safe. Question 10 of Questionnaire 3 ("Do you feel disadvantaged if you use an assistive walking device?") was also excluded, as all participants answered negatively. A new question regarding social interaction was added (Question 11, LRMS Questionnaire). These changes led to the final 11-item 4-point scale LRMS Questionnaire (Appendix, LRMS Questionnaire — Laboratory for Research of the Musculoskeletal System) that was used until the collection of the desired number of participants, as described in the statistical analysis section. Additionally, in 10 participants, the LRMS Questionnaire was repeated after 5 days to assess test–retest reliability.

Statistical Analysis of the LRMS Questionnaire

Exploratory factor analysis (EFA): Using the maximum likelihood extraction method with Varimax rotation, EFA was conducted for all participants to determine the factor structure of the 11 questions of the LRMS Questionnaire. The selection of factors was based on the following criteria: a) eigenvalues ≥1, b) questions with factor loadings >0.25[25,26]. The number of factors to retain was also confirmed using a Monte Carlo Principal Component Analysis (PCA) parallel analysis.

Confirmatory factor analysis (CFA): CFA was used first to confirm the structure revealed by the EFA. CFA was carried out using the Analysis of Moment Structure (AMOS) Version 21.0[27]. The sample size required for the CFA was based on researchers' conventions, ranging from the participants' ratio 3:1 to as high as 12:1[28]. The LRMS consisted of 11 questions; thus, our sample size of 173 individuals is within the above guidelines. Rejecting or accepting a model was based on some global fit indices: (1) chi-square–degrees of freedom (df) ratio; (2) the root mean square error of approximation (RMSEA); (3) the comparative fit index (CFI); (4) the normed fit index (NFI); (5) the goodness-of-fit index (GFI); and (6) the adjusted GFI (AGFI). The chi-square–df ratio <2.0[29], RMSEA <0.08[30], CFI >0.90[30], GFI >0.85[31], AGFI >0.80[31], and NFI >0.90[32] indicate an acceptable fit.

Construct validity: Two methods were used to assess the construct validity of the LRMS Questionnaire. First, traditionally, the convergent or criterion validity of the LRMS Questionnaire was determined by establishing its correlation to FES-I, GDS-15, Tinetti Assessment Tool, TUG and Morse Fall Scale using Spearman's correlation coefficient. Moderate or high correlation between the LRMS Questionnaire and the well-established tools would support the validity of the LRMS Questionnaire in measuring fall risk. Second, it was assessed by the fit of the data to the one-parameter Item Response Theory (Rasch) model. The Rasch measurement model assumes that the data from an instrument are unidimensional[33]. Thus the model can be used to test whether the questions in the scale belong to a single underlying construct[34]. Testing the fit of the data to the Rasch model is equivalent to testing the theoretical construct validity and adequacy of the scale[35]. The data derived from the LRMS Questionnaire were thus fitted to the Rasch model, operationalized by the unconditional maximum likelihood approach. Moreover, we examined the presence of sub-dimensions as an independent confirmation of the unidimensionality of the scale as criteria: a) a cut-off of 50% of the variance explained by the Rasch model, b) an eigenvalue of the first residual factor smaller than 3, and c) unexplained variance in the 1st contrast of 4% or 5% using PCA analysis of the residuals[36].

Known-groups validity: In the LRMS Questionnaire, known-groups validity was examined in terms of its ability to distinguish between subgroups of patients formed based on their previous fracture status (no vs yes). An independent sample t-test was used for statistical analysis.

Item analysis: In the LRMS Questionnaire, item analysis of the questions was performed by analyzing the item discriminating power (corrected item correlation) and the item difficulty (item mean) depicted by explanatory data analysis.

Interpretability: Interpretability refers to the degree to which one can assign qualitative meaning to quantitative scores. It includes the floor and ceiling effect and MIC (minimal importance change)[37,38]. Floor or ceiling effects are considered to be present if more than 15% of respondents achieved the lowest or highest possible score, respectively[39]. The MIC was expressed as 0.5 x SD at the baseline.

Measurement error: The measurement error is the error of the score not attributed to the construct that is being measured and expressed as the standard error of measurement (SEM), using the formula: SEM = SD x $\sqrt{}$(1 − ICC) with SD as the standard deviation of all patients at baseline. MDC (minimal detectable change) is the change of the score that exceeds the SEM and was calculated as SEM x 1.96 x $\sqrt{}$2 at the individual level.

Cut-off point of the LRMS Questionnaire total score: A receiver operating curve (ROC) analysis[40] was conducted to obtain the cut-off level of the LRMS total score for differentiation between subgroups of patients formed on the basis of their fall risk status, calculating the respective areas under the curve (AUC). The areas under the ROC curve (AUC) with standard error and 95% C.I. were calculated using the maximum likelihood estimation method, and the sensitivity and specificity of different cut-off points of the LRMS total score were estimated using TUG (low risk <12 vs high risk ≥12)[41], FES-I (low risk <14 vs high risk ≥14)[42], and the Tinetti Assessment Tool (low risk ≥24 vs high risk <24)[43] as gold standard methods of fall risk. The moderate risk scores

Gender: Male / Female, n (%)	53 (30.6%) / 120 (69.4%)
Age (years): Mean ± SD (min – max)	72.3 ± 6.3 (60–91)
Weight (kg): Mean ± SD (min – max)	73.1 ± 11.5 (45–110)
Height (m): Mean ± SD (min – max)	1.65 ± 0.1 (1.44–1.89)
BMI (kg/m²): Mean ± SD (min – max)	26.8 ± 3.7 (18.8–38.4)
Hypertension: n (%)	108 (62.4%)
Diabetes: n (%)	46 (26.6%)
Depression: n (%)	26 (15.0%)
Fracture: n (%)	44 (26.4%)

SD=standard deviation, n=number.

Table 1. Descriptive statistics of the participants.

	Factor 'other factors'	Factor 'muscle capacity'
Question 1	0.518	
Question 2	0.626	
Question 3	0.620	
Question 4	0.316	
Question 5	0.629	0.380
Question 6	0.528	0.581
Question 7		0.982
Question 8	0.421	
Question 9	0.303	
Question 10	0.269	
Question 11	0.266	

**Extraction Method: Maximum Likelihood, rotation: Varimax. Only loadings with values >0.25 are presented.*

Table 2. Factor loadings of the LRMS subscales.

for FES-I (9–13) and Tinetti (19–23) were merged into the other categories for the purposes of the ROC analysis.

Internal consistency (reliability): The internal consistency of the LRMS Questionnaire was determined by calculating Cronbach's alpha coefficient[44]. A Cronbach alpha (a) coefficient value of 0.7 indicates sufficient reliability for research purposes and suggests that the questions are inter-dependent and homogeneous in terms of the construct they measure. For clinical applications, a value >0.8 is desirable[45].

Test–retest reliability (stability): The test–retest reliability indicates the stability of patients' response over time, and it was determined by calculating ICC (intraclass correlation coefficient)[46] between the initial assessment of the LRMS Questionnaire and the reassessment after 5 days. Because this coefficient does not correct for systematic differences and agreement by chance, the scores of the 2 assessments were tested for systematic differences by using the paired t-test. Finally, the Bland–Altman plot[47] was used as a visual method of assessing stability.

All tests were two-sided, and a p-value of <0.05 was used to denote statistical significance. All analyses were carried out using the statistical package SPSS vr 21.00 (IBM Corporation, Somers, NY, USA) and the Rasch-Model Computer program MINISTEP[36].

Results

Data from 200 participants were collected. After carefully examining the eligibility criteria, 27 individuals were excluded due to an MMSE ≤24. The remaining 173 were included in the analysis. Descriptive statistics of the

	FES-I	GDS-15	Tinetti Balance	Tinetti Gait	TUG	Morse
LRMS 'other factors'	0.787	0.561	−0.764	−0.731	0.768	0.770
LRMS 'muscle capacity'	0.693	0.401	−0.728	−0.736	0.779	0.654
LRMS Total	0.820	0.562	−0.812	−0.789	0.831	0.795

**All Pearson's correlation coefficients are statistically significant (p<0.001), FES-I=Falls Efficacy Scale-International, GDS-15=Geriatric Depression Scale-15, TUG=Timed Up and Go.*

Table 3. Convergent-criterion validity of the LRMS Questionnaire.

demographic and clinical characteristics of the participants are presented in Table 1.

Reliability and Validity of the LRMS Questionnaire

Exploratory factor analysis (EFA): The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was equal to 0.835, showing suitable data for factor analysis. The hypothesis of no inter-correlation of items was rejected by Bartlett's test of sphericity (x^2=498.1, df=55, p<0.001). The 11 questions were analyzed via the maximum likelihood extraction method using a Varimax rotation. Two factors, with eigenvalues of >1 and loadings ≥0.25, were identified. The eigenvalue for the first factor was 4.00, explaining 37% of the variance and the eigenvalue for the second factor was 1.15, explaining 10.5% of the variance. Factor loadings, which are the correlation coefficients between the items and the factor, ranged from 0.266 to 0.629 for Factor 1, from 0.279 to 0.982 for Factor 2 (Table 2).

Confirmatory factor analysis (CFA) new structure: A two-factor model of LRMS based on EFA was examined by CFA, giving acceptable global fit indices. The resulting global fit indices X^2=70.5, chi-square–df ratio=1.60, RMSEA=0.060, CFI=0.944, NFI=0.866, GFI=0.936, and AGFI=0.903 showed that the two-factor solution proposed by the exploratory factor analysis could be retained. Although the fit indices of CFA for the two-factor model were acceptable, the scree test and Monte Carlo PCA for parallel analysis (the criterion value of the second eigenvalue was 1.30, higher than the eigenvalue of the second factor of our data which was 1.15) indicated a single-factor structure. Moreover, the 2 factors had 2 questions with common high loadings (Questions '5' and '6') and 1 question with common low loadings (Question '10'), which could lead us to adopt a single-factor model. The resulting global fit indices, from CFA analysis of 1 factor, X^2=78.13, chi-square–df ratio=1.77 RMSEA=0.062, CFI=0.925, NFI=0.852, GFI=0.928, and AGFI = 0.900, showed that the single-factor solution could be adopted. However, careful review of the questions included in the above factors, indicated that factor 2 (Questions '6' and '7') can be interpreted as related to participants' motor status and can be written as 'muscle capacity' and factor 1 as all other factors associated with fall risk and can be written as 'other factors.'

Convergent or criterion validity: Table 3 summarizes the correlation between the LRMS subscales and the total score with other tools. The highest correlation coefficients are presented between the LRMS total score and TUG (r=0.831), FES-I (r=−0.820), Tinetti balance (r=−0.812), Tinetti gait (r=−0.789), GDS-15 (r=−0.562) and Morse (r=0.795). The above result indicated a high correlation between the LRMS Questionnaire subscales and the total score with other tools that satisfied the criterion validity.

Known-groups validity: The LRMS 'other factors', 'muscle capacity', and total score well discriminated between sub-groups of patients based on their different fracture status (no vs yes). LRMS 'other factors', 'muscle capacity', and total score were higher for patients with fracture compared to those without one (p<0.001).

Item analysis: The results of the item analyses revealed difficulty indices (item mean divided by total item score) of the 11 questions ranging between 0.1 and 0.53. The most difficult item was Question '4' (0.53), while the easiest item was Question '10' (0.1). The discriminative index is the item-to-total correlation using Pearson's product-moment correlation coefficient. Coefficients greater than 0.28 are considered to have satisfactory discriminative properties. The item discriminative indices of the LRMS items ranged from 0.23 to 0.70. The most discriminative item was Question '5' (r=0.70), while the least discriminative item was Question '11' (r=0.23).

Interpretability: The percentage of respondents scoring at the lowest possible level of the scale and at the highest possible level were for the LRMS 'other factors' (1.7%, 0.6%), 'muscle capacity' (34.5%, 2.9%), and total score (1.7%, 0.6%). The critical value of 15% was surpassed only for the 'muscle capacity' factor, presenting floor effects. The MIC values for 'other factors,' 'muscle capacity,' and total score were 2.1, 0.8, and 2.7, respectively.

Measurement error: The error associated with the LRMS 'other factors', 'muscle capacity', and total score at a given point in time (SEM) was 0.44, 0.23, and 0.51, respectively. The corresponding MDC values were 1.22, 0.31, and 1.41, respectively.

Cut-off points of the LRMS Questionnaire total score: The AUC of the LRMS total was 0.930 (95% C.I. 0.88–0.98, p<0.001) with a cut-off point of 10.5,

Fall risk based on	AUC	SE	p-value	Cut-off	Point	Sensitivity	Specificity	95% C.I.
FES-I [1]	0.919	0.022	<0.001	11.5	85%	89%	0.88	0.96
TUG [1]	0.930	0.024	<0.001	10.5	86%	98%	0.88	0.98
Tinetti[1]	0.947	0.019	<0.001	10.5	93%	91%	0.91	0.98

[1] larger test result indicates more positive test, FES-I=Falls Efficacy Scale-International, TUG=Timed Up and Go, AUC=area under the curve, SE=standard error, C.I.=confidence interval.

Table 4. The cut-off points of the LRMS total score of estimating fall risk using different tools as gold standard.

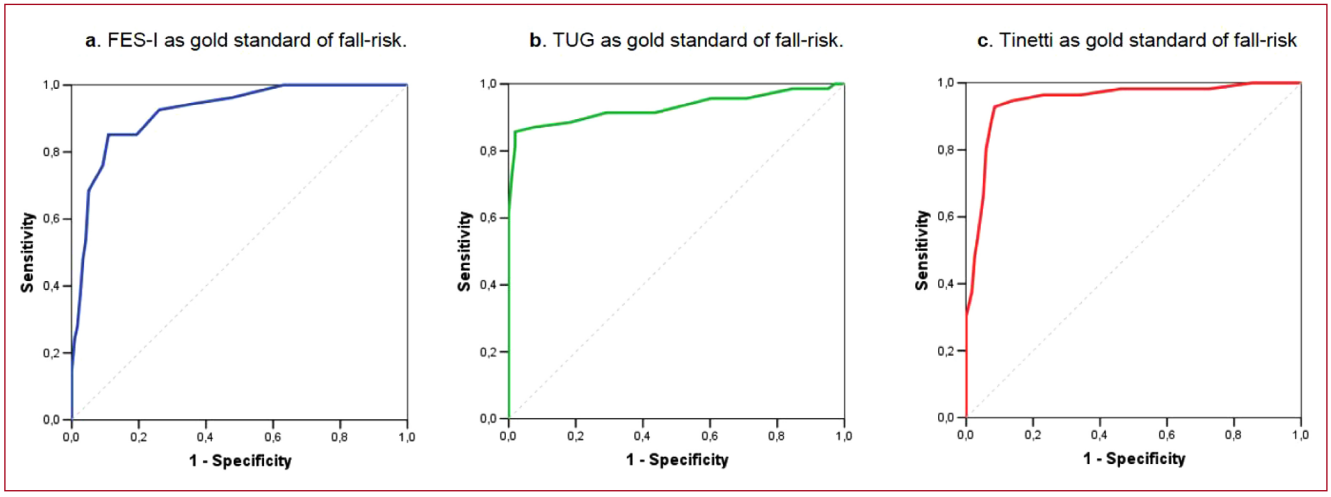

Figure 1. ROC analysis of LRMS total score of estimating fall risk using different variables as gold standard (a. FES-I, b. TUG, c. Tinetti). **(Figure was created from SPSS).*

sensitivity of 86%, and specificity of 98% using TUG as the gold standard of fall risk. This indicates that patients with an LRMS total score higher than 10.5 have an 86% probability of falling in the future, while patients with an LRMS total score less than 10.5 have a 98% probability of not falling in the future. Additionally, the AUC was 0.919 (95% C.I. 0.88–0.96, p<0.001) with a cut-off point of 11.5, sensitivity of 85%, and specificity of 89% when using FES-I as the gold standard of fall risk. The AUC was 0.947 (95% C.I. 0.91–0.98, p<0.001) with a cut-off point of 10.5, sensitivity of 93%, and specificity of 91% using Tinetti as the gold standard of fall risk (Table 4 – Figure 1).

Internal consistency reliability: The internal consistency of the LRMS 'other factors', 'muscle capacity' factor, and total score was measured with Cronbach's alpha and estimated as 0.737, 0.735, and 0.807, respectively, which indicate excellent internal consistency for total score and sufficient reliability for the sub-scales.

Test–retest reliability: The paired samples t-test between initial assessment and re-assessment of LRMS subscales and total score indicated no statistically significant difference. ICC between initial assessment and reassessment of the LRMS other factors', 'muscle capacity' factor, and total score was 0.989, 0.977, and 0.991 (p<0.001), respectively. The Bland–Altman plot is presented in Figure 2 for the total score. Inspection of the scattergram showed that all differences were within the mean difference ± 2 SDs, thus confirming the agreement between the 2 assessments. The above results of stability indicated that the LRMS 'other factors', 'muscle capacity', and total score were remarkably consistent between the two occasions. (Table 5)

Construct validity of the LRMS Questionnaire by the Rasch model: The data from the LRMS were fitted to the Rasch partial credit model. Items were ordered by their level of difficulty and it was found that Question '10' was the most difficult (62.44), whereas Question '4' was the easiest to answer (35.41). The Rasch analysis estimates the goodness-of fit of the real data to the modeled data. Information weighted (infit) and outlier sensitive (outfit) mean square statistics (MnSq) for each item were calculated to test whether there were items that did not fit with the model expectancies. Acceptable values for

(n = 10)	ICC 95% C.I.	Paired samples t-test		p-value
		Initial	Re-assessment	
		Mean ± SD		
LRMS 'other factors'	0.989* (0.96–1.00)	6.20 ± 3.79	6.30 ± 4.02	0.343
LRMS 'muscle capacity'	0.977* (0.95–1.00)	1.20 ± 1.48	1.30 ± 1.49	0.594
LRMS Total	0.991* (0.96–1.00)	7.40 ± 4.52	7.60 ± 4.70	0.343

*p<0,001, C.I.=confidence interval, ICC=Intraclass Correlation Coefficient, n=number, SD=standard deviation.

Table 5. Test–retest reliability of the LRMS Questionnaire.

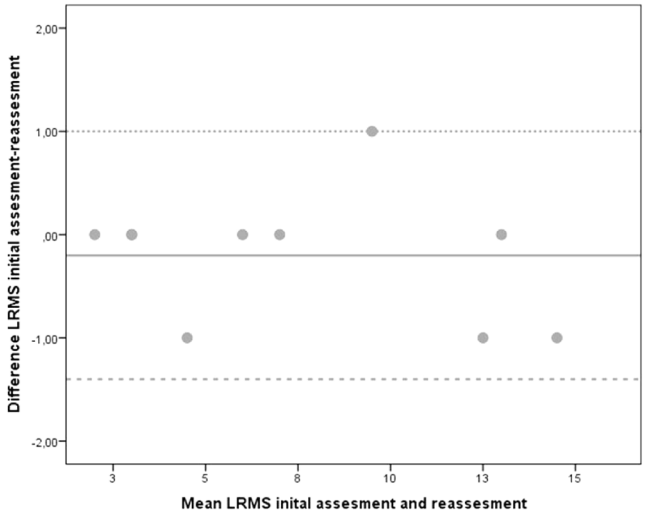

Figure 2. Bland-Altman plot of the LRMS total score. Mean difference=-0.2 (95% C.I.–1.4 to 1.0). **(Figure was created from SPSS).*

infit and outfit were within the range 0.7–1.3 for MnSq. Questions '2' and '10' showed marginal levels of misfit, as determined by the Infit and Outfit statistic. The resulting fit indices, the variance explained by the Rasch model=45%, eigenvalue of the first residual factor=1.9, and unexplained variance in the 1st contrast=7.2% using PCA analysis of the residuals showed that the unidimensionality of the scale could be marginally accepted.

Discussion

According to the current literature, despite the large number of tests and questionnaires currently available, a single measure to predict fall risk has not yet been recognized, and therefore multiple tools are used in everyday practice[5,10]. This highlights the multifactorial nature of the problem and the challenges that arise when designing new tools. The LRMS Questionnaire showed sufficient internal consistency, excellent test–retest reliability, and high correlation with the already established tools for fall risk assessment. It is short, as it consists of 11 items and can also be self-reported, which makes it easy to use without assistance from specially trained personnel in approximately 10 minutes or less. It can also be delivered by phone to people who cannot leave their home. Despite the identification of two factors ('muscle capacity' and 'other factors'), our analysis showed that the total score can also be used alternatively, making the scoring process easy to perform. According to the sensitivity and specificity defined by ROC analysis, 10.5 can be used as the cut-off point for separating low- and high-risk individuals. The sample of this study was chosen to be community-dwelling individuals over 60 years of age, as they are active members of society and are also exposed to most of the risk factors of falls in their everyday lives. The gold-standard tools used in the validation process were selected, out of many that exist, specifically for their wide use in clinical practice according to the literature[5,19] and our experience and also because of the

fact that they are relatively easy to perform. Even though the Morse Fall Scale is designed for inpatient use, we decided to include it in the study, as it has questions similar to those of the LRMS Questionnaire and also because we believe that future studies could extend the use of the LRMS in the hospital setting.

Most of the tools available in the literature require the assessment of both a questionnaire and clinical evaluation to calculate a score predictive of fall risk. However, the strong correlation of the LRMS Questionnaire with measures that require clinical evaluation indicates that it could be used as an initial questionnaire-only based self-assessment screening tool. The number of tools with similar design in the current literature is limited[19]. The Falls Risk Assessment Tool (FRAT) is used in the primary care setting and is based on the assessment of several key risk factors, such as history of falls, prescribed medications and gait and balance disorders[24]. It is a questionnaire designed to assess the presence of risk factors like the LRMS Questionnaire. The FRAT-up tool is a validated online tool for risk prediction for community-dwelling older adults used to calculate the probability of falling within the next 12 months[48]. Even though they were found to be valid in risk assessment and prediction of falls, the authors highlighted the heterogeneity of the data available from different studies, which often arose due to difficulties in uniform and objective measurements. For example factors like "pain" and "dizziness" are difficult to assess, and each study might approach them differently in terms of severity, frequency, or specific time periods of the symptoms.

Due to the lack of objectivity in the assessment of the various risk factors, different questionnaires could be developed evaluating the same risk factors from a different standpoint. Another example of a validated self-rated fall risk Questionnaire is the Fall Risk Questionnaire (FRQ)[49], which includes 13 yes or no questions, assessing similar risk factors to those of the LRMS Questionnaire. Despite the small sample size (40 individuals) and the fact that the majority of participants were older than 80 years of age, they reported highly acceptable results (Cronbach's alpha=0.746, AUC=0.981, sensitivity=100% and specificity=83.3%). Notably, they attributed higher scores to the questions related to the risk factors that are more closely related to falls, such as imbalance and history of falls. This also highlights the fact that, differences in both the risk factors assessed and in the scoring system used in each tool, contribute to the diversity in currently existing questionnaires.

Overall assessment of all aspects of each risk factor might be more helpful in data interpretation and fall prediction but it would result in a massive amount of data and it would also require numerous questions that would make the tool hard to implement in everyday practice. To this end, modern technology could be a major part of the solution. Machine learning algorithms have already been implemented to evaluate fall risk after hospital admission, and their results seem promising[50,51]. The ability of machine learning algorithms to gather and process large amounts of data could be very helpful in detecting more possible risk factors than humans and accurately predicting the fall risk and identifying individuals at risk. Of course, it is important to bear in mind that the training process of the algorithms is a tedious task and requires very big data samples. The complexity of this process further highlights the importance of simple self-rated screening tools with high sensitivity and specificity like the LRMS Questionnaire. Also, future studies could investigate whether the integration of the LRMS questions in a machine learning algorithm would reduce the amount of data necessary for calculation.

The importance of identifying individuals at risk is highlighted by the potential interventions needed to prevent falls. Multidisciplinary efforts are required from this perspective[6]. Based on the LRMS Questionnaire, a primary care physician could assess the different answers of each individual to determine what might be necessary to reduce fall risk and develop a personalized prevention plan. Physical therapy can target balance and mobility, family doctors can adjust medications to reduce polypharmacy when possible, psychologists and psychiatrists can identify and treat depression and anxiety, and ophthalmologists can optimize vision difficulties[52]. Extrinsic factors related to falls, such as home hazards (poor lighting, uneven surfaces, stairs, lack of handrails) could be targeted by social care services[53]. The key to effective interventions is the coordinated effort and collaboration among the different specialists involved.

The present study also has limitations that need to be considered. First, the LRMS Questionnaire was developed as an initial screening tool that can identify Greek individuals at risk who need more thorough evaluation. The results of this study indicate that it is a valid tool for use in Greek community-dwelling older adults. The language used to formulate the questions was understandable by the participants and led to responses that were close to reality, as shown by the high sensitivity and specificity. We believe that further studies are needed to extend the use of the LRMS Questionnaire in other countries, as the special characteristics of other populations are different from those of Greeks. Additionally, more data are needed for groups that are at an even higher fall risk, such as nursing home residents, and people with neurological disorders and cognitive impairment. People with cognitive impairment were excluded from this study because of their inability to adequately understand and answer the questions, but as they are at an increased fall risk, other approaches are needed to properly assess them[54]. In addition, individuals unable to leave home were not studied, while they might also be at increased risk due to mobility restrictions. The LRMS Questionnaire, while not delivered over the phone in the present study as a standard practice, offers this possibility, and we believe it could be used to design further interventions in this group of people.

Furthermore, effort was made to include as many major risk factors as possible according to the literature, and many revisions of the original Questionnaire were made to reach its final form. However, there are still factors that were not included in the final version, such as hearing impairment, footwear, and outdoor environment, as they were excluded after reviewing participants' answers. It would be of interest, though, to investigate whether some of the questions removed from the final version of the LRMS Questionnaire would be more relevant in other populations.

Overall, our results indicate that the LRMS Questionnaire is a reliable and accurate tool for identifying older adults at a high fall risk and could be used as an initial screening tool in primary care. It can be either self-administered or administered by non-specialized personnel in a short period of time. Further studies are needed to extend the use of the Questionnaire in subgroup categories and other settings and to monitor responses after implementation of appropriate interventions.

Ethics Approval

Approved by KAT Hospital's Scientific Committee and Board of Directors on Dec 19th 2017 (No 26/19-12-2017). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Authors' contributions

C.A.: study design, data collection, wrote manuscript, Y.D.: study design, study supervision, A.G.: study design, statistical analysis, wrote manuscript, I.K.: data collection, I.K.T.: study design, J.V, I.A.D, G.P.L, E.C: study supervision. All authors provided critical feedback and approved the final version of the manuscript.

Disclaimer

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Appendix

Questionnaire 1

1. Έχετε πέσει μέσα στον τελευταίο χρόνο; Όχι (0), 1 φορά (5), πάνω από 1 φορά (10)	**1. Have you had a fall during the past year?** No (0), once (5), more than once (10)
2. Πόσο εύκολα σηκώνεστε όταν πέσετε; Εύκολα (0), δύσκολα (5), δεν μπορώ να σηκωθώ (10)	**2. How easy is it for you to stand up after a fall?** Easy (0), difficult (5), I can't get up (10)
3. Πού πέσατε; Σπίτι (10), σκάλες (10), δρόμος στην πόλη (5), αγροτικός δρόμος (5), ύψος (0)	**3. Where did you fall?** Home (10), stairs (10), urban road (5), rural road (5), height (0)
4. Πέσατε επειδή: Αισθανθήκατε ζάλη (10), είχατε δυσκολία στην όραση (10), είχατε δυσκολία στην ακοή (5), είχατε ακράτεια ή απώλεια ούρων (5), εξωτερική παρέμβαση (σπρώξιμο, δυνατός άνεμος) (0)	**4. Did you fall because of:** Dizziness (10), vision difficulty (10), hearing difficulty (5), urinary incontinence or leakage (5), external intervention (wind, pushing) (0)
5. Πιστεύετε ότι θα πέσετε επειδή δεν βαδίζετε καλά; Όχι, βαδίζω ανεξάρτητος (0), θέλω ελάχιστη βοήθεια στη βάδιση (κρατιέμαι σε τοίχο/μπάρα ή φοράω/κρατάω βοήθημα) (5), θέλω μεγάλη βοήθεια στη βάδιση (με κρατούν και χρησιμοποιώ βοηθήματα) (10)	**5. Do you feel you will fall because of walking difficulties?** No, I walk unassisted (0), I need minimal walking assistance (wall, crutch) (5), I need much walking assistance (assistive devices, help from others) (10)
6. Αισθάνεστε ότι οι άλλοι θα σας περιγελάσουν αν κρατάτε ή φοράτε βοήθημα; Όχι (0), μερικές φορές (5), ναι (10)	**6. Do you feel that other people will make fun of you if you use an assistive walking device?** No (0), sometimes (5), yes (10)
7. Φοράτε ασφαλή υποδήματα; Πάντα (0), μερικές φορές (5), όχι (10)	**7. Are your shoes safe?** Always (0), sometimes (5), no (10)
8. Έχετε τροποποιήσει το σπίτι σας κάνοντάς το ασφαλέστερο; (φωτισμός, καλώδια, σκάλες κ.λπ.) Ναι (0), όχι, είμαι κάτω από 65 ετών (5), όχι, είμαι πάνω από 65 ετών (10)	**8. Have you done any changes to make your home safer (lighting, cables, stairs)?** Yes (0), no I am less than 65 years old (5), no I am more than 65 years old (10)
9. Πάσχετε από κάποια από τις παρακάτω παθήσεις; Κατάθλιψη ή άλλο ψυχιατρικό νόσημα (10), νευρολογικό πρόβλημα (Parkinson, σκλήρυνση κ.λπ.) (10), καρδιακή ανεπάρκεια (10), αρτηριακή υπέρταση (5), σακχαρώδης διαβήτης (5), ρευματολογικές παθήσεις (5), τίποτα από τα παραπάνω (0)	**9. Do you have any of the conditions mentioned below?** Depression or other psychiatric condition (10), neurological conditions (Parkinson's, multiple sclerosis or other) (10), heart failure (10), hypertension (5), diabetes mellitus (5), rheumatic conditions (5), nothing of the above (0)
10. Λαμβάνετε τα φάρμακά σας τις σωστές ώρες και σύμφωνα με τις οδηγίες των γιατρών; Ναι (0), μερικές φορές (5), όχι (10)	**10. Do you take your medications as prescribed by your doctor?** Yes (0), sometimes (5), no (10)

Questionnaire 2

1. Έχετε πέσει μέσα στον τελευταίο χρόνο; Όχι – συνεχίστε στην ερώτηση 5 (0), 1 φορά (5), πάνω από 1 φορά (10)	**1. Have you had a fall during the past year?** No – continue to question 5 (0), once (5), more than once (10)
2. Πόσο εύκολα σηκωθήκατε όταν πέσατε;* Εύκολα (0), δύσκολα (5), δεν μπορούσα να σηκωθώ μόνος/η μου (10)	**2. How easy is it for you to stand up after you fell?*** Easy (0), difficult (5), I couldn't get up without help (10)
3. Πού πέσατε;* Σπίτι (μέσα ή στην βεράντα/αυλή) (10), σκάλες (10), δρόμος στην πόλη (5), αγροτικός δρόμος (5), ύψος (0)	**3. Where did you fall?*** Home (inside or yard) (10), stairs (10), urban road (5), rural road (5), height (0)
4. Πέσατε επειδή:* Αισθανθήκατε ζάλη (10), είχατε δυσκολία στην όραση (10), είχατε δυσκολία στην ακοή (5), είχατε ακράτεια ή απώλεια ούρων (5), εξωτερική παρέμβαση (σπρώξιμο, δυνατός άνεμος, γλίστρημα σε νερό) (0), χωρίς αιτία (πχ. παραπάτημα) (0)	**4. Did you fall because of:*** Dizziness (10), vision difficulty (10), hearing difficulty (5), urinary incontinence or leakage (5), external intervention (wind, pushing) (0)
5. Πιστεύετε ότι θα πέσετε επειδή δεν βαδίζετε καλά; Όχι, βαδίζω ανεξάρτητος (0), θέλω ελάχιστη βοήθεια στη βάδιση (κρατιέμαι σε τοίχο/μπάρα ή φοράω/κρατάω βοήθημα) (5), θέλω μεγάλη βοήθεια στη βάδιση (με κρατούν και χρησιμοποιώ βοηθήματα) (10)	**5. Do you feel you will fall because of walking difficulties?** No, I walk unassisted (0), I need minimal walking assistance (wall, crutch) (5), I need much walking assistance (assistive devices, help from others) (10)
6. Αισθάνεστε ότι οι άλλοι θα σας περιγελάσουν αν κρατάτε ή φοράτε βοήθημα; Όχι (0), μερικές φορές (5), ναι (10)	**6. Do you feel that other people will make fun of you if you use an assistive walking device?** No (0), sometimes (5), yes (10)
7. Φοράτε ασφαλή υποδήματα; Πάντα (0), μερικές φορές (5), όχι (10)	**7. Are your shoes safe?** Always (0), sometimes (5), no (10)
8. Έχετε τροποποιήσει το σπίτι σας κάνοντάς το ασφαλέστερο; (φωτισμός, καλώδια, σκάλες κ.λπ.) ναι (0), όχι, είμαι κάτω από 65 ετών (5), όχι, είμαι πάνω από 65 ετών (10)	**8. Have you done any changes to make your home safer (lighting, cables, stairs)?** Yes (0), no I am less than 65 years old (5), no I am more than 65 years old (10)
9. Πάσχετε από κάποια από τις παρακάτω παθήσεις; Κατάθλιψη ή άλλο ψυχιατρικό νόσημα (10), νευρολογικό πρόβλημα (Parkinson, σκλήρυνση κλπ) (10), καρδιακή ανεπάρκεια (10), αρτηριακή υπέρταση (5), σακχαρώδης διαβήτης (5), ρευματολογικές παθήσεις (5), τίποτα από τα παραπάνω (0)	**9. Do you have any of the conditions mentioned below?** Depression or other psychiatric condition (10), neurological conditions (Parkinson's, multiple sclerosis or other) (10), heart failure (10), hypertension (5), diabetes mellitus (5), rheumatic conditions (5), nothing of the above (0)
10. Λαμβάνετε τα φάρμακά σας τις σωστές ώρες και σύμφωνα με τις οδηγίες των γιατρών; Ναι (0), μερικές φορές (5), όχι (10), δε λαμβάνω συστηματικά κανένα φάρμακο (0)	**10. Do you take your medications as prescribed by your doctor?** Yes (0), sometimes (5), no (10), I do not take any medications (0)
**Questions 2-4 were answered only by those who answered "once" or "more than once" in question 1.*	

Questionnaire 3

1. Έχετε πέσει μέσα στον τελευταίο χρόνο; Όχι (0), 1 φορά (1), 2 φορές (2), πάνω από 2 φορές (3)	**1. Have you had a fall during the past year?** No (0), once (1), twice (2), more than twice (3)
2. Πόσο συχνά αισθάνεστε ζάλη; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**2. How often do you feel dizziness?** Never (0), sometimes (1), often (2), very often (3)
3. Πόσο συχνά νιώθετε αστάθεια; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**3. How often do you feel unsteadiness?** Never (0), sometimes (1), often (2), very often (3)
4. Πόσο συχνά η δυσκολία στην όραση σας επηρεάζει στη βάδιση; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**4. How often does your vision difficulty affect your gait?** Never (0), sometimes (1), often (2), very often (3)
5. Πόσο συχνά η δυσκολία στην ακοή σας επηρεάζει στη βάδιση; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**5. How often does your hearing difficulty affect your gait?** Never (0), sometimes (1), often (2), very often (3)
6. Πόσο συχνά σηκώνεστε κατά τη διάρκεια της νύχτας για να πάτε τουαλέτα; Όχι (0), 1 φορά (1), 2 φορές (2), πάνω από 2 φορές (3)	**6. How many times do you go to the bathroom during the night?** No (0), once (1), twice (2), more than twice (3)
7. Πιστεύετε ότι θα πέσετε κάνοντας τις καθημερινές σας δραστηριότητες; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**7. Do you feel that you might fall during your everyday activities?** Never (0), sometimes (1), often (2), very often (3)
8. Πόσο εύκολα νιώθετε ότι μπορείτε να σηκωθείτε όταν πέσετε; Εύκολα (χέρια) (0), με μικρή δυσκολία (έπιπλα) (1), με μεγάλη δυσκολία (έπιπλα και βοήθεια) (2), δεν σηκώνομαι μόνος/η μου (3)	**8. How easy is it for you to stand up after a fall?** Easy (using my hands) (0), minimal difficulty (using furniture) (1), great difficulty (furniture and assistance) (2), I cannot stand up alone (3)
9. Χρειάζεστε βοήθεια στη βάδιση; Ποτέ (0), μερικές φορές (1), θέλω λίγη βοήθεια (μπαστούνι) (2), θέλω μεγάλη βοήθεια (Πι, με κρατούν οι άλλοι) (3)	**9. Do you need assistance during walking?** Never (0), sometimes (1), I need minimal assistance (walking stick) (2), I need great assistance (stand assist walker, others hold me) (3)
10. Αισθανεστε μειονεκτικά αν χρειαστεί να κρατήσετε βοήθημα βάδισης; Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	**10. Do you feel disadvantaged if you use an assistive walking device?** Never (0), sometimes (1), often (2), very often (3)
11 Φοράτε ασφαλή υποδήματα (αθλητικά παπούτσια, ειδικά παπούτσια βάδισης); Ποτέ (0), μερικές φορές (1), συχνά (2), πάντα (3)	**11. Are your shoes safe (sport shoes, special walking shoes)?** Never (0), sometimes (1), often (2), always (3)
12. Έχετε τροποποιήσει το σπίτι σας για να κινείστε πιο άνετα και με μεγαλύτερη ασφάλεια; (φωτισμός, καλώδια, χαλάκια, μπάρα στις σκάλες) Όχι, είμαι >70 ετών (3), όχι, είμαι <70 ετών (2), ναι, είμαι >70 ετών (1), ναι, είμαι <70 ετών (0)	**12. Have you made modifications in order to move into your house more safely (lighting, cables, little carpets, stair protection)?** No I am older than 70 y.o.(3), no I am younger than 70 (2), yes I am older than 70 (1),no I am younger than 70 (0)
13. Λαμβάνετε κάποια από τα παρακάτω φάρμακα: Αντι-υπερτασικά, διουρητικά, αντικαταθλιπτικά, αντιεπιληπτικά, φάρμακα για το σάκχαρο ή ινσουλίνη; κανένα (0), 1 φάρμακο από τα παραπάνω (1), 2-3 από τα παραπάνω (2), ≥4 από τα παραπάνω	**13. Do you take any of these medications:** Antihypertensives, diuretics, antidepressants, antiepileptics, antidiabetics or insulin? none of the above (0), 1 of the above (1), 2-3 of the above (2), ≥4 of the above
14. Λαμβάνετε τα φάρμακά σας σύμφωνα με τις οδηγίες των γιατρών; Ποτέ (0), μερικές φορές (1), συχνά (2), πάντα (3)	**14. Do you take your medications as prescribed by your doctor?** Never (0), sometimes (1), often (2), always (3)

LRMS (Laboratory for Research of the Musculoskeletal System) Questionnaire

1. **Έχετε πέσει μέσα στον τελευταίο χρόνο;** Όχι (0), 1 φορά (1), 2 φορές (2), πάνω από 2 φορές (3)	1. **Have you had a fall during the past year?** No (0), once (1), twice (2), more than twice (3)
2. **Πόσο συχνά αισθάνεστε ζάλη ή αστάθεια;** Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	2. **How often do you feel dizziness or unsteadiness?** Never (0), sometimes (1), often (2), very often (3)
3. **Πόσο συχνά η δυσκολία στην όραση σας επηρεάζει στη βάδιση;** Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	3. **How often does your vision difficulty affect your gait?** Never (0), sometimes (1), often (2), very often (3)
4. **Πόσο συχνά σηκώνεστε κατά τη διάρκεια της νύχτας για να πάτε τουαλέτα;** Όχι (0), 1 φορά (1), 2 φορές (2), πάνω από 2 φορές (3)	4. **How many times do you go to the bathroom during the night?** No (0), once (1), twice (2), more than twice (3)
5. **Πιστεύετε ότι θα πέσετε κάνοντας τις καθημερινές σας δραστηριότητες;** Ποτέ (0), μερικές φορές (1), συχνά (2), πολύ συχνά (3)	5. **Do you feel that you might fall during your everyday activities?** Never (0), sometimes (1), often (2), very often (3)
6. **Πόσο εύκολα νιώθετε ότι μπορείτε να σηκωθείτε όταν πέσετε;** Εύκολα (χέρια) (0), με μικρή δυσκολία (έπιπλα) (1), με μεγάλη δυσκολία (έπιπλα και βοήθεια) (2),δεν σηκώνομαι μόνος/η μου (3)	6. **How easy is it for you to stand up after a fall?** Easy (using my hands) (0), minimal difficulty (using furniture) (1), great difficulty (furniture and assistance) (2), I cannot stand up alone (3)
7. **Χρειάζεστε βοήθεια στη βάδιση;** Ποτέ (0), μερικές φορές (1), θέλω λίγη βοήθεια (μπαστούνι) (2), θέλω μεγάλη βοήθεια (Πι, με κρατούν οι άλλοι) (3)	7. **Do you need assistance during walking?** Never (0), sometimes (1), I need minimal assistance (walking stick) (2), I need great assistance (stand assist walker, others hold me) (3)
8. **Πιστεύετε ότι το σπίτι σας είναι κατάλληλο για να κινείστε άνετα και με ασφάλεια (φωτισμός, μικρά χαλάκια, έπιπλα, διαρρύθμιση, αντιολισθητικό στο μπάνιο);** Καθόλου (3), λίγο (2), αρκετά (1), είναι ιδανικό (0)	8. **Do you believe that your home is suitable in order for you to move comfortably and safely (lighting, small carpets, furniture, anti-slip mat for bathroom)?** Not at all (3), little (2), suitable enough (1), ideal (0)
9. **Λαμβάνετε κάποια από τα παρακάτω φάρμακα: Αντι-υπερτασικά, διουρητικά, αντικαταθλιπτικά, αντιεπιληπτικά, φάρμακα για το σάκχαρο ή ινσουλίνη;** κανένα (0), 1 φάρμακο από τα παραπάνω (1), 2-3 από τα παραπάνω (2), ≥4 από τα παραπάνω	9. **Do you take any of these medications: antihypertensives, diuretics, antidepressants, antiepileptics, antidiabetics or insulin?** None of the above (0), 1 of the above (1), 2-3 of the above (2), ≥4 of the above
10. **Λαμβάνετε τα φάρμακά σας σύμφωνα με τις οδηγίες των γιατρών;** Ποτέ (0), μερικές φορές (1), συχνά (2), πάντα (3)	10. **Do you take your medications as prescribed by your doctor?** Never (0), sometimes (1), often (2), always (3)
11. **Πόσο συχνά έρχεστε σε κοινωνική επαφή με άλλους ανθρώπους;** Μένω με την οικογένειά μου ή 6-7 φ/εβδ (0), πολύ συχνά (4-5 φ/εβδ) (1), συχνά (2-3 φ/εβδ) (2), σπάνια (1 φ/εβδ ή όχι κάθε εβδ.) (3)	11. **How often do you socialize with other people?** I live with my family or 6-7 times/week (0), very often (4-5 times/week) (1), often (2-3 times/week) (2), rarely (1 time/week or less) (3)