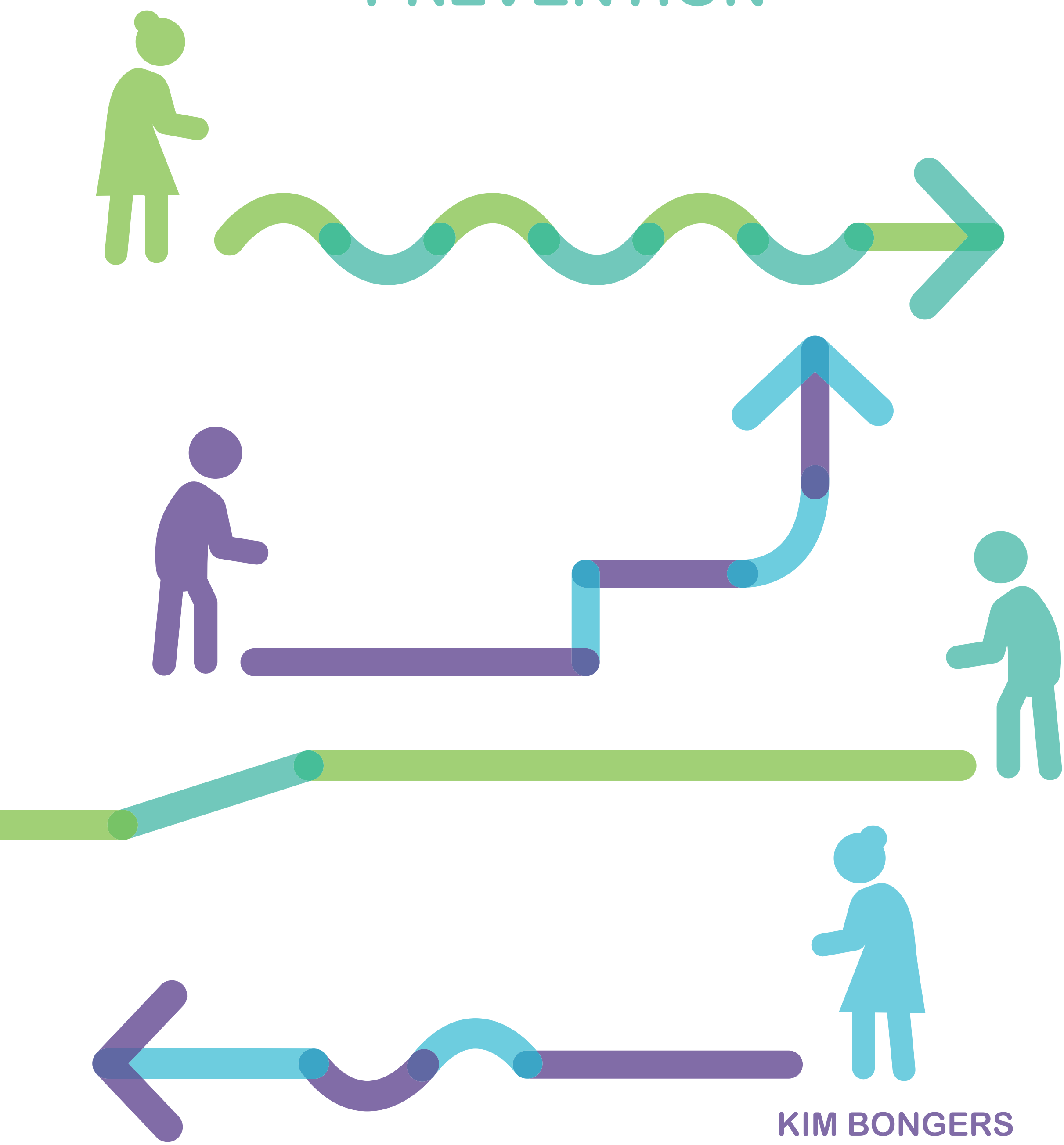
SENIOR STEP STUDY:
FIRST STEPS TOWARDS SELF-MANAGEMENT IN FALLS PREVENTION



KIM BONGERS

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Doctoral Thesis

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by
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CHAPTER 1

GENERAL INTRODUCTION

Vignette: Mrs. A.

Mrs. A. is 71 years old and falls recurrently each year. Her most recent fall was outside when she lost her balance because of a stone under her shoe. Medical history showed chronic lower back pain, severe arthrosis on both hips and knees and a hearing impairment. Mrs. A. alternately used pain medication and received physical therapy for her hips and knees. Two years ago she lost her husband and she has been living in an apartment since then. The pain in her joints influences her daily functioning. Her mobility is independent with alternate use of a cane. She does her own housekeeping and groceries. Twice a week she volunteers in a care center in her neighborhood. She wants to stay independent for as long as possible, and therefore, is motivated to monitor and improve her own balance and mobility. She asked her general practitioner what she could do to improve her self-management with regard to this, but only received the advice “to stay as active as possible”.

BACKGROUND

It has been well documented that our society is aging. In 2015, 3.0 million out of the 16.9 million people in the Netherlands were aged 65 years and older. It is to be expected that this number will rise to 4.2 million in 2040, comprising almost 24% of the total population.[1] If we want to reach and maintain sustainable healthcare for all, healthcare improvements should be more focused on preventive strategies and activate older persons to be more involved in their own health-related well-being. In January 2015, the Dutch government made a policy on this subject, although is it still unclear what the effects of this policy are and how this policy can be supported.
In our aging population, the number of frail older people who have mobility problems and suffer from recurrent falls is rapidly increasing. In this perspective, a fall is usually defined in epidemiological studies as "an unexpected event in which a person comes to rest on the ground, floor or lower lever".[2] Such studies learned that on average one third of all community-dwelling older persons of 65 years and older fall at least once a year.[3] In the Netherlands, in 2015, 97,400 persons of at least 65 years old visited the emergency department because of fall-related injuries.[4] These numbers will increase together with the aging of the population. The high incidence of falling has serious personal and societal impact. Among others, the often occurring decline in mobility and balance, may have a direct negative effect on social functioning, and consequently on well-being, autonomy and quality of life.[5] Furthermore, falling and their related injuries greatly increase healthcare costs.[5-7] Changes in mobility could be early warning signals for an individual's deterioration in health status and for falls in the near future.[6] The possibility to quickly identify changes in mobility at home by the older person him/herself or an informal caregiver, would allow early implementation of appropriate fall prevention strategies. Such changes in a person's mobility could also be early warning signals for future falls and a deterioration in health status, but following these changes objectively may also be a means of monitoring signals of recovery after a previous fall.
Currently, there are several limitations and problems in the treatment and prevention of fall risk. One problem concerns the heterogeneity of the population of fallers and, subsequently, the right selection of older persons for each intervention, and the fine tuning of this intervention, specifically if this is a self-management intervention. Moreover, the treatment and prevention of fall risk is difficult and complex, leading to variable success.[8] Multidisciplinary and multifactorial interventions based on exercise programs and home safety interventions seem most successful so far, but rely only on professionals. The person prone to fall has no active part in managing these problems, however there could be considerable potential in that area. The efficacy of self-management has not been studied nor shown.[8]

Current fall related research dominantly comes from a medical perspective and has concentrated on case finding and fall prevention. As said, to reach sustainable and good quality healthcare systems in our aging societies, policymakers, health insurers and patient associations are more and more expressing their belief that older persons should be more actively involved in their own healthcare. Researchers are beginning to follow this lead on self-management, which is also underlined by the chronic care model.[9-11] The chronic care model defined self-management as the process in which patients largely take responsibility for their own health, well-being, and disease monitoring and minimize the impact of their impairments on their way of living. However, self-management of mobility and fall risk received little attention in previous research. Deteriorating mobility is a risk factor for falling[6] and the ability to quickly identify changes in their mobility could give older persons the opportunity to take responsibility of their own mobility-related well-being. Adequate self-management could minimize the impact of their fall tendency on their lives and could improve quality and effectiveness of our fall-related healthcare services. Moreover, self-management of mobility and balance may empower older adults and could help to limit the increasing demands on healthcare.

However, meeting the goals of improved self-management and allowing the identification of relevant changes in mobility are only possible with a mobility self-assessment tool that is simple, quick, reliable, feasible and has sufficient predictive validity for future falls. Improvement of a person as shown on the self-test could indicate the effectiveness of a treatment or self-management program, and worsening on the self-test might indicate a new medical problem with increased likelihood of falling. Currently, insufficient possibilities are available for Mrs. A. and other older persons and their caregivers to assess and improve their own mobility and fall risk. When developing such a self-assessment tool for the home setting several aspects have to be considered. From the start of the innovation process the relevant stakeholders, that is the older person and his/her caregiver, should be taken into account. The applicability, reliability and validity of such a self-assessment falls and mobility tool should be carefully evaluated. The intended effects should be tested and ultimately evidence based, that is an older person should not fall more often, preferably less often, and the tool has to be safe to use. Furthermore, cost-effectiveness or efficiency should be demonstrated before wider implementation is warranted and supported by healthcare insurances.

AIMS AND OUTLINE OF THE THESIS

The overall aim of the Senior Step Study is to empower seniors, like Mrs. A., by stimulating their self-management abilities in monitoring their mobility and ultimately reduce their fall risk. The Senior Step Study investigated whether it is possible to develop a test that an older person can potentially perform, and which may indicate the person's mobility, balance and risk for falling, by firstly examining which mobility measures would have the most potential to become part of a self-management tool that has sufficient predictive value for future falls. Secondly, a project was started in which older persons themselves used the newly developed self-assessment tools at home for a period of six months, during which usefulness, safety, feasibility, reliability and their relation to falling was assessed. Finally, the best self-management tool acquired in this innovation and development process was used in a first intervention study for improving mobility and lowering fall risk in three different settings. During the entire development, the willingness of older persons to participate in research into self-management and the willingness to use the self-assessment tool was monitored, to be able to conclude whether co-creation and co-evaluation are feasible in developing self-management tools to improve older persons' healthcare.

Step by step the Senior Step Study is described in the following five chapters of this thesis:

- **Chapter 2** examines whether older persons are equally wanting to participate in research on self-management of mobility and fall risk compared to participating in other intervention studies.

- **Chapter 3** studies which mobility measures have the most potential to become a self-management tool for older persons for the assessment and monitoring of frailty, mobility and fall risk.

- **Chapter 4** describes the study in which 56 older persons weekly measure their mobility at home using three possible self-management tools: maximal step length, gait speed and chair test.

- **Chapter 5** presents the best self-management tool from the previous chapters as an intervention for improving mobility and lowering fall risk in three different settings: community-dwelling, homes for the aged and community centers.

- **Chapter 6** provides a summary and general discussion of the results and experiences acquired in the abovementioned studies.

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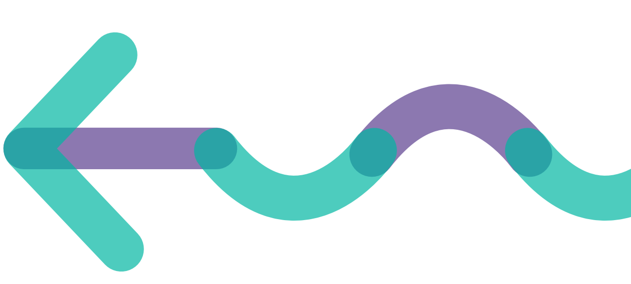
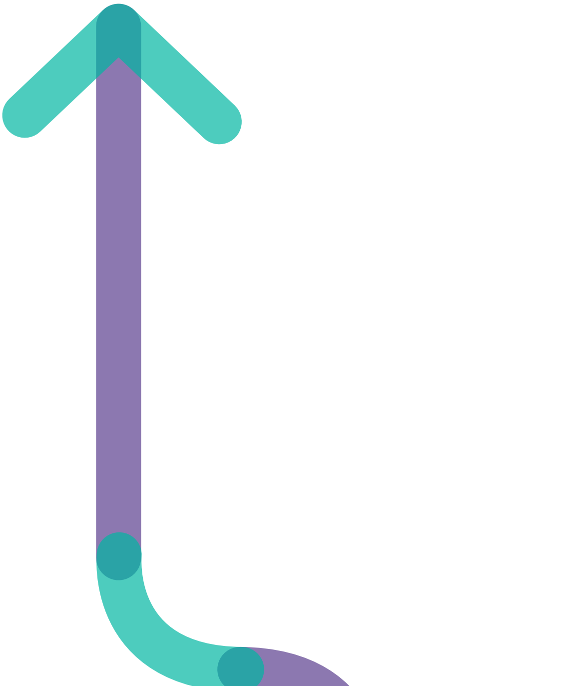


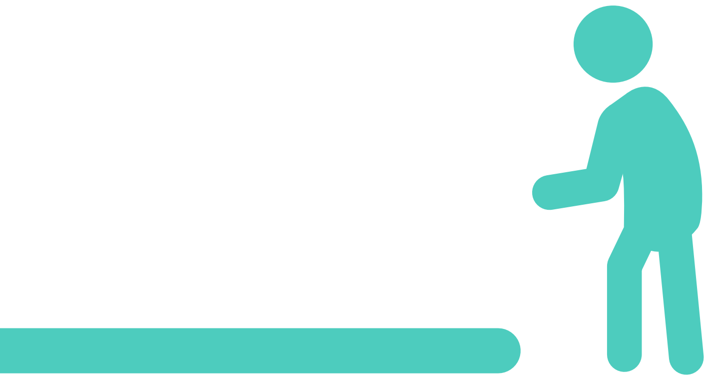
CHAPTER 2

RECRUITING OLDER PERSONS FOR SELF-MANAGEMENT TASKS



2

SELF-MANAGEMENT TASKS TO IMPROVE MOBILITY AND REDUCE FALL RISK ARE NOT LEADING TO LOWER RESEARCH PARTICIPATION IN OLDER ADULTS



Kim Bongers, Yvonne Schoon, Marcel Olde Rikkert

Submitted

ABSTRACT

Objective: to evaluate the recruitment process and explore the reasons mentioned by older people from three different settings for (not) participating in the Senior Step Study, an intervention study on self-management of mobility and fall risk.

Methods: Subjects were community-dwelling or based in homes for the aged. Effectiveness of different recruitment procedures was analyzed for each setting separately. Also, we analyzed reasons for accepting and declining participation between the settings.

Results: Total inclusion rate was 27.9%. A personal first approach did not improve inclusion rate. More subjects consented to participate after an introductory meeting compared to persons not having one ($p<0.01$). For different settings, subjects gave different reasons for participation. No differences were found in the reasons for refusing participation. Especially in the homes for the aged, people refused to participate because the research was too burdensome.

Conclusion: Inclusion rates are comparable to other self-management studies with older people. An introductory meeting during which the study design and profits of participating are explained, and formal interim evaluations of the recruitment process may benefit the recruitment.

Practice implications: recruiting older persons for self-management tasks is possible with the right recruitment process, enabling more research into this increasingly important research topic.

INTRODUCTION

The Senior Step Study is an intervention study on self-management of mobility and fall risk by older people. The recruitment of participants for the study took almost a year longer than initially expected. This finding suggests that older persons may not be highly motivated to participate in self-management intervention studies, though these are getting increasingly important[1]. In self-management studies persons have to act and direct themselves in contrast to more passively participating in most other intervention studies[2].

Research has been performed on methods to improve recruitment of older subjects in fall prevention trials and intervention trials, but so far not in self-management studies[2-4]. Many reviews on improvement of recruitment stated that studies should describe their recruitment strategies better to get sufficient data on external validity and to improve chances for implementation[5-9]. Therefore, the aim for this study was to evaluate the recruitment process of the Senior Step Study and explore the reasons mentioned by older people for (not) participating.

METHODS

Older persons from Nijmegen, the Netherlands, were asked to participate in the Senior Step Study (ClinicalTrials.gov identifier: NCT01792180). The local medical ethics committee approved the study (approval number 2012-300). Eligible subjects were aged 70 years or older, fell at least once in the previous year and were able to walk a distance of 6m. Subjects not speaking or understanding the simple Dutch instructions were excluded. Subjects were community-dwelling older persons, homes for the aged residents and older persons regularly visiting community centres. The research team was advised by local senior organisations, home care workers, caregivers of homes for the aged, local newspapers, and supervisors in community centres on the best approach to introduce the study, which resulted in different approaches (i.e. writing, telephone, face-to-face and group meetings) at each recruitment site. If an older person seemed interested in participating after the first approach, an introductory meeting was scheduled at the subject's home. During this meeting, we explained study design, benefits, rights and obligations of participating. This information was also given on paper, enabling consultation of family members. One week later, the subject was asked to participate.

During the recruitment, the approach of new potential subjects was adjusted if necessary, based on the experiences from the research team, and by active guidance from our contacts at the recruitment sites and subjects who already participated in the study.

Researchers recorded every contact in logs, including recruitment approach, number of contact moments with members of the research team, and reasons for (not) participating. One researcher (KB) categorized these reasons. A second researcher (YS) categorized a random sample of 33 subjects over which interobserver agreement with Cohen's kappa was 0.89 (95% confidence interval: 0.70-1.00) and 0.75 (95% CI: 0.59-0.91), for the reasons for participating and not participating, respectively.

Differences in descriptives and recruitment outcomes between participants and non-participants in all three settings were compared using t-tests for continuous, and Chi-squares tests for categorical variables. Approaching a subject for the first time by writing or telephone was considered as non-personal, face-to-face meetings and addressing potential subjects in group meetings was considered as personal contact. Effectiveness of these recruitment approaches was calculated for each setting separately. Differences between settings for reasons to participate and refuse participation were analyzed using one-way ANOVA with Bonferroni posthoc correction for multiple testing. Significance was set at $p<0.05$.

RESULTS

Of 380 eligible subjects, 163 were community-dwelling, 169 were from homes for the aged, and 48 came from community centres. In those settings, 59 (36.2%), 30 (17.8%), and 17 (35.4%) consented to participate, respectively, with a total inclusion rate of 27.9%.

Mean age for participants and non-participants was 79.5 (SD±6.3) versus 81.9 (±7.2) in the community-dwelling setting ($p=0.07$), 82.5 (±7.8) versus 85.7 (±5.6) in the homes for the aged setting ($p=0.22$), and 73.7 (±7.2) versus 80.7 (±5.7) in the community centre setting ($p<0.02$). There were no significant differences within community-dwelling and community centre settings for sex.

There was no significant difference in inclusion rate between a personal and non-personal first approach within each setting (Table 1). In all three settings more subjects consented to participate if they had an introductory meeting compared to not having had an introductory meeting ($p<0.01$ in all three settings). Mean number of contact moments with the researchers before a subject decided to participate was significantly different between participants and non-participants in the community-dwelling (4.2 (SD±1.3) versus 3.5 (±1.6), ($p<0.01$)) and homes for the aged setting (4.2 (±1.3) versus. 3.1 (±1.8), ($p<0.01$)), but not for community centre participants: 3.8 (±0.8) for participants and 4.6 (±2.2) for non-participants ($p=0.20$).

Subjects recruited via community-dwelling gave significantly different reasons for participating compared to subjects in homes for the aged settings, and subjects recruited via community centre settings ($p<0.01$ and $p<0.05$, respectively) (Table 2). Community-dwelling subjects mainly participated because it could benefit either themselves, other people or science. There were no significant differences between the settings for the categories of reasons to refuse participation.

Table 1. Number (%) of inclusions and refusals to participate in the Senior Step Study according to a non-personal (mail or telephone) and personal (meetings) recruitment approach

	Non-personal approach		Personal approach	
	Inclusions	**Refusals**	**Inclusions**	**Refusals**
Community-dwelling (n(%))	49 (40)	72 (60)	8 (30)	19 (70)
Homes for the aged (n(%))	16 (19)	70 (81)	9 (16)	47 (84)
Community centre (n(%))	5 (63)	3 (38)	12 (36)	21 (64)
Total study population (n(%)))	70 (33)	145 (67)	29 (25)	87 (75)

Table 2. Reasons for (not) participating in the Senior Step Study mentioned by subjects approached at home, in homes for the aged, and in their community centre

Reasons for participating[1]	**Community-dwelling n=59 (%)**	**Homes for the aged n=30 (%)**	**Community centre n=17 (%)**
Participating benefits his/herself	12 (20)	3 (10)	2 (12)
Participating benefits other people	1 (2)	-	1 (6)
It is useful to participate	11 (19)	2 (7)	3 (18)
Research is important	16 (27)	3 (10)	-
Other reasons	3 (5)	5 (17)	-
No particular reason	14 (24)	12 (40)	5 (29)
Unknown	2 (3)	5 (17)	6 (35)
Reasons for not participating	**Community-dwelling n=104 (%)**	**Homes for the aged n=139 (%)**	**Community centre n=31 (%)**
Not allowed by another person	11 (11)	8 (6)	-
Too much of a burden to participate	24 (23)	40 (29)	5 (16)
Does not need it yet	3 (3)	4 (3)	4 (13)
No time for participating	7 (7)	5 (4)	7 (23)
Study design	5 (5)	-	-
Not interested	14 (13)	34 (24)	3 (10)
Cognitively not able to participate	-	3 (2)	1 (3)
Other reasons	14 (13)	14 (10)	3 (10)
No particular reason	6 (6)	4 (3)	-
Unknown	20 (19)	27 (19)	8 (26)

Numbers represent numbers and percentages (%) of (non-)participants per setting, rounding may cause the percentage to exceed 100%.

[1] Significantly different between the three settings ($p<0.01$).

DISCUSSION AND CONCLUSION

Discussion

Although the recruitment for the Senior Step Study took almost a year longer than initially expected, overall inclusion rate was moderate to good (27.9%), especially in the community-dwelling setting (36.2%). A personal first approach to the older person did not make a difference in the inclusion rate, but an introductory meeting seemed to benefit inclusion.

Our inclusion rate is comparable with a range of inclusion rates (20%-38%) found in self-management studies with older persons[2,10-13]. Reed et al [10] (inclusion rate 38%) recruited subjects through their general practitioner, not directly by the researchers as was the case in our study. Furthermore, all these studies included younger chronically ill persons. Subjects participating in our study were not recruited because of a chronic illness and might therefore be less intrinsically motivated to participate in this study. However, the comparable inclusion rate, indicates that older persons are willing to participate in self-management research.

Reviews on improving recruitment of older people for research in general[4-9,14] indicate that frail older persons are more likely to participate if they are approached by someone personally[6,15]. However, in our study a personal approach made no difference in inclusion rate. We combined several recommendations from literature in the introductory meeting at the subject's home[2-9,14-15]. For instance, usefulness of participating was discussed during this meeting. Researchers were easily approachable for potential subjects and their families, and subjects who decided to participate had more contact moments compared to subjects who did not participate in the community-dwelling and home for the aged settings. The 'extra' effort put into the recruitment process through the introductory meeting and being easily approachable was successful[4].

The reason mentioned most often for not participating in our study, especially in the homes for the aged setting, was that people considered it too much of a burden, as reported in other studies[2].

Several care organisations helped our study during the recruitment, and all approaches were fitted to each recruiting site, as suggested by literature[10,15]. Researchers made interim evaluations and adjustments if necessary and participants also guided subsequent recruitment. Because this study did not start out as a study into recruitment, we cannot state whether the adjustments yielded more inclusions. However, without the interim evaluations the researchers and contacts would have recruited excessively but unsuccessfully. An example was the ceasing of the community centre setting recruitment, because in this setting we could not include sufficient participants for valid comparison with the other settings (48 versus 163 community-dwelling elderly and 169 home for the aged residents). Subjects in this setting stated they felt stigmatized upon participating, because people would know they fell and thus were getting unsuccessfully old.

A strength of this study was that the reasons for (not) wanting to participate in were collected from a large community based sample of older persons. This helped understanding the recruitment process and formulating preliminary statements about recruitment in future self-management studies.

Conclusion

The increasing importance of self-management in this aging society warrants more research into self-management by older persons, and our results show that older persons are willing to participate if the burden is low, and they are well informed at the start.

Practice Implications

Researchers are able to recruit older persons for self-management studies more easily using the results from our study. This enables more research into this increasingly important research topic.

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We thank Maartje Graauwmans, Leontien van Nieuwenhuijzen and Naomi Likumahwa for their contribution to the recruitment.

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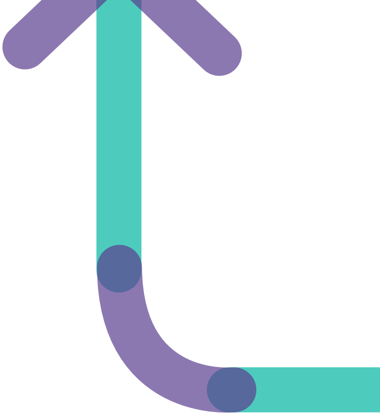
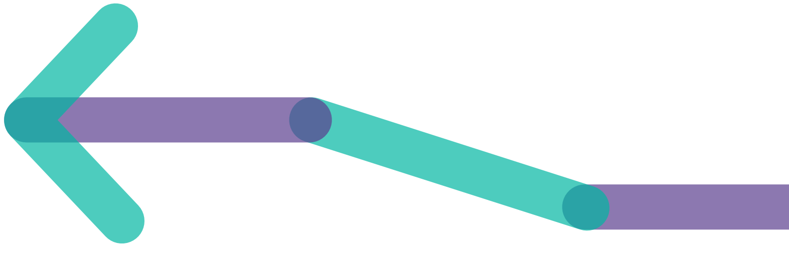


CHAPTER 3

THREE SIMPLE MOBILITY TESTS FOR MONITORING FRAILTY, MOBILITY AND FALL RISK



3a

Gait speed as a test for monitoring frailty in community-dwelling older people has the highest diagnostic value compared to step length and chair rise time

Yvonne Schoon, Kim Bongers, Janneke van Kempen, René Melis, Marcel Olde Rikkert

Eur J Phys Rehabil Med 2014;50(6):693-701.

ABSTRACT

Background. Frailty reflects a state of increased risk of negative health outcomes, such as falls and mortality. Self-management in recognition and monitoring of frailty is a prerequisite for effective and efficient care for the elderly. Mobility may be self-monitored with simple reliable tests, such as maximum step length (MSL) test, gait speed (GS) test, or chair rise test (CR).

Aim. The aim was to investigate whether a complex frailty assessment may be replaced by simple stand alone mobility tests as a prerequisite for self-monitoring of frailty.

Design. This was an observational cross-sectional study.

Setting. The study was performed in an outpatient clinic.

Population. The study subjects were community-dwelling older people aged 70 years or older.

Methods. In all subjects, frailty status was assessed using a standardised geriatric assessment that included Fried's frailty phenotype and the Frailty Index (FI). Mobility was assessed with the MSL, GS and CR.

Results. A total of 593 subjects with mean age of 76.8 years (±4.8 [SD]), 56% female, participated in the study. GS showed a correlation of r=-0.60 with both the Fried score and the FI. The MSL correlated best with the Fried score: r=-0.52, and the CR correlated best with the FI: r=0.51. The GS had an area under the curve of 0.92 for assessing the dichotomised frailty state.

Conclusion. Compared with step length and chair rise time, gait speed has the strongest correlation with frailty, the highest diagnostic value, and it is the simplest single measure that can replace the complex frailty assessment as a self-test for monitoring frailty at home.
Clinical rehabilitation impact. The self-monitoring of frailty is likely to be possible with GS, which may be a valuable tool for empowering older individuals.

INTRODUCTION

To reach sustainable and good quality health care systems in most of our aging societies, substantial improvements have to be made. One of the options often mentioned is that self-management should be promoted. Self-management, according to the chronic care model, is defined as the process in which patients largely take responsibility for their own health, well-being, and disease monitoring and minimise the impact of their impairments on their lives.

Self-management in old age most often has to be directed at the consequences of multiple diseases, multiple disabilities especially in mobility and cognition, and frailty, of which frailty is a rather new construct. Although there are numerous definitions of frailty, it may be characterised as a health status with limited compensation for external stressors, and frailty predicts poor health outcomes, such as falls, hospital admissions, and mortality.[1] Impairments in mobility and balance are common in older people, generally reflect an individuals' overall state of health, and are crucial for autonomy together with cognitive function.[2-4] Therefore, mobility measures also reflect and are part of the frailty construct.[3] The option to enable older subjects themselves to identify and monitor their frailty status by measuring a single mobility measure at home would imply an excellent innovation for older persons resulting in increased empowerment and self-management. Therefore, it is valuable to study the overlap between the multidimensional construct of frailty and a single measure of frailty, which is suitable for a repeated self-test. The complementary question is how much information the frailty items add that are not based on mobility measures. To meet this goal, this mobility assessment should be simple, reliable and feasible with sufficient diagnostic accuracy for frailty. Maximum step length (MSL) is a simple, reliable, responsive, and feasible measure of mobility in frail older people.[5-7] Gait speed (GS) also has demonstrated validity for predicting future adverse effects, such as disability, hospitalisation, institutionalisation, falls, and death, and thereby seems to have a similar prognostic value as frailty.[8,9] The chair rise test (CR), which is part of the Short Physical Performance Battery (SPPB)[4,10], predicts all the disabilities that affect activities of daily living (ADL).[11] The current study investigated whether the MSL, GS, and CR were sufficiently correlated with, and explain the variability in, frailty status in community-dwelling older people to be potentially useful for the self-monitoring of frailty.

MATERIALS AND METHODS

Study Population

As part of the Validation Study of the Two-step Older persons Screening (TOS-study)[12], six general practitioners recruited older subjects from their practices, which were located in urban (two practices), suburban (one practice), and rural (three practices) areas in and around Nijmegen (The Netherlands). The local ethics committee approved the study (approval number 2009/223). Patients who were too ill to be screened and patients who were either receiving treatment from a geriatrician or who had received a comprehensive geriatric assessment in the past three months were excluded. A total of

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1100 older patients were asked for their informed consent, and 593 of these subjects were willing to participate in the study. All the mobility, frailty, and performance tests were administered by a specialised geriatric nurse and a geriatrician as part of a strictly standardised geriatric assessment at the geriatric outpatient clinic. Patients were excluded from a specific test if they could not perform it independently or safely, based on the judgment of the geriatric nurse or the patients themselves. While administering the mobility tests, the geriatric team was not aware of the outcome of the frailty measures.

Patient Assessment Measures

Disability was evaluated with the Katz-15 index (which measures basic and instrumental activities of daily living [ADL], with a score range of 0-15, with lower scores indicating better functional performance). Disease burden and diversity were determined using the Cumulative Illness Rating Scale for Geriatrics (CIRS-G; scored on a scale from 0-4 for each of 14 categories [maximum score 56], with higher scores reflecting a larger number of comorbidities).[13] Cognitive status was evaluated with the Mini Mental State Examination (MMSE, with a score range of 0-30, with higher scores indicating better cognitive status)[14] and the Frontal Assessment Battery (FAB, with a score range of 0-6, with higher scores indicating better cognitive status).[15] Mood was evaluated with the Geriatric Depression Scale (GDS, with a score range of 0-15, with higher scores indicating depression).[16] Each subject was asked about his or her level of activity (maximum walking distance in metres). The subjects were also asked to state the number of falls they had experienced during the 12 months prior to the study.

Mobility Measures

For the MSL test, the subjects were instructed to step forward with one leg as far as possible and then to bring the other leg up to the first leg in one step.[6] A trial was successful when the subject stepped in one fluid movement and was unsuccessful when more than one step was needed to maintain balance or when balance was lost. After two practice trials, the procedure was repeated at least three times, with a maximum of five trials to obtain three successful trials. The step length was measured, with a mark on the floor, as the distance between the starting position and the final position of the leg that stepped first; the length was later normalised with respect to leg length (the distance between the spina iliaca anterior superior and the lateral malleolus). The MSL was calculated as the maximum step length (the maximum MSL) and the mean of the three successful step lengths (the mean MSL).
The GS test was performed on an electronic walkway that was 5.6 m long and 0.89 m wide (GAITRite®). The subjects walked on the walkway twice at their preferred velocity, and their GS was recorded over 4 m. The mean GS was calculated as the mean speed of the two separate walks.
The SPPB included gait speed (time to walk 4 m), five chair stands (time to rise from a chair and return to a seated position without using the arms five times), and a balance test (the ability to stand with the feet together in the side-by-side, semi-tandem, and tandem positions).[4] A summary performance score (range 0-12) for the three tasks was created for each subject, with higher scores indicating better lower body function. For the CR, the subjects were asked to stand up from a chair five times consecutively as

rapidly as possible, with their arms folded across their chest. The time between the first and fifth times the subject achieved a complete standing position was recorded, and the test was performed only once.

Frailty

Frailty was assessed using both the Fried criteria, with the subjects scored on each criterion (range 0-5; 0: not frail; 1 or 2: pre-frail; 3 or higher: frail)[1], and the Frailty Index (FI).[17] The Fried criteria included self-reported unintentional weight loss (defined as 4.5 kg or 5% of body weight over the previous year), self-reported exhaustion (defined as an affirmative answer to two questions), low energy expenditure (measured with the LASA Physical Activity Questionnaire and defined as <393 kcal/week for males and <280 kcal/week for females), slow gait speed (defined as <0.76 m/s), and weak handgrip strength (defined as <30 kg for males and <18 kg for females). Handgrip strength was measured with a JAMAR™ hand dynamometer. The GS measurement from the SPPB was used to evaluate the Fried criterion of slow GS. The FI (score range 0-1) was measured as the ratio of the number of deficits present to the total number of items on a 45-item deficit list included in the Comprehensive Geriatric Assessment, with higher FI scores indicating a higher degree of frailty.[17-19] A subject with an FI score ≥0.25 was considered frail. For the 45-item deficit list, see Supplementary data available online, Appendix 1.

Statistical Analyses

Scatterplots of the mobility tests in relation to the frailty phenotype outcomes were made which showed assuming a linear relation between gait speed and frailty phenotype to be justified to determine that all correlations were determined by calculating the Pearson correlation coefficients between mobility and the frailty measures. The percentage of explained variance for GS was compared with the other frailty factors by multiple linear regression analysis with the Fried categories as dependent continuous variable. Measures with correlations with frailty status of at least r=0.5 were considered potentially useful as self-tests for frailty. The diagnostic value of the mobility tests for distinguishing between frailty states, using the dichotomous Fried categorisation (frail versus non-frail), or the dichotomous FI as the dependent variable, was calculated as the area under the curve (AUC) of the receiver operating characteristics. A multiple linear regression analysis was performed to evaluate the relationship between frailty status, as measured with the FI or the Fried categories (as the dependent continuous variable), and the three potential self-tests.

RESULTS

Of the study cohort (n=593), 462 subjects could perform all of the assessed mobility and frailty tests. The MSL test was successfully performed by 547 subjects (16 performed the MSL test incorrectly, and 30 were excluded from performing the MSL test because it was unsafe). The leg length measurements of three subjects were missing; those values were imputed by using the mean leg lengths of ten individuals of the same gender and height. The GS test was performed for 518 subjects. For five subjects, walking was either impossible or unsafe. In another three subjects, GS was measured during one walk instead of two separate walks. Technical problems with the GAITRite caused missing values for 70 subjects (a random sample). The CR was completed by 540 subjects. The CR was not attempted by 25 subjects: it was deemed unsafe for 10 subjects, 1 subject refused, and 14 subjects were unable to stand up. The CR was attempted but not completed by 28 subjects: 6 subjects fell backwards in the chair, and 22 subjects used their arms while standing up. Overall, the MSL test was feasible for 95% of the study sample (563/593), the GS test for 99% (588/593, not including the GAITRite technical problems), and the CR for 91% (540/593).

The baseline characteristics of the subjects are reported in Table 1. The mean age of the study participants was 76.8 years (standard deviation [SD] ±4.8; range 70-92), and 56% were female. A fall during the past 12 months was reported by 35%, and a walking aid was used by 21%. The mean MMSE score was 27.3 (±2.8), the mean Katz score was 1.4 (±1.9), and the mean CIRS-G score was 8 (±4.4). The mean FI score was 0.22 (±0.12), and 10% of the study population was frail according to the Fried criteria.

The overall variance in frailty phenotype explained by each of the frailty phenotype items are reported in Table 2. GS explained 42% of the variance, which is lower than the variance explained by the energy expenditure-item (45%). Adding the exhaustion frailty phenotype item to GS, this percentage increased to a maximum of 68%.

Table 1. The baseline characteristics of the study population (n=593)

Characteristic	Mean±SD or %
Age (years)	76.8±4.8
Female	56%
Fall history	35%
Walking aid	
-none	78.8%
-cane	7.9%
-walker	13.2%
-wheelchair	0.2%
Systolic blood pressure (mmHg)	151±18
Diastolic blood pressure (mmHg)	83±10
Heart rate (beats/min)	68±11
Body mass index (kg/m^2)	27.6±4.3
Number of (I)ADL disabilities Katz (0-15)	1.4±1.9
CIRS-G (0-56)	8±4.4
MMSE (0-30)	27.3±2.8
FAB (0-6)	15.6±2.2
GDS (0-15)	2.1±2.2
Handgrip strength (kg)	24.8±10.1
TUG (sec)	9.5±4.6
SPPB, balance (0-4)	3.4±1
SPPB, GS (0-4)	3.6±0.8
SPPB, chair rise (0-4)	2.3±1.3
SPPB, total score (0-12)	9.3±2.6
FI	0.22±0.12
Fried category	
-not frail (score of 0)	47%
-pre-frail (score of 1 or 2)	43%
-frail (score of 3, 4, or 5)	10%

Note: Numbers between parentheses are score ranges.

Table 2. Univariate and multivariate linear regression models for each frailty phenotype item, and for gait speed combined with another Frailty item, for the presence of the frailty phenotype

Each frailty phenotype item	**B**	**Standard Error B**	**β**	**p-value**	**95% CI**	**R^2**
Weight	1.872	0.191	0.373	0.000	1.496 to 2.248	0.14
Gait speed	2.434	0.119	0.646	0.000	2.2 to 2.667	0.42
Exhaustion	1.615	0.079	0.645	0.000	1.461 to 1.77	0.42
Energy expenditure	1.933	0.088	0.672	0.000	1.761 to 2.105	0.45
Handgrip strength	1.552	0.078	0.641	0.000	1.4 to 1.704	0.41
Combined frailty phenotype items						
Gait speed	2.22	0.117	0.589	0.000	1.99 to 2.451	0.47
Weight	1.156	0.155	0.232	0.000	0.851 to 1.461	
Gait speed	1.986	0.091	0.527	0.000	1.807 to 2.165	0.68
Exhaustion	1.308	0.061	0.522	0.000	1.189 to 1.427	
Gait speed	1.656	0.108	0.439	0.000	1.443 to 1.869	0.61
Energy expenditure	1.387	0.083	0.481	0.000	1.224 to 1.549	
Gait speed	2.01	0.092	0.534	0.000	1.83 to 2.19	0.68
Handgrip strength	1.261	0.059	0.521	0.000	1.145 to 1.376	

The correlation between the Fried frailty score and the CR score was moderate (r=0.47), and the correlations between the Fried frailty score and MSL (r=-0.52) and GS (r=-0.60) were good (all p-values <0.001). The correlation between the FI and MSL was moderate (r=-0.49), and the correlations between the FI and the CR (r=0.51) and GS (r=-0.60) were good (all p-values <0.001). Thus, GS was most highly correlated with frailty status (both r=-0.60). The mean scores on the mobility tests differed significantly among participants belonging to different Fried's frailty categories (p-values <0.001; see Table 3). GS also had the highest diagnostic value for detecting the dichotomised frailty phenotype, with an AUC of 0.92 (see Table 4). Adding age and gender to the logistic regression model did not change the results. There were similar results from the linear regression of the mobility measures with the FI as the dependent outcome measure. For the linear regression model results, see Supplementary data available online, Appendix 2. Using the Fried cut-off value for gait speed (0.76 m/s), sensitivity was 90% and specificity was 76%, a cut-off value of 0.80 m/s changed sensitivity to 85% and specificity to 91%, and a still higher cut-off value of 0.90 m/s, further improved the specificity to 96%, but lowered sensitivity to 61%.

Table 3. The maximum step length (MSL), gait speed (GS), and chair rise (CR) test results for the subjects with the three frailty phenotypes (not frail, pre-frail and frail)

Test	Type of result	Total group	Not frail	Pre-frail	Frail
MSL (cm/cm)	n	547	275	234	38
	Mean±SD	1.06±0.23	1.17±0.2	0.99±0.21	0.8±0.2
	95% CI	1.04-1.08	1.14-1.19	0.96-1.02	0.73-0.86
GS (m/sec)	n	518	257	216	45
	Mean±SD	1.01±0.26	1.13±0.2	0.96±0.22	0.59±0.24
	95% CI	0.99-1.04	1.1-1.16	0.93-0.99	0.51-0.66
CR (sec)	n	540	270	234	36
	Mean±SD	15.1±6.7	12.9±3.6	16.5±7.7	23.1±9.6
	95% CI	14.6-15.8	12.5-13.4	15.5-17.5	19.8-26.3

Note: The overall statistics (Anova) was significant, with p-value 0.000. The contrasts of MSL, GS, and CR results between the frailty states were all significant, with p-values ≤0.002, except for MSL between pre-frail and frail was not significant (p=0.32).

Table 4. The AUC (diagnostic accuracy or c-statistic) derived from the ROC of the maximum step length (MSL), gait speed (GS), and chair rise (CR) tests for detecting frailty versus non-frailty, according to the frailty phenotype (Fried) and frailty assessed by using the Frailty Index

		Frailty phenotype				**Frailty Index**			
	n	**AUC value[a]**	**95% CI**	**AUC value[b]**	**95% CI**	**AUC value[a]**	**95% CI**	**AUC value[b]**	**95% CI**
MSL	547	0.84	0.77-0.90	0.86	0.80-0.91	0.77	0.72-0.81	0.79	0.75-0.83
GS	518	0.92	0.87-0.96	0.92	0.88-0.97	0.81	0.76-0.85	0.82	0.78-0.87
CR	540	0.81	0.75-0.88	0.83	0.76-0.89	0.76	0.71-0.80	0.79	0.75-0.83

Notes: AUC: Area under the curve of receiver operating characteristics (ROC) of mobility measures for the frail versus non-frail condition; 95% CI: 95% confidence interval.

[a] AUC value for the mobility test alone; b AUC value for the mobility test, age, and gender.

DISCUSSION

In this study, we showed that all three single mobility measures exhibited moderate to good correlations with the frailty phenotype and the FI, though GS was superior to CR and MSL, indicating that GS may be an appropriate self-test for monitoring frailty. Because there is no gold standard for assessing frailty, we used two different measures of frailty: the Fried concept, which defines frailty as a physical phenotype or syndrome that can be assessed using five distinct criteria (a categorical variable), and Rockwood's "accumulation of deficits" concept of frailty, which posits that a person with more deficits is frailer and has a greater risk of adverse health outcomes (a continuous variable).[20] The Fried items separately explained a substantial fraction of variance in the overall frailty phenotype. The diagnostic accuracy of all mobility tests were good, and slightly improved by adding age and gender. If you want to screen a large population for frailty, a higher specificity value is important to obtain as little as possible false-positive outcomes. However, a higher sensitivity value will be superior if you want to diagnose as many elderly as possible for frailty. Thus, when concerning self-monitoring of frailty, a high sensitivity is recommended, in that you do not want to miss a frail older person. Afterwards, a professional can test whether a person is really frail and start interventions if necessary.

A strength of this study is that it was conducted in a large, community-based sample of older subjects with sufficient numbers of frail and non-frail subjects to produce baseline characteristics that are representative of the entire population.[21] The percentage of subjects exhibiting a frailty phenotype was highly comparable to that in the original sample in which this frailty measure was first validated.[1] Therefore, the findings are likely to have high external validity. In addition, mobility and frailty were measured using high-quality, standardised geriatric assessments, and the individuals conducting the mobility assessments were blinded to the individual frailty outcomes, which strengthens the internal validity of the results. The most important limitation of this study is the use of cross-sectional data collection. Second, the GS data were collected at a geriatric outpatient clinic and not at the subjects' homes; thus, the ecological validity of the study's GS data is uncertain. However, this methodology did increase the quality of the data collection, which justifies the procedure in this first step towards the self-monitoring of frailty. The electronic problems with the GAITRite limited the collection of GS measurements; nonetheless, it is likely that the missing measurements occurred completely at random and therefore only decreased the power of the analyses. The device was carefully checked before the measurements were recommenced to ensure that these technical problems did not influence the other measurements.

Frailty measurement cannot be performed by older individuals themselves, as it is a multidimensional construct requiring several measurements. Therefore we tried to determine the proportion of GS for the diagnostic value of frailty status, being well aware that slow GS was also one of the criteria of the Fried frailty phenotype. Thus, it may have been obvious that we found a strong correlation between GS and frailty phenotype. However, we also found a good correlation between GS and FI, even though GS is not part of the FI. We conclude, therefore, that a simple GS measurement may be sufficient in diagnosing whether a_person is frail.[22] A GS assessment is usually safe and easy to perform, even with frailer subjects, because it is based on normal walking. Walking aids may also be used during longitudinal monitoring. The MSL and the CR test the maximum performance, challenging older individuals to do their best. In our experience, all three tests can be safely performed if the proper instructions are provided. However, their safety in a self-assessment setting should be evaluated. The equipment necessary for performing the three mobility tests is limited to a ruler for measuring MSL and a stopwatch for the GS and CR tests. In contrast, the SPPB require more equipment and professional supervision.[4]

Conclusions

To our knowledge, there are no published reports yet concerning instruments for self-monitoring frailty, mobility, or other geriatric measures. We investigated whether a simple mobility test was sufficiently valid to be potentially useful for the self-monitoring of frailty in community-dwelling older people. Although the lack of data limits our ability to compare our results to those of other studies, it also underlines the importance of our study. In many countries, ageing is predicted to cause a sharp reduction in the health care workforce; thus, the self-monitoring and prevention of frailty and frailty-related health crises will be critical for supporting sustainable health care, especially for the frail elderly. We have shown that the self-monitoring of frailty is likely to be possible with GS, which may be a valuable tool for empowering older individuals. However, further investigations are strongly needed to establish the validity of GS in older people's home environments, to assess its predictive value, and to study the options for interventions that are partially or completely directed and monitored by older individuals themselves.[23]

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SUPPLEMENTARY DATA

Appendix 1. The 45 items of the Frailty Index. A score of 0 indicates that the item was not present; a score of 1 indicates that the item was present.

Number	Item	Measured during
1	Exhaustion	Geriatrician interview
2	Weight loss	Geriatrician interview
3	Inactivity	Geriatrician interview
4	Unconsciousness	Geriatrician interview
5	Dizziness	Geriatrician interview
6	Problems with physical exercise	Geriatrician interview
7	Urinary incontinence	Geriatrician interview
8	Cardiac problems	CIRS-G + Geriatrician interview
9	Vascular problems	CIRS-G + Geriatrician interview
10	Haematopoietic problems	CIRS-G + Geriatrician interview
11	Respiratory problems	CIRS-G + Geriatrician interview
12	Upper digestive tract problems	CIRS-G + Geriatrician interview
13	Lower digestive tract problems	CIRS-G + Geriatrician interview
14	Endocrine problems	CIRS-G + Geriatrician interview
15	Liver problems	CIRS-G + Geriatrician interview
16	Kidney problems	CIRS-G + Geriatrician interview
17	Urogenital problems (not including incontinence)	CIRS-G + Geriatrician interview
18	Musculoskeletal problems	CIRS-G + Geriatrician interview
19	Neurological problems	CIRS-G + Geriatrician interview
20	Loss of appetite	Geriatric nurse interview
21	Sleeping problems	Geriatric nurse interview
22	Polypharmacy	Geriatric nurse interview
23	Memory problems	MMSE + Geriatrician interview
24	Vision problems	Geriatrician interview + physical examination
25	Hearing problems	Geriatrician interview + physical examination
26	Help with bathing	Katz + Geriatric nurse interview
27	Help with dressing	Katz + Geriatric nurse interview
28	Help with personal appearance	Katz + Geriatric nurse interview
29	Help with using the toilet	Katz + Geriatric nurse interview
30	Help with rising from a chair	Katz + Geriatric nurse interview
31	Help with eating	Katz + Geriatric nurse interview
32	Help with using a telephone	Katz + Geriatric nurse interview
33	Help with travelling	Katz + Geriatric nurse interview

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34	Help with shopping	Katz + Geriatric nurse interview
35	Help with preparing a meal	Katz + Geriatric nurse interview
36	Help with housework	Katz + Geriatric nurse interview
37	Help with taking medication	Katz + Geriatric nurse interview
38	Help with dealing with money	Katz + Geriatric nurse interview
39	Walking problems	Geriatrician interview
40	Falling	Geriatrician interview
41	Depression	GDS + Geriatrician interview
42	Anxiety	HADS-A + Geriatrician interview
43	Lack of meaningful daily activities	Geriatric nurse interview
44	Loneliness	Geriatric nurse interview
45	Social isolation	Geriatric nurse interview

Appendix 2. Univariate and multivariate linear regression models for the maximum step length (MSL), gait speed (GS), and chair rise (CR) tests of frailty as measured by the frailty phenotype (Fried) and Frailty Index (FI)

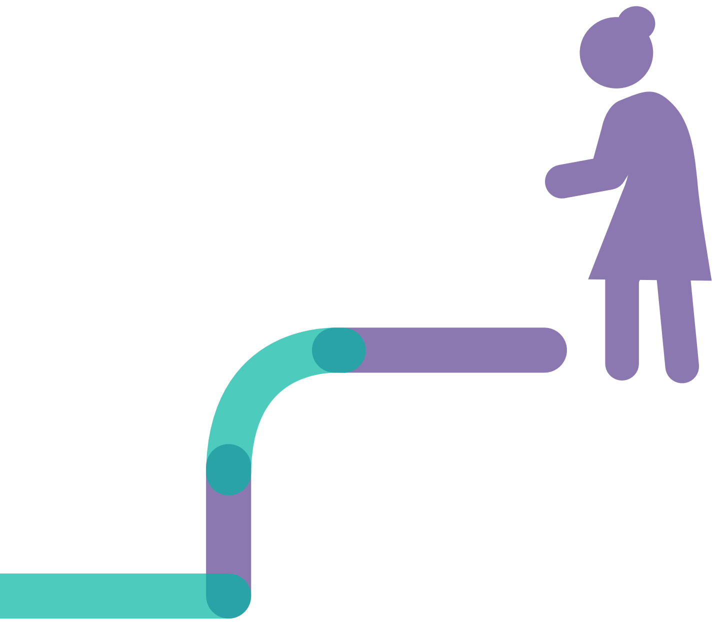
Frailty phenotype	**B**	**SE B[a]**	**β**	**p-value**	**95% CI**	**R^2**	**Adjusted R^2**
MSL max	-2.3	0.164	-0.515	0.000	-2.625 to -1.98	0.27	Na
MSL max	-1.977	0.802	-0.443	0.000	-2.63 to -1.594		
Age	0.042	0.009	0.195	0.000	0.025 to 0.060	0.30	0.30
Gender	-0.067	0.081	-0.033	0.408	-0.227 to 0.092		
GS	-2.539	0.148	-0.604	0.000	-2.829 to -2.249	0.36	Na
GS	-2.138	0.167	-0.508	0.000	-2.465 to -1.81		
Age	0.042	0.009	0.179	0.000	0.024 to 0.059	0.39	0.39
Gender	0.152	0.077	0.068	0.049	0.000 to 0.304		
CR	0.072	0.006	0.469	0.000	0.061 to 0.084	0.22	Na
CR	0.06	0.006	0.39	0.000	0.049 to 0.071		
Age	0.065	0.008	0.3	0.000	0.049 to 0.081	0.31	0.31
Gender	0.141	0.075	0.068	0.061	-0.007 to 0.289		
Frailty Index	**B**	**SE B[a]**	**β**	**p-value**	**95% CI**	**R^2**	**Adjusted R^2**
MSL max	-0.229	0.017	-.0489	0.000	-0.263 to -0.194	0.24	Na
MSL max	-0.204	0.021	-0.437	0.000	-0.246 to -0.163		
Age	0.004	0.001	0.163	0.000	0.002 to 0.006	0.27	0.26
Gender	-0.011	0.009	-0.051	0.203	-0.028 to 0.006		
GS	-0.255	0.015	-0.595	0.000	-0.285 to -0.226	0.35	Na
GS	-0.221	0.017	-0.516	0.000	-0.255 to -0.187		
Age	0.004	0.001	0.156	0.000	0.002 to 0.006	0.37	0.37
Gender	0.006	0.008	0.027	0.443	-0.010 to 0.022		
CR	0.008	0.001	0.505	0.000	0.007 to 0.009	0.26	Na
CR	0.007	0.001	0.443	0.000	0.006 to 0.008		
Age	0.006	0.001	0.251	0.000	0.004 to 0.007	0.32	0.31
Gender	0.006	0.008	0.027	0.449	-0.010 to 0.022		

Notes: [a] = Standard Error of B.

3

3b

The predictive value of gait speed and maximum step length for falling in community-dwelling older persons



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ABSTRACT

Background: falling is a major health problem.

Objective: to investigate the predictive value for falls of the maximum step length and gait speed.

Design: prospective cohort study.

Setting: geriatric outpatient clinic.

Subjects: 352 community-dwelling older persons screened by their general practitioner.

Methods: maximum step length and gait speed were recorded as part of a comprehensive geriatric assessment. One year follow-up was performed using the fall telephone system.

Results: 136 (39%) of all subjects (mean age 76.2 years, standard deviation: 4.3, 55% female), fell at least once, of whom 96 were injured. Predictive values for any falls of both maximum step length and gait speed were low (area under the curve (AUC): 0.53 and 0.50), and slightly better for recurrent falls (maximum step length AUC: 0.64 and gait speed AUC: 0.59). After adding age, gender and fall history to the prediction model, the AUC was 0.63 for maximum step length and 0.64 for gait speed, and for recurrent falls the AUC was 0.69 both for maximum step length and gait speed. The prediction of fall-related injuries showed similar results. A higher maximum step length score indicated a lower likelihood for falls (HR 0.36; 95%CI 0.17-0.78).

Conclusions: maximum step length and gait speed as single-item tools do not have sufficient power to predict future falls in community-dwelling older persons.

INTRODUCTION

Falling is a major problem in our aging population [1,2]. The ability to quickly identify changes in mobility by clinicians, which could be early warning signals for future falls and a deterioration in health status [1], would allow early implementation of appropriate fall prevention strategies. In addition, identifying changes in mobility at home by patients themselves, would offer an excellent opportunity for older persons to take responsibility for their own mobility related well-being. This could minimize the impact of their fall tendency on their lives, and, moreover, might also mean a significant step in reaching a more improved and sustainable quality of our fall related health care services. However, meeting the goal of improved self-management and allowing the identification of relevant changes in mobility, is only possible with a mobility assessment tool that is simple, quick, reliable, feasible, and has sufficient predictive validity for future falls.

Maximum step length potentially is such a measure, as it simply is the maximum distance someone can step out without losing balance. Gait speed, measured over four meters, can potentially also be such a measure. Recent studies have investigated the predictive value for future falls of maximum step length and gait speed, but are equivocal [2-13]. Several studies showed maximum step length to be simple, reliable, and feasible in measuring balance and mobility in both community-dwelling and frail older individuals, however, prospective studies linking maximum step length and falling are limited [2-6]. gait speed proved to be feasible, valid, and predictive for future adverse effects, such as falls, in community-dwelling older individuals [7-13]. However, the relationship between falls and gait speed has yet to be thoroughly explored using a fall assessment that is less prone to recall bias. Before these tests can be used as self-assessments in the home-setting, the present study, therefore, studied the predictive value for falling of maximum step length and gait speed as a single-item tool in a one year follow-up study in community-dwelling older individuals using a more reliable method of fall follow-up: the fall telephone (FT) system [14,15].

METHODS

Study Population

This study was part of the Two-step Older persons Screening study (TOS-study), in which six general practitioners (GPs) began to screen all their patients aged over 70 years for frailty [16]. Patients judged to be too ill to be screened by the GPs, and patients who were either currently receiving treatment from a geriatrician or who had received a comprehensive geriatric assessment in the past three months, were excluded. A total of 1159 older patients were screened, and 593 of these subjects were included in the TOS-study. Subjects were excluded from a specific test if they could not perform it independently or safely, based on the judgment of the geriatric nurse or subjects themselves. The local ethics committee approved the study (approval number 2009/223).

Comprehensive Geriatric Assessment

A specialized geriatric nurse and geriatrician administered all test as part of a standardized geriatric assessment at a geriatric outpatient clinic. Functional performance was evaluated with the Katz-scale (Katz-15 item scale, which measures basic and instrumental activities of daily living, score range 0-15, lower scores indicating better functional performance) [17]. Disease burden was assessed using the Cumulative Illness Rating Scale for Geriatrics (CIRS-G; 14 categories scored on a 0-4 scale (maximum score 56), higher scores reflecting more comorbidities) [18]. Cognitive status was evaluated with the Mini Mental State Examination (MMSE, range 0-30, higher scores indicating better cognitive status) [19]. Geriatric Depression Scale evaluated mood (GDS, range 0-15, higher scores indicating more depressive symptoms) [20]. Short Physical Performance Battery (SPPB) included usual gait speed measured over four meters, five chair rises without using arms, and the ability to stand in the side-by-side, semi-tandem, and tandem positions (summary score (range 0-12), higher scores indicating better lower body function) [21]. Timed Up and Go (TUG) assessed the number of seconds needed to stand up, walk 3 meters past a line on the floor as quickly as possible, turn around, walk back to the chair, and sit down again with the back against the chair (best of two trials) [22]. Frailty was assessed using the Fried criteria (range 0-5; 0: not frail, 1-2: pre-frail, ≥3: frail): unintentional weight loss (defined as 4.5 kg or 5% of body weight over the previous year), self-reported exhaustion (defined as an affirmative answer to two questions), low energy expenditure (assessed with the Minnesota Leisure Time Physical Activity Questionnaire [23], and defined as <393 kcal/week for males and <280 kcal/week for females), slow gait speed (defined as <0.76 m/s, using the SPPB measurement), and weak grip strength (defined as <30 kg force for males and <18 kg for females) [24]. Grip strength was measured with a JAMAR™ hand dynamometer.

Maximum Step Length

Maximum step length was assessed asking subjects to step forward with one leg as far as possible and to bring the other leg up to the first in one fluid movement without use of a walking aid [4]. A trial was unsuccessful when more than one step was needed to maintain balance or when balance was lost. After two instruction trials, the subject performed a maximum of five trials to obtain three successful trials. Step length was measured as the distance between the starting and final position of the leg that stepped first, and was normalized with respect to leg length (step length divided by the distance between the spina iliaca anterior superior and lateral malleolus). Maximum step length was calculated as the maximum step length among the three successful trials.

Gait Speed

The gait speed measurement of the SPPB was used [21], in which the time needed for subjects to walk a distance of four meters at their usual speed (a walking aid was allowed), was measured by hand using a stopwatch. Subjects performed the test twice and gait speed was calculated as the mean speed of the two separate walks.

Falls

Falls were defined as "an unexpected event in which the subject comes to rest on the ground, floor, or lower level" [25]. At baseline subjects were asked the number of falls they experienced in the past 12 months. After completing the baseline assessment, subjects were instructed about the FT system. The FT system (ASK Community Systems, Rotterdam, the Netherlands) is a computerized system that automatically contacts subjects by telephone using pre-recorded messages, and proved to be feasible, reliable, and valid for assessing falls in older persons [14,15]. The FT system telephoned subjects weekly on their day of preference, and subjects reported the number of falls in the past week twice (in case a wrong number was entered the first time). If the call was not answered, the system called back up to a maximum of four times per day and then tried again the following day. The research assistant called subjects to verify each registered fall and those with no reply to the FT system.

3

Statistical Analyses

The study population was divided into three groups based on whether they fell zero, one, or two or more times during the one year follow-up (No-Fall group, One-Fall group, and Recurrent-Falls group, respectively). Baseline characteristics of these groups were compared using one-way ANOVA. Predictive values of the absolute cut-offs of baseline measures of maximum step length and gait speed for one or more future falls and recurrent (>1) falls were calculated as the areas under the curve (AUCs) of the receiver operating characteristic curves. Logistic regression models for fall risk (any faller or recurrent faller as dependent variable) included maximum step length and gait speed as predictor, along with the following covariates: age, gender and fall history. Additional analysis was performed with logistic regression for gait speed and maximum step length for predicting any injury, serious injury, and falls at one month, three months, and six months of follow-up, separately. Cox proportional hazards models were determined for gait speed and maximum step length, both as continuous and categorical values (based on tertiles). Significance was set at two-tailed $P<0.05$. All analyses were done using SPSS, version 20.0.01 (SPSS, Chicago, Illinois).

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RESULTS

Figure 1 shows the flow of subjects from the source population to the subjects who completed follow-up (n=388). Data of all subjects who successfully performed both maximum step length and gait speed (n=352) were used in the analyses. The median follow-up time was 53 weeks.

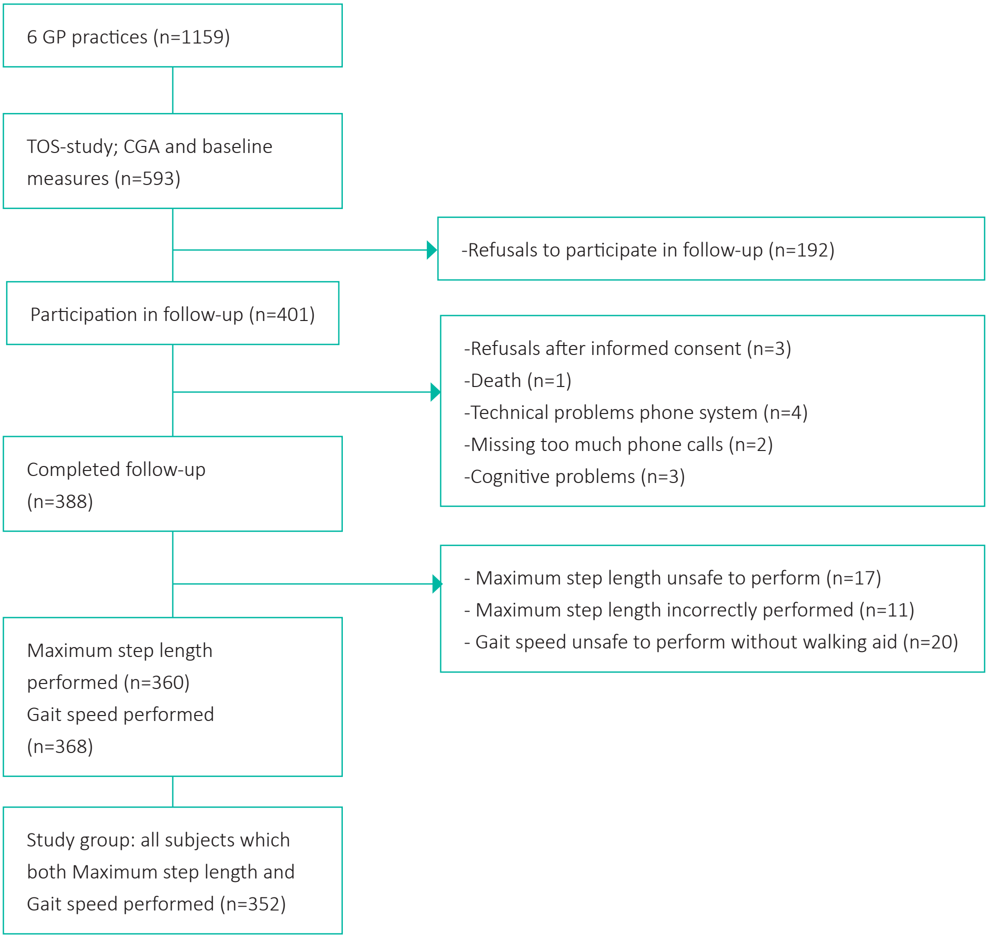

Figure 1. The flow of subjects from the source population to the analysed subjects.

In total, 285 falls (median 1.0 ±3.6) were reported for 136 subjects (39%), 52 of them (15%) fell recurrently during follow-up (median number of falls 2.0 with a range of 1 to 38). Of all reported falls, 95.8% could be verified by the research assistant. Mean time to the first fall was 142 ±114 days. There were 38 fallers without injury, 73 fallers with minor injuries, 23 fallers with serious injuries and 2 fallers with unknown injury.

Baseline characteristics of the total study group, No-Fall group, One-Fall group, and Recurrent-Falls group are reported in Table 1. Mean age of the study group was 76.2 (±4.3) years; 55% were female, and 34% reported at least one fall during the previous year. The Recurrent-Falls group was significantly older than the No-Fall and One-Fall groups (77.6 years versus 76.3 and 75.9 years, respectively, p=0.04). Fall history was significantly more common in the One-Fall (43%) and Recurrent-Falls groups (52%) compared to the No-Fall group (25%, p<0.001). The Recurrent-Falls group used a walking aid significantly more, had a significantly lower grip strength, performed significantly worse on all the mobility measures (TUG, SPPB, gait speed and maximum step length), and had a significantly higher mood score (GDS) when compared to the other groups. There were more injurious falls in the Recurrent-Falls group and a shorter time to the first fall (both p<0.001).

Table 1. Comparison of community-dwelling older subjects who did not fall with those who fell once and those who fell more than once during the follow-up period

	Total group (n=352)	**No Fall (n=216)**	**One Fall (n=84)**	**Recurrent Falls (n=52)**	**Overall p-value**
Age (years)	76.2±4.3	75.9±4.3	76.3±4.2	77.6±4.4	0.04
Gender (m/f)	159/193	104/112	38/46	17/35	0.13
Fall history	34%	25%	43%	52%	0.000
Fried frailty categories					0.24
-not frail (score 0)	49.7%	52%	52.5%	36%	
-pre-frail (score 1,2)	45.5%	42.5%	44%	60%	
-frail (score 3,4,5)	4.8%	5.5%	3.5%	4%	
Walking aid					0.04
-none	84%	85%	88%	69%	
-cane	7%	6%	6%	15.5%	
-walker	9%	9%	6%	15.5%	
MMSE (0-30)	27.8±2	27.7±2.1	28.1±1.5	27.6±2.1	0.21
GDS (0-15)	2.0±2.2	1.9±2.1	1.7±1.8	2.9±2.6	0.007
Katz (0-15)	1.0±1.2	0.9±1.2	1.1±1.2	1.3±1.2	0.09
CIRS-G (0-56)	7.7±4.2	7.6±4.3	7.4±3.8	8.6±4.6	0.25
Hand grip strength (kg)	25.5±9.7	26.8±10.0	25.2±9.4	20.9±7.9	0.000
TUG (sec)	8.8±3.3	8.6±3.0	8.7±3.4	10.0±4.1	0.03
SPPB (0-12)	9.7±2.0	9.8±1.9	10.0±1.9	9.0±2.3	0.01
Gait speed (m/s)	1.13±0.34	1.13±0.32	1.20±0.38	1.03±0.32	0.02
Maximum step length	1.08±0.22	1.10±0.22	1.12±0.18	0.98±0.25	0.001
No injury/ Injury	na	na	30/52	8/44	0.000

Notes: Overall p-value of the ANOVA between the groups. The results are presented as the means ± standard deviation. The numbers between parentheses are the score ranges. MMSE: Mini Mental State Examination; GDS: Geriatric Depression Scale; CIRS-G: Cumulative Illness Rating Scale for Geriatrics; TUG: Timed Up and Go test; SPPB: Short Physical Performance Battery; Maximum step length corrected for leg length. na= not applicable.

Logistic regression models showed low predictive values for any future fall for maximum step length (AUC 0.53) and gait speed (AUC 0.50) (Table 2). Maximum step length was slightly superior to gait speed for recurrent falls (AUC 0.64 versus AUC 0.59, respectively). The model that combined gait speed with age, gender and fall history resulted in slightly better predictive values for any future fall (AUC 0.64) and recurrent falls (AUC 0.69). The predictive value of maximum step length combined with age, gender and fall history (AUC 0.63 for any future falls and AUC 0.69 for recurrent falls) was slightly less predictive than the complete model based on gait speed. The prediction for falls at one, three, and six months of follow-up did not show an improved predictive value for either test (data not shown). The predictive value of maximum step length and gait speed for any future fall resembles the predictive value for any injury, and, similarly, the predictive value for recurrent falls resembles the predictive value for a serious injury (Table 2).

Table 2. Areas Under the Curve (AUC) of the Receiver Operating Characteristics (ROC) figure showing the diagnostic value of baseline Gait Speed and Maximum Step Length measures for predicting falls and recurrent falls, and any injury and serious injury

		Prediction of any fall (n=136/352)		Prediction of recurrent falls (n=52/352)		Prediction of any injury (n=96/350)		Prediction of serious injury (n=23/350)	
	Model	**AUC* value**	**95% CI**	**AUC* value**	**95% CI**	**AUC* value**	**95% CI**	**AUC* value**	**95% CI**
Maximum step length	Maximum step length [a]	0.53	0.47-0.59	0.64	0.55-0.72	0.54	0.47-0.61	0.65	0.54-0.76
	Maximum step length [b]	0.57	0.51-0.63	0.66	0.57-0.75	0.60	0.54-0.67	0.68	0.58-0.79
	Maximum step length [c]	0.63	0.57-0.69	0.69	0.61-0.77	0.62	0.56-0.69	0.69	0.58-0.79
Gait speed	Gait speed [a]	0.50	0.43-0.56	0.59	0.50-0.68	0.52	0.46-0.59	0.57	0.45-0.70
	Gait speed [b]	0.58	0.52-0.64	0.65	0.57-0.72	0.60	0.54-0.67	0.66	0.55-0.76
	Gait speed [c]	0.64	0.58-0.70	0.69	0.61-0.77	0.62	0.56-0.69	0.67	0.56-0.77

Notes: 95% CI: 95% confidence interval.

*AUC=Area under the receiver operating characteristic curves for the Maximum step length and Gait speed for fallers versus non-fallers, for recurrent fallers versus non-fallers, for any injury versus non-injury, and for serious injury versus non-injury.

[a] Model for Maximum step length or Gait speed alone

[b] Model including age and gender

[c] Model including age, gender, and fall history

Maximum step length as a continuous predictor had a hazard ratio of 0.36 (95%CI 0.17-0.78, p=0.01) per unit (1m) increase in maximum step length. When maximum step length was divided into categories based on tertiles, subjects with a maximum step length greater than 1.18m showed a lower chance for falling, with a hazard ratio of 0.65 (95%CI 0.44-0.96, p=0.03) relative to a reference group of people with a maximum step length between 1-1.18m (middle tertile). The HR of 1.02 for subjects with a maximum step length <1m (lowest tertile) was not significantly increased compared to the reference group. Gait speed was not significantly related to the time to the first fall.

DISCUSSION

This study showed maximum step length and gait speed as simple single-item tools to have low predictive values for any falls within 12 months, and moderately predictive values for recurrent falls. The full model, including age, gender and fall history, was best for predicting future falls, but still not sufficiently strong to be used in clinical practice. This prospective study showed that though tempting by their simplicity, gait speed and maximum step length measured cross-sectionally cannot be used for predicting or anticipating upcoming falls.

Using a more reliable assessment of falls follow-up did not result in de same predictive values of gait speed as found in previous research [9,11]. This study did confirm earlier findings that gait speed is better in predicting recurrent falls than first-time falls, and adding fall history to the model increases the predictive ability of GS [9,12,13]. However, since AUCs were not above the relevant 0.7 threshold, they still cannot be used in clinical practice. Future research into these cross-sectional predictions should therefore be discouraged.

Although several thresholds have been suggested for gait speed for different health outcomes [11], our findings, based on tertiles, did not give significant thresholds. However, the findings did show that a higher maximum step length at baseline resulted in a lower chance for falling compared to a median or lower maximum step length . These results are in accordance with the findings of Schulz et al. who found that older fallers could not step as far as older non-fallers [26].

The current prospective study used a large, community-based sample of older subjects of which 93% successfully completed the one year follow-up. Furthermore, all measurements at baseline were assessed using high-quality, standardized geriatric assessments. Another major strength of this study was the use of the FT system, which is a reliable and valid tool to prospectively record falls, and resulted in few missing data through the verification of falls by the research assistant [14,15]. It also gave the ability to accurately document any fall-related injuries.

A limitation of the present study was the selection bias caused by informed consent refusal, and, more importantly, not being able to safely carry out maximum step length and gait speed, and not being able to use the FT system. The subsequent attrition of the frailest subjects, supported by lower frailty levels compared to other community-dwelling populations reported in literature [24], might indicate an underestimation of the predictive value of maximum step length and gait speed. However, our study group showed a fall history (34%) and percentage of fallers (39%) comparable with literature [27], and therefore, external validity should be confirmed.

The current study demonstrated that maximum step length and gait speed as simple mobility measurements are insufficient to predict fall risk. It remains to be studied whether repeated (self-)

measurements of maximum step length and gait speed show better predictive values for falls and have clinical relevance for self-management in predicting increased fall risk, as we would wish that (pre-)frail older persons could do.

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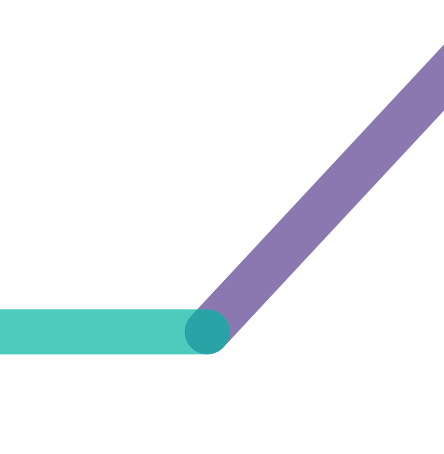
CHAPTER 4

REPEATEDLY SELF-ASSESSING MAXIMUM STEP LENGTH AND GAIT SPEED AT HOME



4a

Safety, feasibility and reliability of the maximal step length, gait speed and chair test measured by seniors themselves: the Senior Step Study

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Marcel Olde Rikkert

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ABSTRACT

Self-management of mobility and fall risk might be possible if older adults could use a simple and safe self-test to measure their own mobility, balance and fall risk at home. The aim of this study was to determine the safety, feasibility and intra-individual reliability of the Maximal Step Length (MSL), Gait Speed (GS) and Chair Test (CT) as potential self-tests for assessing mobility and fall risk. Fifty-six community-dwelling older adults performed MSL, GS and CT at home once a week during a four-week period, wherein the feasibility, test-retest reliability, coefficients of variation and linear mixed models with random effects of these three self-tests were determined. Forty-nine subjects (mean age 76.1 yrs (*SD*: 4.0), 19 females (42%)) completed the study without adverse effects. Compared with the other self-tests, MSL gave most often (77.6%) valid measurement results and had the best intraclass correlation coefficients (0.95 (95% confidence interval: 0.91–0.97). MSL and GS gave no significant training effect, whereas CT did show a significant training effect ($p<0.01$). Community-dwelling older adults can perform MSL safely, correctly and reliably, and GS safely and reliably. Further research is needed to study the responsiveness and beneficial effects of these self-tests on self-management of mobility and fall risk.

INTRODUCTION

In our aging population, the number of frail older people who have mobility problems and suffer from recurrent falls is rapidly increasing. This decline in mobility and balance has a direct negative impact on social functioning, and consequently on well-being, autonomy and quality of life.[1] Changes in mobility could be early warning signals for an individual's deterioration in health status and for falls in the near future.[2] Self-management of mobility and fall risk might be possible if older adults could use a simple and safe self-test to measure their own mobility, balance and fall risk at home. Furthermore, if self-test results deteriorate, professionals can be consulted at an early stage to diagnose the causes of the decreased mobility and, if possible, to initiate interventions aimed at preventing future falls and optimizing healthcare for older people. Moreover, self-management of mobility and balance may empower older adults and could help to limit the increasing demands on healthcare, which is important if we are to realize a sustainable healthcare system in our aging societies.

The overall aim of the Senior Step Study is to empower seniors by stimulating their self-management abilities in monitoring their mobility and ultimately reduce their fall risk. The Senior Step Study investigates whether it is possible to develop a test that an older person can potentially perform, and which may indicate the person's mobility, balance and risk for falling. Improvement on the self-test could indicate the effectiveness of a treatment or self-management program, and worsening on the self-test might indicate a new medical problem. Self-management of fall risk requires a test that is first and foremost simple and safe, whilst also being reliable and valid. If all of these requirements are taken into account then only a few simple mobility tests, such as the Maximal Step Length (MSL), Gait Speed (GS), and Chair Test (CT) have the potential to become a self-management tool. MSL is a feasible and reliable measure of mobility and balance capacity in community-dwelling older adults as well as in frail older individuals [3-6]. GS has been well studied and was shown to be predictive for future adverse effects, such as disability and falls, in community-dwelling older adults [7-9]. CT is part of the Short Physical Performance Battery [10], and was found to predict any ADL disabilities [11]. Professionals use the more complex combined mobility measures like Timed-up-and Go test (TUG), Hierarchical Assessment of Balance and Mobility (HABAM), Performance-Oriented Mobility Assessment (POMA), and Short Physical Performance Battery (SPPB), for monitoring mobility [10, 12-15]. These measures are difficult to perform by seniors themselves as they require a professionally trained eye to accurately assess mobility, they are not possible to perform on one's own (e.g. evaluate one's own walking), or they take more than five minutes to perform. Some of these measures consist of dual tasking which negatively influences safety and reliability of the assessment. MSL, GS and CT are much more simple one-item tools that may be promising self-tests. However, to the authors' knowledge, these tests were always assessed by a professional and have never been studied as potential self-management tools used by community-dwelling older adults. Therefore, the current research studied the intra-individual reliability of the MSL, GS and CT, and investigated how safe and feasible these are as potential self-tests for assessing mobility and fall risk by community-dwelling older adults.

METHOD

Subjects

This prospective study was part of the Validation Study of the Two-step Older persons Screening study (TOS study) in which six general practitioners' practices screened all their patients aged 70 years and over for frailty [16]. Patients judged to be too ill to be screened and patients who were either currently receiving treatment from a geriatrician or who had received a comprehensive geriatric assessment in the past three months were excluded. A total of 1100 older patients were asked to provide informed consent and 593 of these subjects were included in the TOS study (Figure 1). After baseline measurement, subjects were asked to participate in the fall follow-up study for one year and 398 subjects consented to this. Detailed information about the rational and design of the TOS study are described by van Kempen et al. [16]. Subjects and their informal caregivers from two participating practices outside the city of Nijmegen, the Netherlands, were then asked to participate in the Senior Step Study. Individuals were excluded when they were not able to: understand the instructions to perform the tests, walk (with or without a walking aid), speak and understand Dutch, answer the falls telephone or did not have an informal caregiver who could answer the falls telephone for them. All subjects provided written informed consent. The local medical ethics committee approved the study (approval number 2009/223).

Design

A trial period of four weeks to get used to performing the potential self-tests was chosen to study the safety, feasibility and reliability of these tests performed by the older adults at home. Subjects performed the MSL, GS and CT at home once a week, on the same day and around the same time, accompanied by their informal caregiver. To make the tests more feasible for an older population, dual tasking by the subject was avoided by asking the informal caregiver to record the time performing GS and CT. On the first visit the researcher explained and practiced the potential self-tests with the subjects and their informal caregivers. During this the researcher judged whether the subject and caregiver were able to execute the self-tests correctly and safely. Instructions were given a maximum of three times and if the subjects and caregivers were still not able to perform the self-tests, the subject was excluded. During this visit, all materials for executing the self-tests were given, including forms to note the results of the self-tests for each week. After one month, the researcher visited the subjects and asked them to execute the self-tests. All errors made and lack of safety in performance were recorded by the researcher.

Descriptive measures

At baseline several questionnaires were assessed. Disability was evaluated with the Katz scale (Katz-15 item scale, which measures basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating a better functional performance)[17]. Disease burden was assessed with the Cumulative Illness Rating Scale for Geriatrics (CIRS-G; scored on a scale from 0-4 for each of 14 categories,

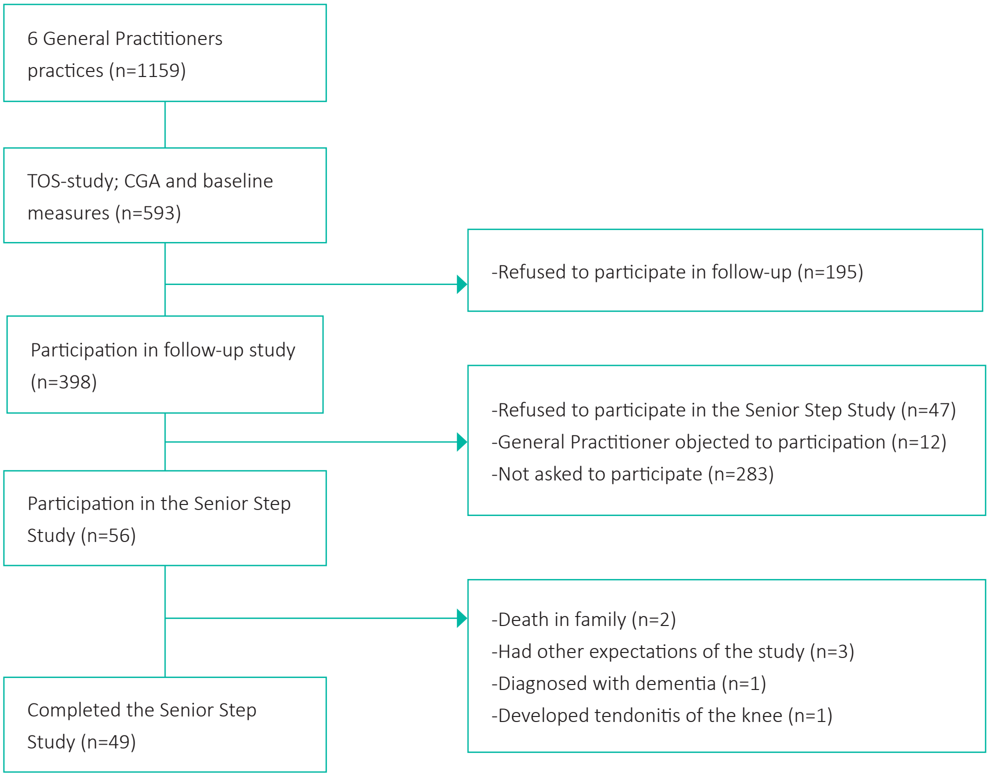

Figure 1. The flow of subjects from the source population to the analyzed subjects.

higher scores reflecting more comorbidity) [18]. The Self Management Ability Scale (SMAS-30) was used to evaluate self-management (30 items, score range 0-100, higher scores indicating better self-management) [19]. Daily physical activity was assessed using the LASA Physical Activity Questionnaire (LAPAQ), which assessed walking, cycling, gardening, sports, and household activities (scoring the total minutes per day for all physical activities) [20]. Objective information on any deterioration in mobility of the subjects during the study was obtained at baseline and after one month using the standardized balance and mobility measures TUG [13,14] and SPPB [10]. For TUG, the subject, when seated with their back against a chair, was instructed to stand up, walk three meters past a mark on the floor as quickly as possible, turn around, walk back to the chair, and sit down again with their back against the chair [13,14]. The time in seconds needed to complete this test was measured. TUG was performed twice and the fastest performance was used. The SPPB included gait speed (time to walk four meters at their normal walking speed), five chair stands (time to rise from a chair and return to a seated position without using arms), and a balance test (ability to stand with the feet together in the side-by-side, semi-tandem, and tandem positions) all measured using a stopwatch [10]. A summary performance score (range 0-12) for the three tasks was created for each subject, higher scores indicating better lower body function [10].

Falls

During the four weeks of participation, subjects' fall incidents were monitored by the falls telephone (FT). The FT system is a computerized system that automatically contacts subjects by telephone using pre-recorded messages. This system (ASK Community Systems, Rotterdam, the Netherlands) has been shown to be a feasible, reliable, and valid method of assessing falls in older people [21,22]. The FT automatically phoned the subjects once a week on their day of preference, and subjects were asked to report the number of falls in the past week twice (in case a wrong number was entered the first time). If the call was not answered, the system called back up to a maximum of four times a day and tried again the following day. The research assistant called subjects to verify each registered fall and subjects with no reply to the FT. A fall was defined as "an unexpected event in which the subject comes to rest on the ground, floor, or lower level" [23].

Self-tests

Maximum Step Length (MSL)

Subjects measured the MSL without the help of their informal caregiver. The modified version of MSL first described by Schoon et al. (2010) was used in the present study. For subjects to measure their own MSL, a poster with the initial position of the feet and a ruler in centimeters was provided (170 x 50 cm, made by the researchers). Anti-slip was attached to the underside of the poster to prevent subjects from slipping during the performance of the test. Subjects were instructed to stand with both feet on the indicated position and to step maximally forward on the printed ruler with their right leg, and to bring the left leg up to the first leg in one step. In this position, subjects could read their distance stepped. A trial was successful when the subject stepped in one fluid movement and unsuccessful when more than one step was needed to maintain balance or when balance was lost. Every week subjects performed two practice trials after which they performed the MSL at least three times, with a maximum of five trials to obtain three successful trials. Subjects performed MSL wearing the same firm comfortable shoes each week, which were selected by the researcher during the first study visit.

Gait Speed (GS)

Subjects measured their GS with help of their informal caregiver. During the first study visit the researcher indicated a track between 5.5 and 6.5 meters at the subject's home, where the subject had to start and finish the walking track. Along this track, the informal caregiver was instructed to measure the time needed to cover the distance between two fixed landmarks (e.g. furniture, door posts, paintings) and to start and stop the time, respectively. The distance between the two landmarks was between 3.5 and 4.5 meters, depending on the furniture in the subject's home. Subjects performed GS twice, were instructed to walk at their normal walking speed, and wore the same shoes as during MSL.

Chair Test (CT)

The CT was also measured by subjects with help of their informal caregivers. It was derived from the chair test of the Short Physical Performance Battery [10]. During CT subjects were asked to stand up from a chair five times consecutively, as fast as possible with their arms folded across their chest. The informal caregiver recorded the time between when the subject started moving and the fifth time the subject was completely standing. Subjects were instructed to continue the test until the final sitting position. CT was performed once using a chair which the researcher selected from the subject's home during the first study visit.

Analysis

MSL was normalized with respect to leg length in centimeters by dividing step length by the distance between the anterior superior iliac spine and lateral malleolus, which was measured during the TOS study. MSL was calculated each week as the maximum MSL among the three successful step lengths. GS was calculated as distance divided by time in m/s and the mean GS of the two walks was used in the analyses. Not all errors made by the subjects resulted in incorrect measurements, for instance, performing the MSL only four times (two practice trials and two measurement trials) still gave two correct measurements for the analyses. Therefore, the following errors were considered as correct measurements: MSL: Completed 2 practice trials but only 1 measurement trial, completed 2 practice trials but only 2 measurement trials, no extra trial after an unsuccessful measurement trial, and poster too short (only the trials that were still measurable with the ruler on the poster were taken into account); GS: Completed only 1 measurement trial, performed 1 measurement trial too many, caregiver said 'Yes' when the measurement started, subject performed practice trials, and time not measured by informal caregiver (only when another person other than the subject measured the time); and CT: Caregiver said 'Yes' when the measurement started, and time not measured by informal caregiver (only when another person other than the subject measured the time).

Reasons for drop-out were registered. Descriptives of drop-outs were compared to those who completed the study, using independent-sample t-tests for continuous variables and Chi-squares tests for categorical variables. Safety was analyzed by calculating the fall ratios (falls per week) for each subject from at least six months before baseline and during the four weeks follow-up of the study, which were compared using a dependent-sample t-test. Adverse events during the performance of the self-tests were recorded. Feasibility was assessed using the number and variety of errors recorded during the monthly visit of the researcher.

To test whether the group had a stable balance and mobility, TUG and SPPB were compared between baseline and after one month using dependent-sample t-tests. After this, reliability was analyzed in three ways for each self-test separately. Test-retest reliability was assessed over the four weeks using the intraclass correlation coefficient (ICC: variance(subjects) / (variance(subjects) + variance(error))) [24,25]. To demonstrate the variability of the self-tests within each subject, a coefficient of variation (CV: $SD_{\text{repeated measurements}}$/mean) was calculated for each subject separately. The median of all subject CVs was compared between the self-tests. Linear mixed models with random effects were used to demonstrate

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whether there was a training effect and to assess the size of the residual error. Significance was set at $p<0.05$. All statistical analyses were performed using IBM SPSS Statistics 20 (SPSS, Chicago, Illinois).

RESULTS

Of the 583 subjects participating in the TOS study [16], fifty-six older adults with a mean age of 75.8 yrs (SD:3.9), with 24 women (43%), and their informal caregivers consented to participate in the Senior Step Study (Figure 1). The study population differed significantly (p<0.05) at baseline of the TOS study from the subjects participating in the follow-up study in that there were more males, they were younger, showed less comorbidity, had better mobility performance, and were less impaired in their activities of daily living. Fall history was comparable between the participating and non-participating subjects (data not shown). Seven subjects dropped out: Two because of a death in the family, three had other expectations of the study, one was diagnosed with dementia and not able to follow the instructions, and one developed a tendonitis of the knee. No significant differences were found between the drop-outs and the subjects who completed the study (Table 1).

Table 1. Baseline Characteristics of the Senior Step Study Population, the Subjects who Completed this Study and the Drop-Outs

	Study population (n=56)	**Participants (n=49)**	**Drop-outs (n=7)**	**p**
Age, years	76.2 (3.9)	76.1 (4.0)	77.3 (3.1)	.44
Female, n(%)	24 (42.9)	19 (42.2)	5 (45.5)	.41
SPPB	10.6 (1.7)	10.6 (1.6)	10.3 (2.4)	.66
TUG, seconds	7.9 (2.5)	7.7 (1.9)	9.20 (5.2)	.50
LAPAQ, minutes/day	151.3 (88.6)	152.9 (88.1)	138.3 (100.4)	.71
SMAS-30	64.7 (12.7)	65.1 (13.3)	61.6 (6.0)	.54
Katz-15	0.7 (1.0)	0.7 (0.9)	0.9 (1.6)	.77
CIRS-G	8.1 (4.4)	7.9 (4.4)	9.1 (4.4)	.50
Fall history, n(%)	21 (37.5)	17 (34.7)	4 (57.1)	.25

Note: All data presented as means ± standard deviation unless stated otherwise. SPPB: Short Physical Performance Battery, summary performance score (range 0-12) for three tasks, higher scores indicating better lower body function; TUG: Timed Up & Go; LAPAQ: LASA Physical Activity Questionnaire, minutes per day for sports activities, non-sports activities, and all physical activities; SMAS-30: Self-Management Ability Scale, 30 items, score range 0-100, higher scores indicating better self-management; Katz-15: Katz-15 item scale, basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating better functional performance; CIRS-G: Cumulative Illness Rating Scale for Geriatrics, scored on a scale from 0-4 for each of the 14 categories, higher scores reflecting more comorbidity.

All subjects (n=55) could perform the three potential self-tests, except for one subject who was not able to execute CT. There were no adverse events during the performance of the self-tests. Fall ratios were

0.023 (95%CI 0.006–0.040) and 0.022 (95%CI 0.007–0.052) falls per week, before and during the study, respectively, and did not differ significantly (p=.63). Two subjects fell once and one subject fell three times during the four weeks of follow up. Feasibility of GS and CT was limited because of the need for an informal caregiver to measure time. The variability of observed errors for each self-test was large and the number of flawless measurements in week 1 was low, with 57.1%, 34.7% and 30.1% for MSL, GS and CT, respectively. When all measurements that yielded a valid measurement were counted, MSL showed the highest rate of correct measurements (77.6%) compared to GS (44.9%) and CT (38.8%).

ICCs were calculated for each self-test with MSL showing the strongest reliability ($ICC_{agreement}$ 0.95 (95%CI 0.91–0.97)) compared to GS (0.89 (95%CI 0.80–0.95)) and CT (0.71 (95%CI 0.51–0.86)). Figure 2 shows the CVs of all subjects for each self-test. CVs are small with MSL showing the smallest intra-individual variation of the CV per subject with a median of 3.4%. Linear mixed models with random effects did not give a significant improvement on the self-tests during the study except for CT (p<.01). Furthermore, residual errors were small for all self-tests (Table 2).

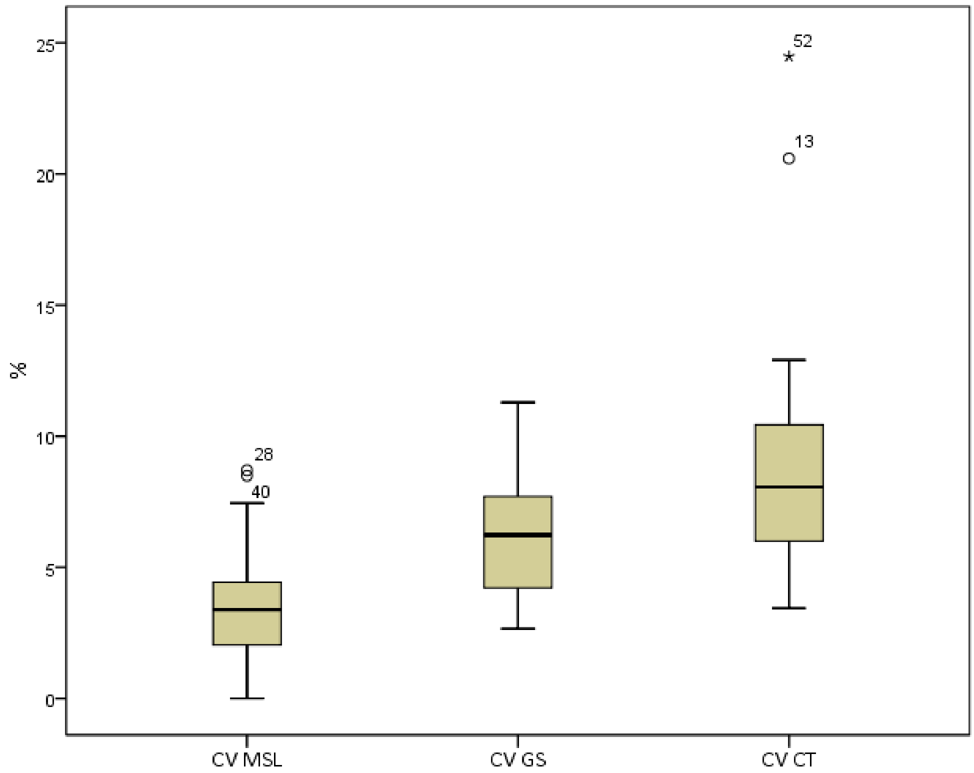

Figure 2. Boxplots of the intra-individual coefficients of variation in a 4 week time-series for each self-test. Boxplots display median and quartiles. CV: coefficient of variation; MSL: maximal step length; GS: gait speed; CT: chair test.

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Table 2. Linear Mixed Models with Random Effects

		B	p	95% CI
MSL	Intercept	1.10	<.001	1.04–1.16
	Slope	0.008	.070	-0.001–0.016
	Residual	0.001	<.001	0.001–0.002
GS	Intercept	1.23	<.001	1.13–1.32
	Slope	0.013	.130	-0.004–0.031
	Residual	0.007	<.001	0.004–0.010
CT	Intercept	12.70	<.001	11.23–14.18
	Slope	-0.339	.006	-0.572– -0.107
	Residual	0.914	<.001	0.589–1.419

Note: MSL: maximal step length; GS: gait speed; CT: chair test; B: estimate; CI: confidence interval.

DISCUSSION

The Senior Step Study aimed to develop a self-management tool for community-dwelling older adults to repeatedly assess and monitor their own balance, mobility and risk for falling. There was no significant difference in fall ratio before and during the study, and there were no adverse events during the performance of the self-tests, indicating that MSL, GS and CT are safe for older people to use at home. MSL was the only feasible test, showing the least amount of errors and the highest percentage of correct measurements. MSL was also the most reliable self-test, showing the highest ICC and the smallest CV in an intra-individual time series of four weeks. Both MSL and GS gave no significant training effect during four weeks of study, while the CT performance did significantly improve over time.

Feasibility of GS and CT was limited as an informal caregiver was needed to measure time. Without the informal caregiver, GS and CT would become too complex for the older person due to the additional dual task component of measuring time. They would also lose their superiority to other mobility measures like TUG and POMA, which are also difficult for seniors to perform by themselves. MSL, however, did not need an informal caregiver for assessment and showed the least amount of errors made, indicating that MSL is the only feasible self-test. The large amount of errors made could be explained by the first instructions which were given directly after the baseline measurement, that lasted almost two hours. Subjects stated they were getting tired and restless, and researchers found that the subjects combined several tests together when performing the self-tests. MSL does have potential to be a self-test for mobility, because it is simple, easy, and quick to asses by the older person himself, especially compared to other mobility measures and even questionnaires. Most mobility measures take more time to perform or are not possible for seniors to assess (e.g. evaluating one's own walking), and questionnaires are often too subjective to objectively assess mobility, making comparisons between populations and

individuals difficult [10, 12-15]. Nevertheless, the percentage of correct measurements for MSL is 77.6%, which should be at least 85% if MSL were to be used as a single item self test of mobility and fall risk.
All three potential self-tests showed very good test-retest reliability, indicating that older people can assess the self-tests reliably over time. For application in individuals, ICC values as high as 0.90 and preferably 0.95 are required [26]. This is the case for MSL, demonstrating its reliability as a self-test for community-dwelling older adults. Furthermore, both MSL and GS gave no significant slope in the overall regression line, indicating that no training effect occurred during the study.
The study population had a prevalence of falls which was comparable to a community-dwelling older population (38.5%) [27], the TOS study population (fall history 35%) [28], and the follow-up study (36%), limiting the selection bias when looking at falling. However, the study population did show a good overall performance in mobility compared to the non-participating subjects, making it difficult to generalize the assessed feasibility and reliability of MSL and GS to a more frailer and older population. More research in a frailer population is, therefore, needed.
The strengths of the current study were the prospective follow-up time of four weeks and the good compliance. Intercurrent illnesses are unlikely to happen in a four week period, which allows for a valid reliability analysis. Furthermore, four weeks is enough for subjects to get used to performing the tests by themselves at home. The reasons for drop-out indicate that older adults are able and willing to perform these tests on a weekly basis. To the authors' knowledge, this is the first study to have explored the clinimetric properties of MSL, GS and CT assessed by older people themselves in their own homes. As mentioned above, the safety of such a test is an important factor in this older population and so the sample size of this study was warranted. Furthermore, the study population was large enough to show significant reliability.
Due to the lack of comparable studies, it was not possible to compare the data with other findings on self-management. If we want older people to manage their own mobility, fall risk, and, subsequently, their own health status then more research in this area will be needed. In addition, research is needed to determine the responsiveness of MSL and GS to periods of illness or to an intervention aimed at improving a person's health status. Also, the predictive value of these tests for future falls or other negative health outcomes remains a topic for future study.
In conclusion, community-dwelling older adults are capable of repeatedly performing MSL safely, correctly, and reliably, and GS safely and reliably, which shows the potential of using these tests to improve self-management of balance, mobility and fall risk.

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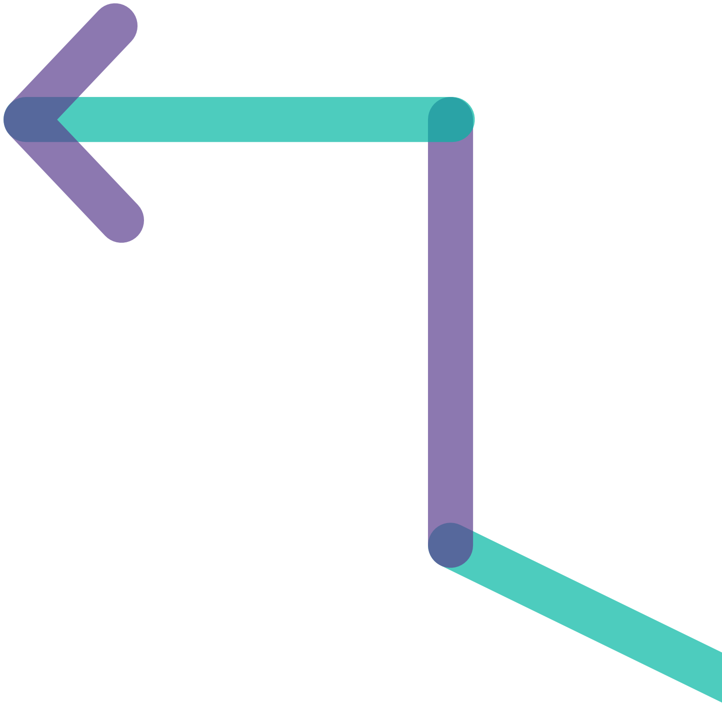

4b

Feasibility of repeated self-measurements of maximum step length and gait speed by community-dwelling older persons

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ABSTRACT

Objectives: self-management of mobility and fall risk can be important in fall prevention, however, it remains unstudied. Therefore, the current study assessed whether community-dwelling older persons were able to repeatedly self-assess Maximum Step Length (MSL) and Gait Speed (GS) in their own home for a six-month period, how these tests changed during this period, and if these changes were related to falling.

Design: prospective study

Setting: at home

Participants: 56 community-dwelling older adults (24 women (43%), mean age of 76.2 (SD 3.9)) entered the study, 45 completed the study.

Methods: subjects performed MSL and GS once a week in their own home during a six-month period. Primary and secondary outcomes: repeated MSL and GS measurements were the primary outcomes. Falls, self-management and mobility were the secondary outcomes.

Results: self-assessment of MSL and GS by older persons is feasible. Compliance of repeatedly self-measuring MSL and GS was good; median number of weekly measurements were 23.0 (88%) and 21.0 (81%) for MSL and GS, respectively. Drop-outs showed less self-management abilities compared to the subjects who completed the study (P=0.049). Linear mixed models showed a small significant improvement in MSL and GS over time (P<0.001), without an influence on falling.

Conclusion: most community-dwelling older persons are able and willing to repeatedly assess their MSL and GS. Self-managing mobility and fall risk did not increase fall occurrence. The fact that older persons can be actively involved in their own healthcare is clinically relevant. Further studies are needed to examine the (cost-) effectiveness of self-management in fall prevention interventions.

INTRODUCTION

Falling is a major problem in today's aging population, causing not only highly relevant physical and social impairments, but also increasing health-related costs.[1-3] Policymakers are strongly emphasizing that older persons should be more actively involved in their own healthcare, and scientists are following this lead on self-management, which is also underlined by the chronic care model.[4-6] However, self-management of mobility and fall risk received little attention in previous research. Deteriorating mobility is a risk factor for falling[1] and the ability to quickly identify changes in their mobility could give older persons the opportunity to take responsibility of their own mobility-related well-being. Adequate self-management could minimize the impact of their fall tendency on their lives and could improve quality and effectiveness of our fall-related healthcare services.

Improving self-management of mobility and fall risk by identifying relevant changes in mobility is only possible with a simple and safe assessment tool that older persons can easily integrate in their normal daily life. Furthermore, such an assessment tool needs to be feasible, reliable, valid, and should have the ability to sufficiently predict future falls. Previous studies showed the Maximum Step Length (MSL) and usual Gait Speed (GS) to have the potential to be such self-assessment tools.[2, 7-19]

MSL is a simple and reliable measure for the assessment of balance and mobility in community-dwelling and frail older individuals.[2, 7-10] Predictive studies linking MSL to fall risk are still limited.[9, 11] GS proved to be a feasible and valid measure to predict future adverse events, such as disability and falls, in community dwelling older persons.[11-19] An important limitation of most of these studies was that only a single baseline MSL or GS measurement was assessed by a professional in a clinical setting. It can be reasoned that mobility assessment at only one time point may preclude identification of a large proportion of the persons at risk, as they may experience a rapid or gradual decline in mobility and balance over time, and may or may not pass in due time a population based cut off point.[19] Also, single or infrequent evaluations may not be representative of a person's true locomotion ability, because of large within subject variability in frail older persons.[19-21]

In our previous research we already showed that MSL and GS are safe, feasible and reliable self-assessment tools of mobility and fall risk for community-dwelling older persons.[22] However, research on repeatedly measuring MSL and GS over a longer period of time is still lacking. Therefore, the current exploratory study primarily investigated the feasibility of repeatedly measuring MSL and GS by community-dwelling older persons for a six-month period, but also how MSL and GS changed during this period, whether these changes were related to experiencing a fall, and what the implications of these results are in the field of self-management research in older persons.

METHODS

Subjects

This prospective study was a preplanned part of the Validation Study of the Two-step Older persons Screening study (TOS-study), in which six general practitioners' practices organized frailty screening for all their patients aged 70 years and over.[23] Detailed information about the rational and design of the TOS-study, and the subsequent recruitment of the participants for the Senior Step Study were described previously.[22, 23] Subjects and their informal caregivers from two participating practices outside the city of Nijmegen, the Netherlands, were asked to participate in the Senior Step Study. Individuals were excluded when they were not able to understand the instructions to perform the tests, not able to walk (with or without a walking aid), did not speak and understand Dutch, were not able to answer the falls telephone, or did not have an informal caregiver who could answer the falls telephone for them. All subjects provided written informed consent. The research ethics committee - region Arnhem-Nijmegen approved the study (approval number 2009/223).

Design

A six-month follow-up period was chosen to explore the repeated assessments of MSL and GS by older persons. Subjects were advised to perform the MSL and GS at home once a week, on the same day and around the same time, accompanied by their informal caregivers. The informal caregiver was asked to record the time needed to perform GS, to avoid dual tasking of the subject. The researcher explained and practiced the potential self-tests with the subjects and their informal caregivers during the first study visit, which took place at the subject's home. Instructions were given a maximum of three times and the researcher judged whether the subject and caregiver were able to execute the self-tests correctly and safely. If the subjects and/or caregivers were not able to perform the self-tests independently, the subject was excluded.[22] After one month the researcher re-visited the subject and their informal caregiver and asked them to execute the self-tests. Errors made were recorded by the researcher and explained to the subject. At the end of the study, the researcher visited the subject again and recorded errors made during the performance of the self-tests.

Descriptive measures

Mobility was assessed by the researcher at the subject's home at baseline and monthly during the six-month follow-up using the standardized balance and mobility measures: Timed Up and Go (TUG)[24, 25] and Short Physical Performance Battery (SPPB).[26] For TUG, the subject, when seated with their back against a chair, was instructed to stand up, walk three meters past a mark on the floor as quickly as possible, turn around, walk back to the chair, and sit down again with their back against the chair.[24, 25] The time in seconds needed to complete this test was measured. TUG was performed twice and the fastest performance was registered. The SPPB included gait speed (time to walk four meters at their normal walking speed), five chair stands (time to rise from a chair and return to a seated position without using arms), and a balance test (ability to stand with the feet together in the side-by-side, semi-tandem, and

tandem positions); all measured using a stopwatch. A summary performance score (range 0-12) for the three tasks was created for each subject, higher scores indicating better lower body function.[26]
At baseline and after six months the following questionnaires were assessed: disability was evaluated with the (modified) Katz scale (Katz-15 item scale, which measures basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating a better functional performance);[27] disease burden was assessed with the Cumulative Illness Rating Scale for Geriatrics (CIRS-G; scored on a scale from 0-4 for each of 14 categories, higher scores reflecting more comorbidity);[28] the Self Management Ability Scale (SMAS-30) was used to evaluate self-management (30 items, score range 0-100, higher scores indicating better self-management);[29] and daily physical activity was assessed using the LASA Physical Activity Questionnaire (LAPAQ), which determined walking, cycling, gardening, sports, and household activities (scoring the total minutes per day for all physical activities).[30]

Falls

A fall was defined as "an unexpected event in which the subject comes to rest on the ground, floor, or lower level".[31] Fall incidents were monitored by the falls telephone (FT) during the six-month follow-up. The FT system (ASK Community Systems, Rotterdam, the Netherlands) is a computerized system that automatically contacts subjects by telephone using pre-recorded messages and was found to be a feasible, reliable, and valid method of assessing falls in older people.[32, 33] Subjects were automatically phoned by the FT system once a week on their day of preference, and subjects were asked to report the number of falls in the past week twice (in case a wrong number was entered the first time). The system called back up to a maximum of four times a day and tried again the following day if the call was not answered. The research assistant called subjects to verify each registered fall and subjects with no reply to the FT.

Self-tests

Maximum Step Length (MSL)

Subjects measured their MSL without the help of their informal caregiver. The present study used the modified version of MSL first described by Schoon et al.[10] Subjects were provided with a poster displaying a ruler in centimeters and with an indication for the initial position of the feet (170 x 50 cm, made by the researchers). To prevent subjects from slipping during the performance of the test, anti-slip was attached to the underside of the poster. Subjects were instructed to stand with both feet on the indicated position and to step maximally forward on the printed ruler with their right leg, and subsequently bring the left leg up to the first leg in one step. In this position, subjects could read their distance stepped. When the subject stepped in one fluid movement a trial was successful and when more than one step was needed to maintain balance or when balance was lost a trial was unsuccessful. Every week subjects performed two practice trials after which they performed the MSL at least three times, with a maximum of five trials to obtain three successful trials. Every week subjects wore the same firm comfortable shoes, which were selected by the researcher during the first study visit.

Gait Speed (GS)

Subjects measured their GS with help of their informal caregiver. A track between 5.5 and 6.5 meters at the subject's home, where the subject had to start and finish the walking track, was indicated by the researcher during the first study visit. The informal caregiver was instructed to measure the time needed to cover the distance between two fixed landmarks along this track (e.g. furniture, door posts, paintings), and to start and stop the time, respectively. Depending on the furniture in the subject's home, the distance between the two landmarks was between 3.5 and 4.5 meters and this distance was used for the analyses. Subjects performed GS twice at their normal walking speed and wore the same shoes as during MSL.

Analyses

Leg length, measured during the TOS-study as the distance between the anterior superior iliac spine and lateral malleolus, was used to normalize MSL by dividing step length by leg length. The maximum MSL among the three successful step lengths was used as the MSL of that specific week. Distance was divided by time in m/s to calculate GS and the mean of the two walks of that specific week was used in the analysis.

Feasibility

Reasons for drop-out were registered and descriptive variables assessed at baseline of the study of the persons who dropped out were compared to those who completed the study using independent-sample t-tests for continuous variables and Chi-squares tests for categorical variables. The same analyses were used to compare subjects who fell during the six-month follow-up (fallers) to those who did not fall (non-fallers).

A full description of the errors in self-testing mobility seen by the researchers was described previously.[22] Feasibility of repeatedly measuring MSL and GS was explored by looking at the median and quartiles of the number of weekly measurements. This was done for all subjects together, and also for the subjects who completed the study. A coefficient of variation (CV: $SD_{\text{repeated measurements}}/mean_{\text{of all assessments so far}}$) over all weekly measurements was calculated for each subject separately to demonstrate the variability of the self-tests within each subject.

Analysis of changes over time

Differences between the measurements of week 1 and week 26 were calculated. Because not all subjects had a measurement in week 1 and 26, differences were also calculated between the first measurement and last measurement of each subject. The course of MSL and GS over time (each week during the 6 month period) was explored using error bars displaying means and 95% confidence intervals (95%CI). Linear mixed models with random effects were used to study all weekly measurements of MSL and GS. Having a fall history and experiencing a fall during the six-month follow-up were added as covariates. Changes in TUG, SPPB, Katz-15, CIRS-G, SMAS-30 and LAPAQ between baseline and after six months were compared using paired samples t-tests. Significance was set at $p<0.05$. All statistical analyses were performed using IBM SPSS Statistics 20 (SPSS, Chicago, Illinois).

RESULTS

Fifty-six older adults with a mean age of 76.2 years (SD 3.9), with 24 women (42.9%), and their informal caregivers consented to participate in the Senior Step Study.[22]

Feasibility

In total eleven out of 56 subjects (19.6%) dropped out of the Senior Step Study. Seven of which dropped out within the first month and gave the following reasons: two dropped out because of a death in the family, three had other expectations of the study, one was diagnosed with dementia and not able to understand the instructions, and one developed a tendonitis of the knee. One subject dropped out after three months because it was physically too demanding and her informal caregiver was not able to perform the measurements correctly. Finally, three subjects dropped out during the last month of the study: one experienced a fall not related to the study and suffered a hip fracture, one was diagnosed with colon cancer and had to be operated on immediately, and one suffered from encephalitis which resulted in a hospital and nursing home stay. Drop-outs differed significantly at baseline from the subjects who completed the study in that they showed less self-management ability (p=0.049, Table 1). Subjects who fell during the six-month follow-up did not differ significantly from those who did not fall. Fifteen subjects fell once during follow-up, one subject fell twice, one subject fell three times, and two subjects each fell four times. In the study group (including drop-outs) the feasibility of repeatedly self-measuring MSL and GS during the 26-week period was high with a median (25% and 75% percentiles) number of weekly measurements of 23.0 (18.0 and 25.8) and 21.0 (16.3 and 23.8) for MSL and GS, respectively. When only looking at the subjects who completed the study (n=45), feasibility was even higher for both MSL and GS (median of 24.0 (21.0 and 26.0) and median of 22.0 (20.0 and 24.0), respectively). Almost all subjects without any weekly measurements were the drop-outs from within the first month. The exception was the drop-out from within the third month of follow-up.

Intra-individual variation calculated as the CV per subject for both self-tests was small (median of 3.5% for MSL and median of 6.5% for GS) (Figure 1).

Changes over time

Mean (±SD) difference between week 1 and week 26 in the study group was 0.09 (0.10) and 0.10 (0.13) for MSL and GS, respectively, while the mean (±SD) difference between the first and last measurement was 0.09 (0.09) and 0.07 (0.13) for MSL and GS, respectively. The course of MSL and GS over the six-month follow-up period is depicted in Figure 2. Linear mixed models with random effects showed a significant but small improvement in MSL and GS over time (p<0.001) (Table 2). Having a fall history or experiencing a fall during the follow-up did not have a significant effect on this improvement. The mobility measures TUG and SPPB improved significantly between baseline and after six months (7.59s versus 7.14s (p=0.004) and 10.69 versus 11.24 (p=0.018) for TUG and SPPB, respectively).

Table 1. Baseline Characteristics Of The Senior Step Study Population, The Subjects Who Completed This Study And The Drop-Outs

	Study population (n=56)	**Participants (n=45)**	**Drop-outs (n=11)**	**p-value**
Age, years	76.2 (3.9)	75.8 (3.9)	77.7 (3.5)	0.154
Female, n(%)	24 (42.9)	19 (42.2)	5 (45.5)	0.554
SPPB	10.6 (1.7)	10.7 (1.5)	10.0 (2.3)	0.230
TUG, seconds	7.9 (2.5)	7.6 (1.8)	9.0 (4.3)	0.336
LAPAQ, minutes/day	151.3 (88.6)	156.1 (84.9)	129.5 (106.0)	0.396
SMAS-30	64.7 (12.7)	66.3 (13.1)	57.6 (8.1)	0.049*
Katz-15	0.7 (1.0)	0.6 (0.9)	0.9 (1.3)	0.440
CIRS-G	8.1 (4.4)	7.8 (4.5)	9.5 (3.7)	0.250
Fall history, n(%)	21 (37.5)	15 (33.3)	6 (54.5)	0.169

Notes: All data presented as means ± standard deviation unless stated otherwise. * p-value < .05. SPPB: Short Physical Performance Battery, summary performance score (range 0-12) for three tasks, higher scores indicating better lower body function; TUG: Timed Up & Go; LAPAQ: LASA Physical Activity Questionnaire, minutes per day for sports activities, non-sports activities, and all physical activities; SMAS-30: Self-Management Ability Scale, 30 items, score range 0-100, higher scores indicating better self-management; Katz-15: Katz-15 item scale, basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating better functional performance; CIRS-G: Cumulative Illness Rating Scale for Geriatrics, scored on a scale from 0-4 for each of the 14 categories, higher scores reflecting more comorbidity.

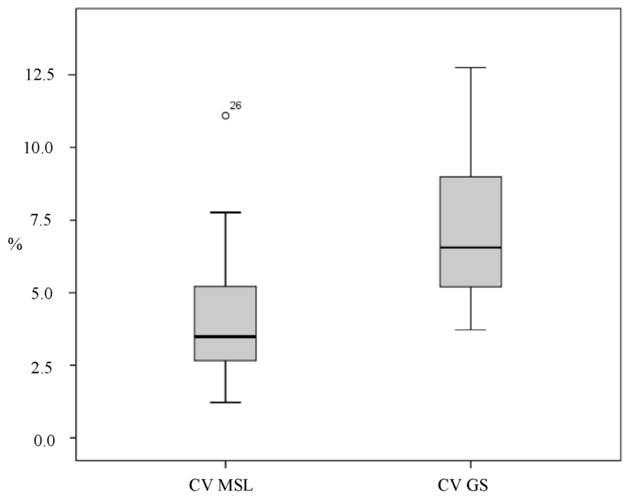

Figure 1. Boxplots of the intra-individual coefficients of variation in a 26 week time-series for each self-test. Boxplots display median and quartiles. CV: coefficient of variation; MSL: maximum step length; GS: gait speed.

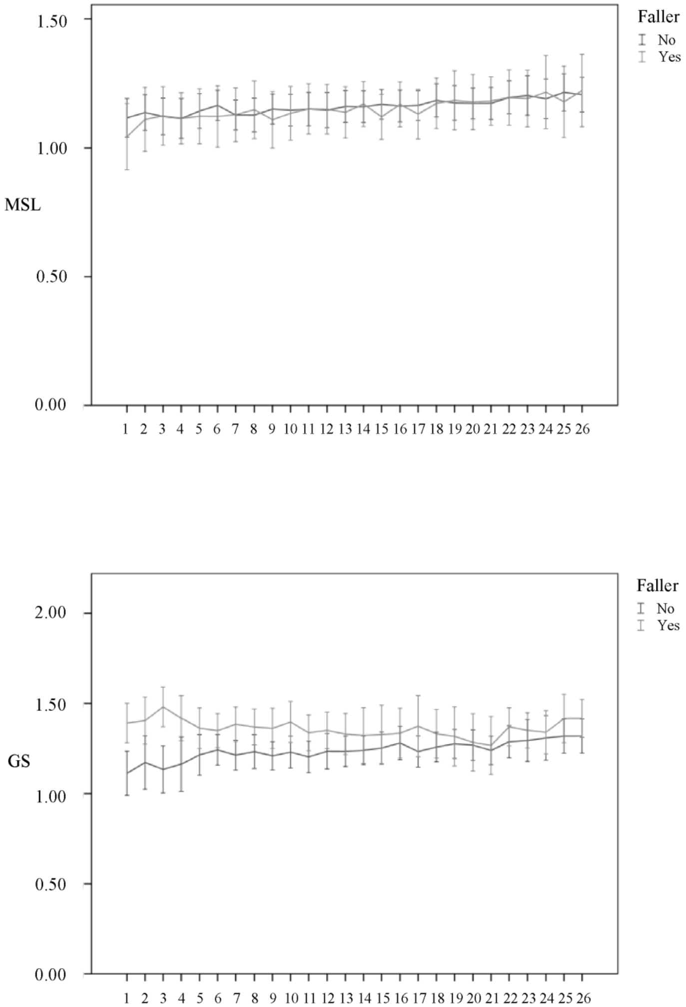

Figure 2. Mean and 95% confidence intervals of the course over the six-month follow-up of the maximum step length and gait speed measured by seniors who fell at least once during the follow-up period compared with non-fallers.

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Table 2. Linear Mixed Models With Random Effects Showing The Change Of MSL And GS Over Time And The Possible Influence Of Being A Faller Or Having A Fall History On This Change

		B	p-value	95% CI
MSL[a]	Intercept	1.113	<0.001	1.066-1.161
	Time	0.004	<0.001	0.003-0.005
	Residual	0.001	<0.001	0.001-0.001
MSL[b]	Intercept	1.129	<0.001	1.072-1.186
	Time	0.003	<0.001	0.002-0.005
	Fall history	-0.048	0.342	-0.148-0.052
	Time*fall history	0.001	0.570	-0.002-0.003
	Residual	0.001	<0.001	0.001-0.001
MSL[c]	Intercept	1.125	<0.001	1.066-1.184
	Time	0.003	<0.001	0.002-0.004
	Faller	-0.032	0.516	-0.129-0.066
	Time*faller	0.001	0.305	-0.001-0.003
	Residual	0.001	<0.001	0.001-0.001
GS[a]	Intercept	1.240	<0.001	1.170-1.311
	Time	0.002	0.022	0.0003-0.004
	Residual	0.007	<0.001	0.006-0.008
GS[b]	Intercept	1.222	<0.001	1.136-1.307
	Time	0.002	0.023	0.000-0.004
	Fall history	0.056	0.446	-0.091-0.204
	Time*fall history	-0.001	0.452	-0.005-0.002
	Residual	0.007	<0.001	0.006-0.008
GS[c]	Intercept	1.197	<0.001	1.112-1.283
	Time	0.003	0.011	0.001-0.005
	Faller	0.116	0.103	-0.024-0.256
	Time*faller	-0.002	0.204	-0.006-0.001
	Residual	0.007	<0.001	0.006-0.008

Note: MSL: maximum step length; GS: gait speed; B: estimate; CI: confidence interval

[a] Model including only the self-test (MSL or GS)

[b] Model including the self-test (MSL or GS), time and having a fall history

[c] Model including the self-test (MSL or GS), time and having experienced a fall during the six-month follow-up

DISCUSSION

The main finding of this study was the high number of weekly measurements and the small intra-individual variation which showed that older people are willing and able to repeatedly assess their MSL and GS in their own homes for a period of six months as a measure of their mobility. Repeatedly self-assessing MSL and GS resulted in a slight improvement on these measures which was mirrored by the improved mobility measured by TUG and SPPB, but did not result in improved self-management ability scores. Having a history of falling or experiencing a fall during follow-up did not influence these results. To the author's knowledge this was the first study to explore whether older persons are able to repeatedly measure their MSL and GS at home as a measure of their mobility and fall risk. The good compliance of more than 80% in this study confirmed this hypothesis and therefore showed that it is possible to get older people to be actively involved in the management of their own mobility and fall risk, which is in line with studies showing the possibility of self-management in other chronic diseases, such as COPD and diabetes.[34, 35] However, the small improvement on the self-tests and mobility measures over time does give concern about the reliability of monitoring with these tests. Obviously, the weekly assessments of MSL and GS seem to train older persons and it would, therefore, be very interesting to study whether this improvement lasts during a longer follow-up period. This may limit the validity of these tests as a screening tool for fall risk (in case this does not change), but on the other hand, it may mean a possible therapeutic effect of repeatedly performing MSL and GS by community-dwelling older persons. We did not find an improvement in ADL activities and total activity minutes per day as measured by the LAPAQ, so the effect of these tests as training tools needs to be further studied.

Although the study population measured their MSL and GS very regularly no change in self-management abilities was found. SMAS-30 was already validated and proved to be reliable in an older population, with good reproducibility after 16 weeks.[29] It could be reasoned that the six-month follow-up was too short to achieve improvements in self-management abilities. The SMAS-30 scores were comparable to the scores of community-dwelling older and partly frail individuals found in the studies of Schuurmans et al,[29] but higher compared to a study with 55-year old lonely women.[36] Because the drop-outs in the current study showed less self-management abilities compared to the subjects who completed the study, it could be reasoned that the study population already consisted of a selection of self-managing older persons, which limits the feasibility of our self-tests for a frailer population.

Strengths and limitations

A strength of this Senior Step Study was the prospective follow-up of many descriptives over six months. Furthermore, the 19.6% drop-out rate was comparable to other studies with frail older persons, and can be interpreted as rather low as it demanded a higher responsibility of the subjects included compared with other studies in which treatments are simply administered.

A limitation of this study was the possible selection bias.[22] Compared to the non-participating subjects, the Senior Step Study population did show a good overall performance in mobility making it difficult to generalize the observed ability of repeatedly self-assessing MSL and GS to a more frailer population. When looking at falling and self-management abilities, the selection bias seemed limited in this study population. Fall prevalence was comparable to a community-dwelling older population (38.5%),[37] the TOS-study (35% had a fall history),[38] and the follow-up study (36%). As mentioned above, self-management abilities were comparable to those found by Schuurmans et al,[29] but higher compared with findings of Kremers et al.[36] Another limitation was that the current study only looked at the influence of falling on a group-level. Because there were only 19 fallers, the sample size was too small to accurately explore the relation between repeated measurements of MSL and GS and falls in individual cases, and whether changes in the self-tests within individuals could be predictive for future falls or other negative health outcomes. Therefore, it would be interesting to repeat the study in a larger and frailer population.

CONCLUSIONS

The implications for clinical practice and future research are promising. The good compliance shows that we can engage older persons in their own health care. This may also open possibilities for self-management in other health care areas, such as frailty and functional status. MSL and GS are simple one-item tools and perhaps other one-item tools for other health conditions can also be performed by seniors themselves. The definitive place of the MSL and GS in prevention and monitoring falls according to the chronic care model requires further study, including self-management. It is promising that self-management of mobility and fall risk did not increase falling.

If we want to engage older persons to take an active part in their own healthcare, especially in fall prevention, interventions should be shaped in a way that suites them. This Senior Step Study took the first step by exploring that older persons were willing and able to use MSL and GS weekly as a self-management tool for monitoring their mobility and fall risk. Further studies are needed to examine the exact relation of these self-management capabilities with fall prevention, and to confirm that such self-management capabilities can also be realized in larger and frailer populations.

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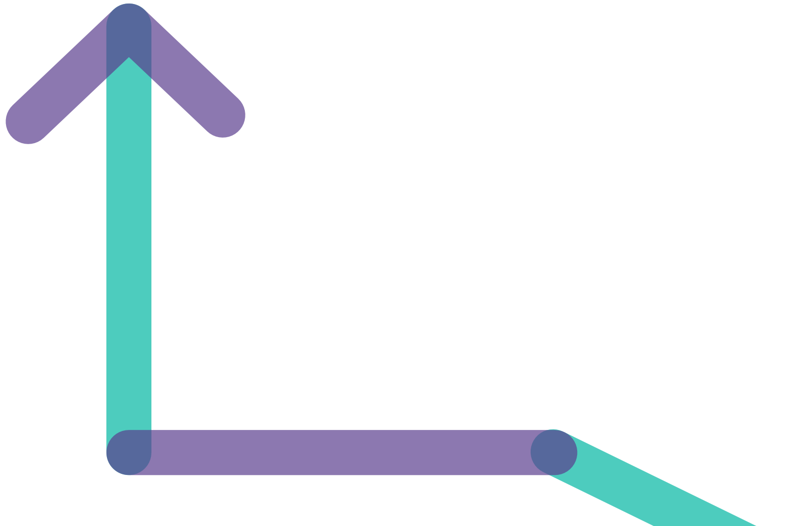
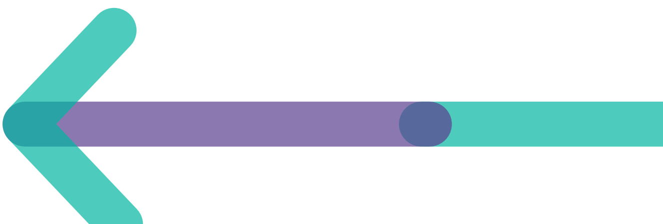


CHAPTER 5

SELF-MONITORING MOBILITY IN A SELF-MANAGEMENT FALL PREVENTION PROGRAM



5

Self-monitoring of mobility in a self-management fall prevention program is acceptable, feasible and safe in older persons

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Submitted

ABSTRACT

Objectives: self-monitoring of mobility and self-management of fall prevention are promising routes for patient empowerment. The current study explored acceptability, feasibility and safety of self-monitoring of mobility in a fall prevention program.

Design: single-blind randomized pilot study.

Setting: at home, homes for the aged and community centres.

Participants: 86 persons (mean age 80.3 years (SD 6.3), 56 women (65.1%)), of whom 78 completed the study.

Intervention: the intervention group measured their gait speed weekly for 6 months as part of a self-management fall prevention program.

Measurements: change scores of health perception and mental wellbeing (Medical Outcomes Study 20-item short form (MOS-20)) were compared between the two groups as acceptability measure. Feasibility was assessed by the drop-out rate and compliance to self-monitoring of mobility. Safety was assessed by fall incidence, injurious falls and fear of falling during the 6 months follow-up.

Results: health perception (MOS-20) decreased significantly in the control group (P =.024), but remained stable in the intervention group. Drop-out rate was low (9.3%), and compliance was good: 80% of possible measurements were performed. There was a suggestion of 1.0 fall less (P=.155) in the intervention group.

Conclusions: self-monitoring of mobility in a fall prevention program is acceptable, feasible and safe in community-dwelling and home for the aged populations, making it worth to further explore self-management fall-prevention studies.

INTRODUCTION

In today's ageing population falling is a major problem, causing physical and social impairments and increasing health-related costs[1-3]. To reach sustainable healthcare, policymakers are encouraging older persons to be more actively involved in their own healthcare. Researchers are beginning to follow this lead on self-management, also advocated by the chronic care model[4-6]. The ability of older persons to quickly identify changes in their mobility could give them a tool to take responsibility of their own mobility-related well-being. Previous results of the Senior Step Study showed that gait speed as a single-item tool has the potential to be a self-management tool for mobility and fall risk, and showed that older people are willing to engage in their own healthcare using this tool[7,8]. However, further research is needed to study whether self-monitoring of one's own mobility as self-management of fall risk is acceptable, technically feasible and safe in older populations. To be acceptable, regular self-management should not decrease mental wellbeing. The current study is to the authors' knowledge the first to explore acceptability, feasibility and safety of self-monitoring of mobility in a fall prevention program in community-dwelling older persons, home for the aged residents and older persons regularly visiting a community centre in a randomized controlled pilot study. Furthermore, we investigated whether self-monitoring influences fall incidence compared to older persons not engaged in their own mobility-related healthcare.

METHODS

Participants

Older persons from the region of Nijmegen, the Netherlands, were asked to participate in the Senior Step Study (ClinicalTrials.gov identifier: NCT01792180). Eligible individuals were aged 70 years or older, fell at least once in the previous year and were able to walk (with or without a walking aid). Not speaking and understanding Dutch, not able to answer the falls telephone (FT), and not having an informal caregiver who could answer the FT for them were exclusion criteria.

Participants were recruited from three settings: community-dwelling, home for the aged (seven recruitment homes), and community centres (six recruitment community centres). All participants provided written informed consent. The local medical ethics committee approved the study (approval number 2012-300).

Design

During the 6-month follow-up period of this single-blind pilot study, participants were randomized to the intervention or control group. Randomization took place on the individual level in the community-dwelling setting and on cluster level in the other two settings.

Assessments at baseline (T0) and after six months (T6) took place at the participants' home. In order to preserve the blinding of the researcher collecting the outcome data, research assistants explained the intervention separately. Monthly telephone calls made by the research assistants were used to measure adherence and monitor safety measures beside the FT.

Intervention

Participants in the intervention group measured their usual gait speed weekly during six months using the Mobility Feedback Device (MFD) (2M Engineering ltd, Valkenswaard, the Netherlands). The MFD is a telemonitoring instrument embedded in a picture frame, which was placed in the subjects home (community-dwelling setting) or in an easily available common room (other two settings), and measured gait speed with two infrared sensors when participants walked past. The sensors were placed at approximately four meters apart from each other. At the bottom of the frame a display showed the gait speed in kilometers per hour. Participants monitored their gait speed twice every week. The MFD of community-dwelling participants had an internal alarm to remind participants of the next planned measurement. Participants from the other two settings were reminded during a weekly open session with the research assistant.

An instruction book with every day exercises, designed for this study, was given to participants in the intervention group in case participants wanted to improve mobility based on their gait speed measurement. The instruction book consisted of low to medium intensive exercises and simple to complex exercises. Exercises were tailored to the participants' physical condition by using the MFD's feedback. For instance, participants with a low gait speed were recommended to perform simple and low intensity exercises. Use of the instruction book was not mandatory. Participants were asked to register type and duration of the exercises if they performed them, in an activity diary. The control group had no intervention besides the weekly telephone calls from the FT.

All participants were told about the connection between gait speed and falls, and reducing fall risk by exercising.

Outcomes

Acceptability and Mental wellbeing

Subjective general health and mental wellbeing measured with the Medical Outcomes Study 20-item short form (MOS-20) were studied as proxies of subjective acceptability of the self-monitoring engagement. The MOS-20, assessed at T0 and T6, covers 6 dimensions: physical functioning, role functioning, social functioning, mental health, current health perceptions, and (physical) pain[9,10].

Feasibility, compliance and safety

Outcomes for objective feasibility were drop-out rate and compliance to the MFD. Compliance was assessed as the number of weekly measurements and detailed by the reasons for not having a measurement.

Outcomes for safety were falls experienced during the study, injuries obtained during a fall and fear of falling. A fall was defined as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level"[11]. During the study fall incidents were monitored by the FT. All participants were instructed about the FT during the first visit of the research assistant. The FT system (ASK Community Systems, Rotterdam, the Netherlands) is a computerized system that automatically contacts participants by telephone and was found feasible, reliable, and valid for assessing falls and fall related injuries in older people[8,12,13]. Fear of falling was assessed at T0 and T6 using the Falls Efficacy Scale-International (FES-I)[14].

Effectiveness of fall prevention program

During visits of the researcher at T0 and T6 mobility was assessed using the Short Physical Performance Battery (SPPB)[15] and Timed Up and Go (TUG)[16,17]. Daily physical activity was assessed using the LASA Physical Activity Questionnaire (LAPAQ)[18]. The Self Management Ability Scale (SMAS-30) was used to evaluate self-management[19], disability with the (modified) Katz scale (Katz-15)[20].

At baseline disease burden was assessed using the Cumulative Illness Rating Scale for Geriatrics (CIRS-G)[21], cognitive status using the Mini Mental State Examination (MMSE)[22], and frailty with the Fried criteria[23].

Statistical Analysis

Baseline characteristics of the intervention and control group were compared using independent samples t-test for continuous variables and Chi-squares tests for categorical variables. Baseline characteristics of the three settings were compared using univariate analysis of variance.

Change scores (T6 minus T0) were calculated for the six dimensions of the MOS-20. Change scores were compared between the intervention and control group using analyses of covariance with setting, age and baseline scores as covariates.

Reasons for drop-out were registered. Baseline characteristics of the participants who completed the study were compared to those who dropped out using independent-sample t-tests for continuous variables and Chi-squares tests for categorical variables.

Reasons for not having a weekly MFD measurement were categorized as: permissible reasons (vacation, sickness), wrong use of the MFD, impersonal reasons (e.g. MFD not functioning), drop-out, other reasons, and unknown. The total number of measurements was corrected for the impersonal and permissible reasons. Compliance to the MFD was assessed for all participants who completed the study by dividing the number of weekly measurements by the total number of possible measurements. Less than 15% drop-out rate and at least 80% compliance were judged as objective criteria for feasibility of the self-monitoring set up.

Safety was analyzed by comparing fall incidence and injurious falls between intervention and control group using independent samples t-tests. Percentage of fallers during the study was compared between both groups using Chi-squares tests. Change scores (T6 minus T0) were calculated for fear of falling (FoF) and compared between both groups by analysis of covariance with baseline FoF, age and setting as covariates. Safety was defined as occurrence of less or equal number of falls in the intervention group, less or equal injurious falls and not getting more FoF compared to the control group.

Post-hoc the abovementioned analyses were also performed within each setting.

Change scores were also calculated for SPPB, TUG, LAPAQ, SMAS-30, and Katz-15. Again, analyses of covariance were used to compare the change score between both groups, with setting, age and baseline scores as covariates.

Significance was set at $p<0.05$. All statistical analyses were performed using IBM SPSS Statistics 22 (SPSS, Chicago, Illinois, USA).

RESULTS

Because the intervention in the home for the aged and community centre settings was shaped as a group intervention for all participants present in the homes or community centres at that timeslot, all individuals participating in these groups were allowed to participate in the study to increase acceptability. However, we started the analyses only with persons fulfilling all inclusion criteria. One hundred and five participants consented to participate in the study of whom 86 met all inclusion criteria.

Of the 86 participants (mean age 80.3 years (SD 6.3), 56 were female (65.1%)), 58 participants were community-dwelling, 20 participants lived in a home for the aged, and eight participants regularly visited a community centre. Participants from the home for the aged setting were significantly older and more frail compared to the participants from the other two settings (Table 1).

Forty-three participants were randomized to the intervention group, and 43 to the control group. The intervention group had a significantly worse subjective health on the MOS subscale of role functioning compared to the control group ($p=.013$) (Table 1). Within each setting there were no significant differences between both groups.

Table 1. Baseline characteristics of participants with a recent fall in the community-dwelling, home for the aged and community centre settings

	Participants included (n=86)						
			Setting		Randomization		
	Community-dwelling (n=58)	Home for the aged (n=20)	Community centre (n=8)	p-value	Intervention group (n=43)	Control group (n=43)	p-value
Age, years	79.1 (6.1)	84.3 (5.3)	79.0 (6.4)	**.004**	79.9 (5.5)	80.9 (7.0)	.373
Female, n(%)	37 (63.8)	12 (60.0)	7 (87.5)	.374	29 (67.4)	27 (62.8)	.651
MOS-20,physical functioning	46.3 (32.3)	35.8 (33.5)	29.2 (26.4)	.226	39.9 (31.9)	44.6 (32.9)	.508
MOS-20, role functioning	43.1 (46.3)	32.5 (43.8)	37.5 (51.8)	.668	27.9 (41.3)	52.3 (47.5)	**.013**
MOS-20, social functioning	73.1 (28.2)	47.0 (32.0)	62.5 (36.2)	**.005**	60.0 (33.5)	72.1 (28.3)	.074
MOS-20, mental health	76.3 (18.9)	60.4 (22.7)	64.5 (18.9)	**.007**	70.2 (21.0)	72.7 (20.8)	.579
MOS-20, current health perception	62.8 (23.5)	48.3 (23.2)	58.1 (22.7)	.062	58.8 (25.0)	59.1 (23.0)	.964
MOS-20, pain	39.2 (34.4)	57.9 (32.3)	53.1 (24.8)	.085	41.7 (34.8)	47.7 (33.1)	.417
SPPB	8.9 (2.8)	6.4 (3.2)	8.4 (3.6)	**.007**	8.5 (3.1)	8.16 (3.2)	.495
TUG, seconds	10.2 (4.5)	18.8 (13.0)	13.8 (7.7)	**<.001**	12.2 (7.7)	12.8 (9.0)	.747
LAPAQ, minutes/day	118.5 (64.6)	78.9 (70.4)	147.4 (119.5)	**.042**	111.8 (71.2)	112.1 (77.7)	.987
SMAS-30	63.6 (12.4)	53.6 (7.8)	61.3 (14.5)	**.006**	60.9 (12.7)	61.3 (12.0)	.884
Katz-15	1.8 (1.9)	4.1 (2.7)	4.0 (3.4)	**<.001**	2.8 (2.8)	2.2 (2.2)	.244
FES-I	30.7 (9.4)	34.5 (11.0)	34.0 (16.4)	.341	32.8 (11.4)	31.0 (9.7)	.430
CIRS-G	9.5 (5.2)	13.9 (4.9)	9.9 (5.0)	**.027**	10.3 (5.3)	10.2 (5.4)	.929
MMSE	28.1 (1.9)	26.0 (3.5)	27.8 (3.2)	**.005**	27.7 (2.7)	27.4 (2.6)	.626
Frail, yes (%)	6 (10.3)	9 (45.0)	1 (14.3)	**.003**	9 (20.9)	7 (16.3)	.579
Setting, n(%)							1.00
- Community-dwelling					29 (67.4)	29 (67.4)	
- Home for the aged					10 (23.3)	10 (23.3)	
- Community centre					4 (9.3)	4 (9.3)	

Notes*:* All data presented as means with standard deviation within parentheses unless stated otherwise. MOS-20: Medical Outcomes Study 20-item short form (6 dimensions: physical functioning, role functioning, social functioning, mental health, current health perceptions, and (physical) pain (each dimension a score range 0-100, higher scores indicating better health)); SPPB: Short Physical Performance Battery (summary performance score (range 0-12) for three tasks, higher scores indicating better lower body function); TUG: Timed Up & Go (higher scores indicating lower mobility); LAPAQ: LASA Physical Activity Questionnaire (minutes per day for all physical activities); SMAS-30: Self-Management Ability Scale (30 items, score range 0-100, higher scores indicating better self-management); Katz-15: Katz-15 item scale (basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating better functional performance); FES-I: Falls Efficacy Scale-International (scale from 1-4 for each of 16 items, total scores ranging from 16-64, higher scores indicating more fear of falling); CIRS-G: Cumulative Illness Rating Scale for Geriatrics (scale from 0-4 for each of 14 categories, higher scores reflecting more comorbidity); MMSE: Mini Mental State Examination (range 0-30, higher scores indicating better cognitive status); Frail: Fried Frailty score (range 0-5; 0-2: not frail, ≥3 frail) based on the Fried criteria: unintentional weight loss, self-reported exhaustion, low energy expenditure, slow gait speed, and weak grip strength.

Acceptability and mental wellbeing

Analysis of the change scores gave a significant difference in current health perception (MOS-20) between the intervention and control group (p=.024) in that the current health perception of the control group decreased during the 6-month follow-up, while the current health perception of the intervention group did not change (Table 2).

Table 2. Changes in outcomes of the intervention and control group following 6 months self-monitoring of gait speed

	Intervention group (n=43)	**Control group (n=43)**	**p-value**
MOS-20,physical functioning	-2.8 (25.0)	-1.2 (26.4)	.411
MOS-20, role functioning	11.1 (38.0)	-4.8 (39.5)	.776
MOS-20, social functioning	-3.9 (22.3)	-1.4 (25.9)	.640
MOS-20, mental health	-2.0 (11.3)	-0.8 (11.4)	.496
MOS-20, current health perception	-1.3 (17.1)	-3.9 (16.4)	**.024**
MOS-20, pain	7.1 (26.8)	-2.4 (40.5)	.587
SPPB	0.3 (1.5)	0.5 (2.0)	.268
TUG, seconds	0.4 (3.6)	-0.2 (5.3)	.697
LAPAQ, minutes/day	-5.3 (61.0)	0.9 (55.6)	.880
SMAS-30	-1.0 (7.2)	-2.3 (6.7)	.378
Katz-15	0.1 (1.3)	-.02 (1.3)	.523
FES-I	2.1 (6.9)	-1.6 (7.0)	.110

Notes: All data presented as means with standard deviation within parentheses unless stated otherwise. MOS-20: Medical Outcomes Study 20-item short form (6 dimensions: physical functioning, role functioning, social functioning, mental health, current health perceptions, and (physical) pain (each dimension a score range 0-100, higher scores indicating better health)); SPPB: Short Physical Performance Battery (summary performance score (range 0-12) for three tasks, higher scores indicating better lower body function); TUG: Timed Up & Go (higher scores indicating lower mobility); LAPAQ: LASA Physical Activity Questionnaire (minutes per day for all physical activities); SMAS-30: Self-Management Ability Scale (30 items, score range 0-100, higher scores indicating better self-management); Katz-15: Katz-15 item scale (basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating better functional performance); FES-I: Falls Efficacy Scale-International (scale from 1-4 for each of 16 items, total scores ranging from 16-64, higher scores indicating more fear of falling).

Feasibility, compliance and safety

Of the 86 participants eight participants dropped out (9.3%): six community-dwelling (five from the intervention group, one from the control group), and two home for the aged residents (both from the intervention group). Four participants dropped out because they felt participation too demanding. Other drop-out reasons were: participation was too time consuming, withdrawal from study by their children, participant found participating not necessary anymore, and few participants were not capable of walking anymore. Differences between drop-outs and participants who completed the study are shown in Table 3.

Table 3. Baseline characteristics of the participants who completed the study and those who dropped-out

	Participants (n=78)	Drop-outs (n=8)	p-value
Age, years	80.3 (6.4)	80.9 (5.3)	.796
Female, n(%)	52 (66.7)	4 (50.0)	.346
MOS-20,physical functioning	43.2 (32.5)	33.3 (30.9)	.416
MOS-20, role functioning	42.9 (46.8)	12.5 (23.1)	**.008**
MOS-20, social functioning	68.5 (30.3)	42.5 (34.5)	**.025**
MOS-20, mental health	72.9 (20.5)	57.5 (19.9)	**.045**
MOS-20, current health perception	60.1 (23.8)	48.1 (23.7)	.180
MOS-20, pain	44.2 (34.6)	50.0 (26.7)	.645
SPPB	8.3 (3.1)	8.3 (4.1)	.978
TUG, seconds	12.3 (7.7)	14.6 (13.7)	.451
LAPAQ, minutes/day	113.4 (75.7)	97.8 (58.4)	.573
SMAS-30	61.4 (12.4)	57.9 (12.1)	.447
Katz-15	2.3 (2.3)	4.8 (3.3)	**.007**
FES-I	31.7 (10.8)	34.1 (8.6)	.536
CIRS-G	10.3 (5.4)	10.8 (5.0)	.824
MMSE	27.7 (2.4)	26.0 (4.3)	.298
Frail, yes (%)	13 (16.7)	3 (37.5)	.149

Notes: All data presented as means with standard deviation within parentheses unless stated otherwise. MOS-20: Medical Outcomes Study 20-item short form (6 dimensions: physical functioning, role functioning, social functioning, mental health, current health perceptions, and (physical) pain (each dimension a score range 0-100, higher scores indicating better health)); SPPB: Short Physical Performance Battery (summary performance score (range 0-12) for three tasks, higher scores indicating better lower body function); TUG: Timed Up & Go (higher scores indicating lower mobility); LAPAQ: LASA Physical Activity Questionnaire (minutes per day for all physical activities); SMAS-30: Self-Management Ability Scale (30 items, score range 0-100, higher scores indicating better self-management); Katz-15: Katz-15 item scale (basic and instrumental activities of daily living, with a score range of 0-15, lower scores indicating better functional performance); FES-I: Falls Efficacy Scale-International (scale from 1-4 for each of 16 items, total scores ranging from 16-64, higher scores indicating more fear of falling); CIRS-G: Cumulative Illness Rating Scale for Geriatrics (scale from 0-4 for each of 14 categories, higher scores reflecting more comorbidity); MMSE: Mini Mental State Examination (range 0-30, higher scores indicating better cognitive status); Frail: Fried Frailty score (range 0-5; 0-2: not frail, ≥3 frail) based on the Fried criteria: unintentional weight loss, self-reported exhaustion, low energy expenditure, slow gait speed, and weak grip strength.

Reasons for not having a weekly measurement were permissible reasons (14.5%), wrong use of the MFD (2.2%), impersonal reasons (30.9%), drop-out (19.5%), others (9.9%), and unknown (23.0%). After correcting the total number of measurements for the impersonal and permissible reasons, the compliance of self-monitoring gait speed using the MFD was good, with a median (25% and 75% centiles) percentage of measurements of 82.1% (57.6% and 100%) for participants who completed the study (n=78).
There was a significant difference between the three settings (p=.014) in that the community centre participants had significantly lower compliance compared to the community-dwelling participants.

In total 40 falls were registered in the intervention group and 82 falls in the control group. Fall incidence did not differ between the intervention (mean incidence 0.9 (SD 1.8)) and the control group (mean 1.9 (SD 4.1)) (p=.155). Also, the number of fallers in the intervention group (n=17 (39.5%)) did not differ from the control group (n=19 (44.2%)) (p=.662). The incidence of injurious falls did not differ between the intervention (mean incidence 1.4 (SD 1.5)) and the control group (mean 1.7 (SD 2.4)) (p=.637). FoF did not differ between the intervention and control group (p=.110, Table 2). There were no differences in FoF within each setting.

Analysis of the change scores gave no significant differences between the intervention and control group (Table 2).

DISCUSSION

The current study showed that self-monitoring of mobility as part of a fall prevention program gave good participant acceptability, good technical feasibility and compliance, but not yet an overall positive effect on falls rate decline, though there appears to be a trend towards a beneficial effect.
Mental wellbeing is important to older persons and the current study showed that self-monitoring of mobility as part of a fall prevention program did not change subjective general health and mental wellbeing, assuming that there is no problem with subjective acceptability of the intervention. Moreover, current health perception decreased in the control group, suggesting a net positive effect of self-monitoring on mental wellbeing, although we did not see this change in the other dimensions of subjective general health. Drop-out rate (9.3%) was low for a study requiring participants' responsibility, when compared to most other intervention studies (18.5%-23%)[24,25]. Compliance was more than 80% for participants who completed the study and was comparable to our previous study based on self-monitoring[8]. The current research method is safe, because participants in the intervention group did not fall more and they were not more fearful of falling. However, the study sample was too small for a powered analysis of fall frequency changes, which also was not the study's primary aim.
A strength of the current study was the prospective follow-up over 6 months of many variables in older persons in three settings. The design of the study (randomized, single-blind) made it possible to

thoroughly investigate the effect of self-monitoring on mental wellbeing. When looking at falling and self-management abilities, our study population was comparable to those mentioned in literature[19,26,27]. Furthermore, participants were older and showed lower overall performance in mobility compared to participants from our previous study[8], and the number of frail participants was comparable to literature[23,28,29], making our results generalizable not only for a community-dwelling population, but also for a more frailer population. Interesting findings were the results in the home for the aged setting: equal drop-out rate, fall data and compliance compared to the other two settings, suggesting that even with the low inclusion rate self-management is possible in this older and more frail population. A recent review confirmed that elements of self-management are still possible in older persons with cognitive decline[6]. The small sample size in the home for the aged and community centre settings was a limitation of the current study. During recruitment, especially in the community centre setting, participants stated they felt stigmatized when asked to participate, because participating meant they had fallen in the previous year and thus were getting old. For this reason the intervention was shaped in a group intervention in these settings. A further limitation was the lack of qualitative data to explore in depth participants' acceptability and feasibility.

In conclusion, the increasing importance of self-management in this ageing society warrants acceptable, feasible and safe self-management research methods that do not decrease an older person's mental wellbeing. It would be highly interesting whether elements of interventions with proven effectiveness could be transferred to a self-management strategy and remain effective[30]. The current study showed that self-monitoring of mobility in a fall prevention program in community-dwelling and home for the aged populations could be first steps in such experiments. Mental wellbeing remains the same for a longer period of time and there is also a trend towards fall prevention in the intervention group. All this makes it very interesting and possible to further study self-monitoring in fall prevention studies in older people.

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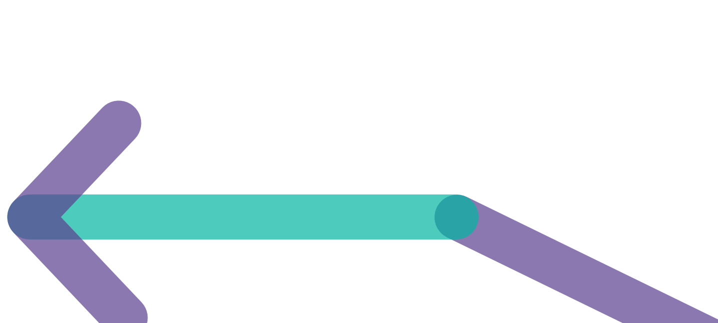

CHAPTER 6

SUMMARY AND GENERAL DISCUSSION

In this thesis we have focused on the aim of the Senior Step Study, which was to empower seniors by stimulating their self-management abilities in monitoring their mobility and ultimately reduce their fall risk. In order to do so, we investigated whether it was possible to develop a test that an older person can potentially perform, and which may indicate the person's mobility, balance and risk for falling. This chapter provides a summary and a general discussion of our findings beyond the discussion points already addressed within the previous chapters. We will focus on self-management research in general and specific points concerning our findings, and the older population and self-management in a more general meaning, resulting in recommendations for future studies and clinical practice.

SUMMARY OF THE MAIN FINDINGS

Recruiting older persons for self-management tasks

Chapter 2 evaluated the recruitment process and explored the reasons mentioned for (not) participating in an intervention study on self-management of mobility and fall risk by older community-dwelling people, and persons recruited at homes for the aged and community center settings. Total inclusion rate was 27.9%. Starting recruitment with a personal approach did not improve inclusion rate and more subjects consented to participate after an introductory meeting during which, among other items, the study design and benefits of participating were discussed. Especially in the homes for the aged setting, people refused to participate because the research was judged by them as too burdensome. This study showed that recruiting older persons for self-management tasks is possible with the right recruitment process. Moreover, we learned that formal interim evaluations of the recruitment process may benefit the recruitment.

Three simple mobility tests for monitoring frailty, mobility and fall risk

The diagnostic value of three simple mobility tests that may assess the phenotype frailty in 593 community-dwelling older people is examined in chapter 3a. The maximum step length test, the gait speed test, and the chair rise test were all sufficiently correlated with frailty status in community-dwelling older people and thus, might be useful for frailty self-monitoring. Gait speed was the best mobility assessment of frailty with a correlation of r=-0.60 both with the Fried frailty score and the Frailty Index score. In addition, gait speed had the best diagnostic value (with an area under the curve of 0.92) to assess the dichotomized state of frailty. Feasibility of all three tests was high, with adherence ranging from 91% to 99%, and they could be safely performed when proper instructions were provided. However, the safety of performing these tests as a self-assessment test was not measured in all settings in this study and should be evaluated in future research. We found that frailty self-monitoring may be possible using gait speed, which could be a valuable tool to empower older individuals.

Chapter 3b examined the predictive value of two potential self-monitoring tools, the maximum step length test and the gait speed test, for fall risk in the same cohort of community-dwelling older persons described in chapter 3a. A one-year follow-up assessment for fall incidents was performed using the fall telephone system. Of the 352 participants, 39% reported falling, with a total of 285 falls. The predictive values for falls using the maximum step length and gait speed were low and slightly better for recurrent falls. A higher maximum step length score indicate a lower likelihood of an older participant falling, with a hazard ratio of 0.36 (95% Confidence Interval (CI) = 0.17-0.78). We concluded that individual tests are not sufficiently valid to predict future falls in community-dwelling older people.

Repeatedly self-assessing maximum step length and gait speed at home

The safety, feasibility, and intra-individual reliability of the maximum step length, gait speed, and chair test as potential self-tests for assessing mobility and fall risk was determined in chapter 4a in 56 community-dwelling older persons. Compared with the other self-tests, maximum step length gave the most often (77.6%) valid measurement results, and had the best intraclass correlation coefficient (0.95 (95%CI: 0.91-0.97)). Maximum step length and gait speed showed no training effect. These results show that community-dwelling older persons can perform maximum step length and gait speed safely and reliably.

Chapter 4b assessed whether the same population as in chapter 4a was able to repeatedly self-assess maximum step length and gait speed in their own home for a six-month period. Compliance of repeatedly self-measuring these mobility tests was good, with 88% and 81% for maximum step length and gait speed, respectively. Subjects who dropped-out showed less self-management abilities compared to the participants who completed the study (p=0.049). Both maximum step length and gait speed improved slightly over time, without an influence on falling. Self-managing mobility and fall risk did not increase fall occurrence. We concluded that most community-dwelling older persons are able and willing to repeatedly self-assess these tests.

Self-monitoring mobility in a self-management fall prevention program

Chapter 5 explored acceptability, feasibility and safety of self-monitoring of mobility by using the newly developed Mobility Feedback Device in a fall prevention program. This Mobility Feedback Device automatically allowed to measure gait speed of the older subjects unobtrusively and very simply at their own homes. In this single-blind randomized pilot study 86 persons from the community-dwelling, homes for the aged and community center settings, participated, and the intervention group used the Mobility Feedback Device weekly for six months as part of a self-management falls prevention program. Current health perception decreased in the control group, but remained stable in the intervention group (p=0.024). Inclusion was low in the community center setting. Drop-out rate was 9.3% and compliance to the Mobility Feedback Device was 80%, indicating that self-monitoring of mobility in a fall prevention program is acceptable, feasible and safe in community-dwelling and home for the aged populations. However, fall risk did not decrease using the Mobility Feedback Device.

DISCUSSION

Because of our aging society and the rising costs of our healthcare, policy makers are encouraging researchers to get older persons actively involved in their own health-related wellbeing. This greatly stimulates all the research that nowadays is performed into the self-management of chronic diseases. The Senior Step Study was started, because we noticed that the self-management of fall risk was missing in the field of self-management research, and we therefore started the development of a self-management tool for fall risk. In this general discussion we will focus on recent developments in 'Self-management of falls prevention programs' and the evaluation and outcomes of our self-management fall prevention related to these recent advances in the field. Next, under the 'Population' heading, we will discuss the recruitment and selection of subjects for self-management research and self-management falls prevention programs.

Self-management falls prevention programs

As discussed in the general introduction of this thesis, several aspects are important in the development process of a new tool. For example, when evaluating the development of gait speed (GS) as a self-management tool in this study, relevant stakeholders, i.e. the older person and his/her caregiver, were consulted several times during the development process, from the grant application to the development of the Mobility Feedback Device. Furthermore, the safety and feasibility of self-monitoring GS at home have been carefully evaluated. The intended effects of at least not falling more often and safe use, were reached, however, (predictive) validity was not yet evaluated. We did not look into individual repeated measurements of GS and how these may be directly related to falls and fall risk. Furthermore, the cost-effectiveness of our self-management fall prevention program still needs further study. In this project, we captured the crucial developmental steps of co-creation with stakeholders, safety and feasibility study, and preliminary effectiveness study (pilot), which should be followed by more formal testing of (cost-)effectiveness. Luckily, nowadays more researchers are recognizing the importance of self-management of falls and fall risk, and will take similar steps in the long track from developing an innovation to large-scale implementation. Table 1 shows current research being performed in this area. All the interventions, whether based on training or e-health, are still in the developmental stage. Initial results are promising, because the interventions are safe, acceptable, and/or are similarly related to fall risk compared to conventional fall risk tests. However, all studies indicate that further research for (cost-)effectiveness and implementation is still needed before a self-management intervention can be routinely used to monitor falls and fall risk, and get implemented more widely in older populations. These results are fully in line with the advances made in our Senior Step Study.

Table 1. Overview of several recent studies developing and evaluating various self-management tools for fall prevention

	Population	Intervention	Results	Further steps in development
Senior Step Study	86 older persons, 70+ years, community-dwelling, residents of homes for the aged, visitors of community centers	**E-health:** Mobility Feedback Device (weekly measurement of gait speed at home)	Safe, acceptable and feasible	Individual measurements related to falling, validity, cost-effectiveness
Robinson et al [1]	9 older people with primary biliary cirrhosis, 63-80 years old	**Training:** Strength and Balance Training (exercise program at home, supervision of professional, stimulation of self-management)	Longer, but not more intensive periods of clinical intervention are necessary to move thorough incremental stages of behavior change.	Developing a wide range of strategies and behaviors to empower older persons to develop an ongoing active commitment to intervention.
Sherrington et al [2]	Intended recruitment of 350 older people with recent fall-related lower limb or pelvic fracture, 60+ years	**Training:** Individual exercise program, goal setting and fall prevention education, under supervision of professional	No results yet, protocol of randomized controlled trial was described	Aims: compare effect of intervention with usual care on, among others, balance, mobility and fall risk, cost-effectiveness, cost –utility, safety and tolerability, and determine features associated with uptake of the intervention.
Rasche et al [3]	79 older persons who downloaded the app and were 50+ years old.	**E-health:** Aachen fall prevention app: smartphone application, a three-step self-assessment based on “Aachen Falls Prevention Scale”: standardized yes-no questions, balance test and rating their own subjective fall risk. Once every three months.	Short duration of usage, significant relationship between objective fall risk and self-assessment results obtained by the app.	Extend capabilities of the app to provide suitable arrangement to support prevention measures. Investigate incentives to increase adherence. Longer data collection needed to provide insights for incorporating mHealth solutions into fall prevention.
Di Rosa et al [4]	29 older persons, 65+ years old, experienced at least one fall in previous year, able to walk unassisted for five minutes.	**E-health:** Wireless sensor insole system: a pair of electronic insoles connected to smartphone and backend computer server for Gait Analysis Tool. Algorithm of parameters from gait analysis gave Fall Risk Index. The system is worn two weeks during daily life.	Fall Risk Index calculated by the system performed similarly to conventional fall risk tests.	Large scale prospective studies for further validation, determine added value to traditional measures, evaluate ability to predict changes in fall risk over time, assess sensitivity to changes in response to therapeutic interventions.

From a broader perspective, falls and fall risk are not the only areas in which self-management research is being performed. As part of a longer series of self-management evaluation studies in old age, we specifically would like to point at similar developments in a number of chronic age-related diseases, for instance: self-management group exercises reduce the incidence of disability in older adults [5]; physical activity self-management and coaching is feasible in persons with Huntington's disease [6]; an individualized exercise-focused self-management program showed to be feasible in older persons [7]; computer and mobile technology interventions for self-management in chronic obstructive pulmonary disease seem effective [8]; and self-management interventions can be feasible and potentially beneficial for older persons with cognitive decline [9]. The emphasis of policy makers on the necessity of reducing healthcare costs and the mentioned promising results of the self-management interventions (of which most are still in development) for falls and chronic diseases, make research into self-management useful and necessary as a next step towards a healthcare system that is sufficiently taking into account the specific needs and options for older people with multiple chronic diseases.

Outcomes of the program

Besides looking at the development of our self-management fall prevention program, we also have to discuss several aspects concerning the evaluation and outcomes of the program. Interesting findings were the small, but significant improvements on the self-tests over a six month period. Also, mobility measured by Timed Up and Go-testing and on the Short Physical Performance Battery increased during that period, though, we did not find an improvement in ADL activities and physical activities. This might suggest that performing the self-tests weekly will train the older person and this could be an unexpected advantage of our self-management tool, with a possible therapeutic effect of repeatedly performing the self-test. When given feedback on their mobility, a faster GS might stimulate the individual Plan-Do-Check-Act cycle of the older person. However, because the aim of the Senior Step Study was to monitor falls and fall risk, a training effect while performing the self-test might limit the validity of the tool to assess an increased risk for falling. In essence, the norms or cut-off values for each individual warning for increased fall risk might change continuously by this training effect. This could be compensated in future research by new machine learning algorithms, which might be the best way to personalize self-management tools. Furthermore, other research showed that an increased GS can lead to more falls [10]. Thus, self-management with a training effect on GS might also have adverse effects related to increased GS, and should be carefully monitored for this.

Update self-management studies on mobility

The aim of the studies from Table 1 was mostly to directly decrease fall risk and the number of falls, not monitor fall risk. Rasche et al found a short duration and limited use of their fall prevention app, not enforced by personal contacts, which subjects only used once every three months [3]. Robinson et al showed that subjects who were seen every four weeks for a period of six months developed a long-term active commitment to their training intervention [1]. This suggests that being repeatedly accustomed with self-management for a long period of time could make the older person continue with the intervention after the supervision of the professional stops. The stimulus of repeated (positive) feedback together with transparency of training results, as used in our own study, might point at a possible improvement for self-management tools, in which training of the subjects is the object and adherence to the intervention, as mentioned above, is often limited.

Repeatedly measuring gait speed

Another aspect in the evaluation of the Senior Step program, is that in our study usual GS is being repeatedly measured for the first time by older persons at home over a long period of time. This contrasts with routine care application of GS measurements in clinical care, in which usually just a single mobility measurement is carried out by a professional. It can be reasoned that single or infrequent evaluations may not be representative of a person's true locomotion ability, because of large within-participant variability in frail older persons [11-13]. Also, mobility assessment at only one time point may preclude identification of a large proportion of the persons at risk as they may experience a rapid or gradual decline in mobility and balance over time, and may or may not pass in due time a population-based cut-off point [11]. These individualized repeated measurements of mobility make it possible to link these measurements to personal fall data and other data such as the occurrence and timing of fall-related injuries, the total mobility range, indoor-outdoor movement patterns, the changes in fear of falling, etcetera. However, the techniques to extend the GS monitoring to this whole range of other related parameters were not yet available when our studies were carried out, while this very well could be the innovation route of the near future. However, we directly should be cautious not to realize a data-overload, especially on the side of the older person and his/her caregivers. If we want to reach personalized healthcare and personalized self-management of fall risk, we need to change our "one size fit all" self-management view, as was in essence still the innovation we studied, and go beyond this to accommodate innovations to the individual older person.

Improvement by the monitoring=training effect

This leads to the next aspect in the evaluation of our program. Although it was not a primary aim of our study, we found no improvements in self-management abilities in our study population. One has to wonder if such an improvement, is to be expected or even should be a prerequisite for an effective self-management intervention. Biggest part of our intervention was to self-manage mobility by repeatedly measuring GS and we found that older persons are able to do this. However, the self-management abilities of our study population were comparable to community-dwelling older and partly even in frail individuals [14]. Self-management competencies were stronger compared to a study with 55-year-old women [15]. Our study showed that drop-outs had less self-management abilities compared to subjects who completed the study (Chapter 4). However, in our subsequent study subjects from the homes for the aged setting showed less self-management abilities compared to the drop-outs from the previous study. So it is still difficult to define a minimum capacity of self-management abilities needed for older subjects to be successfully included in self-management studies similar to ours. Moreover, none of the other self-management studies (see Table 1) provided a minimum of self-management abilities or self-efficacy, nor did they select their subjects on this inclusion criterion. In our view, it would nevertheless be wise to measure the self-management abilities of the candidate subjects at the start of future studies. This way statements could be made for inclusion and/or exclusion criteria by which an older person may turn out to be eligible for a self-management program of fall risk or other health-related outcomes, while another person may not be eligible.

Self-management for falls

A central outcome of our program was that self-monitoring of mobility did not yet show a positive effect on falls rate decline, though there was a trend towards a beneficial effect. None of the studies on the self-management of falls mentioned in Table 1 looked prospectively at falls during their study, except that Sherrington et al aim for this [2], but this study still has to be performed. Di Rosa et al linked their Fall Risk Index to three conventionally used performance-based assessments of fall risk: the Tinetti Performance Oriented Mobility Assessment Tool, Timed Up and Go test, and Dynamic Gait Index [4], but did not look prospectively at falling as we did in our study. As said, we found a trend towards a prevention of falling, but our sample size was too small to detect a moderate or small effect size. Now that we have established the safety of self-assessing mobility at home and found a suggestion towards fall prevention, it is wise to study the relation of self-assessing mobility and falls in future research in a larger rigidly performed randomized controlled trial, and we recommend other researchers to do the same.

Qualitative study of self-management

Although we looked at acceptability and feasibility in a quantitative manner, we did not perform qualitative research to study in depth the opinions and experiences of older persons with the self-management intervention. This also limits our current knowledge on the acceptability and feasibility of our self-management tool. Due to time limits, it was not possible to perform such a qualitative study. Robinson et al did so and found that older persons and physiotherapists have different views on how self-management and adherence to an exercise-based falls prevention program need to be introduced and supervised [16]. They emphasize that it is immensely important to study the view of older persons on self-management of fall risk and falls, because in self-management the professional is not always present to give instructions after the intervention started. Besides qualitative research, other outcome measures could help to elucidate the older person's view on self-management, such as Patient Reported Outcome Measures, in which the wellbeing throughout the study and the way the self-management intervention fits into the subjects' lives, can be incorporated. Therefore, when developing a self-management tool for personalized healthcare of the older person, researchers should best cooperate as much as possible with the individual older person, and consider a qualitative process and feasibility study in conjunction to the effect evaluation.

Population

In order to study who benefits most from an intervention, the recruitment and selection of subjects is always an important phase in research. In the next section of the general discussion the recruitment and selection of subjects for self-management fall prevention interventions will be discussed.

Recruitment

To realize an adequate selection of the right population, recruitment procedures are of ultimate importance in research and should be described clearly to acquire sufficient data to judge external validity and to improve chances for implementation [17-18]. Our recruitment rate (27.9%) is comparable with a range of other recruitment rates (20%-38%) found in self-management studies with older persons [19-23]. However, all these studies recruited younger (years of age ranging from 37 to 91) and/or chronically ill persons. Subjects participating in our study were not recruited because of a chronic illness and might therefore be less intrinsically motivated to participate in this study. In one study the subjects were recruited through their general practitioner [20] and not directly by the researchers as was the case in our study. However, the comparable recruitment rate indicates that older persons may be equally willing to participate in self-management research. During recruitment several care organizations and participants helped us, and all approaches were fitted to each recruiting site, as suggested by literature [20,24]. This form of co-creation in the recruitment process benefited our recruitment. A recent guideline concerning medical research with older persons also gives evidence and consensus based recommendations concerning recruitment of older persons for medical research [25]. We used several of their suggestions and put 'extra' effort into the recruitment process through an introductory meeting and being easily approachable for older persons and their caregivers. However, this did not result in the enrolment of sufficient subjects in the homes for the aged setting and the community center setting. In general, recruitment strategies have to be adjusted to fit these type of settings for older persons better. For instance, we learned that the recruitment of older persons from the community centers may lead to persons feeling stigmatized, while this may be avoided when such potential drawbacks of recruitment are thought over well before the recruitment starts. The use of reminders, organizing continuous monitoring of recruitment rate, planning for interim evaluations of the inclusion process, and allowing for adjustments in the study protocol are all valuable recommendations to stimulate and personalize the recruitment [25]. If these adjustments do not lead to the recruitment of sufficient subjects in these settings, researchers should conclude at an early stage that a self-management procedure and/or the evaluation part of it, are not sufficiently feasible, and should be improved in co-creation, before investing even more efforts.

In the homes for the aged setting the reason mentioned most often for not wanting to participate in our study was that people considered it too much of a burden, as was reported in other studies [19]. It was not clear whether the burden was felt most by the assessments from the researcher, the falls telephone system, the repeated measurements using the Mobility Feedback Device, or all of these together. It is, therefore, important to explicitly ask older study subjects about their experienced study burden. This is possible by an interim evaluation with the subjects, during which mutual expectations and burden-to-benefit ratio can be discussed [25]. Study duration, often the longer the better in the scope of the researchers, may also result in increased burden. Similarly, we described and considered it as a strength of our study that the prospective follow-up lasted over six months. However, it could be questioned if this really is a strength or did it result in subject overburdening and a wrong balance in the burden-to-benefit ratio. This could have been evaluated more explicitly, as we also advocate for other self-management studies, all requiring efforts from older subjects.

In all our studies, subjects showed a good compliance to the self-tests and drop-out rate (9%) was low when compared to most other intervention studies and self-management intervention studies (drop-out rates ranging from 17% to 23%) [22-23,26-27]. This indicates that older persons, once we enrolled them, were willing, motivated and able to continue their study participation. This is in line with the general experiences in research with older subjects. The subjects find it rewarding to be part of a new group and have positive social interactions. This should be part of the recruitment and adherence strategy in all trials, and specific meetings should be organized to fuel this social interaction with research subjects.

Frailty and selection for self-management

Following the recruitment process, the final study population has to be selected based on inclusion and exclusion criteria, and the willingness of subjects to participate who have considered all pros and cons, and especially the practical consequences of participation. As the heterogeneity in older populations is increasing with respect to many characteristics, especially for complex functions such as mobility, researchers always have to describe very carefully which selection of this broad aging population is finally studied. Both for internal and external validity of the results this is crucial. Therefore, we payed a lot of attention to these aspects in our studies, and learned a relevant lesson related to self-management by frail older persons.

As discussed in our first home study (Chapter 4), there may have been selection bias in this study, because subjects were recruited from an ongoing study which, resulted in study subjects showing a better overall performance in mobility compared to the non-participating individuals. However, subjects from the subsequent home study (Chapter 5), who were recruited from the general population, were older and showed lower overall performance in mobility compared to the subjects from our previous study. Also, the number of frail subjects (10% in the community-dwelling, 45% in the homes for the aged, and 14% in the community center setting) was comparable for the community-dwelling population to the studies of Fried et al (7% of community-dwelling population) [28] and Bandeen-Roche et al (15% of community-dwelling population) [29], but higher compared to the study of Buckinx et al (25% of nursing home population) [30]. Not only is the number of frail subjects higher in our study, we also found that self-management of falls and fall risk was still possible in the frail subjects of the homes for the aged setting. This suggests that our results are externally valid not only to a community-dwelling population, but also to a more frailer population, which is confirmed by a recent review stating that elements of self-management are still possible in older persons with cognitive decline [9]. In order to reach an efficient healthcare system it is good to know that even frail older persons may be capable of self-managing their fall risk, when these procedures are developed and repeatedly adapted in co-creation with these frail subjects or their representatives.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This thesis provided new evidence and directions for self-management in the monitoring of falls and fall risk. The main conclusions can be summarized as follows:

1. Self-management of falls prevention interventions, which are needed in sustain the costs of our healthcare systems, are feasible and show promising results for the further stages of development, which they still have to go through to reach personalized healthcare interventions for older persons.
2. The “one size fits all” view of most interventions is outdated and innovations need to be accommodated to the individual older person for better recruitment, adherence and individual effects and benefits for the older persons. A detailed description of which older person will benefit from a self-management intervention will accommodate this.
3. To reach maximum output, older persons need to be involved in the entire research and innovation process (co-creation), from initial research idea up to the evaluation of the innovation.
4. When evaluating self-management interventions in frail older persons, qualitative research and Patient Reported Outcome Measures should be used to carefully optimize the burden-to-benefit ratio.

Recommendations for future research

Future studies on self-management of falls and fall risk should focus their intervention more on the individual older person. Individualized repeated measures must be linked to personal fall risk, falls and other health-related outcomes, and the views of older persons on self-management need to become more clear to optimize personalized healthcare. Letting older persons participate in the development of innovations and research will provide valuable information and can result in studies that are more suited to the needs of older persons with innovations and research based on their experiences, problems and wishes. This co-creation will increase the support and legitimacy of the innovation and research, and may also lead to better recruitment and more adherence during the study. Furthermore, this gives an opportunity to discuss and assess the burden of participating, which should be minimal in studies. The number of visits or assessments should be minimized and Patient Reported Outcome Measures might be used to monitor and reduce the burden of older persons participating in research. Furthermore, cost-effectiveness of the innovations needs to be studied.

Take-home message for the clinician and Mrs. A.

Our aging society and the increasing costs of our healthcare systems force clinicians and researchers to get older persons to be actively involved in their own health-related wellbeing. Personalized self-management interventions will be essential in the near future and clinicians need to shift their focus from only caring for a patient to actively empowering them. Several innovative tools are being developed for the self-management of falls and fall risk and it will not be long before these will become available in regular practice.

Vignette: Mrs. A.

After having read this thesis, the general practitioner of Mrs. A. explained that self-management of mobility and fall risk is possible and several innovations are being developed, of which one or more will probably be available for her in the near future. Besides "staying as active as possible", Mrs. A. possibly might be able to contribute to the development of such tools by actively engaging in the development of these tools through co-creation and study participation.

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CHAPTER 7

SAMENVATTING | SUMMARY IN DUTCH

SAMENVATTING | SUMMARY IN DUTCH

In 2015 waren in Nederland 3 miljoen 65-plussers en naar verwachting zal dit oplopen tot 4,2 miljoen in 2040, wat dan betekent dat bijna 24% van de Nederlandse bevolking 65 jaar of ouder zal zijn. Om voor al deze mensen goede zorg, welzijn en wonen te realiseren, en ervoor te zorgen dat dit ook voor de samenleving betaalbaar blijft, zal er meer focus moeten liggen op preventie en zullen ouderen gestimuleerd moeten worden om zelf met hun gezondheid aan de slag te gaan.
Vallen is één van de gezondheidsproblemen onder ouderen die betaalbare goede zorg en welzijn ernstig onder druk zetten en zal met de vergrijzing alleen maar toenemen. Maar liefst een derde van de 65-plussers valt minstens één keer per jaar en in 2015 hebben 97.400 ouderen in Nederland de Spoedeisende Hulp bezocht vanwege valgerelateerde letsels. Verminderde mobiliteit levert een verhoogd risico op vallen en vallen vermindert weer de mobiliteit en actieradius van ouderen. Deze vicieuze cirkel maakt het belangrijk om ouderen de mogelijkheid te geven meer verantwoordelijkheid te nemen voor hun eigen 'val- en mobiliteit gerelateerd welbevinden', mits dit voor hun goed en veilig te doen is. Een startpunt kan zijn om de oudere zelf de mogelijkheid te geven om snel veranderingen in mobiliteit te meten en op die manier een verhoogd valrisico aan te zien komen door vroege waarschuwingssignalen. Echter, dit zelf managen van het valrisico en dus de mogelijkheid om relevante veranderingen in mobiliteit te identificeren is alleen haalbaar met een instrument waarmee ouderen simpel, snel en betrouwbaar hun mobiliteit kunnen meten en dat daarnaast ook nog toekomstig vallen kan voorspellen.

Ouderen werven voor zelfmanagementtaken

Bij het ontwikkelen van een meetinstrument dat kan worden gebruikt als zelfmanagementinstrument is het belangrijk om te weten of ouderen dit instrument willen gebruiken en of zij mee willen doen aan onderzoek hiernaar. In hoofdstuk 2 beschrijven we het wervingsproces van ons onderzoek en hebben we onderzocht welke redenen ouderen noemen om wel of juist niet deel te nemen aan een interventiestudie naar zelfmanagement van mobiliteit en valrisico. Het gaat hierbij om thuiswonende ouderen, ouderen wonend in een verzorgingshuis en ouderen die regelmatig het buurthuis bezoeken. In totaal heeft 27,9% van de gevraagde ouderen meegedaan aan het onderzoek. Het maakte hierbij niet uit of een oudere voor de eerste keer werd benaderd via een persoonlijk contact of juist via een advertentie. Indien mogelijk werd na het eerste contact een kennismakingsgesprek met één van de onderzoekers ingepland. Tijdens dat gesprek werden onder meer de studieopzet en de voordelen van meedoen aan het onderzoek besproken. Het bleek dat meer ouderen meededen nadat er een kennismakingsgesprek had plaatsgevonden dan wanneer er geen gesprek was geweest. Opvallend was dat vooral ouderen uit het verzorgingshuis deelname weigerden, omdat zij vonden dat deelname te belastend voor hen was. Deze studie liet zien dat het werven van ouderen voor zelfmanagementtaken mogelijk is door een goede wervingsstrategie. Daarnaast leerden we dat tussentijdse evaluaties van het wervingsproces de werving positief kan beïnvloeden. Dit geeft namelijk de mogelijkheid om te voorkomen dat er onnodige tijd en moeite wordt gestopt in strategieën die geen deelnemers opleveren en er juist meer energie gaat naar het uitbreiden van goed werkende strategieën.

Drie simpele mobiliteitstesten voor het monitoren van kwetsbaarheid, mobiliteit en valrisico

Een belangrijke stap in de ontwikkeling van een zelftest voor zelfmanagement van valrisico is het bekijken welke testen hiervoor in aanmerking komen. Dit staat in hoofdstuk 3 beschreven. Hoofdstuk 3a start met de drie mogelijke zelftesten, te weten de maximale staplengte, de loopsnelheid en de stoeltest, en beschrijft in hoeverre deze testen kwetsbaarheid bij ouderen kunnen voorspellen. Hiervoor is bij 593 thuiswonende ouderen een volledig geriatrisch onderzoek uitgevoerd, waarbij tevens deze drie mogelijke zelftesten zijn afgenomen. De uitvoerbaarheid van de drie testen was goed: bij 91-99% van de thuiswonende ouderen konden de testen worden uitgevoerd. Ook hadden de drie testen een goede voorspellende waarde voor kwetsbaarheid, waarbij die van de loopsnelheid het beste was.
Hoofdstuk 3b beschrijft of de maximale staplengte en loopsnelheid toekomstig vallen kunnen voorspellen. Uit de eerder genoemde onderzoekspopulatie van hoofdstuk 3a zijn 352 ouderen één jaar lang gevolgd met de valtelefoon. Hiermee konden de ouderen wekelijks aangeven of ze gevallen waren en zo ja, hoe. Gedurende die periode vonden er 285 vallen plaats bij 39% van de deelnemende ouderen. Een grotere maximale staplengte ging gepaard met een lagere waarschijnlijkheid om te vallen. Echter, de voorspellende waarde van zowel de maximale staplengte als de loopsnelheid was laag voor toekomstig vallen en werd iets beter voor het voorspellen van herhaaldelijk vallen.

Herhaaldelijk zelf thuis de maximale staplengte en loopsnelheid meten

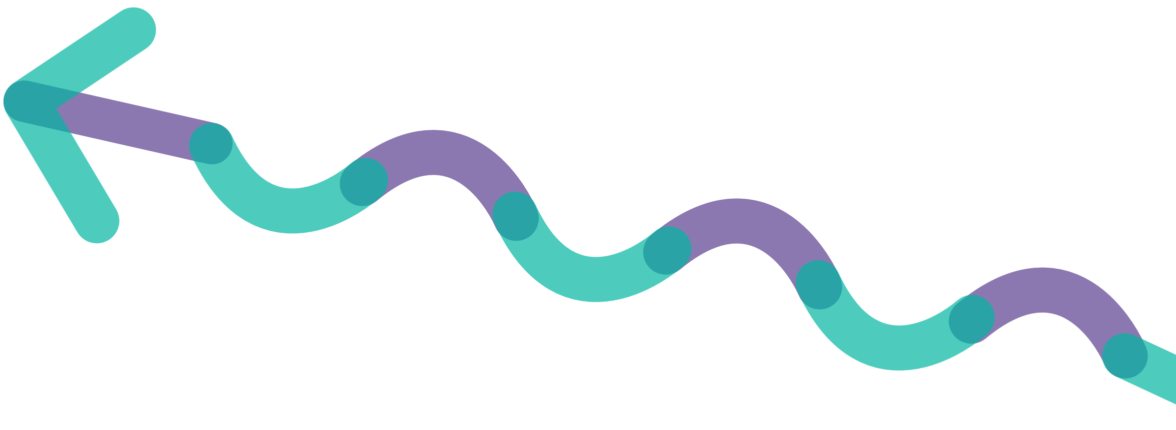
Behalve dat een zelftest voor vallen een goede voorspellende waarde moet hebben, moet de test ook haalbaar, betrouwbaar en veilig zijn in gebruik. Bij 56 thuiswonende ouderen zijn de zelftesten ook onderzocht op deze eigenschappen en dit staat beschreven in hoofdstuk 4a. Vergeleken met de andere twee mogelijke zelftesten gaf de maximale staplengte de meeste goede metingen (77,6%) en kwamen de gemeten uitkomsten voor deze test steeds het meest overeen met die van de week ervoor. Zowel maximale staplengte als loopsnelheid lieten geen verbetering (training) zien in de eerste maand waarin zij werden gebruikt, wat aangeeft dat beide testen betrouwbaar zijn. Deze resultaten toonden aan dat de maximale staplengte en de loopsnelheid betrouwbaar uitgevoerd kunnen worden door thuiswonende ouderen.
Dezelfde 56 thuiswonende ouderen beschreven in hoofdstuk 4a, hadden ook toegezegd om een half jaar lang thuis hun maximale staplengte en loopsnelheid te meten. In hoofdstuk 4b hebben we gekeken of dit ook mogelijk is en vonden dat het trouw blijven gebruiken van de testen goed was voor beide testen. Wel lieten beide testen een kleine verbetering zien gedurende de zes maanden, iets dat kan wijzen op een trainingseffect, maar dit had geen invloed op vallen. Het zelf managen van mobiliteit en valrisico zorgde gelukkig niet voor een verhoging van het aantal vallen. Dit alles liet zien dat de meeste thuiswonende ouderen zelf veilig en herhaaldelijk deze testen kunnen en willen gebruiken.

Het zelf monitoren van mobiliteit in een zelfmanagement valpreventieprogramma

Uit ons onderzoek bleek dat de loopsnelheid de meeste potentie had om doorontwikkeld te worden tot een zelfmanagementinstrument voor het monitoren van valrisico. De loopsnelheid test is daarom door ons doorontwikkeld tot de “loopmeter”, een fotolijstje waarmee de oudere thuis zelf zijn/haar eigen loopsnelheid kan meten. In totaal hebben 86 thuiswonende ouderen, ouderen wonend in een verzorgingshuis en ouderen die regelmatig het buurthuis bezoeken, meegedaan in ons vervolgonderzoek, waarbij de helft de loopmeter thuis ging gebruiken als onderdeel van een valpreventieprogramma. Alle deelnemende ouderen zijn zes maanden gevolgd. We hebben daarbij onderzocht in hoeverre deelname aan het valpreventieprogramma invloed had op de ervaren gezondheid en het valrisico van ouderen. Het valrisico daalde niet door het gebruik van de loopmeter. De ervaren gezondheid van de groep die de loopmeter gebruikte, veranderde niet, terwijl de ervaren gezondheid in de groep zonder loopmeter, juist minder werd. Er waren weinig uitvallers (9,3%). Helaas wilden weinig mensen die regelmatig in een buurthuis komen, meedoen aan het onderzoek. Het trouwe gebruik van de loopmeter was goed. Dit alles toont aan dat het zelf monitoren van mobiliteit in een valpreventieprogramma acceptabel, haalbaar en veilig is voor thuiswonende ouderen en ouderen wonend in een verzorgingshuis.

Concluderend

Persoonlijke zelfmanagementinterventies zijn essentieel voor een verbetering van zorg, welzijn en wonen in een vergrijzende en steeds mondiger wordende samenleving. In de nabije toekomst moeten clinici en onderzoekers hun focus verleggen van het alleen maar zorgen voor en onderzoeken van een patiënt, naar het actief stimuleren en het in staat stellen van de patiënt om actief met zijn/haar gezondheid aan de slag te gaan en dit ook zelf te evalueren. Verscheidene innovatieve instrumenten worden op dit moment ontwikkeld voor het zelfmanagement van vallen en het onder controle krijgen, en zo mogelijk verminderen, van het valrisico. Onze loopmeter is daarvan een innovatief en bruikbaar voorbeeld, en het zal niet lang duren voordat veel meer van deze instrumenten beschikbaar komen in de reguliere gezondheidszorg. Kortom, interventies met en onderzoek van zelfmanagementstrategieën bij ouderen hebben de toekomst. Dit proefschrift probeert een zekere eerste stap op dit terrein te zetten, zonder in methodologische valkuilen te trappen.

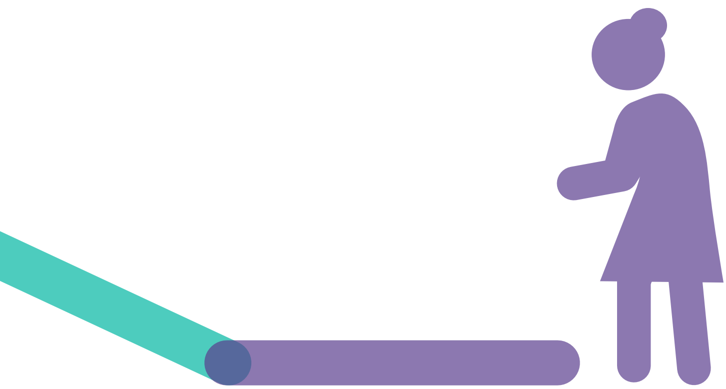


CHAPTER 8

DANKWOORD | ACKNOWLEDGEMENTS

CURRICULUM VITAE

LIST OF PUBLICATIONS



DANKWOORD | ACKNOWLEDGEMENTS

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CURRICULUM VITAE

Kim Bongers werd geboren op 19 juli 1986 in Arnhem. In 2004 behaalde zij haar gymnasium diploma aan het Canisius College te Nijmegen. Vervolgens rondde zij de bachelor opleiding Biomedische wetenschappen (2008) en de masteropleiding Bewegingswetenschappen (2010) af aan de Radboud Universiteit Nijmegen. In 2011 startte zij als promovenda op de afdeling Geriatrie van het Radboudumc in Nijmegen binnen één van de onderzoeksprojecten van het Nationaal Programma Ouderenzorg, te weten 'de Senior Stap Studie', waarvan de resultaten in dit proefschrift staan beschreven. Sinds april 2016 is Kim werkzaam als kwaliteitsmedewerker bij thuiszorgorganisatie Interzorg Thuiszorg te Oss en Nijmegen.

Kim Bongers was born on July 19, 1986 in Arnhem, the Netherlands. In 2004 she graduated from secondary school 'Canisius College' in Nijmegen, the Netherlands. She subsequently received her Bachelor's degree in Biomedical Sciences (2008) and her Master's degree in Clinical Human Movement Sciences (2010) at the Radboud University Nijmegen. In 2011 she started as a PhD-student on the 'Senior Step Study' at the department of Geriatric Medicine of the Radboud University Medical Center Nijmegen. The results of this research are presented in this thesis. In April 2016, Kim started working as a quality staff member for Interzorg Thuiszorg, a home care organisation located in Oss and Nijmegen.

LIST OF PUBLICATIONS

Kim Bongers, Yvonne Schoon, Marcel Olde Rikkert. Self-monitoring of mobility in a self-management fall prevention program is acceptable, feasible and safe in older persons. *Submitted*

Kim Bongers, Yvonne Schoon, Marcel Olde Rikkert. Self-management tasks to improve mobility and reduce fall risk are not leading to lower research participation in older adults. *Submitted*

Kim Bongers, Yvonne Schoon, Marcel Olde Rikkert. Feasibility of repeated self-measurements of maximum step length and gait speed by community-dwelling older persons. *BMJ Open. 2016;6(8):e011538*

Kim Bongers, Yvonne Schoon, Maartje Graauwmans, Marlies Hoogsteen-Ossewaarde, Marcel Olde Rikkert. Safety, feasibility and reliability of the maximal step length, gait speed and chair test measured by seniors themselves: the Senior Step Study. *J Aging Phys Ac 2015;23(3):438-43*

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Yvonne Schoon, **Kim Bongers**, Janneke van Kempen, René Melis, Marcel Olde Rikkert. Gait speed as a test for monitoring frailty in community-dwelling older people has the highest diagnostic value compared to step length and chair rise time. *Eur J Phys Rehabil Med 2014;50(6):693-701*