Self-monitoring of Physical Frailty; a Proactive Approach in Community-dwelling Elderly People

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***Abstract*—The main objective of the dissertation was to develop and evaluate a self-monitoring and feedback system that can be used by community-dwelling elderly people to gain insight into (changes in) indicators of physical frailty that are predictors of increased risk of disability. To achieve this, the following research questions were addressed: 1) What is the predictive value of physical frailty indicators on disability in community-dwelling elderly people?, 2) Can simple, innovative technologies be used to obtain valid and reliable estimates of physical frailty indicators?, and 3) How can simple, innovative technologies be integrated into a self-monitoring system that provides regular feedback to elderly people regarding (changes in) physical frailty indicators? The studies described in the dissertation show that physical frailty indicators (e.g., physical activity, weight, grip strength, balance) are predictive of disability development in community-dwelling elderly people. Simple, innovative technologies that can be used by elderly people to obtain valid and reliable estimates of these indicators are a bathroom scale that can measure weight and balance, a Grip-ball that can measure grip strength, and a smartphone that can measure the amount of daily physical activity. These devices were incorporated into a self-monitoring and feedback system during a user-centered design process. Small scale usability tests and a pilot study show that the system satisfied most needs of the end users and, despite a few technical errors, elderly people considered the system easy-to use which resulted in good adherence to the daily monitoring regimen.**

Keywords- frailty; elderly people; physical functioning, telemonitoring; self-management

I. INTRODUCTION

The number of frail elderly people is increasing in the Netherlands and other Western societies [1]. Frail elderly people have an increased risk of adverse health outcomes such as disability, fall incidents, hospitalization, institutionalization and even death compared to non-frail elderly people [2]-[4]. As a consequence, frailty is also strongly associated with increased use of (informal) healthcare and community services [5] [6].

A difficulty in offering interventions to (frail) community-dwelling elderly people aimed at disability prevention or reduction is to identify people who might benefit most from such programs at a stage that disability is not yet present or still reversible. Various methods are currently being used to screen elderly people in the community to determine their level of frailty; and with that their eligibility for participation in preventive intervention programs since frailty is considered to be a state of pre-disability [7]. Most frequently used screening methods are self-report questionnaires, checklists used by care professionals (sometimes including physical performance tests), and clinical judgment of care professionals [8] [9]. Disadvantages of these screening methods are that the decision to offer a preventive intervention program is based on a single cross-sectional assessment of frailty, that the number of false-positive classifications is too high [10], and that screening methods are often not part of daily routine in primary care [11]. Finally, and more importantly, the current top-down approach in which care professionals decide whether preventive interventions should be started based on the outcome of a frailty screening instrument, does not facilitate the participation of frail elderly people in making decisions regarding their own health care. This is unfortunate since involvement of elderly people in their own care process can empower them and improve patient outcomes [12] [13]. The increasing uptake of every day technologies, such as smartphones, computers, and internet among elderly people and in health care, creates opportunities to support elderly people in their own health behaviors and involve them in the care process [14].

The main objective of this thesis is to develop and evaluate a self-monitoring and feedback system that can be used by community-dwelling elderly people to gain insight into (changes in) indicators of physical frailty that are predictors of increased risk of disability. To achieve this, the following research questions are addressed:

1. What is the predictive value of physical frailty indicators on disability in community-dwelling elderly people?
2. Can simple, innovative technologies be used to obtain valid and reliable estimates of physical frailty indicators?
3. How can simple, innovative technologies be integrated into a self-monitoring system that provides regular feedback to elderly people regarding (changes in) physical frailty indicators?

II. Predictive value physical frailty indicators

A systematic review and longitudinal study with one year follow-up were conducted to study the predictive value of physical frailty indictor, such as weight, gait speed, balance, physical activity, grip strength, and exhaustion, on disability development in older adults aged above 65 years.

A. *Systematic literature review*

A systematic search was performed in 3 databases (PubMed, CINAHL, and EMBASE) from January 1975 until April 2010. Prospective, longitudinal studies that assessed the predictive value of individual physical frailty indicators on disability in Activities of Daily Living (ADL) in community-dwelling elderly people aged 65 years and older were eligible for inclusion. Articles were reviewed by two independent reviewers who also assessed the quality of the included studies. After initial screening of 3081 titles, 360 abstracts were scrutinized, leaving 64 full text articles for final review. Eventually, 28 studies were included in the review. The methodological quality of these studies was rated by both reviewers on a scale from 0 to 27. All included studies were of high quality with a mean quality score of 22.5 (SD 1.6). Findings indicated that physical frailty indicators can predict ADL disability in community-dwelling elderly people. Slow gait speed and low physical activity/exercise seem to be the most powerful predictors followed by weight loss, lower extremity function, balance, muscle strength, and other indicators. These findings should be interpreted with caution because the data of the different studies could not be pooled due to large variations in operationalization of the indicators and ADL disability across the included studies. Nevertheless, the review suggests that monitoring physical frailty indicators in community-dwelling elderly people might be useful to identify elderly people who could benefit from disability prevention programs [15].

B. *Longitudinal study*

The aim of this one-year follow-up study was to investigate the predictive value of self-reported decline in weight, exhaustion, walking difficulty, grip strength and physical activity on development of disabilities in community-dwelling elderly people. Community-dwelling elderly people aged 70 years or older were recruited via four Dutch general practitioners. 687 participants received a questionnaire at baseline regarding weight loss, exhaustion, walking difficulty, grip strength, physical activity, and disability. The same questionnaire was sent to them after one year follow-up. Disability was operationalized in two ways: as increased dependence and as increased difficulty in daily activities. Univariate and multivariate logistic regression analyses were used to determine whether self-reported decline in five physical indicators at baseline predicted development of dependence or increased difficulty in daily activities after 1 year. The analyses were controlled for age, gender and baseline disability. 401 participants with a mean age of 76.9 years (SD 5.2) were included in the analyses. 84 of them reported increased dependence (21%) and 76 reported increased difficulty (19%) in daily activities after one year follow-up. All physical indicators, except weight loss, were significant univariate predictors of disability. Multivariate analyses revealed that self-reported decrease in physical activity (e.g., walking, cycling, gardening) was a significant predictor of development of dependence (OR = 1.89, 95% CI = 1.02-3.51) and development of difficulty (OR = 1.98, 95% CI = 1.05-3.71) in daily activities. Based on the findings from this study, it can be concluded that community-dwelling elderly people who report decreased physical activity have a higher risk to develop disability after 1-year follow-up [16].

III. Validity and reliability of self-monitoring technologies

Four studies were conducted to evaluate the validity and reliability of balance measurements conducted with a modified bathroom scale, grip strength measurements conducted with a Grip-ball, and physical activity measurements conducted with a smartphone-based activity monitoring application. These validation studies have revealed that simple self-monitoring technologies can be used to provide valid and reliable estimates of indicators of physical frailty in community-dwelling elderly people.

A. *Balance measurements of a bathroom scale*

Validity and reliability of balance measurement of a modified bathroom scale were studied during a cross-sectional study and a six-month follow-up study. The aim of the cross-sectional study was to investigate the construct validity of a bathroom scale measuring balance in elderly people. Participants for this study were recruited via nursing homes and an organization that provides exercise classes for community-dwelling elderly people. Eligibility criteria for both groups were: aged 65 years or older and being able to step onto a bathroom scale independently. The balance measurements of the bathroom scale were compared to the following three clinical balance measurements that were conducted by a geriatric physiotherapist: Performance Oriented Mobility Assessment (POMA), Timed Up and Go (TUG), and Four Test Balance Scale (FTBS). An independent samples t-test was performed to determine whether nursing home patients scored lower on these four balance tests compared to community-dwelling elderly people. Correlations were calculated between the bathroom scale balance scores and those of the clinical balance tests for nursing home patients and community-dwelling elderly people separately. Forty-seven nursing home patients with a mean age of 81 years (SD 6.40) and 54 community-dwelling elderly people with a mean age of 76 years (SD 5.06) participated in the study. The results showed that nursing home patients had significantly lower scores on all four balance tests compared to community-dwelling elderly people. Correlations between the bathroom scale scores and the POMA, TUG, and FTBS in nursing home patients were all significant: .49, -.60, and .63 respectively. These correlations were not significant in active community-dwelling elderly people, -.04, -.42, and .33 respectively. Linear regression analyses showed that the correlations for the bathroom scale and POMA, bathroom scale and TUG, and bathroom scale and FTBS did not differ statistically between nursing home patients and community-dwelling elderly people. These results suggest that the modified bathroom scale is useful for measuring balance in elderly people. However, the added value of this assessment method for clinical practice remains to be demonstrated [17].

The aim of the six-month follow-up study was to study the relation between balance scores of a modified bathroom scale and falls and disability in a sample of older adults. Participants were recruited via physiotherapists working in a nursing home, geriatricians, exercise classes, and at an event about health for older adults. Inclusion criteria were similar to the cross-sectional study described above. Forty-one nursing home patients and 139 community-dwelling older adults stepped onto the modified bathroom scale 3 consecutive times at baseline to measure their balance. Their mean balance score on a scale from 0 to 16 was calculated; higher scores indicated better balance. Falls and disability were measured at baseline and after 6-months follow-up using questionnaires. The cross-sectional relation between balance and falls and disability at baseline was studied using t-tests and Spearman correlations. Univariate and multivariate logistic regression analyses were conducted to study the relation between balance measured at baseline and falls and disability development after 6 months follow-up. Hundred twenty-eight participants with complete data sets (25.8% male, 24 nursing home patients) and a mean age of 75.33 years (SD 6.26) were included in the analyses of this study. Balance scores of participants who reported at baseline that they had fallen at least once in the past 6 months were lower compared to non-fallers, 8.9 and 11.2 respectively ($P < .001$). The correlation between mean balance score and disability sumscore at baseline was -.51 ($P < .001$). No significant associations were found between balance at baseline and falls after 6 months follow-up. Baseline balance scores were significantly associated with the development of disability after 6-months follow-up in the univariate analysis (OR = .86, 95% CI = .76-.98) but not in the multivariate analysis when correcting for age, gender, and baseline disability (OR = .95, 95% CI =.80-1.12). Therefore, it can be concluded that there is a cross-sectional relation between balance measured by a modified bathroom scale and falls and disability in older adults. Despite this cross-sectional relation, longitudinal data showed that balance scores have no predictive value for falls and might only have limited predictive value for disability development after 6-months follow-up.

B. Grip strength measurements of a Grip-ball

The purpose of this cross-sectional study was to evaluate the reliability and validity of grip strength measurements obtained with a Grip-ball in older adults. Forty nursing home patients and 59 community-dwelling older adults aged 60 years or older were invited to participate in this study. Grip strength in both hands was measured 3 consecutive times during a single visit using the Grip-ball and Jamar dynamometer. Test-retest reliability was described using Intraclass Correlation Coefficients (ICCs). Concurrent validity was evaluated by calculating Pearson's correlations between the mean Grip-ball and Jamar dynamometer measurements and between the highest measurement out of 3 trials. Known-groups validity was studied using t-tests. Eighty eight participants (33 men) with a mean age of 75 years old (SD 6.8) were included in this study. ICCs for the Grip-ball were .97 and .96 for the left and right hand respectively ($P<.001$). ICCs for the Jamar dynamometer were .97 and .98 for the left and right had respectively ($P<.001$). Pearson's correlations between the mean scores of the Grip-ball and Jamar dynamometer were .71 ($P <.001$) and .76 ($P <.001$) for the left and right hand respectively. Pearson's correlations between the highest scores out of 3 trials were .69 ($P <.001$) and .78 ($P <.001$) for the left and right hand respectively. T-tests revealed that the Grip-ball and Jamar dynamometer both detected grip strength differences between men and women, and not between nursing home patients and community-dwelling older adults. Grip-ball measurements did not confirm higher grip strength of the dominant hand whereas the Jamar dynamometer did. Based on these finding, the conclusion an be drawn that the Grip-ball provides reliable grip strength estimates in older adults. Correlations found between the Grip-ball and the Jamar dynamometer measurements suggest acceptable concurrent validity. The Grip-ball seems capable of detecting 'larger' grip strength differences but might have difficulty detecting 'smaller' differences that were detected by the Jamar dynamometer. The Grip-ball could be used in practice to enable home-based self-monitoring of grip strength in older adults. However, for the implementation of the Grip-ball as a screening and monitoring device in practice, it is important to gain insight into intersession reliability during home-based use of the Grip-ball and clinical relevance of changes in grip strength.

C. Measuring physical activity with a smartphone

Since smartphones are equipped with built-in accelerometers they can be used for self-monitoring of physical activity which is an important health behavior and predictor of functioning, especially in older adults. The objective of this study is to investigate the validity of a smartphone-based activity monitoring application in adults aged below and above 65 years old. Ten adults aged below 65 years and ten adults aged 65 years or older were asked to monitor their daily physical activity with a smartphone and an ActiGraph GT3X for 7 consecutive days. Spearman correlations between the counts per minute of the two devices were calculated for adults aged below and above 65 years separately. For both devices, each monitored minute was classified into four categories of activity intensity based on the counts per minute: sedentary, light, moderate, and high activity intensity. Association and agreement between the two devices was analyzed using Pearson's correlations, paired t-tests and Bland-Altman plots. Data from 8 adults aged below 65 years and 7 adults aged above 65 years could be included in the analyses due to malfunctioning of the Actigraph GT3X (n=3) or smartphone (n=1) or due to usability problems with the smartphone-based application that had to be operated to monitor activity (n=1). Spearman correlations between the counts per minute of the smartphone and the ActiGraph were .76 and .84 for adults aged below and above 65 years respectively. Pearson's correlations between the two devices for total number of minutes spent in different activity intensity categories per day per participant were high in both groups (range .79-.99). Paired t-tests and Bland-Altman plots revealed that the smartphone underestimates the number of sedentary minutes per day in participants aged below and above 65 years with 5.74% and 6.35% respectively compared to the ActiGraph. In addition, the smartphone overestimated the number of minutes spent at moderate intensity in adults aged below 65 years by indicating almost twice as many minutes spent in this activity intensity category compared to the Actigraph. Furthermore, the number of minutes spent at light activity intensity in adults aged above 65 years was overestimated with 8.22% by the smartphone compared to the ActiGraph. In conclusion, the activity monitoring application needs to be optimized before it can be implemented in practice. Concurrent validity of the smartphone-based activity monitoring application was better in adults aged above 65 years compared to adults aged below 65 years. Differences seem to exist between individual participants.

IV. USER-CENTERED DEVELOPMENT AND TESTING OF THE MONITORING AND FEEDBACK SYSTEM

The modified bathroom scale, Grip-ball, and smartphone were integrated into a monitoring and feedback system in close collaboration with elderly people and care professionals during a User-Centered Design (UCD) process. The iterative user-centered development process consisted of the following phases: (1) Selection of user representatives; (2) Analysis of users and their context; (3) Identification of user requirements; (4) Development of the interface; and (5) Evaluation of the interface in the lab. Subsequently, the monitoring and feedback system was tested in a pilot study by five patients who were recruited via a geriatric outpatient clinic. Participants used a bathroom scale to monitor weight and balance, and a mobile phone to monitor physical activity on a daily basis for six weeks. Personalized feedback was provided via the interface of the mobile phone. Usability was evaluated on a scale from 1 till 7 using a modified version of the Post-Study System

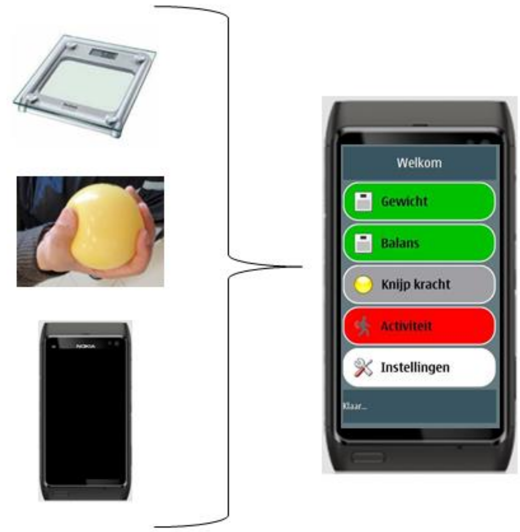

Figure 1: The monitoring and feedback system

Usability Questionnaire (PSSUQ); higher scores indicated better usability. Interviews were conducted to gain insight into the experiences of the participants with the system. The developed interface uses colors, emoticons, and written and/or spoken text messages to provide daily feedback regarding (changes in) weight, balance, and physical activity. Figure 1 shows a screenshot of the interface. Participants of the pilot-study rated the usability of the monitoring and feedback system with a mean score of 5.2 (SD .90) on the modified PSSUQ. The interviews revealed that elderly people were able to use the system and appreciated the feedback that was provided to them. The monitoring and feedback system satisfied most needs and preferences of the elderly people and, despite a few technical errors that occurred during the pilot study which annoyed the users and sometimes caused confusion, they considered the system easy-to-use which resulted in good adherence to the daily monitoring regimen. It can be concluded that involvement of elderly users during the development process resulted in an interface with good usability. However, the technical functioning of the monitoring system needs to be optimized before it can be used to support elderly people in their self-management [18].

Collaboration with end-users during user-centered design (UCD) of telecare products as described above can help to take the needs and requirements of potential end-users into account during the development of innovative telecare products and services. However, this multidisciplinary collaboration often poses challenges to the persons involved. Understanding how members of multidisciplinary development teams experience the UCD process might help to gain insight into factors that members with different backgrounds consider critical during the development of telecare products and services. Therefore, a qualitative study that was conducted to gain insight into experiences of 25 members of multidisciplinary development teams of four different Research & Development (R&D) projects during the UCD process of telecare products and services. The R&D projects aimed to develop telecare products and services that can support self-management in elderly people or patients with chronic conditions. Seven participants of this study were representatives of end-users (elderly persons or patients with chronic conditions), three were professional end-users (geriatrician and nurses), five were engineers, four were managers (of R&D companies or engineering teams), and six were researchers. All participants were interviewed by a researcher who was not part of their own development team. The following topics were discussed during the interviews: aim of the project, role of the participant, experiences during the development process, points of improvement, and what the project meant to the participant. These interviews revealed that multidisciplinary collaborations can be challenging and that various barriers and facilitators influenced the development process. Multidisciplinary team members from different backgrounds often experience similar barriers (e.g., different members of the development team speak a 'different language') and facilitators (e.g., team members should voice expectations at the start of the project to prevent miscommunication at a later stage). However, some barriers and facilitators are only experienced by stakeholders who share a similar background (e.g., only managers of R&D companies experience that differences of opinion about a business case is a barrier and only end-users express that the project manager has an important facilitating role in end-user participation). Insights into these similarities and differences can improve understanding between team members from different backgrounds which optimizes collaboration during the user-centered development of telecare products and eHealth applications that support care and wellbeing [19].

V. Discussion and Recommendations

The studies described in the dissertation show that physical frailty indicators (e.g., weight, balance, grip strength, and physical activity,) are predictive of disability development in community-dwelling elderly people and that simple, innovative technologies can be incorporated in a self-monitoring and feedback system that elderly people can use to obtain valid and reliable estimates of (changes in) these indicators. Based on the research presented in this dissertation, the self-monitoring and feedback system was further optimized so that it can be used by community-dwelling elderly people to gain insight into (changes in) indicators of their physical functioning. This could support and facilitate a more pro-active approach in early detection of increased risk for disability with a stronger focus on self-management. The system, or its separate parts, can be used by elderly people with different levels of physical functioning as long as they are able to learn how to use the system, which makes it less applicable for elderly people with cognitive deficits.

Based on the current (lack of) knowledge regarding the variability of indicators of physical functioning and the clinical relevance of changes in such indicators, feedback can now only be based on current guidelines of healthy/normal weight, grip strength, and physical activity. Since the modified bathroom scale is a new measuring instrument for which no guidelines are available, feedback regarding balance is currently more difficult to interpret compared to the other indicators that are measured by the self-monitoring system. The disadvantage of using current guidelines to provide feedback is that these guidelines are mostly reactive. They only signal changes in indicators of physical functioning when they are already below the cutoff point for 'healthy' or 'normal' functioning. Due to this, current guidelines might not stimulate a pro-active approach. Furthermore, separate guidelines exist for separate indicators of physical functioning which does not facilitate interpretation the combination (of changes in) indicators that are present in one person. A possible strength of the self-monitoring and feedback system could be that the combination of four physical frailty indicators is taken into account which makes it possible to detect changes in multiple indicators at once.

Some elderly persons might prefer to use the system independent of professional care processes whereas others, for example those who already have lower physical functioning, might use the system in a care context with support of care professionals. In case of the latter, a database should be developed in which the self-monitoring data of the elderly person can be stored and presented to a care professional. This database should be seamlessly embedded in the care process and should communicate with existing information infrastructures of involved care professionals. Depending on the care context and purpose with which the monitoring and feedback system is being used, the monitoring regimen that elderly persons choose to follow can differ.

The system can be integrated with other care technologies or services that support health and independent living in community-dwelling elderly people. Examples of such technologies could be Ambient Assisted Living (AAL) technologies (e.g., sensors for fall detection or detection of activity), health risk appraisal services, or services that provide interventions that support people in maintaining an active lifestyle or improving physical functioning. Such integrated pro-active systems can support independence in older persons. However, in order for such integrated systems to succeed, new business models should be developed in which the costs and benefits of such interventions for different stakeholders are specified. Such business cases are needed to facilitate implementation of innovations.

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Before the self-monitoring and feedback system can be implemented in practice, future research is needed regarding several issues. Currently, a study is being conducted in which 13 community-dwelling elderly people use the optimized monitoring and feedback system on a daily basis for 6 months independent of a care context. This study will provide insight into the long-term experiences and acceptance of the system. Furthermore, information will be collected regarding falls, disability, illness, health care use, and physical functioning using questionnaires, diaries, and bi-monthly examinations by a geriatric physical therapist. Combining this information with the self-monitoring data that was collected by community-dwelling elderly people using the self-monitoring and feedback system will provide insight into how the home-based self-monitoring measurements can be interpreted and into the clinical relevance of changes that are detected. Besides the ongoing feasibility study, future research should focus on the clinical relevance of changes in (a combination of) indicators of physical frailty that predict disability development should be studied. Large scale cohort studies can provide insight into the development of such indicators in elderly people over time. Big data or data mining methodologies could be used to identify patterns or pathways that lead to adverse outcomes. Furthermore, ways to integrate the system in daily care (or welfare) routines should be explored. Different organizations and elderly users of the system might have different requirements for this integration. Needs and preferences of elderly persons and professionals working in such organizations should be taken into account. Finally, the possibilities to provide training and/or tailored disability prevention programs to community-dwelling elderly people using the system to support them in their self-management should be examined. Such research should also focus on (cost-)effective components of such interventions. Physical activity might be considered a relevant component of such training or intervention programs since it is an important health behavior for preventing and reducing disability. Further exploration and improved understanding of the issues mentioned above can support the implementation of the self-monitoring and feedback system in practice which might facilitate a more proactive approach regarding frailty and disability prevention in community-dwelling elderly people.

REFERENCES

[1] United Nations. World Population Ageing 2009. New York: United Nations, 2010.

[2] K. E. Ensrud, et al, "A comparison of frailty indexes for the prediction of falls, disability, fractures, and mortality in older men," J Am Geriatr Soc, vol 57, 2009, pp. 492-498, doi: 10.1111/j.1532-5415.2009.02137.x.

[3] L. P. Fried, et al, "Frailty in older adults: evidence for a phenotype," J Gerontol A Biol Sci Med Sci, vol. 56, 2001, pp. M146-156.

[4] M. D. Rothman, L. Leo-Summers, and T. M Gill, "Prognostic significance of potential frailty criteria," J Am Geriatr Soc, vol. 56, 2008, pp. 2211-2116, doi: 10.1111/j.1532-5415.2008.02008.x

[5] S. Rochat, et al, "Frailty and use of health and community services by community-dwelling older men: the concord health and ageing in men project.,"Age Ageing, vol. 1, 2010, pp. 1-6, doi: 10.1093/ageing/afp257

[6] S. Hoeck, G. Francois, J. Geerts, J. van der Heyden, M. Vandewoude, and G. van Hal, "Health-care and home-care utilization among frail elderly persons in Belgium," Eur J Public Health, vol 22, 2012, pp. 671-677.

[7] G. Abellan an Kan, Y. Rolland, H. Bergman, J. E. Morley, S. B. Kritchevsky, and B. Vellas, "The I.A.N.A. Task Force on frailty assessment of older people in clinical practice," J Nutr Health Aging, vol. 12, 2008, pp. 29-37.

[8] T. Pialoux, J. Goyard, and B. Lesourd, "Screening tools for frailty in primary health care: a systematic review," Geriatr Gerontol Int, vol. 12, 2012, pp. 189-197, doi: 10.1111/j.1447-0594.2011.00797.x

[9] S. A. Sternberg, A. Wershof Schwartz, S. Karunananthan, H. Bergman, and A. Mark Clarfiels, "The identification of frailty: a systematic literature review," J Am Geriatr Soc, vol. 59, 2011, pp. 2129-2138, doi: 10.1111/j.1532-5415.2011.03597.x

[10] E. Pijpers, I. Ferreira, C. D. A. Stehouwer, and A. C. Nieuwenhuijzen Kruseman, "The frailty dilemma. Review of the predictive accuracy of major frailty scores," Eur J Inter Med, vol. 23, 2012, pp. 118-123, doi: 10.1016/j.ejim.2011.09.003

[11] B. Vellas, et al, "Looking for frailty in community-dwelling older persons: the Gérontopôle Frailty Screening Tool (GFST)," J Nutr Health Aging, vol. 17, 2013, pp. 629-631, doi: 10.1007/s12603.

[12] H. De Haes, "Dilemmas in patient centeredness and shared decision making: a case for vulnerability," Patient Educ Couns, vol. 62, 2006, pp. 291-298.

[13] S. J. Grifin, A. L. Kinmonth, M. W. Veltman, S. Gillard, J. Grant, and M. Stewart, "Effect on health-related outcomes of interventions to alter the interaction between patients and practitioners: a systematic review of trials," Ann Fam Med, vol. 2, 2004, pp. 595-608.

[14] A. Piau, E. Campo, P. Rumeau, B. Vellas, and F. Nourhashemi, "Aging society and gerontechnology: a solution for an independent living?" J Nutr Health Aging, vol 18, 2014, pp. 97-112, doi: 10.1007/s12603

[15] J. Vermeulen, J. C. L. Neyens, E. Van Rossum, M. D. Spreeuwenberg, and L. P. De Witte, "Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review," BMC Geriatr, vol. 11, 2011, pp. 33, doi: 10.1186/1471-2318-11-33

[16] J. Vermeulen, M. D. Spreeuwenberg, R. Daniëls, J. C. L. Neyens, E. Van Rossum, and L. P. De Witte, "Does a falling level of activity predict disability development in community-dwelling elderly people?" Clin Rehabil, vol. 12, 2012, pp. 1-9, doi: 10.1177/0269215512465209

[17] J. Vermeulen, J. C. L. Neyens, M. D. Spreeuwenberg, E. Van Rossum, J. Duchene, D. J. Hewson, L. P. De Witte, "Construct validity of a modified bathroom scale that can measure balance in elderly people," J Am Med Dir Assoc, vol. 13, 2012, pp. e1-5, doi: 10.1016/j.jamda.2012.06.009

[18] J. Vermeulen, J. C. Neyens, M. D. Spreeuwenberg, E. van Rossum, W. Sipers, H. Habets, D. J. Hewson, and L. P. de Witte, "User-centered development and testing of a monitoring system that provides feedback regarding physical functioning to elderly people", Patient Prefer. Adherence, vol. 7, 2013, pp. 843-854, doi: 10.2147/PPA.S45897

[19] J. Vermeulen, R. Verwey, L. M. J. Hochstenbach, S. van der Weegen, Y. P. Man, and L. P. de Witte LP, "Experiences of Multidisciplinary Development Team Members During User-Centered Design of Telecare Products and Services: A Qualitative Study," J Med Internet Res, vol. 16, 2014, pp. e124, doi 10.2196/jmir.31