ICT-Supported Interventions Targeting Pre-frailty: Healthcare Recommendations from the Personalised ICT Supported Service for Independent Living and Active Ageing (PERSSILAA) Study

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Abstract. As society ages, healthcare systems are preparing for an increasing prevalence of frail, co-morbid and older community-dwellers at risk of adverse outcomes including falls, malnutrition, hospitalisation, institutionalisation and death. Early intervention is desirable and pre-frailty, before onset of functional decline, may represent a suitable transition stage to target, albeit evidence for reversibility and appropriate interventions are limited. No consensus on the definition, diagnosis or management of pre-frailty exists. This work describes 25 healthcare related findings from the recently completed PERsonalised ICT Supported Service for Independent Living and Active Ageing (PERSSILAA) project, funded under the 2013–2016 European Union Framework Programme 7 (grant #610359). PERSSILAA developed a comprehensive Information and Communication Technologies (ICT)-supported platform to screen, assess, intervene and then monitor community-dwellers in two regions (Enschede in the Netherlands and Campania in Italy) in order to address pre-frailty and promote active and healthy ageing, targeting three important pre-frailty subdomains: nutrition, cognition and physical function. Proposed definitions of pre-frailty, ICT-based approaches to screen and monitor for the onset of frailty and targeted management strategies employing technology across these domains are described. The potential of these 25 healthcare recommendations in the development of future European guidelines on the screening and prevention of frailty is explored.

Keywords: Pre-frailty · Frailty · Information and communication technology
Healthcare recommendations · Guidelines

1 Introduction

Recent trends associated with demographic ageing have resulted in an increased prevalence of older adults, aged >65 years [1]. With this, health and social care providers and policy makers are recognising a higher prevalence of frailty in community-dwelling older adults [2]. Although no consensus definition of frailty is accepted, most consider it to be a multi-factorial, age-associated loss of physiological reserve

characterised by an increased vulnerability to stressors that results in a propensity for adverse healthcare outcomes [3–6]. Estimates of prevalence differ depending on the population studied, sampling strategy employed and frailty classification applied. Reflecting this, reported frailty rates for persons aged over 65 years varies from 6.9% or lower in large population-based studies [7] to as high as 75% in primary care cross-sectional samples [8]. Data similarly vary by region with higher levels found in developing countries [9] compared with more developed nations [2].

The choice of frailty classification is also important with two main approaches commonly used to define frailty: the Frailty Phenotype [7] and the Frailty Index. Fried's Frailty Phenotype characterised by physical signs and symptoms suggesting frailty classifies individuals as frail if they meet three or more of the following five criteria: weight loss (>5% in last year), exhaustion, weakness (decreased grip strength), slow walking speed (>6 to 7 s for 15 feet), and decreased physical activity (males <383 kilocalories; females <270 kilocalories) [7]. Modified versions exist that deviate slightly from this initial description. The Frailty Index is characterised by an accumulation of deficits identified from a list of predefined variables that are used to create a proportion or decimal from 0 (no deficits) to 1 (maximum number of deficits present) [10]. Multiple indices are available with varying numbers of deficits. While complementary, they measure different constructs [11] with Fried's phenotype usually reporting lower prevalence rates [12]. A recent systematic review of the weighted prevalence of frailty from cross sectional data in community-based cohorts of older adults aged ≥ 65 estimated that the overall weighted prevalence was 10.7% [2]. In addition, many other factors impact upon the prevalence of frailty such as sex and socioeconomic status [13]. For example, 8.5% of women in the European Union (EU) aged between 65 and 74 years are frail compared with 4.1% of males [14]. Within the EU the prevalence of frailty in community-dwelling older adults aged over 65 years varies between studies with data suggesting that between 5.8% and 27.3% [15] are frail.

Pre-frailty, is a prodromal 'risk' state before the onset of frailty. However, no definition of pre-frailty is established or widely used. Instead, a cut-off score on a frailty screen or frailty assessment scale defines it as an intermediate level before the development of functional decline. For example, a score of one or two on the Fried's Frailty Phenotype denotes pre-frailty. The proportion of frail, older adults living in the community is variable depending on the sample and setting but can reach half [2]. Many more, up to 60% of those aged over 65, can be classified as pre-frail [15], though again this depends on the approach used to categorise pre-frailty [16].

While the development of frailty is often considered permanent, evidence suggests it is a dynamic process with some patients converting from frail to pre-frail and even becoming robust again [17]. Despite this, once established, frailty is difficult to reverse [18] with less than 1% of persons considered frail becoming robust over five years [17]. Given that frailty is associated with an increased incidence of chronic medical conditions [19, 20], hospitalisation [21–23], readmission to hospital after discharge [24], higher healthcare costs [25], institutionalisation [3], and death [26], there is a need to promote active and healthy ageing and instigate measures to prevent frailty [6, 27–30].

From a practical perspective targeting pre-frailty is a reasonable approach, though at present there is insufficient evidence to support this [31]. Specifically, the use of multi-factorial interventions to screen, monitor and manage prodromal states related to

pre-frailty such as mild cognitive impairment [32–34], or reduced physical activity in the presence of sarcopenia [35, 36] appear most appropriate. Likewise, combinations of targeted, coordinated and preventative interventions delivered in the community can reduce adverse healthcare outcomes [37]. Recently, data from intervention studies targeting pre-frailty has shown the potential for using combined physical and nutritional interventions to delay or prevent onset of frailty, though compliance with the intervention can often be suboptimal or unclear [38]. While there is growing interest and uptake in the use of information and communications technology (ICT) by older adults, the presence of frailty affects these persons´ ability to access and utilise technological devises [39]. Some limited data suggests that incorporating complex interventions such as physical exercise regimes into ICT devises may improve compliance and produce positive effects on quality of life [40]. The goal of using ICT to either prevent onset or progression of frailty is included in the action plan of the European Innovation Partnership on Active and Healthy Ageing [27] and centres around the construct of recognising functional decline manifest by impairment in activities of daily living (ADL), an older person-important outcome.

As few studies have used frailty as an outcome measure [41], the overarching aim of PERsonalised ICT Supported Services for Independent Living and Active Ageing (PERSSILAA) was to examine whether frailty can be prevented and whether an ICT-based intervention designed to target pre-frail community dwelling older people can delay onset of frailty and functional decline. Specifically, although some data on individual or combined interventions exists, no study has examined the use of a multi-domain, ICT supported platform targeting pre-frailty in its ability (utility and feasibility) to prevent functional decline and subsequent onset of frailty. Similarly, while several national and international Geriatric and Gerontological societies provide best practice recommendations for addressing frailty [6, 42], given the paucity of studies, no guidelines exist for the management of pre-frailty.

2 Overview of the PERSSILAA Project

The PERSSILAA project was funded under the European Commissions' Framework Programme 7 between 2013 and 2016, (see grant number 610359). It consisted of a consortium of eight partners from five EU countries from across the medical, social and technological sciences as well as including partners from industry, academia and end-user organisations. The primary objective of PERSSILAA was to develop an ICT-based platform to identify and manage older community dwellers at risk of functional decline and frailty (i.e. pre-frail older adults) to determine if such an intervention could influence frailty trajectories. This multimodal service model focuses on three core frailty domains, specifically nutrition, cognition and physical function. Supported by an interoperable ICT service infrastructure, PERSSILAA uses an intelligent decision-support system and gamification strategies to encourage end-users to engage with the platform. PERSSILAA was designed specifically for older community dwellers aged over 65 who as part of the project were (1) screened by a trained rater or were self-assessed to identify and stratify them according to their frailty status, (2) triaged or stratified to the appropriate ICT-based solution to meet their needs (targeting one, more

or all three frailty domains), (3) monitored (unobtrusively) to identify their trajectory of ageing and (4) managed with ICT supported services through local accessible community structures.

The design of the study is described in more detail elsewhere and below but in summary, an 'ideal' service model was developed and refined through a series of meetings with older adults taking a participatory design and iterative approach [43]. An important outcome of this initial work was the need to offer multi-modal screening, stratification and management strategies to older patients, as they are a heterogeneous group with different skills and expectations [43]. The need for education, particularly with respect to ICT skills was highlighted, as was the need for older adults themselves to direct their own management and for participants' primary care physicians to be informed without creating additional burden (i.e. integrating the process and results).

Thus, the PERSSILAA screening and intervention modules consisted of both face to face and remote (postal and online ICT) components. Suitable participants identified in one of the two evaluation sites, Enschede in the Netherlands and Campania in Italy, were screened for frailty using a two-step screening process. Initially a brief pre-screen (conducted by post, online or in person) was performed. This was followed by a more detailed assessment in person to confirm their status for individuals screening positive for pre-frailty (i.e. the target group). In Enschede, older adults aged 65–75 recruited through primary care, selected by their family doctor were recruited. In Campania, older adults aged over 65 were recruited through local church communities, selected by the Naples Curia Diocesana. Once identified as pre-frail, PERSSILAA services targeted specific trainings modules for both health and ICT (ehealth) literacy and where appropriate, based on the screening and triage component, were used to provide physical training, cognitive training (Guttmann NeuroPersonalTrainer®) and nutritional advice (NUTRIAGEING^{TM} website) to participants. PERSSILAA services were designed to be accessible and thus were offered in multiple formats i.e. in person or online via personal or tablet computers, so older adults could use them with supervision or independently. To enhance the user experience and encourage compliance, in addition to a standard version, a gamified version was also developed, which while designed to be fun and interactive, encouraged on-going participation, also known as 'serious gaming'. For example, in one version older adults were encouraged to build a boat to escape from a virtual island but could only gather the pieces required if they used the trainings modules. Gamification is shown to encourage older people to use telemedicine [44], generate more engaging assessment strategies, [45] and can be used to promote and motivate behaviour to support lifestyle change [46]. The project also investigated the degree to which the PERSSILAA platform was acceptable, efficacious and ultimately effective to real world users in a real world setting, in preventing onset of frailty among pre-frail older adults. As this was an evaluation rather than a validation study, the priority was to show acceptability and proof of concept. PERSSILAA services were studied in two different populations of older people in two of the partner countries, Italy and the Netherlands. To maximise the results two different evaluation studies were performed. In Campania, a prospective cohort study was conducted to examine the uptake, acceptability and usability of the platform among older Italians. In Enschede, a multiple cohort randomised controlled trial (mcRCT) design was applied and 82 participants in the Netherlands were recruited, of whom half (n = 46) received

the intervention. Cost effectiveness was assessed with the Monitoring and Assessment Framework for the European Innovation Partnership on Active and Healthy Ageing (EIP on AHA) tool [47]. The project was funded to last for three years. All participants provided informed consent prior to being included and then assessed at baseline, scheduled intervals and the end point. Additional details including a full list of publications can be found at: www.perssilaa.eu.

3 Recommendations from the PERSSILAA Project

The main results of the project were subdivided and examined by topic to provide recommendations on addressing frailty and functional decline through the identification and targeting of pre-frailty. Results were grouped to be of interest to a broad interdisciplinary audience and developed by the consortium as a whole, led by individual partners according to their area of expertise. These were broadly categorised into three themes: (a) Healthcare related recommendations, (b) ICT related recommendations and (c) Organisational (institutional) recommendations. This work reviews and summarises the healthcare specific findings derived from the project. To compile these, partners were tasked according to their relevant specialty to develop related recommendations based on the work completed during the project. There are several recommendations within each theme. The results presented here describe the clinically (healthcare) relevant outcomes of the study that could be used to contribute to the development of guidelines for the screening of and prevention of frailty in older EU citizens.

3.1 Definition of Pre-frailty

Although pre-frailty is usually identified as a prodromal state before frailty and subsequent functional decline develop, no clear definition of pre-frailty exists. As part of the project the investigators performed a narrative, state of the art literature review to examine existing definitions of frailty and pre-frailty. As with frailty, no consensus definition was found. Instead, pre-frailty is most often characterised by reference to frailty and classified as a transitional stage on the trajectory from full independence (robust state) to increasing functional dependence (frailty). Pre-frailty, like frailty is measured by several short-screening instruments but is defined by a cut off score below that for frailty. For example, pre-frailty is present when one or two of the Fried frailty phenotype characteristics are present. It is proposed that identifying this prodromal phase at an early stage will allow the introduction of measures to prevent onset of frailty [28]. In order to select a sample, the PERSSILAA investigators adopted a definition of pre-frailty consistent with the goals of the project. After reviewing several possible definitions, a multi-domain definition targeting the key frailty domains. Given that many of the consortium were also member of the EIP on AHA A3 Action Group on frailty prevention, the definition of pre-frailty used in PERSSILAA was based on an adapted version of the A3 groups' definition of frailty [48]. This definition describes pre-frail older adults as those *at an increased risk of poor clinical outcomes, such as the development of disability, dementia, falls, hospitalisation, institutionalisation or increased mortality* where one or more pre-frailty states (e.g. mild cognitive

impairment, sarcopenia, physical and functional impairment, dysthymia and social isolation) is evident.

Recommendation: *Pre-frailty should be considered a multi-domain, multi-factorial syndrome.*

Recommendation: *The EIP on AHA definition of frailty could be adapted to define pre-frailty.*

Recommendation: *The EIP on AHA A3 action group are ideally placed to take the lead in developing a definition of pre-frailty to support and stimulate debate on a consensus definition of this important prodromal condition and emerging public health priority.*

3.2 Screening for Pre-frailty

Multiple short screening instruments to identify frailty are currently available and in use in clinical practice [49]. Despite this, no single instrument is currently recommended, likely relating to differences in approaches to identify frailty syndromes [6]. Further, only a few instruments are able to accurately differentiate pre-frailty from frailty. PERSSILAA was predicated on a two-step screening and assessment strategy in an attempt to correctly categorise participants as pre-frail (i.e. the target condition). This was modified during the project where redundancy was identified. Screening followed by more comprehensive assessment is recommended given the expected high prevalence of pre-frailty in community samples, the relative high sensitivity but low specificity of the screening instruments and the resources required to screen in this setting [50]. Instruments were selected following a literature review. Thus, the two stage selection process involved (1) the screening of people ≥ 65 years by trained volunteers/self-screening by email or postal questionnaire to exclude robust subjects and those with established frailty and (2) a face to face assessment by trained multidisciplinary staff of those classified as pre-frail in order to confirm if they were pre-frail. Each domain included in PERSSILAA was screened using this approach.

The screening and assessment instruments used at each stage are presented in Fig. 1. During the first iteration (the first round) the scales were rationalised producing a more streamlined final version. Screening began in 2014. In overview, the first step divided participants into robust, pre-frail and frail using a 'global' frailty scale combined with individual measures of nutrition, cognition and physical function. The Groningen Frailty Indicator (GFI), a 15-point yes-no questionnaire exploring physical, cognitive, social and psychological components of frailty was used as a global measure, using a cut-off of $\geq 4/15$ for moderate-severe frailty [51]. The INTERMED was initially trialled but did not provide sufficient additional information to justify its inclusion. Instead, the GFI was used alone in the final version given that it is shorter and already validated in all the languages of the project. Participants were further screened using instruments specific to the selected pre-frailty domains using stage specific cut off scores. The final instruments selected were the Mini-Nutritional Assessment (MNA) short form to identify nutritional deficits, the 8-item Alzheimer's disease 8 questionnaire (AD8) for cognitive deficits and the Short-form 36 questionnaire (SF-36) to screen for physical impairment. The KATZ activities of daily living (ADL) scale and the Quick Memory Check (QMC), initially trialled during the first iteration were

considered to be too impractical for self-screening. In the second step (face-to-face assessment), older adults were evaluated to confirm if they were pre-frail. Nutritional deficits were identified with the remainder of the MNA (G-R), cognitive impairment with the Quick Mild Cognitive Impairment (Q*mci*) screen [52–59] using age and education adjusted cut-offs [60], and physical function using the short physical performance battery (using the Timed Up-and-Go Test, the Two-Minute Step Test, the Chair-Stand Test, and Chair-Sit-and-Reach Test).

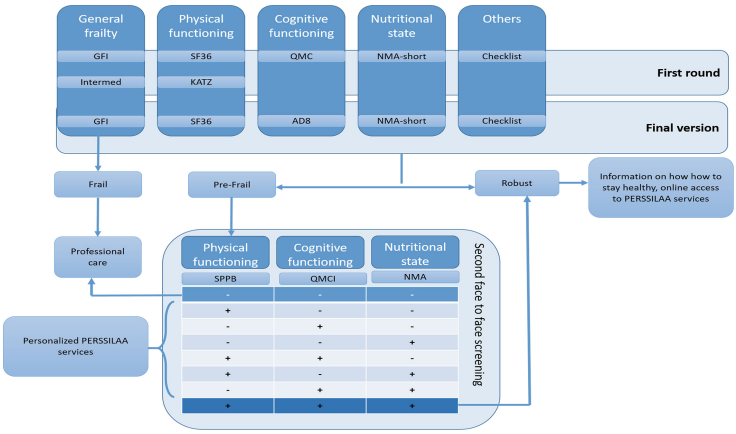

Fig. 1. Two-step screening protocol for the PERSSILAA project showing the first and final version of the first screening step [61].

The results showed that the PERSSILAA screening service with the addition of demographic data is useful in quickly and accurately classifying older community dwellers as robust, pre-frail or frail. In all, 4071 participants were screened. The majority of these participants (n = 2,438) were classified as robust (60%). An additional, 916 (23%) were characterised as having a high probability of being pre-frail and were thus suitable for further assessment (step two). There were no significant differences in age though frail patients were more likely to be female. The baseline characteristics of patients are presented in Table 1, below.

The face to face assessment (second step) confirmed that of those screening positive for pre-frailty, that 90% were pre-frail. Logistic regression showed that those screening positive were truly pre-frail and showed that the first-step screening process had an overall good to excellent accuracy (area under the curve of 0.87 with a moderate to high sensitivity (77%) and specificity (84%). Analysis of the face to face assessment showed good agreement among the classifications of pre-frail and robust individuals. These results suggest that the two-step screening and assessment approach developed for PERSILLAA was able to correctly categorise pre-frail community-dwelling older adults.

Statistical assessment of accuracy using receiver operating characteristic curve analysis showed that the MNA (assessing nutrition) was the most accurate individual

Table 1. Characteristics of participants included in baseline screening by frailty classification.

Variable	Robust	Pre-frail	Frail	Total
Number of participants	2438	916	717	4071
Age (± standard deviation)	69.71 ± 4.18	70.44 ± 4.71	70.82 ± 5.97	70.06 ± 4.63
Gender (% female)	48%	56%	61%	52%
Groningen frailty indicator (± standard deviation)	0.97 ± 1.08	2.49 ± 1.36	6.35 ± 1.56	2.24 ± 2.33
Alzheimer's disease 8 questionnaire (± standard deviation)	0.19 ± 0.39	1.03 ± 1.28	1.86 ± 1.91	0.66 ± 1.22
Short-form 36 questionnaire for physical impairment (± standard deviation)	91.57 ± 9.89	65.33 ± 26.36	54.88 ± 29.86	79.21 ± 24.71
Mini-nutritional assessment – short form score (± standard deviation)	11.71 ± 1.04	10.36 ± 1.66	9.52 ± 2.53	10.70 ± 1.67

predictor of pre-frailty with an area under the curve of 0.80, indicating good accuracy, supporting the known important role nutrition plays in the development of frailty [62].

Recommendation: *Multiple pre-frailty sub-domains should be addressed when screening for and assessing pre-frailty among older adults and should include cognitive, physical, nutritional, social and other domains*.

Recommendation: *More research is required in this area and future studies should capture multiple pre-frailty domains along with global measures of frailty*.

Recommendation: *A two-step screening and assessment approach is an acceptable and accurate means to identify pre-frailty in a community setting, though more research is needed to confirm this.*

3.3 ICT Training Modules to Manage Pre-frailty

Three training modules were developed during the project, one for each of the three-domains targeted: (a) nutrition, (b) cognition and (c) physical function. This section outlines how each module was developed, the results of their implementation, the conclusions drawn by the PERSSILAA researchers and the recommendations made. This section also examines the importance of health literacy, which impacts on patient satisfaction and healthcare utilisation and costs among older adults [63]. It also includes a preliminary analysis of the effects of the training platform on participant's quality of life.

Nutrition Training Module

Nutrition is central in the development of frailty [62] and is especially important for older adults. Ageing is associated with increased risk of becoming malnourished [64] or undernourished i.e. at risk of malnutrition [65]. Although data varies considerably by setting and sample surveyed, it is estimated that between 10–35% of community

dwelling older adults are at risk with prevalence rates in acute hospitals approaching 45% [66]. Up to 65% of residents in long-term care are reported to be at risk of malnutrition [67]. The cause is often inappropriate food consumption [68], manifest by a gap between actual nutrient consumption and recommended dietary intake. Education on healthy eating and nutrition is therefore crucial to provide adequate and reliable information to consumers and healthcare providers to promote healthy diets in all settings. The NUTRIAGEING website (http://nutriageing.fc.ul.pt/) is an easy-to-use, "app-like" interface designed to promote and translate scientific knowledge into usable person-centred nutritional advice for the general public. It's three areas are: (1) Healthy eating, (2) Recipes and videos, and (3) Vegetable gardens. The "Recipes and videos" subsection includes 15 videos of recipes developed by the Portuguese Chef Hélio Loureiro. The functionality of the website was tested with 45 older adults and their carers in two day care centres in Portugal. In feedback sessions most participants rated the site as excellent. Take home messages included the need to make websites connecting science and public health such as the NUTRIAGEING™ website: (1) easy to use, (2) evidence-based and (3) readily accessible (appealing and enjoyable format) to encourage access and learning.

Recommendation: *Nutritional education, required to promote healthier eating habits among the general population and in particular pre-frail older adults, can be delivered successfully online*.

Recommendation: *Educating caregivers on the benefits of nutrition using ICT-supported platforms such as the* NUTRIAGEING™ website *is important and may benefit older adults directly – more research is required to confirm this*.

Recommendation: *Educating cooks and professionals involved in food preparation on the benefits of healthy foods and nutrition using ICT supported platforms such as the* NUTRIAGEING™ website *is important and may benefit older adults directly – again, research is required to confirm this*.

Recommendation: *ICT platforms, if user friendly and intuitively designed, can support wider public health goals by providing the general population including older adults but also healthcare professionals with reliable information and easy-to-use tools, which may increase their knowledge of nutrition and healthy eating*.

Cognition Training Module

Demographic ageing is associated with an increased prevalence of cognitive impairment including mild cognitive impairment (i.e. subjective and objective cognitive deficits without impairment in ADL function) [69] and dementia (i.e. subjective and objective cognitive deficits with a clear impact upon ADL function) [70]. Recent data suggests that the incidence [71] and prevalence [72, 73] of dementia is reducing in developed countries, likely in response to higher levels of education and other socioeconomic factors such as diet and exercise which have improved cardiovascular and cerebrovascular health over recent generations [74]. Cognitive brain training has also been postulated to slow progression from prodromal stages of cognitive impairment to more advanced stages [75]. Further, studies examining multi-domain interventions directed to at risk population's show that cognitive stimulation combined with lifestyle modification (diet and exercise) and focused cardiovascular risk-factor management can reduce progression to dementia [33].

In PERSSILAA the mean AD8 score for the total sample of 4,071 participants screened at baseline was 0.66 ± 1.22 compared to 1.03 ± 1.28 for pre-frail older adults, (See Table 1). Frail participants approached a score of two or greater on this screen suggesting that these were more likely to screen positive for cognitive impairment [76], albeit the specificity of the AD8 at this cut-off is low [77]. The mean Q*mci* screen score of pre-frail participants, providing more detailed evaluation of specific cognitive domains at the face to face assessment, was 64.5/100 ± 11.32, within the accepted range of cut-off scores for separating mild cognitive impairment from normal cognition: between 64 and 70/100 [60] suggesting that many of these participants were manifesting early evidence of cognitive deficits in keeping with cognitive pre-frailty. The median and interquartile range of Q*mci* screen scores are presented in Table 2.

Table 2. Distribution of Quick Mild Cognitive Impairment (Q*mci*) screen scores including maximum score, median and interquartile range for pre-frail older adults including in second level assessment.

Subtest	Max score	Median	Interquartile range (Q3−Q1) = ±
Orientation	10	10	(10 − 10) ± 0
Registration	5	5	(5 − 5) ± 0
Clock drawing	15	15	(15 − 15) ± 0
Delayed recall	20	12	(16 − 12) ± 4
Verbal fluency	20	8	(11 − 5) ± 8
Logical memory	30	16	(18 − 12) ± 6
Total Q*mci* screen score	100	65	(72 − 58) ±14

During the course of the evaluation, pre-frail older adults were asked to complete the cognitive training modules over a period of 12 weeks, 3 times per week with each session lasting for an hour. The cognitive training tasks were selected from the Guttmann NeuroPersonalTrainer® and incorporated into the platform in two blocks: the first group (Block 1) were assessment-oriented tasks and the second group (Block 2) training-oriented tasks. Block 1 was composed of 10 different tasks, Block 2, 25 tasks. Both sets of tasks addressed the primary cognitive functions related to ADL. At the completion of each session, users received a score from 0 to a maximum of 100 points. The therapeutic range was set between 65%-85% of peak performance and difficulty levels were adjusted according to individual performance. Cognitive training was trialled in both evaluation sites. In Enschede (Netherlands) 18 older adults participated individually completing a total of 893 tasks during 107 sessions. In Campania (Italy) 53 participated in 15 collective (group) sessions: a total of 223 individual log in's to the trainer. Usability testing showed that most participants who were evaluated, eight participants in the Netherlands and ten in Italy, were satisfied. The average satisfaction score across the two sites using the system usability scale (SUS), a subjective 10-item Likert scale measuring usability [78], was 64/100 supporting the usability of the cognitive training module. Interview sessions were also completed with users who provided additional information on the format of the NeuroPersonalTrainer®. Based upon these results the following recommendations were made:

Recommendation: *Cognitive training tasks for use with pre-frail older adults should be easy to understand and use. Important information should be provided in a large, conspicuous, non-crowded format in the person's central visual field.*

Recommendation: *The visual display on cognitive training devices for pre-frail older adults should be simple; avoiding distracting visual stimuli (such as elaborate backgrounds and flashing or flickering lights) unless they are used judiciously to signal a specific required action or function.*

Recommendation: *Clear instructions should be provided to pre-frail older adults before each cognitive training task, particularly where additional effort is required on behalf of the end user (e.g. sustained attention tasks).*

Recommendation: *Immediate feedback should always be provided to pre-frail older adults after completing individual cognitive training activities. Aggregated information should also be provided to show trends or evolution in performance over time.*

Recommendation: *The difficulty of cognitive training tasks for pre-frail older adults should be tailored to each individual's level based upon normative data for these tasks.*

Recommendation: *Cognitive training modules for pre-frail older people should be adapted to mobile/smart technologies and devices. Engagement with training should be encouraged with techniques such as gamification or through the use of group work (either remotely or at centralised locations).*

Recommendation: *Fields that represent pre-frail older adults' interests or hobbies should be used throughout cognitive tasks (in the form of images, texts, words etc.) to personalise the experience for older adults.*

Physical Training Module

Frailty and pre-frailty are associated with a defined frailty phenotype characterised by Fried's criteria which includes symptoms of weakness, exhaustion, reduced physical activity and slow walking speed [7]. Frailty is also associated with prodromal disease states such as sarcopenia, osteopenia and osteoporosis that contribute and exacerbate the impact of frailty related adverse outcomes such as falls and hip fractures [79]. Identifying early physical decline is therefore important to initiate interventions to prevent these events. Regular physical activity, particularly resistance exercises can slow the development of frailty [80]. Data also suggests that exercise interventions can improve ADL function among frail older adults and delay progression of functional impairment or disability, though which particular interventions offer the most benefit is unclear [81]. The Otago Exercise Programme (OEP), an established, validated, cost-effective home-based tailored falls prevention programme [82], reduces the risk of falls and mortality among older community dwellers [83], though it is unknown whether it can be used remotely by pre-frail older patients. A technology-supported self-management, physical training module platform, based on the OEP, was developed for use on the PERSSILAA platform, structured around an existing system called the Condition Coach (CoCo) [84], containing advice and instructional videos, which were adapted for use with pre-frail older adults through an iterative design approach [85]. Participants using the physical training module were asked to log in and train online three times a week over three months. Data showed that there were high levels of compliance and tolerance with the programme. Of the participants finishing the

complete protocol (i.e. 12 weeks of training), the majority continued using the service for up to one year. High levels of satisfaction were reported, an average score of 84/100 on the SUS. In the mcRCT average Chair Stand Test and Two minutes step test scores increased for those using the physical training model compared to controls, though this did not reach statistical significance.

Recommendation: *Strategies to motivate pre-frail older adults to begin and to continue using physical training modules on ICT supported platforms should be included as part of the implementation process.*

Recommendation: *A 'home' online physical training module provided on an ICT supported platform is feasible for pre-frail older adults, though professional support seems useful and should be provided as back up.*

Recommendation: *The provision of physical training modules on ICT supported platforms to pre-frail older adults, at risk of frailty or functional decline may enable them to improve their physical fitness, though more evidence is required.*

Health and ICT Literacy

Older adults now represent the fastest growing section of society [1] and are biggest users of healthcare. Despite this, insufficient attention is paid to their understanding of health literature and few measures have been put in place to improve this [86]. PERSSILAA identified this as one of the biggest challenges in introducing ICT-supported screening, triage and management strategies. It is known that simple measures can rapidly improve older person's understanding [87] and this is also applicable to eHealth literacy skills [88]. To overcome these difficulties, health and ICT literacy programmes were developed in Italy, utilising a 'Train the Trainer' approach with healthcare professionals and local volunteers teaching older adults as part of the PERSSILAA response. In total, 2,560 older adults attended ICT training, with a median of 14 people attending per lesson. Feedback was excellent with older adults reporting that they would not have been able to interact with the training and monitoring modules without it (see Sect. 3.5).

3.4 Effects on Quality of Life

Frailty [89] and its subdomains including nutritional and physical impairment are associated with reduced quality of life in older adults [90, 91]. As part of the planning for the PERSSILAA project a survey conducted with participants suggested pre-existing high levels of loneliness and depressive symptoms. In all, 73% reported feeling empty and 74% mow mood or depressive symptoms. To explore this further, the European Quality of Life–5 Dimensions questionnaire (Euroqol EQ-5D), scored from 0 (worst imaginable health state) to 100 (best imaginable health state), was used to measure the effects of the PERSSILAA training modules on participants' quality of life. This was also included to facilitate an economic analysis of the cost effectiveness of the project. The EQ-5D was measured at baseline and end-point for those participating in the mcRCT. The final mean score increased compared with the initial assessment by a mean of 10 points suggesting that those using PERSSILAA reported a higher quality of life after using the platform. The Short-Form 12 (SF-12), which includes both physical and mental domains taken from the more comprehensive SF-36

was used to measure perceived health. Higher scores were found on the Mental Component Survey of the SF-12 for those using PERSSILAA training services compared to the control group, suggesting that better mental health is associated with the use of the platform. Based on this, we concluded that participation with the project design improved perceived quality of life. This would be expected given that several components of the PERSSILAA training modules such as exercise [92] and nutrition [93] are known to improve participant motivation, mood and quality of life.

Recommendation: *Engaging in online multi-domain training modules to manage pre-frailty may improve the perceived quality of life of older adults.*

3.5 Monitoring for the Development of Frailty – Frailty Transitions

Frailty is increasingly being recognised as a dynamic syndrome where individuals may transition through different trajectories from frail to pre-frail or robust [17]. The evidence however suggests that this is usually unidirectional with few older adults transitioning from frail to pre-frail or robust when followed in longitudinal studies [17]. However, these have been limited by the type of data available, which relies on face to face assessment. While technology can provide unobtrusive monitoring, it may also distract end-users and lead to 'attention theft', necessitating a more non-invasive approach in the home environment, particularly when daily activities are being measured [94]. Further, while useful with younger adults, it is unclear if such models are applicable to pre-frail or frail older participants. While older adults do engage with ICT, its uptake is low [95]. Further, it is challenging to combine all the information collected in a meaningful way in order to obtain an overview of the everyday functioning of pre-frail older adults. Different approaches to monitoring were used in PERSSILAA to overcome these challenges depending on the pre-frailty domain assessed. To facilitate monitoring, software was provided on the portal, and on mobile and home sensing devices. All data were collected automatically and uploaded into the PERSSILAA database for analysis. The following approach was taken: transitions between different frailty states (robust, pre-frail and frail) were examined using the GFI data at baseline and end-point. Nutrition was monitored using two questionnaires to evaluate eating habits: the 24-h dietary recall and an additional 'general' questionnaire developed by the PERSSILAA investigators. To supplement this, a 'smart scale' (weighing scale connected wirelessly to a computer application) was used to monitor participant's weight on a daily basis. For cognition a shorter version of the full Guttmann NeuroPersonalTrainer® was developed to enable monitoring of cognitive function over time in short sessions of less than 15 min comparing each score with baseline and the previous results. For physical function a step counter was chosen to monitor daily physical activity and obtain an overview of physical functioning, all collected by means of a smartphone application. Wellbeing was also measured daily using a smartphone application recorded. The acceptability of the monitoring module was evaluated through semi-structured interviews and by measuring how frequently the technology was used over one month of follow-up.

In all, 169 participants had completed the GFI at baseline and end-point, of whom 78% remained robust, while half remained stable: pre-frail or frail. One quarter transitioned from frail to pre-frail and from pre-frail to robust. One fifth converted from

pre-frailty to established frailty (See Fig. 2). The proportion transitioning is higher than that reported previously and likely represents differences in the way that data is collected and a shorter period of follow-up. There was no statistically significant difference in overall 'global' frailty status as measured by the GFI between those included in the mcRCT as cases utilising the PERSSILAA training modules and pre-frail controls, $p > 0.05$. In addition, 12 participants took part in the monitoring feasibility sub-study. Each completed a survey at baseline to understand their usual self-reported familiarity and ease with using ICT. These were then followed for one month with daily weights ('smart scale') and a pedometer to assess fluctuations in weight and physical activity. Overall, the compliance of participants was modest suggesting that ICT monitoring devices should be carefully designed to meet their requirements. Most participants stated that they understood the importance of a healthy diet and physical exercise for their overall health.

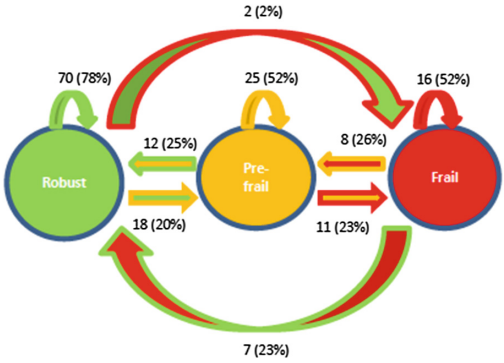

Fig. 2. Frailty transitions (n = 169) for participants with baseline and end-point Groningen Frailty Indicator scores between 2014–16 [61].

It was also found that most participants enjoyed the 'brain training' games but preferred not to be confronted or compared with the results of peers. Overall, the results of the continuous ICT monitoring showed mixed results and showed that while open to new technology to improve their health, it must meet their needs and expectations. Thus, further research is required to examine the benefits of continuous monitoring. Striking the balance between non-invasive monitoring that is non-obtrusive and avoids 'attention theft' and more obvious strategies that increase awareness and encourage use of ICT are needed to gain wider acceptance among this target group.

Recommendation: *There is likely to be no 'one-size-fits-all' approach to monitoring older community dwellers for pre-frailty. However, ICT training is required for older adults in order for them to engage with monitoring, particularly where end-user feedback is required.*

Recommendation: *Monitoring of everyday function must be complemented by meaningful (older adult-specific) information to support the adoption of healthier behaviours.*

Recommendation: *Technology to support the prevention of functional decline must go beyond the disease oriented-perspective and focus, instead, on strategies to maintain independence in daily activities.*

Recommendation: *When remotely monitoring older adults' health (pre-frailty) status using ICT technologies, systems should provide feedback on the data collected.*

4 Conclusions

This work describes the healthcare findings of the three-year, FP7-funded, PERSSILAA project, highlighting the potential of a multi-domain, ICT-based service module employing gamification techniques in targeting pre-frail older adults living in the community at risk of becoming frail and developing functional decline. The results of the project are discussed in terms of the healthcare recommendations that can be drawn from the project that could be used to support the development of European guidelines on managing pre-frailty. This is much needed as frailty represents an important emerging public health challenge for the EU [96]. To date, interventions have been predominantly reactionary in response to manifest frailty or confined to limited evidence-based, clinical approaches to manage frailty including exercise training and nutritional supplementation [97]. Giving the increasing numbers of older adults in the EU [1], there is now recognition that preventative approaches are urgently required [96] and interest has focused on the ability of technology to support early detection and monitoring of those at greatest risk [43].

The results of PERSSILAA demonstrate both the acceptability and feasibility of deploying an integrated ICT-based platform for use by with older adults, who traditionally find the use of such technology difficult [98], especially where they have coexisting physical or cognitive impairment [99, 100]. As far as we are aware, this is the first study to examine the experience of using ICT among older, pre-frail, community dwellers. The results show that these rated all three training modules (nutritional, cognitive and physical) high for usability. Further, results were consistent for the two disparate populations sampled: older Dutch community-dwelling adults attending general practice (their family doctor) and older Italians living in communities centred on their local church. Although only older Portuguese individuals assessed the NUTRIAGEING^{TM} website, it unlikely that their views differ considerably from the other participants in Italy or the Netherlands.

In total, PERSSILAA screened over four thousand community-dwellers and showed the feasibility of employing multi-modal screening approaches including postal and online questionnaires and targeted approaches through primary care to identify suitable participants in such studies. The screening approach using validated short frailty and domain-specific instruments shows the potential of and necessity for a two-step screening and assessment approach in order to identify suitable participants. This was important and is consistent with evidence that two-step screening is preferable [50]. It also supports evidence that primary care is a suitable target to identify community-dwellers at risk of developing frailty and an appropriate location for the implementation of such approaches [101]. The study demonstrated clear frailty transitions over the course of the project with only small numbers (2%) transitioning from

robust to frail during follow-up. Reversibility was also seen with one quarter of frail and pre-frail individuals transitioning to a lower frailty status.

eHealth interventions offer the option for older people to assess both information and therapeutic strategies while networking with peers and healthcare professionals [102]. Despite this, few studies have incorporated eHealth literacy interventions into studies evaluating health outcomes. Another important result from PERSSILAA is that health literacy and ICT (eHealth) literacy are useful in supporting older people to access such services. Older Italians taking part in PERSSILAA felt they benefited most from the social environment created by the classrooms provided. In contrast to this, Dutch participants preferred to train alone and preferred not compare results with their peers. This likely reflects different cultural backgrounds and suggests that a one size fits all approach is unlikely to be successful when integrating ICT into the everyday lives of older Europeans to improve their health status. Gamification is now increasingly recognised as an important strategy to motivate behaviour change and has shown the potential to significantly increase adherence and improve healthcare outcomes [46]. PERSSILAA is also one of the first studies to study the effects of gamification [43] on older adults and how it may help engage them with ICT training modules.

The results also highlight many of the challenges and limitations of undertaking similar studies, particularly the difficulty of sampling an ill-defined population: pre-frail, older adults, who while at risk for subsequent frailty and functional decline may not be aware of this or motivated enough to engage with screening processes. While, the two-stage process enhanced the screening pathway, it is possible that some participants may have been misclassified as no gold-standard independent assessment was performed e.g. by a consultant geriatrician. This is a recognised limitation of such work where the application of screening tests or frailty scales cannot be considered an equivalent [103]. However, several of the screens used have excellent sensitivity though relatively poor specificity meaning that a face-to-face assessment was required to ensure that participants were pre-frail. The results did suggest that this strategy had reasonable accuracy in correctly classifying participants. Another limitation of the project is that due to restricted resources not all those screening positive for pre-frailty had a repeat assessment at the end-point of the study and only a small number were monitored. This limited the ability of the study to demonstrate frailty transitions. Hence, during the evaluation period the results presented may not be representative of the true trajectory of frailty in this population. Such proportionally high (approx. 20%) transitions from one frailty state to another over a short period are in contrast with data presented elsewhere in larger samples over longer periods [17]. Therefore, it is likely that this reflects the limitations of the screening and assessment process itself, delivered both remotely and face-to-face using validated instruments. This said, PERSSILAA aimed to show the potential for self-screening or screening by lay persons, something that is likely to become more widely accepted as healthcare becomes more proactive and less reactive, stepping away from the traditional medical model. Another limitation is that only a small sample trialled the full platform, released in stages as it was developed, which meant that no significant impact upon GFI scores were seen. This limits the project to the development and evaluation of a service platform, which was the main focus of the research. Thus, as a proof of concept PERSSILAA shows the potential to use a multi-domain ICT-based platform with older, pre-frail adults.

In summary, this work presents an overview of 25 healthcare-related recommendations arising from the PERSSILAA project. The study provides the first practical guidance on how to develop and evaluate a novel ICT supported service to identify, assess, manage and then monitor pre-frailty to slow or prevent the emergence of established frailty and associated functional decline, showing the potential for an ICT platform targeting key pre-frailty domains: nutrition, cognition and physical function. The results of this evaluation are being analysed further and future research is being planned to validate the PERSSILAA platform with a suitably powered RCT to determine if ICT-supported services can prevent or delay onset of frailty and functional decline in pre-frail community-dwelling older adults.

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