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Glossary

GP	General Practitioner
HRQoL	Health Related Quality of Life
ICT	Information and Communication Technology
SCV	Statistical Conclusion Validity
SWOT	Strengths, Weaknesses, Opportunities and Threats
LTC	Long-term Care
TUG	Timed Up and Go
STS	Sit-to-Stand transitions
AST	Alternating Step Test

1. Introduction

The first deliverable of Work Package 2 (D2.1) presented an evidence-based inventory of methods that are currently used to assess the socio-economic and clinical impacts of ICT-based solutions in the domain of falls prevention, intervention and security. Furthermore D2.1 provided insights into how socio-economic and clinical impacts are defined, the relevance of measuring these impacts, and overviews of numerous methods used to measure impacts in these domains.

The second Deliverable D2.2 focused on comparing the socio-economic and clinical impact assessment methods regarding defined criteria: financial costs, time effort, awareness, expertise needed, validity and usefulness for decision making and long-term measurements. Thirty one experts responded to an online questionnaire to assess the methods of D2.1.

This deliverable D2.3, is using the results of the former deliverables in order to present a toolkit with the most preferred state of the art methods. This deliverable will also introduce new methods to fill the gap or solve limitations in the the state of the art methods.

1.1 Deliverable Objectives

The purpose of the document is not only to list different methods, but also to characterize each method and its application area, assess each method, including its limitations, and thus provides a trustable catalogue of socio-economic and clinical impact assessment methods based on previous knowledge and on a survey.

Major contributions provided by this Deliverable D2.3 are the development of common approaches and indicators for the measurement of socio-economic and clinical impact, in order to provide a catalogue of common agreed best methods and indicators. In other words, the aim is to propose and share knowledge on which methods would work best.
In response to the magnitude of the falls problem the deliverable includes a toolkit that offers a general compendium of useful references, resources, and presentations that were gathered from existing research, previous knowledge and a survey.

1.2 Summary

The aim of this deliverable is to describe detailed indicators for the measurements of the socio-economic and clinical impact of falls. The deliverable will reflect the work of Tas*k 2.3 Catalogue of socioeconomic and clinical impact assessment methods for falls prevention, intervention and security*. This task focuses on the impact assessment methods to assess the

feasibility of methods in various uses with regard to the socio-economic and clinical impact area, assessment type as well as the life-cycle of the system assessed.
The first part of the document is devoted to describing the state of the art methods, a brief summary of the results consolidated in the previous deliverables (D2.1, D2.2) and a section dedicate to a description of a missing methods in D2.2.
The deliverable continues illustrating the limitation of the methods, especially if evaluated in a different setting. The last section of the deliverable describes methods based on ICT.
Finally, in the annex there is the toolkit of methods – a friendly and easy to use reference guide.

2. State of the Art of (clinically used) fall risk assessment methods

The Deliverable 2.1 has presented an evidence-based inventory of the methods used to assess the socio-economic and clinical impacts of ICT-based solutions in the domain of falls prevention, detection and security. Methods are shared in different components, socio-economic and clinical and general aspects, according to the types of impact assessed; moreover sub classifications are introduced where required in order to describe in detail each component.

Table 1 outlines the preferred / popular methods in each assessment category as assessed by 31 experts in the online survey of D2.2, which are explained in detail in the toolkit section. The category 'New' shows methods which are actually not existing practice methods but could complement or replace gaps (see section 3.5) of existing methods or were missed in the online survey of D2.2 (see sections 3.1, 3.2, 3.3 and 3.4).

Table 1: Best Practice Methods

Category		Method
Medical Assessment Method	**New: Clinical Study**	• Rate of falls • Number of fallers • Fall injury
	Motor Function Tests	• Timed Up and Go Test (TUG) • New: Five Times Sit to Stand test • Tinetti-Mobility Scale/ Performance-Oriented Mobility Assessment (POMA) • Berg Balance Scale • Turn 180°
	Fall Risk Screening Tools	• St. Thomas Risk Assessment Tool in Falling Elderly Inpatients (STRATIFY) • Morse Fall Scale • Downton fall risk index
	Central Sensory Organization	• Computerized Dynamic Posturography (CDP) • Modified Romberg Test of Standing Balance / Modified Clinical Test for Sensory Interaction in Balance (CTSIB) • New: The Groningen frailty indicator (GFI)
	Physical and Functional Ability	• Katz Index of Independence in Activities of Daily Living (Katz-ADL)

Category		Method
		• Barthel ADL Index / Barthel Scale • Lawton Instrumental Activities of Daily Living Scale (IADL)
	Cognition and Mental Health	• Geriatric Depression Scale (GDS) • Mini-Mental State Examination (MMSE) • New: Trail-Making Test Part B
	Health Related Quality of Life	• EuroQoL – the European Quality of Life measure (EQ 5D) • Short Form 36 (SF-36)/ SF-12
	Self-Efficacy	• Falls Efficacy Scale-International (FES-I)
Health Economic Assessment Method		• cost-effectiveness, • cost-benefit analysis • cost-of-illness analysis
General Assessment Method		• New: World Café • Focus group, • surveys/ questionnaires • interview

3. Missing Methods

3.1 Missing methods in D2.2

Some screening tools and *rating scales, such as those* provided *below,* were not mentioned in D2.1/D2.2 due to their limited area of utilization (e.g.: STEADI in USA) or being relatively new and without accomplished verification studies (e.g.: Falls Prevention Scale Aachen in Germany - although the scale presented has been developed by a panel of health care experts, it lacks verification at the current stage. (1)).

The "**Aachen Falls Prevention Scale"** uses a self-assessment tool grading falls risk on a scale of 1 to 10 by the individual after completion of Part I and Part II. Researchers from Germany tested whether older people themselves could answer a self-assessment tool in their own homes (1). The tool was developed by clinicians and physical therapists following a literature review. It included a simple physical test that people could use at home without help from a health professional (the 20 second standing test). The patient or caregiver may further address to healthcare providers for complex tests.
The scale comprises a simple questionnaire with a quick test designed to identify existing balance problems as a first step in assessing the risk of falls in the elderly. The main advantages on using the scale is that it doesn't require specialised healthcare personnel for assessment and therefore, it is contributing in reducing the healthcare costs for prevention. The tool is available for use, but requires further testing.

The US-American Center for Disease Control and Prevention (CDC) created a simple tool kit called STEADI (Stopping Elderly Accidents, Deaths and Injuries) (2) that includes a wealth of information which can be easily downloaded and printed for display in your office or clinic. Materials include assessment tools, case studies, videos and educational hand-outs for your patients. STEADI is based on an algorithm[3] adapted from the American and British Geriatric Societies' clinical practice guidelines[4]. Using STEADI, users will be able to:

- Identify patients at low, moderate, and high risk for a fall;
- Identify modifiable risk factors; and
- Offer effective interventions.

Two validated fall prevention interventions from the STEADI algorithm that can be easily integrated into routine office visits are vitamin D supplementation and medication management. Vitamin D supplementation has been shown to reduce the risk of falling in older adults who are vitamin D deficient and is a simple thing that patients can add to their daily routines.(3-5)

The Groningen frailty indicator (GFI) is a widely used screening instrument for identifying frail older adults. The GFI consists of 15 self-report items and is a feasible way to assess frailty in both community-dwelling and institutionalized older people (6). A study regarding the feasibility of GFI described that the scale has the potential to provide more differentiated information about the salience of specific frailty-related problems, and thus direct a more adequately focused program for the care and support frail older adults need (7).

[3] The STEADI algorithm is available at http://www.cdc.gov/HomeandRecreationalSafety/pdf/steadi-2015.04/Algorithm_2015-04-a.pdf

[4] Adapted from the American and British Geriatric Societies' Clinical Practice Guidelines http://www.cdc.gov/homeandrecreationalsafety/Falls/steadi/index.html?s_cid=tw_injdir15

The inter-relationship between frailty and falls is often associated with poor health outcomes in the older adults (8). A concept of frailty including psychological and cognitive markers is associated with both multiple falls and fractures (9). Frailty was defined by the presence of three or more of the following criteria: unintentional weight loss, weakness, self-reported poor energy, slow walking speed, and low physical activity. Incident recurrent falls were defined as at least two falls during the subsequent year. Incident fractures (confirmed with x-ray reports), including hip fractures, and deaths were ascertained during an average of 9 years of follow-up (10).

Whereas bone strength is determined by the maximal muscle forces which the bones are habitually loaded with, preventing falls is determined by muscle power, the product of force and velocity.

Examples of different methods used to measure neuromuscular Impairments, functions and activity (11):

- Manual muscle testing (MRC 1/5 to 5/5)
- Isokinetic measurements
- Isometric measurements
- One-repetition maximum
- EMG as surrogate for “muscle activity”
- Timed up and go test
- Tinetti Gait and Balance Scale
- Berg Balance Scale
- Short Physical Performance Battery (EPESE Score) of Guralnik, Ferrucci and co-workers with chair rise, tandem standing and gait velocity
- Maximal gait velocity
- Obstacle course
- Different concepts of clinical gait analysis
- Mechanography (Leonardo force plate)
- Hand grip strength

In terms of measures of cognition, only the Mini Mental State Examination was included in D2.1 and D2.2. A considerable body of research has linked impaired cognition to an increased risk of falls (12). In particular, executive function has been highlighted as an independent predictor of future falls (13), even in individuals who do not exhibit balance impairments (14). Therefore, the **Trail Making Test (Part A and Part B)** has been included in the toolkit as a simple measure of executive function which may be feasible to include as part of a comprehensive clinical falls assessment (see Section 8.1.6).

3.2 Video-capture and analysis assessment methods

Observation is a well-practiced research method and has been used across a number of disciplines to better understand what people actually do and how they interact within a specific environment (15). Traditionally, this has required that the researcher physically position themselves within the environment in order to record events, actions, and interactions as they occur. In recent years, with advances in portability and a reduction in the cost of technology, video has become a more accessible tool for monitoring behaviors of humans in public and private spaces (16) Video-captured observation and analysis has been extensively used in health (17), education (18), and nursing research (19). Although the research approach varies by application and target group, video observations have been utilized in three main ways: as stand-alone data for analysis (e.g., of patterns of movement in and around spaces), to stimulate new data (e.g., stimulated recall used to elicit in-depth participant accounts), and as a tool to change practice (e.g., as a mechanism for reflecting on and improving professional practice. (20)

Video- or camera-based analysis were used to understand the causes and circumstances of falls during daily activities, but they could also be used to assess the effects of interventions and are maybe the most common types of sensors used in external sensing. But obviously the sensors cannot capture falls/track the user when out of the range of cameras' visibility.

One benefit of video-captured data is that they provide the opportunity to replay and review events and actions, and achieve levels of detail in observation and analysis that are difficult to capture through direct person-to-person observations (21). It is also argued that video data are less open to subjectivity and selectivity bias, as stored video recordings allow for multiple researchers to analyze the secondary data, improving the validity of the observations (22). Research has highlighted the limitations of existing falls reporting mechanisms, particularly in health care settings, where there is a high degree of unpredictability and complexity. (23) Video capture of falls has been used by researchers to describe the biomechanical features of falls (e.g., cause of imbalance, activity at the time of falling, protective responses, and impact sites) (24-26).

Robinovitch et al. performed an observational study between 2007 and 2010 in 2 long-term care (LTC) facilities in Canada (25). They installed digital cameras in common areas (dining rooms, lounges, hallways) not in private rooms as baths or bedrooms to provide evidence for cause and circumstances of falls and used a structured, validated questionnaire/ fall incident reports triggered by the facilities staff. They captured 227 falls from 130 individuals. Delta View had a network of 216 cameras, and New Vista had 48. The questionnaire focused on causes of imbalance and activity leading to the fall. Fall causes were defined within 7 subcategories by the researchers: incorrect transfer or shift of bodyweight, trip or stumble, hit or bump, loss of support with external object, collapse or loss of consciousness, slip, or could not tell).

The residents from these 2 facilities were similar in demographics and in health status. The most common cause of falls was failures in weight shifting, followed by tripping. During the activities classes walking, sitting down and standing the most falls did occur. In the consequence they emphasized to target on these activities in assessment and prevention strategies, e.g. by using clinical tests like the Timed Up-and-Go test. Also the relevance of external perturbations had to be more focused in clinical assessments. It was criticized that visual impairments were not mentioned by the authors (27) even as they are an important cause

of falls/limitation of activities due to increasing fear of falling. Furthermore the presence of pre-existing gait disorders was not discussed (28).

In a recent paper (29) the authors conclude that Video, as a tool for observational analysis, provides opportunities for fine grained analysis of the biomechanics of fall incidents, expansion of the temporal frames of fall events, examination of recurrent falls, analysis of movements of fallers and frontline workers before the fall, and facilitates stimulated recall by combining video with contextual "insider" knowledge of LTC staff. Translating this knowledge within a LTC service context has the potential to educate frontline workers and management, and inform the development of falls prevention interventions such as improvements in medication management, assistive devices, exercise, environmental hazards and assists, use of wearable hip protectors, staffing, scheduling, and resource management. Video observation also raises ethical issues surrounding privacy and consent which have implications on practice. LTC staff may feel that video monitoring is intrusive, that it generates discomfort or anxiety, and impacts either positively or negatively on their workplace practices which will affect overall acceptability of video within the workplace setting. Availability of the video allows monitoring of LTC staff, and it could be used by higher level management as an instrument to discipline frontline workers. Further work is needed to explore the impact of surveillance on LTC staff and the intentions of use by care facility management.

Finally, with the increasing deployment and relatively low cost of video technology, such tools will become an increasingly pervasive aspect of the many environments. Work is needed to explore how the benefits of video can be exploited, while minimizing harm

3.3 ICT-based Fall Detection and Prediction

Fall detection systems are assistive devices that aim to raise an alert when a fall has occurred. Effective fall detection systems allow appropriate assistance to be provided to individuals as soon as possible after a fall and can reduce fear of falling among older adults (30). ICT solutions for fall detection can be largely categorised as either body-worn solutions e.g. wearable sensors and fall alarm devices, or environmental solutions e.g. in-home motion sensors or video-based systems (31). A repository of ICT systems for falls detection – as well as falls prevention – can be found via the E-NO FALLS website (http://www.e-nofalls.eu/ictrepository/).

Research into environmental fall detection systems has shown that these methods can be highly accurate, although longer-term studies in real-world settings with standardised methodologies are required to confirm the practical implications of these findings (30). Environmental fall detection systems have the advantage of being unobtrusive and requiring minimal user input to operate effectively. However, their main limitation is the limited range in which they can operate, which negatively affects the perceived levels of security these systems provide to end-users (32). Also, issues relating to end-user privacy are barriers to the uptake of such systems, particularly in video-based systems (31).

Until recent years, research into body-worn fall detection technology has suffered from a lack of an established fall definition, a lack of agreement between the methodologies adopted in various studies, and a lack of falls recorded in real-life situations using sensors (33).

To counteract these shortcomings, the FARSEEING consortium compiled a set of recommendations with the aim of standardising data in falls-related studies using body-worn sensors (34). These include recommendations on a standard fall definition, fall reporting methods and frequencies, minimum clinical datasets to describe the faller, sensor configuration and signal characteristics. Defining a multi-phase model for falls recorded using body-worn sensors has also contributed greatly to the understanding of signals obtained for the purposes of fall detection (35). This five-phase model (pre-fall, falling, impact, resting, recovery) facilitates improved understanding of the kinematics and kinetics of falls, and how they can be optimally predicted, detected and responded to.

Since these recommendations for improving the quality of fall detection research have only come into play in recent years, studies to date describe a wide range of fall detection systems and algorithms of varying accuracy (30). As with any body-worn solution, end-user uptake and adherence will be largely determined by the effectiveness, appearance and comfort of the device. Small, light, easy-to-wear devices, particularly wrist-worn devices, appear to be preferred by end-users (31, 32). Smartphone-based fall detection systems are also a potentially useful development in this field due to their convenience for users. Issues relating to power consumption and battery life, as well as accuracy and consistency in detecting falls still need to be resolved before such methods can be applied in practice (36). However, the major challenge to successful use of all body-worn fall detection devices is obtaining satisfactory sensitivity and specificity under real-world conditions. Devices should ideally be sensitive enough to detect all actual falls, while being specific enough to avoid an excessive number of false alarms. False alarms, particularly if they cannot be cancelled by the user, are considered to be a nuisance and are a major barrier to end-user acceptance (31), as well as leading to inefficient use of resources in responding to false alarms.

The FARESEEING Project web-based fall-risk assessment tool (FRAT-up) for evaluating the fall risk within a year., which could be used by general practitioners and health organizations (37). FRAT-up based on 26 common risk factors. The user is asked 26 questions about the health status of the patient, answered using a dichotomous (yes/no) or Likert scale. It showed good validation results of fall risks computed by FRAT-up in a community-dwelling setting and is comparable to externally validated state-of-the-art tools. A prototype is freely available through a web-based application: ffrat.farseeingresearch.eu

An experimental approach to the introduction of ICT-based solutions within the set of assessment methods provided fruitful results within the FARAO Project.

The FARAO project (Fall Risk Assessment in Older adults), funded by Dutch National funds, it is intended to develop and test a miniaturized body-fixed sensor that allows ambulatory measurements of body acceleration and angular velocity data. Algorithms and analyses are developed to detect impending falls (instability) and actual falls in older adults in daily life, during daily physical activities, as well as to predict overall fall risk.

E-NO FALLS can learn from FARAO project, both in the result of the project as well as in the methodology followed to reach project goals. If results are the object of investigation within WP4 of E-NO FALLS, the study of FARAO methodology provides relevant insights for the purposes of present D2.3. Particularly, FARAO approach to assess the efficacy of the prototyped solution is interesting within present survey: older adults wear an activity monitor set of sensors for a week and the analysis of instability of gait during free living conditions is added to the prediction model of falls. This method makes possible to supply specific information about physical activity for better interpretation of the risk behaviour. This approach

has been tested by the VUmc (Amsterdam) in the mobility outpatient clinic. The method is also recognised as a potential outcome to evaluate fall prevention interventions.

Applying the evaluation criteria used within D2.2 to evaluate the existing assessment methods, it is possible to understand that FARAO method is “relatively cheap”, it can be used both in protected environments as well as in “real life” circumstances, and finally it provide information to design user-tailored fall prevention strategies. It demonstrates empirically that ICT-based solution is worth to be integrated to traditional assessment methods, as it integrates “real life” data to the observations and evaluations did by experts and it add replicable and scalable results. Also, daily-life accelerometry is an example of how ICT-based tools can substantially contribute to the identification of individuals at risk of falls, and can predict falls in 6 months with good accuracy (38).

In general sensor-based assessment tools could be very useful to add prognostic value to classical clinical risk factors but more research is necessary to develop sensitive and specific tools.

3.4 Instrumented Performance Tests

Several fall risk assessment tools were developed to identify at-risk populations and guide intervention by highlighting remediable risk factors for falls and fall-related injuries, as discussed in the previous deliverable. Despite the numerous clinical scores developed, these methods often depend on individual observation and subjective interpretation, which make the assessment results inconsistent with limited accuracy, such as some standard tests, Timed Up-and-Go (TUG) Test and Berg Balance Scale. Another issue is that the majority of these assessments are restricted to use in a clinical environment, as their correct execution often requires supervision, and so renders them unsuitable for long-term monitoring.
In this context, researchers have more recently attempted to address some of these deficits by instrumenting new or existing physical fall risk assessments with wearable motion sensors to make such assessments more objective, quicker to administer, and potentially more appropriate for deployment for unsupervised use in the community (39-41).
This is a promising area of investigation, although research in this field has not been as extensive as that involving the use of similar monitoring devices for fall detection.
Briefly, the concept of this measurement involves the analysis of signals collected during movement via body-worn sensor-based devices - mostly containing miniaturized accelerometers, gyroscopes, or both. The signals are usually triaxial, and offer an almost endless range of movement-describing features that would otherwise be unavailable. Various time and frequency domain features are then extracted from the signal and incorporated (often along with other features such as age, gender, body mass index) into algorithms that attempt to predict fall occurrence or classify people into risk categories as precisely as possible. Sensor-based fall risk assessment may also enable identification of specific physiological deficits, which would present an advantage over merely a risk classification.
The physical movement routines to be assessed can be considered as either structured or unstructured, with several sub-options existing for each. For example, a structured routine can be based on complex tasks that people would not normally perform in everyday life, and which may challenge one’s strength, balance, and even cognition. Examples of these include the Timed Up and Go test, the Sit- to-Stand test, and the Alternate Step Test just to name a few. Alternatively, a structured routine may also be composed of a set of simple movements that more closely resemble activities of daily living (ADLs).

Rispens et al. showed in their study, that daily life gait characteristics are associated with fall history, and these findings have to be confirmed by others and supported by prospective data (42).

Howcroft et al. (43) provide critical examination of inertial sensor application for fall risk assessment and identify important areas for future work. The review shows as various activities were used for inertial-sensor-based fall risk assessment. The most frequently assessed activity was level ground walking (45%), followed by Timed Up and Go (TUG) (32.5%), sit-to-stand transitions (STS, 22.5%), standing postural sway (20%), left-right Alternating Step Test (AST) on level ground (15%), and uneven-ground walking (2.5%). Many studies used a combination of activities (20%).
The authors concluded that inertial sensors have the potential to provide a quantitative, objective, and reliable indication of fall risk in the geriatric population, and high levels of accuracy, specificity, and sensitivity have been achieved in fall risk prediction models.
In two recent reports, Marschollek et al. (44) and Greene et al. (45) examined how well the sensor-based fall risk assessment results were able to discriminate between fallers and nonfallers, over a period of 1 or 2 years following the assessment, respectively. Both studies report classification accuracies of approximately 80% using the same movement task, but with different sensor- based devices and in different body locations.

As mentioned before, the TUG represents one of the tests most frequently instrumented. Green et al. (46) showed that quantitative assessment of gait and turning during the TUG test may allow for more objective and sensitive determination of falls risk, improving the quality of care offered to community-dwelling elderly adults at risk of falling and allowing more timely intervention to prevent future falls. The study aims to show that body-worn kinematic sensors can be used to objectively quantify the TUG test and provide a comprehensive, quantitative analysis of timing, gait, and stability for each of the segments of the TUG test.
Furthermore, the authors discuss the iTUG tool that has potential for use in a supervised monitoring protocol where deterioration in a subjects gait and balance would be noted as a change over time in their gyroscope derived parameters obtained while completing the TUG. This could form part of a continuous falls risk assessment protocol, deployed in-home or in a primary care facility.
Finally, several studies has verified the suitability of consumer accelerometers, as those included in recent smartphone, to perform some clinical tests, such as the instrumented TUG test.
The Android uTUG application is the first of a series of standalone applications instrumenting clinical functional tests. In the FARSEEING project (47) the uFall Android application has been developed for monitoring the user's motor activities at home. The applications developed take advantage of the smartphone- embedded inertial sensors and require that subjects wear the smartphone by means of a waist belt. It contains an uTUG application, a stand-alone application for instrumenting the Timed Up and Go test, designed to be self-administrable at home.

3.5 Limitations of the State of the Art Methods

The health care professionals and academic community are looking for methods for fall risk assessment which are "easier, cheaper, better, complementary, undertaken remotely, and predictive" (Stephen Lord, EU Fall Festival, 24th March 2015, Stuttgart). Identifying persons with a high risk of falling can facilitate effective prevention of falls. Several ways of assessing fall risk have been investigated, including questionnaires, physical tests, gait analysis, and physical activity measurements. Yet the predictive value of these models are still limited (48).

The introduction of ICT solutions as tools to be integrated to the assessment methods seems to be a crucial step forward, which is not completed yet, and this is one of the limitations of the state of the art. The research carried out on assessment methods demonstrates that ICT can improve most of the mentioned and analyzed methods. But "how" it can be done, is still under investigation, and only experimental pilots can be mentioned and studied. Therefore, there seems to be the need for further investigation in order to identify assessment methods specifically intended for ICT-based solutions, based on the existing methods. Stephen Lord's speech at EU Falls Festival 2015, as well as other interventions during that event, clearly demonstrated that ICT can be integrated within the existing standard assessment methods. But also that the integration process is still ongoing, for several reasons, both technological as well as clinical. Also ethical and privacy issues require consideration.

The actual used best practice assessments also show other limitations – especially as they only measure single moments in laboratory conditions. The following sections discuss the pros and cons of these (limitation) aspects.

3.5.1 Lab measurement compared to free living

The National Institute for Health and Care Excellence (NICE) (49)and many other guidelines suggest that a standard risk assessment evaluation should be performed in a dedicated setting like a laboratory. However, lab conditions may not reflect usual performances as people may alter their performance due to the lab environment and test condition (trying to do their best), known as Rosenthal effect. On the other hand, home measurements may not be possible to standardize due to the reduced control by clinical experts; and standardized lab measurements are necessary to generate comparable and accurate data.

There are many cases, in fact, in which is not possible simply transfer this assessment to a daily setting (home), but there are still possibilities to perform assessment tests at home:

A promising way to assess fall risk is by means of <u>body-worn sensors in daily life</u>. Trunk accelerations during walking can provide information about personal risk factors for falls related to physical capacity and health status. This information is typically assessed by gait analysis in controlled settings, which has shown that high variability, low stability, and low symmetry of gait are associated with falling (50, 51). The use of body-worn sensors in daily life can add information about physical activity as well as situational fall-risk factors related to one's behavior and environment. This new approach has demonstrated the potential to make an important contribution to fall-risk assessment, as shown by daily-life gait characteristics' associations with falls and the added value of gait characteristics in fall prediction over commonly used methods (42). Even though the previously developed fall-risk model based on daily-life gait characteristics showed a very promising performance there may still be room for improvement.

One aspect to consider is the selection of specific gait episodes in daily life that contain the most relevant information for fall-risk prediction. Previous studies used the mean or median of a gait characteristic over the analyzed epochs of gait, based on the assumption that this would be the most representative estimate for that characteristic. However, as situations in daily life vary, gait characteristics obtained in particular situations may better reflect a person's fall risk than the median of those obtained in all analyzed epochs of gait.
On the one hand, episodes with "low gait quality" may contain information about taking risks or responding to risks in such situations. High-risk situations may be expected to show high variability and low stability and symmetry, as these gait characteristics are associated with falling. On the other hand, situations where people show "high gait quality" might be

informative about the best possible performance they can achieve, which may be closely related to personal risk factors or the performance in a lab or on a treadmill.
Furthermore, in a recent study on intra-individual variability in motor measures such as walking tasks, it has been shown that measures gathered in the home might be more representative of an individual's normal daily functioning. (52) The authors suggest that unobtrusive, continuous in-home assessment provides a promising new tool for the early detection of clinically relevant changes not only affecting cognition, but for a number of other neurologic and general medical conditions.

Even if in laboratory setting there is opportunity to use a sophisticated tool, it seems that some crucial information can be derived from daily life experiences. In fact, authors in a recent study suggest that in addition to observing gait patterns during standard clinical examinations, physicians should also ask patients to report mobility difficulties as well as measure gait velocity to improve the utility of the clinical examination and the identification of patients at high risk of falling. (53) These quick and easy additions to the clinical evaluation could contribute to focus on appropriate interventions in older adults at higher risk of falling.

Finally some specific tests usually used to assess patients at risk of falls have been demonstrated to maintain their sensitivity and specificity only in one setting (54). The TUG (Timed Up and Go) test is a commonly used screening tool for falls risk in the inpatient and the community setting. The TUG test was developed in 1991 as a modified timed version of the Get up and Go (55). The TUG is recommended as a routine screening test for falls in guidelines published by the American Geriatric Society and the British Geriatric Society. The NICE guidelines also advocate the use the TUG for assessment of gait and balance in the prevention of falls in older people.
However, a recent systematic review (54) demonstrates that the diagnostic accuracy of the TUG should not be used for identifying community dwelling adults at high risk of falls in clinical practice.

3.5.2 Standardised Assessment (Single-Moments) compared to Long-term Monitoring

Sensor-based assessments of standardised tasks have been widely studied for the purposes of assessing gait and balance performance, which are key indicators of fall risk and crucial markers of clinical impact in exercise-based falls prevention interventions. Depending on the precise methods used, standardised sensor-based assessments can be as accurate (or possibly more accurate) than clinical assessments of fall risk (56), although clear guidelines on the optimal assessment procedures are still lacking (43). Standardised sensor-based methods are quick, simple, more portable and relatively inexpensive in comparison to previous quantitative methods of assessing gait, balance and fall risk. Previous methods required the use of expensive movement analysis equipment, which required the person to travel to a gait laboratory for assessment, as many clinical settings do not have the space or financial resources to provide such services on site.

Additionally sensor-based assessment methods also more closely mirror current clinical practice, where fall risk is assessed by clinicians using standardised tools in a supervised environment. This could make standardised sensor-based methods easier to implement, as they could be readily integrated into existing falls prevention care pathways.

However, the implementation of standardised sensor-based assessments in practice would require considerable resources, in terms of initial equipment and staff training costs, as well as on-going staff input to carry out assessments, interpret the results, implement appropriate

interventions and review clients over time. In this sense, standardised sensor-based assessment methods may not necessarily offer reduced costs in comparison to current methods of fall risk assessment. In addition, as with standardised clinical assessments, accelerometer-derived measures of gait performance may be subject to day-to-day variations, and long data series' may be required to obtain valid measures of performance over time (57). Also, as discussed in Section 2.2.1, an individual's performance during a single standardised assessment in a clinic/laboratory setting may not be an accurate reflection of their usual performance in daily life.

Long-term monitoring offers a potential novel solution, since it allows individuals to be observed in an unobtrusive manner over time. Body-worn sensors can be used to obtain rich data on older adults' daily physical activity and sedentary behaviour (58). This data can be used to determine patterns of daily activity, including the types of activity undertaken, frequency and durations, for example, via "barcode" representations of physical activity patterns (59). The clinician could use the information gathered to assess deterioration over time or change due to intervention. As well as defining the quantity of activity, a useful measure of fall risk exposure, long-term monitoring methods can also be used to determine the quality of activities undertaken. Accelerometer-based assessment of the amount and quality of daily-life gait has been shown to accurately identify individuals at risk of falls (38, 48). Providing feedback to users on the quality and quantity of their daily activities could help to promote self-management among end-users and a sense of ownership over their own health outcomes.

A major limitation to long-term monitoring methods is the potential for inappropriate and/or inconsistent sensor usage in the absence of supervision. For example, small deviations in lumbar sensor placement may not adversely affect accelerometer-derived daily life gait measures, but larger changes in sensor positioning produce inconsistent, measures and can render the data collected invalid for gait assessment (60). Small, light, unobtrusive and comfortable devices are required to maximise the chances of acceptance by end-users (31). Another limitation that may affect adherence to long-term monitoring methods is end-users' perceptions of control over the monitoring technology and its usage. Privacy and control over situations in which technology is used have been highlighted by older adults as important factors in determining technology acceptance(31). This may be more of a concern in fall-related ICT systems that include video imagery, but should also be considered as a potential barrier to acceptance of sensor-based long-term monitoring systems.

It must be remembered that both standardised assessments and long-term monitoring methods discussed here provide an objective measure that should be evaluated by the clinician in the context of the patient presentation. Due to the multifactorial nature of falls, these measures need to complement current assessment methods to provide the recommended comprehensive multifactorial assessment of each individual (4), and thus facilitate appropriate clinical decision-making.

4. Experts Evaluation of the Toolkit

4.1 Questionnaire

On Monday, 20th of July a short questionnaire was sent to the E-NO FALLS partners. They were asked to distribute the questionnaire within their personal network/contacts.
The questionnaire consisted of 3 closed and 3 open questions. By clicking "send questionnaire" an email programme was opened and questionnaire could send directly to Sandra.prescher@charite.de (WP-leader).

Dear Ladies and Gentlemen,

You are invited to participate in a survey for **E-NO FALLS European Project: European Network for FALL prevention, intervention and security** (for more information see: http://www.e-nofalls.eu), funded under the(Competitiveness and Innovation Framework Programme –CIP of the European Commission.

As part of the project we developed a toolkit about **clinical and socio-economic assessment methods for ICT-based technologies** in medical care (especially regarding fall prevention/intervention and security). The purpose of the document is to provide a useable catalogue of common approaches and indicators for the measurements of the socio-economic and clinical impact. In other word the aim is to propose and share knowledge on which methods would work best and what is missing.

In this survey experts will be asked to read the toolkit and complete a brief questionnaire about the structure, provided information and methods. It will take approximately **5 minutes** to complete the questionnaire.

Your participation in this study is completely voluntary. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate.

For any questions/comments do not hesitate to contact us:
Sandra Prescher, Charité – Universitätsmedizin Berlin (Germany); Sandra.prescher@charite.de (Work-Package Leader)

1. Is the structure of the catalogue transparent and useful? Please tick relevant opinion

Not applicable	Poor	Fair	Good	Very Good	Excellent

Any comments about the structure?

2. Are the methods included relevant for the users of the catalogue? Please tick relevant opinion.

Not applicable	Poor	Fair	Good	Very Good	Excellent

3. Is it possible to adopt the catalogue for other ICT based solutions in health care? Please tick relevant opinion.

Not applicable	Poor	Fair	Good	Very Good	Excellent

Please explain your answer:

4. What should such a catalogue include? What is missing? Please fill in your opinion.

Send Questionnaire

Thank you for answering our questionnaire!

4.2 Results

We received only four completed questionnaires from experts (3 clinicians and 1 technician. They all consider the catalogue useful and clear and believe that it could be used for other ICT based solutions in health care. On the basis of the experts suggestions we modified the structure of the catalogue adding an index and a clearer internal sub-division of the different area of interest. As a result of the small sample we cannot provide more depth in the analysis, nevertheless we received positive feedback on structure and contents.

5. Limitations and Future Research

While the number of studies on the effectiveness of interventions to prevent and detect falls in older adults has increased, many research questions related to fall prevention among older persons identified remain active research questions today.

This document, together with the previous deliverables D2.1 and D2.2, highlights a large number of assessment methods of fall prevention and intervention in the clinical and socio-economic area. Falls are caused by complex interactions between physiological, clinical, environmental, and situational factors which makes fall assessment for prevention and intervention a challenging task (61). No assessment method can integrate all these factors. A collection of methods had to be used for socio-economic and clinical assessment. Furthermore there are missing methods for non-fall-specific assessments, e.g. quality of life.

As demonstrated in the review above, there are a number of gaps and omissions in the existing body of evidence on falls prevention/intervention assessment methods due to several different reasons: the multifactorial nature of fall, the lack of randomized controlled trials in older people, the different settings, and the lack of cost/benefit analysis in evaluation of falls interventions.
This is especially true in the context of ICT-based solutions for falls, as methodological quality of many studies varies widely and there is notable heterogeneity. In fact, much of the evidence comes from circumscribed trials and pilots, and there is a lack of evidence of the longer-term contribution and value of more advanced systems under real life conditions.

On the other side there are a big number of existing methods for some aspects: improvements in quality of life is an important goal of therapeutic activities, but not consistently measured in studies. Overall approximately 800 instruments to measure quality of life exist, but standardization in the development and collection of scales is lacking (62). Quality of life is a subjective assessment which could change more than biological parameters. For fall prevention/intervention assessments actual existing methods are providing information for a single part of these factors.

Although we tried to reduce heterogeneity in the definition of assessment methods as much as possible by grouping them in more homogeneous categories, inconsistency in how to translate these approaches in the real context remains.

Future studies should focus on how to minimize these limitations, and hence the internal validity would be greatly improved. Investigators should choose an RCT design, when feasible, because of its potential to eliminate bias, as well as to control known and unknown confounding variables. In situations when it is unethical or logistically impractical to conduct a randomized trial, high-level quasi-experiments should be used. In addition, attention should be given to selection and number of study samples to improve both internal and external validity.

6. Conclusions

This deliverable, along with the documents D2.1 and D2.2, try to summarize a large amount of information on fall prevention strategies, including indicators and criteria for measurement of socioeconomic and clinical impact assessment and presenting new ICT methods.

In this sense, the Toolkit presented below, constitutes the result of the work done in this WP and is structured in a way easy to understand and use. Despite the fact that it could not encompass all the information on falls, we believe it could be a useful tool for support researchers in ICT-based solutions for falls preventions strategies.

This catalogue/ inventory provides the validation of the impact assessment methods to assess the feasibility of methods in various uses with regard to the socio-economic and clinical impact area.In that way, the catalogue could be useful for many stakeholders, not only clinicians,

The purpose is not only to list different methods but also to characterize a method's application area and the method, including its limitations, by suggesting appropriate assessment criteria and then assessing the methods(toolkit).

The inventory is based on the expertise of the specialist, but also on a literature review and the last studies in impact assessment methodologies on ICT for ageing well.

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8. ANNEX: Toolkit

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The different method sections are coloured differently for easier identification

Legend

	Description of the method
	Applications Area of the method
	Strengths of the method
	Weaknesses of the method
	Further information for the method
	References used
	Method with time measurement
	Necessary Equipment
	Method with questionnaire
	Statistical analysis
	Group discussion
	interview

Please mention: For any significant measurement of clinical and health economic benefit an individual number of user/cases is necessary (power calculation).

8.1 Clinical Methods

8.1.1 Motor Function Test

Method	Time Up and Go Test (TUG)
	Client stands from a chair with an armrest, walks 3m and turns around, returns to chair and sits down.[1-3] Cut off points for level of risk: 10-14 seconds**.**
	Any setting in ambulatory elderly
	Sensitivity = 71% Specificity = 89%. [2-3] The test has concurrent validity due to high correlation scores with the Berg test, Barthel Index, and gait speed. It is easy and quick to perform and does not require specialist equipment.
	• Rely on clinical judgment • Specified cut-off points vary between studies. • The totality of evidence to date is that it has limited predictive ability and should not be used in isolation to identify community-dwelling older people at increased risk of falls.
	This assessment appears to have clinical utility demonstrated by time to administer and little burden to patients. The TUG is recommended as a routine screening test for falls in guidelines published by the American Geriatric Society and the British Geriatric Society [4]. The National institute of Clinical Evidence (NICE) guidelines also advocate the use the TUG for assessment of gait and balance in the prevention of falls in older people.
	1. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991 Feb;39(2):142-8 2. Barry E, Galvin R, Keogh C et al. Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults: a systematic review and meta-analysis. BMC Geriatr. 2014 Feb 1;14:14. 3. Beauchet O, Fantino B, Allali G et al. Timed Up and Go test and risk of falls in older adults: a systematic review. J Nutr Health Aging. 2011 Dec;15(10):933-8 4. National Institute for Health and Care Excellence (NICE). Falls: assessment and prevention of falls in older people, Issue: 2013: https://www.nice.org.uk/guidance/cg161/resources/guidance-falls-

	assessment-and-prevention-of-falls-in-older-people-pdf
Method	**Five Times Sit to Stand Test**
	The Five Times Sit to Stand Test is used as a quick and simple assessment of functional lower limb muscle strength and to quantify functional transfer performance.
	Performance on the Five Times Sit to Stand Test can be used as a predictor of fall risk [1, 2], as part of a comprehensive fall risk assessment.
	• Quick and simple to complete • Inexpensive, as it requires only basic equipment and training to use • Feasible for use in a wide range of clinical and research settings • Normative data [3] and threshold times for estimating fall risk [1, 4] are available for community-dwelling older adults. • Evidence supports its use in specific clinical populations e.g. stroke [5], Parkinson's disease [6].
	Assesses only a limited aspect of functional performance
	It is recommended to use a standard chair (seat height 43-45cm approx.) with arms for testing, and to keep the testing chair consistent for retests. Any modifications required e.g. use of arms to assist movement, assistance required, should be documented.
	1. Buatois S, Miljkovic D, Manckoundia P et al. Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older, *Journal of the American Geriatrics Society*, 2008, 56(8), 1575-1577. 2. Zhang F, Ferrucci L, Culham E et al. Performance on Five Times Sit-to-Stand Task as a Predictor of Subsequent Falls and Disability in Older Persons, *Journal of Aging and Health*, 2013, 25(3), 478-492. 3. Bohannon RW. Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders, *Perceptual and Motor Skills*, 2006, 103(1), 215-22. 4. Tiedemann A, Shimada H, Sherrington C et al. The comparative ability of eight functional mobility tests for predicting falls in community-dwelling older people, *Age and Ageing*, 2008, 37(4), 430-5. 5. Mong Y, Teo TW & Ng SS. 5-repetition sit-to-stand test in subjects with chronic stroke: reliability and validity, *Arch Phys Med Rehabil, 2010*, 91(3), 407-13. 6. Duncan RP, Leddy AL & Earhart GM. Five times sit-to-stand test performance in Parkinson's disease, *Arch Phys Med Rehabil, 2011*, 92(9), 1431-6.

Method	Tinetti-Mobility Scale/ Performance-Oriented Mobility Assessment (POMA)
	The total POMA scale (POMA-T) consists of a balance scale (POMA-B) and a gait scale (POMA-G). [1] The POMA-B carries the subject through positions and changes in position, reflecting stability tasks that are related to daily activities. In the POMA-G, several qualitative aspects of the locomotion pattern are examined. Each item is scored on a 2- or 3-point scale, resulting in a maximum score of 28 on the POMA-T and maximum scores of 16 and 12 on the POMA-B and the POMA-G.
	Originally, the POMA-T was developed to predict falls in an institutionalized population. Later, the scale also was used in various clinical contexts as a measure of mobility impairment and to study the effects of interventions. [2-3]
	• The POMA-T and its subscales POMA-B and POMA-G showed good relative reliability, as well as concurrent and discriminant validity.
	• POMA-G performed less well with regard to these clinimetric properties. • Several adapted version
	It is easily applied in clinical settings; other than a standard chair and a stopwatch, no further equipment is required, and only little experience is needed to master its use. After a few practice sessions, the observer can complete the assessment in less than 15 minutes.
	1. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. J Am Geriatr Soc. 1986; 34:119–126. 2. Faber MJ, Bosscher RJ & van Wieringen PCW. Clinimetric Properties of the Performance-Oriented Mobility Assessment Phys Ther. 2006; 86:944-954. 3. Pardasaney PK, Latham NK, Jette AM et al. Sensitivity to Change and Responsiveness of Four Balance Measures for Community-Dwelling Older Adults, Phys Ther. 2012; 92:388-397

Method	Berg Balance Scale (BBS)
	A 14-item objective measure designed to assess static balance and fall risk in adult populations. [1-2] Some items require that the patient maintains positions of increasing difficulty, from sitting to standing on one leg. Other items evaluate the ability to perform specific tasks, such as reaching forward, turning around and picking up an object from the floor. Scoring is based on the ability to meet certain time or distance requirements and to perform the items independently. Each task is scored on a 5-point scale from 0 to 4 giving a maximum score of 56, which indicates balance ability within the normal range. A score of < 45 indicates individuals may be at greater risk of falling
	Brain injury, Community dwelling elderly, Multiple sclerosis, Orthopedic Surgery, Osteoarthritis, Parkinson's Disease, Spinal Cord Injury, Stroke, Traumatic and acquired brain injury, Vestibular Dysfunction
	• The BBS may be better suited for use with acute stroke patients since the majority of these patients are not able to obtain the measures maximum scores at rehab admission [3]. • In spinal cord injury, BBS scores not associated with the number of falls and not able to discriminate fallers from non-fallers [4] • BBS may be limited in use in Parkinson Disease to those in the middle stages (Hoehn & Yahr 2-3) as it has been noted to exhibit ceiling effects [3, 5]
	• No common interpretation of BBS scores currently exists • The Berg may take longer than other balance measures to administer • In Parkinson disease those in Hoehn and Yahr stages 4 and 5 would be unable to complete the test since an assistive device cannot be utilized during testing. • For vestibular dysfunction, the Berg Balance Scale may not be the best measure to identify individuals at risk of falling [6].
	Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft walkway
	1. Berg K et al.. Measuring balance in the elderly: preliminary development of an instrument. Physiother Can 1989; 41: 304 /311. 2. Berg KO et al. Measuring balance in the elderly: validation of an instrument. Can J Public Health 1992; 83(suppl 2): S7 /S11. 3. www.rehabmeasures.org/Lists/RehabMeasures/PrintView.aspx?ID=888 4. Wirz M et al. Falls in persons with spinal cord injury: validity and reliability of the Berg Balance Scale. Neurorehabil Neural Repair 2010; 4(1): 70-77. 5. Leddy AL, Crowner BE & Earhart GM. Functional gait assessment and balance evaluation system test: reliability, validity, sensitivity, and specificity for identifying individuals with Parkinson disease who fall. Physical Therapy 2011; 91(1): 102-113. 6. Whitney S, Wrisley D & Furman J. Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. Physiother Res Int. 2003;8(4):178-86.

Method	Turn 180°
	TURN 180 is one of the most commonly used physical performance tests with older people. [1,2] The older person needs to stand up and, on request, turn to face the opposite direction, without holding onto chairs, if possible. They must try not to use objects to support their body weight, as this would invalidate the test. They can choose the direction in which they turn. An observer behind the older person counts the steps taken. More than four steps are associated with an increased fall risk [3] and needs further assessment.
	Any setting (hospital and community) Diseases: synopcal and non-syncopal falls
	• Easy to perform
	• Relies on clinical judgment • Specified cut-off points vary between studies.
	1. Simpson JM, Worsfold C, Reilly E & Nye N. A standard procedure for using TURN180: testing dynamic postural stability among elderly people, Physiotherapy, 2002: 88(6):342-353. 2. National Institute for Health and Care Excellence (NICE). Falls: assessment and prevention of falls in older people, Issue: 2013, NICE clinical guideline 161 URL: https://www.nice.org.uk/guidance/cg161/resources/guidance-falls-assessment-and-prevention-of-falls-in-older-people-pdf 3. Nevitt MC, Cummings SR, Kidd ST & Black D. Risk factors for recurrent nonsyncopal falls. A prospective study. JAMA. 1989 May 12;261(18):2663-8.

8.1.2 Fall Risk Screening Tools

Method	STRATIFY - St Thomas's risk assessment tool in falling elderly inpatients
	Fall risk assessment tool: 5 items (previous falls, agitation, vision, toileting, transfer and mobility); score ≥2 used as cut-off [1]
	Hospital setting
	• simple test • shows good clinical sensitivity and specificity of falls among elderly hospital inpatients: High sensitivity and Negative Predictive Value (NPV) - Sensitivity (95% CI): 92.4 (84.2-97.2), Specificity 68.3 (63.3-73.1)% Positive Predictive Value (PPV): 38.8 (31.8-46.2), % NPV: 97.6 (94.9-99.1)[1, 2]
	External validity: if the scale is applied in different setting with a totally different population psychometric properties change depending on the setting, e.g. stratify performed poorly in identifying stroke patients at risk. [3]
	• There are many modified version of the scale with different validity • Population and setting affect STRATIFY performance.
	1. Oliver D, Britton M, Seed P et al. Development and evaluation of evidence based risk assessment tool (STRATIFY) to predict which elderly inpatients will fall: case-control and cohort studies. BMJ. 1997 Oct 25;315(7115):1049-53. 2. Oliver D, Papaioannou A, Giangregorio L et al. A systematic review and meta-analysis of studies using the STRATIFY tool for prediction of falls in hospital patients: how well does it work? Age Ageing. 2008 Nov;37(6):621-7. 3. Lee J, Geller AI & Strasser DC. Analytical review: focus on fall screening assessments. 2013 Jul;5(7):609-21.

Method	Morse Fall Scale
	Morse Fall Scale is multifactorial and should be used in clinical environments and consists of six items: 1. history of falling, 2. secondary diagnosis, 3. ambulatory aids, 4. intravenous therapy, 5. type of gait and 6. mental state. Score 45 used as cut-off. [1]
	Hospital setting
	Sensitivity: 0.72 to 0.96, specificity: 0.51 to 0.83 [1]
	• External validity: if the scale is applied in different setting psychometric features change depending on the setting. • “Time consuming and often inconvenient and were no better at prediction than the clinical judgments made by the primary nurses.” [2, 3]
	1. Morse JM, Black C, Oberle K & Donahue PA prospective study to identify the fall-prone patient. Soc Sci Med. 1989;28(1):81-6. 2. Hempel S, Newberry S, Wang Z, Booth M et al. Hospital fall prevention: A systematic review of implementation, components, adherence, and effectiveness. J Am Geriatr Soc. 2013 Apr;61(4):483-94.Epub 2013 Mar 25. 3. Eagle DJ, Salama S, Whitman D et al. Comparison of three instruments in predicting accidental falls in selected inpatients in a general teaching hospital. J Gerontol Nurs, 1999. **25**(7): p. 40-5.

Method	FRAT UP
	• Assessment tool for evaluating the fall risk within a year • Aimed to general practitioners and health organizations (per-subject evaluation vs. population wide)
	Freely available as a web-based application at ffrat.farseeingresearch.eu
	• Focused on community-dwelling older people • Based on 26 risk factors available in the literature • Exploits available clinical information about the subject
	It has not received any official approval by any medical commission or organization
	1. FARSEEING PROJECT www.farseeingresearch.eu 2. Cattelani L, Palumbo P, Palmerini L, Bandinelli S, Becker C, Chesani F, et al. FRAT-up, a Web-based Fall-Risk Assessment Tool for Elderly People Living in the Community. Journal of Medical Internet Research. 2015;17(2):e41.

Method	Dowtown Index
	Fall risk assessment tool – Known previous falls, medications, sensory deficits, mental state, gait; score 3 used as cut-off [1]
	Hospital setting
	Predictive validity: Sensitivity: 0.91, specificity: 0.27 <u>Acute inpatient rehabilitation</u>: Sensitivity (95% CI): 92.2 (82-97), Specificity 34.2. (27-42)% Positive Predictive Value (PPV): 33.1 (25-41), % NPV: 92.9 (83-97) [2, 3]
	External validity: if the scale is applied in different setting psychometric features change depending on the setting
	1. Downton JH. Falls in the Elderly. London: Edward Arnold, 1993; 128–30. 2. Vassallo M1, Poynter L, Sharma JC et al. Fall risk-assessment tools compared with clinical judgment: an evaluation in a rehabilitation ward. Age Ageing. 2008 May;37(3):277-81. 3. Hempel S, Newberry S, Wang Z et al. Hospital fall prevention: a systematic review of implementation, components, adherence, and effectiveness. J Am Geriatr Soc. 2013 Apr;61(4):483-94.

8.1.3 Central Sensory Organization

Method	Computerized Dynamic Posturography (CDP)
	Computerized Dynamic Posturography (CDP) is a unique assessment technique used to objectively quantify and differentiate among the wide variety of possible sensory, motor, and central adaptive impairments to balance control. As such, CDP is complementary to clinical tests designed to localize and categorize pathological mechanisms of balance disorders. CDP can identify and differentiate the functional impairments associated with the pathological processes. By itself, CDP cannot diagnose pathology or site-of-lesion. During a Computerized Dynamic Posturography testing session, a series of tests are administered that measure how well a patient can maintain balance under different conditions. Some of the tests are designed to mimic different conditions patients encounter in everyday life. Other tests are designed to determine the source of the patient's balance problem. Because of the complex interactions among sensory, motor, and central adapting processes, CDP requires separate protocols to adequately differentiate among impairments. To quantify the failure of adaptive mechanisms to select appropriate sensory inputs and movement response patterns, CDP exposes the patient to a variety of controlled visual and support surface conditions.
	Hospital, protected environments
	Most effective in determining the treatments.
	• Requires high level of expertise and time for properly monitor patients. • Requires a duly tuned preparation, according to the patient’s body.
	High costs in general, specialized personnel required.
	1. Goebel JA (Ed.). A thorough overview of CDP methodology and clinical applications can be found in "Practical Management of the Dizzy Patient, Lippincott Williams & Wilkins Publishers 2000. 2. Stewart M, Chen A, Wyatt R et al. Cost-effectiveness of the diagnostic evaluation of vertigo. Laryngoscope. 1999;108:600-605.

Method	Modified Romberg Test of Standing Balance / Modified Clinical Test for Sensory Interaction in Balance (CTSIB)
	The Romberg test is an appropriate tool to diagnose sensory ataxia, a gait disturbance caused by abnormal proprioception involving information about the location of the joints. It is also proven to be sensitive and accurate means of measuring the degree of disequilibrium caused by the central vertigo, peripheral vertigo and head trauma. [1] It has been used in clinic for 150 years. The Romberg test is used to demonstrate the effects of posterior column disease upon human upright postural control. The Romberg test is used for the clinical assessment of patients with disequilibrium or ataxia from sensory and motor disorders.
	Hospital, protected environments
	There is no consensus in the Reliability (Intra and inter) and validity for Romberg's in the literature as the test is more of qualitative rather than quantitative (objective). However, this test can be used as a quick clinical tool to screen. The introduction of various instrument in the arena of balance assessment and the force plat form usage has given the more objective and accurate measurement.
	• Not Quantitative • Low diagnostic sensitivity and specificity • Low power to determine lesions, predict the risk of falling, reflect the discomfort and ability to perform daily activities.
	Specialized personnel required.
	1. Agrawal Y. The modified Romberg balance test. Otol Neurotol, 2011 Oct,32(8):1309–1311.

Method	The Groningen frailty indicator (GFI)
	The GFI is a widely used screening instrument for identifying frail older adults. The GFI consists of 15 self-report items [1]. A study regarding the feasibility of GFI described that the scale has the potential to provide more differentiated information about the salience of specific frailty-related problems, and thus direct a more adequately focused program for the care and support frail older adults need [2]. Scores range from 0 (not frail) to 15 (very frail). Older adults will be considered transitionally frail if they have a GFI score of 4 or 5. [6]
	In home-dwelling and institutionalized elderly people [4]
	FFI has demonstrated high internal consistency and construct validity when compared to the Tilburg Frailty Indicator and the Sherbrook Postal Questionnaire [3]. It is feasible for use in primary care and its implementation requires less start-up expenses. The GFI score reflects current problems in patients' daily lives [2].
	Age has a statistically significant association with GFI scores. Overall, the GFI discriminates between subgroups with different demographics and diseases/disorders characteristics [4]
	English: https://www.rug.nl/research/portal/files/17485987/Appendices_.pdf Dutch: http://www.platformouderenzorg.nl/screening/functionaliteit/groningen-frailty-indicator-gfi/50
	1. Bielderman A et al. Multidimensional structure of the Groningen Frailty Indicator in community-dwelling older people. BMC Geriatr, 2013. 13(86): p. 1471-2318. 2. Drubbel I et al. Identifying frailty: do the Frailty Index and Groningen Frailty Indicator cover different clinical perspectives? A cross-sectional study. BMC Fam Pract, 2013. 14(64): p. 1471-2296. 3. Metzelthin SF et al. The psychometric properties of three self-report screening instruments for identifying frail older people in the community. BMC Publ Health 2010, 10:176. Mar 31. 4. Peters LL, Boter H, Buskens E, Slaets JP. Measurement properties of the Groningen Frailty Indicator in home-dwelling and institutionalized elderly people. J Am Med Dir Assoc. 2012 Jul;13(6):546-51. 5. Peña FG, Theou O, Wallace L et al. Comparison of alternate scoring of variables on the performance of the frailty index. BMC Geriatrics 2014, 14:25 6. Steverink N, Slaets JPJ, Schuurmans H & van Lis M. Measuring frailty: Development and testing of the Groningen Frailty Indicator (GFI). Gerontologist 2001, 41(special issue 1):236–237

8.1.4 Physical and Functional Ability

Method	Katz Index of Independence in Activities of Daily Living (Katz-ADL)
	The Katz ADL is designed to assess functional status. The index ranks adequacy of performance in the following six functions: bathing, dressing, toileting, transferring, continence, and feeding. If no supervision, direction, or personal assistance is required, then 1 point is given to that functional activity. If the client requires supervision, direction, personal assistance, or total care, then a 0 is assigned to that functional activity. A total score of 6 indicates full function, 4 indicates moderate impairment, and 2 or less indicates severe functional impairment.[1,2]
	Activities of Daily Living; Cognition; Medical specialities: geriatrics, internal medicine, family medicine, psychiatry, neurology, geriatric and neurological rehabilitation
	The Katz ADL Index assesses basic activities of daily living. It does not assess more advanced activities of daily living. The Katz ADL Index is very useful in creating a common language about patient function for all practitioners involved in overall care planning and discharge planning.[3]
	Although the Katz ADL Index is sensitive to changes in declining health status, it is limited in its ability to measure small increments of change in the rehabilitation of older adults. A full comprehensive geriatric assessment should follow when appropriate. There has been little investigation of sensitivity and responsiveness of the Katz Index of ADL. Most problematic is potential for ceiling effects with people with mild limitations in ADLs. This could lead to the index not being responsive to changes in ADLs in people with low levels of disability.[3]
	• The Katz Index of ADL has been adapted into several versions that are comparable to the original, while others have been modified. [4,5] • Available in English, Spanish, Portuguese, German • Time for performance: approx. 6-7 min
	1. Katz S. Assessing self-maintenance: Activities of daily living, mobility and instruments of daily living. JAGS 1983: 31:721-6. 2. Katz S et al. Studies of illness in the aged: The index of ADL: A standardized measure of biological and psychosocial function. JAMA 1963, 185:94-9. 3. Shelkey M & Wallace M. Katz Index of Independence in Activities of Daily Living (ADL). Best Practices in Nursing Care to Older Adults. Issue Number 2, Revised 2012. 4. Reuben DB et al. Measuring physical function in community-dwelling older persons: a comparison of self-administered, interviewer-administered, and performance-based measures. J Am GeriatrSoc 1995; 43: 17-23. 5. LaPlante MP. The classic measure of disability in activities of daily living is biased by age but an expanded IADL/ADL measure is not. J

Method	Katz Index of Independence in Activities of Daily Living (Katz-ADL)
	Gerontol B PsycholSciSocSci 2010; 65: 720-32.

Method	Barthel ADL index; Barthel scale
	The Barthel index measures he functional status in activities of daily living of physically disabled people [1], by reasonable selected functional activities. Ten basic activities of daily living (ADL) are captured: bowels, bladder, grooming, toilet use, feeding, transfers, walking, dressing, climbing stairs, and bathing. The Barthel index was introduced in 1965 and was measured in a 0–20 scale. Although this original version is still widely used, it was modified by Granger et al. [2] when it came to include 0–10 points for every item (total possible score of 0–100). Further refinements were introduced by Shah et al. [3].
	• Activities of Daily Living; Cognition • Medical specialties: geriatrics, internal medicine, family medicine, psychiatry, neurology, geriatric and neurological rehabilitation
	• The activities in the index have been selected because of their perceived social importance. Similarly, the weighting of the items within the index varies according to the professionals' prioritization of the impact a deficit in each area would have on the person. [10] • Widely used in settings with older people. • Administered in 5-10 minutes. • Simple, easy to use and quick to learn. • Compares favourably with other ADL scales.[5]
	• Endpoints are not “true endpoints” as peoples abilities can varying after performance [5], e.g. over time, influenced by environment and equipment • Community rehabilitation / sub acute setting focused. May give broad brush picture, as its ability to reflect change in function limited by a floor effect and lack of sensitivity to change.
	• Copyright at The Maryland State Medical Society • Used freely for non-commercial purposes with the primary reference cited [1] Permission is required to modify the Barthel Index or to use it for commercial purposes. Shorter version of the form is available for use. • Multiple languages translations are available – validation studies in English only (www.mapi-trust.org)
	1. Mahoney FI & Barthel DW. Functional evaluation: The Barthel Index. Maryland State Medical Journal , 1965, 14:61-65 2. Granger CV et al. Stroke rehabilitation: Analysis of repeated Barthel index measures. Archives of Physical Medicine and Rehabilitation, 1979, 60:14-17 3. Shah S et al. Improving the sensitivity of the Barthel Index for stroke

Method	Barthel ADL index; Barthel scale
	rehabilitation. Journal of Clinical Epidemiology , 1989, 42: 703-709. 4. Dewing J. A critique of the Barthel Index. Burford Community Hospital and Oxford Polytechnic 5. http://www.health.vic.gov.au/older/toolkit/05Mobility/docs/Barthel%20Index.pdf

Method	Lawton Instrumental Activities of Daily Living Scale (IADL)
	IADL Scale was developed to assess more complex activities (termed "instrumental activities of daily living") necessary for functioning in community settings. The capacity to handle these complex functions normally is lost before basic ADL scales. Therefore, assessing IADL may identify incipient decline in older adults. It contains 8 items that are rated with a summary score from 0 (low functioning) to 8 (high functioning). This scale can be administered through an interview or by a written questionnaire. The patient or a caregiver who is familiar with the patient can provide the answers. [1-3]
	• Activities of Daily Living; Cognition • Medical specialties: geriatrics, internal medicine, family medicine, psychiatry, neurology, geriatric and neurological rehabilitation
	The IADL has been used in over 3,000 published studies. There is considerable evidence for its reliability and concurrent validity [4], but there is some indication that the IADL is more suitable for assessing women than men. The Lawton IADL is an easy to administer assessment instrument that provides self-reported information about functional skills necessary to live in the community. Administration time is 10-15 minutes. Specific deficits identified can assist nurses and other disciplines in planning for safe hospital discharge.[5]
	A limitation of the instrument includes the self-report or surrogate report method of administration rather than a demonstration of the functional task. This may lead either to over-estimation or under-estimation of ability. In addition, the instrument may not be sensitive to small, incremental changes in function.[5]
	Available in English & Spanish
	1. Graf C. The Lawton Instrumental Activities of Daily Living Scale. American Journal of Nursing, 2008, 108(4), 53-62. 2. Kane RA & Kane RL. Assessing the elderly: A practical guide to measurement, 1981, Lexington, MA: Lexington Books. 3. Lawton MP & Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist,

Method	Lawton Instrumental Activities of Daily Living Scale (IADL)
	1969, 9, 179-86. 4. Loewenstein DA & Mogosky BJ. The functional assessment of the older adult patient. In P. Lichtenberg (Ed.), Handbook of assessment in clinical gerontology 1999, pp. 529-554, New York: John Wiley & Sons. 5. Graf C. The Lawton Instrumental Activities of Daily Living (IADL) Scale. Best Practices in Nursing Care to Older Adults. Issue Number 23, 2013

8.1.5 Cognition and Mental Health

Method	Geriatric Depression Scale (GDS)
	While there are many instruments available to measure depression, the GDS, first created by Yesavage et al. [5], has been tested and used extensively with the older population. It is a brief questionnaire in which participants are asked to respond to the 30 questions by answering yes or no in reference to how they felt on the day of administration. Scores of 0 - 9 are considered normal, 10 - 19 indicate mild depression and 20 - 30 indicate severe depression.
	Medical specialties: geriatrics, internal medicine, family medicine, psychiatry, neurology, geriatric and neurological rehabilitation
	The GDS is not a substitute for a diagnostic interview by mental health professionals. It is a useful screening tool in the clinical setting to facilitate assessment of depression in older adults especially when baseline measurements are compared to subsequent scores.[6]
	The GDS uses self-report, but as a consequence suffers from a high frequency of missing data. The proportion of GDS responses missing differs greatly by level of cognitive functioning. The floor effect limits both instruments. While the internal consistency reliability is apparently greater for the GDS, this may be caused by to the greater number of items on the GDS. We observed a weak relationship between GDS-5 scale scores and clinical indicators of depression (diagnoses, antidepressant use). [6]
	• A free app for iPhone and android for the 15-item GDS and automatically calculate the results; an online application; and translations in more than 30 languages are available here: http://web.stanford.edu/~yesavage/GDS.html • Time for medical assessment: approx. 10-15 min

	1. Koenig HG et al. Self-Rated Depression Scales and Screening for Major Depression in the Older Hospitalized Patient with Medical Illness. Journal of the American Geriatrics Society, 1988, 699-706. 2. Kurlowicz LH & NICHE Faculty Nursing Stand or Practice Protocol: Depression in Elderly Patients. Geriatric Nursing, 1997, 18, 192-199. 3. NIH Consensus Development Panel. Diagnosis and Treatment of Depression in Late Life. JAMA, 1992, 268, 1018-1024. 4. Sheikh RL & Yesavage JA. Geriatric Depression Scale (GDS). Recent Evidence and Development of a Shorter Version. Clinical Gerontologist, 1986, 5, 165-173. 5. Yesavage JA et al. Development and Validation of a Geriatric Depression Screening Scale: A Preliminary Report. Journal of Psychiatric Research, 1983, 17, 37-49. 6. Koehler M et al. Measuring depression in nursing home residents with the MDS and GDS: an observational psychometric study. BMC Geriatrics 2005, 5:1.

Method	Mini-Mental State Examination (MMSE)
	The MMSE is the most commonly used test for complaints of memory problems. It can be used by clinicians to help diagnose dementia and to help assess its progression and severity. It is a fully structured scale that consists of 30 points grouped into seven categories: orientation to place, orientation to time, registration,, attention and concentration,, recall,, language, and visual construction. In general, scores of 27 or above (out of 30) are considered normal. However, getting a score below this does not always mean that a person has dementia - their mental abilities might be impaired for another reason or they may have a physical problem such as difficulty hearing, which makes it harder for them to take the test. [1-3]
	• Activities of Daily Living; Cognition • Medical specialties: geriatrics, internal medicine, family medicine, psychiatry, neurology, geriatric and neurological rehabilitation
	• MMSE is the most widely used instrument for the screening of cognitive impairment worldwide. In addition, when used repeatedly the instrument is able to measure changes in cognitive status that may benefit from intervention. [4] • Needed time for medical assessment: 15 min
	Marginal or absent assessment of some cognitive abilities that are affected early in the course of Alzheimer's disease or other dementing disorders (e.g., limited memory and verbal fluency items and no problem solving or judgment items), its relative insensitivity to very mild cognitive decline (particularly in highly educated individuals), and its susceptibility to floor effects in tracking the progression of dementia in patients with moderate to severe cognitive impairment. [4, 5]
	• The MMSE-1 is freely available on the Internet. The current version of the MMSE (MMSE-2) is owned by Psychological Assessment Resources: http://www4.parinc.com/Products/Product.aspx?ProductID=MMSE

Method	Mini-Mental State Examination (MMSE)
	• The necessary assessment materials are: paper / pen / watch
	1. Folstein M, Folstein SE & McHugh PR. "Mini-Mental State" a Practical Method for Grading the Cognitive State of Patients for the Clinician. Journal of Psychiatric Research, 1975, 12(3); 189-198. 2. Foreman MD & Grabowski R. Diagnostic Dilemma: Cognitive Impairment in the Elderly. Journal of Gerontological Nursing, 1992, 18; 5-12. 3. Foreman MD, Fletcher K, Mion LC & Simon L. Assessing Cognitive Function. Geriatric Nursing, 1996, 17; 228-233. 4. Kurlowicz L & Wallace M. The Mini Mental State Examination (MMSE). Best Practices in Nursing Care to Older Adults. Issue Number 3, January 1999. 5. Lin AL, Laird AR, Fox PT & Gao JH. Multimodal MRI Neuroimaging Biomarkers for Cognitive Normal Adults, Amnestic Mild Cognitive Impairment, and Alzheimer's Disease. Neurology Research International Volume 2012.

Method	Trail-Making Test Part B
	The Trail-Making Test is a simple tool to reflect a wide range of cognitive processes including attention, visual search and scanning, sequencing and shifting, psychomotor speed, cognitive flexibility, ability to execute and modify a plan of action, and multitasking [1]. The term 'executive function' is often used as a broad descriptor of many such cognitive processes, which are required for independent performance of most ADL [2]. Trail-Making Test Part A (TMT-A) requires an individual to draw lines to connect circled numbers that are dispersed on a sheet of paper in sequence, as quickly as possible. Part B (TMT-B) requires an individual to draw lines sequentially connecting 25 circled numbers and letters. The individual's score is the time taken to complete each section.
	TMT-A is often considered as primarily a test of attention, visual scanning and processing speed. TMT-B is usually considered as a measure of executive function. Poor TMT performance is linked to higher incidence of falls among older adults [3].
	• Executive function is an independent predictor of future falls [4, 5], and therefore should be included in comprehensive fall risk assessments • Normative data is available for a variety of age groups to provide context to individuals' scores [6] • Quick and inexpensive to complete and score
	Executive function is an umbrella term comprising multiple components of cognition, therefore many other methods of assessing the construct exist [2]

	TMT-A and B are both freely available online and require little training/familiarisation to implement.
	1. Salthouse TA. What cognitive abilities are involved in trail-making performance? Intelligence, 2011, 39(4), 222-32. 2. Chan RK et al. Assessment of executive functions: Review of instruments and identification of critical issues, Arch Clin Neuropsychol. 2008 Mar;23(2):201-16. 3. Kearney FC et al. The Relationship between Executive Function and Falls and Gait Abnormalities in Older Adults: A Systematic Review, Dementia and Geriatric Cognitive Disorders, 2013, 36(1-2), 20-35. 4. Buracchio TJ et al. Executive function predicts risk of falls in older adults without balance impairment, BMC Geriatrics, 2011, 11, 74. 5. Mirelman A et al. Executive function and falls in older adults: new findings from a five-year prospective study link fall risk to cognition', PLoS One, 2012, 7(6), e40297. 6. Tombaugh TN. Trail Making Test A and B: Normative data stratified by age and education, Archives of Clinical Neuropsychology, 2004, 19(2), 203-14.

8.1.6 Health Related Quality of Life

Method	EuroQoL – the European Quality of Life measure (EQ 5D)
	The EQ-5D is a generic questionnaire designed for self-administration [1] and consists of two pages and includes 5 dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression; each with 3 levels: no problems, some problems, severe problems. The first page consists of five questions; the second page includes a 20cms scale to assess the health of today (EQ VAS). The social tariff, which involves an algorithm for interpolating EuroQoL results to population utilities, can be used to generate a direct value for every state of health.
	• Useable for health economic analysis (QALY-Analysis) • Generic (independent from health condition/ disease)
	• Self-administration, could be send by post/clinical and face-to-face-interviews • Short, the most widely used utility instrument, response in older adults, easily understood by participants
	• Due to his shortness and generic lack of sensitivity to small changes in health status and do not represents all conditions of respondents [3] • outliers posed difficulty for analysis • Further research is needed on the appropriateness of EQ-5D across conditions and patient groups (content validity, construct validity and responsiveness of EQ-5D) [2]
	• Available and validated in more than 150 languages: http://www.euroqol.org/ • Licensing fees are determined by the EuroQol Executive Office depending on the type of study/trial/project, funding source, sample size and number of requested languages
	1. Szende A et al. Measuring Self-Reported Population Health: An International Perspective based on EQ-5D. 2004. 2. Brazier J & Rowen D. NICE DSU Technical Support Document 11: Alternatives to EQ-5D for generating health state utility values, 2011, Sheffield, URL: http://www.nicedsu.org.uk/TSD11%20Alternatives%20to%20EQ-5D_final.pdf 3. Kupatz P & Thielker K. Vergleichende Untersuchung zweier Instrumente zur Messung der gesundheitsbezogenen Lebensqualität in der orthopädischen, rheumatologischen, psychosomatischen und neurologischen Rehabilitation. Abschlussbericht 2013, Bad Doberan.

Method	Short Form 36 (SF-36)/ SF-12
	The SF-36 is a norm-based, generic health status measure and used world-wide, to assess general health concepts - functional status and well-being. The SF36 (36 questions) as well as the SF12 (12 questions) are covering eight domains: physical functioning, role limitations due to physical health problems, bodily pain, general health, vitality, social functioning, role limitations due to emotional problems and mental health. [1]
	• Useable for health economic analysis (QALY-Analysis) • Generic (independent from health condition/ disease), especially recommended for patients with chronic diseases [2]
	• Self-administered or by an interviewer • Sensitive to small differences in health status at moderate-high levels of Qol, psychometric properties tested, normally distributed
	• Floor effect, narrow range of possible health state utility values, range does not encompass death
	• More information: http://www.sf-36.org (SF-36) • Translation for more than 60 countries • To purchase a licence visit http://www.optum.com/optum-outcomes/survey-request-form.html • A preference-based utility index (SF-6D) is also available to investigate economic benefit. • SF-36v2 is available in multiple modes of administration: online, PDA and more; in more than 170 translations and in standard four-week and acute one-week recall periods.
	1. Ware JE & Sherbourne CD, The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care, 1992. **30**(6): p. 473-83. 2. Elliott TE, Renier CM & Palcher JA. Chronic pain, depression, and quality of life: correlations and predictive value of the SF-36. Pain Med 2003;4(4):331-339.

8.1.7 Self-Efficacy

Method	Falls Efficacy Scale-International (FES-I)
	The FES-I as the FES is a measurement tool for the fear of falling and measures the self-confidences in performance of ten essential and non-hazardous daily activities [1]. The FES-I is expansion of FES [2] and included social activities which seems to be more challenging by more active people, The Questionnaire for self-assessment of confidence includes 16 tasks which have to be rated on a scale from 1 to 4 (1- Not at all Concerned, 2-Somewhat concerned, 3-Fairly concerned, 4-Very concerned)
	Hospital, nursing homes, communities: older adults with or without a history of fear of falling.
	• Questionnaire for self-assessment: short and easy to administer, low in costs, no special expertise needed • excellent psychometric properties and discriminatory power • wording takes into account cross-cultural differences, so various translations are available [4]
	• further research is necessary for confirmation of cross-cultural and predictive validity and also the usefulness for cognitively-impaired older adults [3]
	The questionnaire is available in following languages [4]: Brazilian-Portuguese, Chinese, Danish, Dutch (validated), English (validated), French, German (validated), Greek, Hindi, Norwegian, Punjabi, Spanish, Swedish (validated), Swiss-French and Urdu. Also a short version is available with the questions no. 2, 4, 6, 7, 9, 15 and 16 (only validated in Dutch).
	1. Yardley L, Beyer N, Hauer K et al. Development and initial validation of the Falls Efficacy Scale-International (FES-I). Age Ageing, 2005. 34(6): 614-9. 2. Tinetti ME, Richman D & Powell L. Falls efficacy as a measure of fear of falling. J Gerontol, 1990. 45(6): 239-43. 3. Hauer KA, Kempen GI, Schwenk M et al. Validity and sensitivity to change of the Falls Efficacy Scales International to assess fear of falling in older adults with and without cognitive impairment. Gerontology, 2011;57(5): 462-72. 4. http://www.profane.eu.org/fesi.html

8.2 Health Economic Assessment

Method	Cost-effectiveness analysis
	Cost-effectiveness analysis is a method used to evaluate the outcomes and costs of interventions designed to improve health. The results are usually summarised in a series of cost-effectiveness ratios that show the cost of achieving one unit of health outcome for different kinds of patients and variations of an intervention. These ratios present the net expenditure of health resources in monetary units as the numerator and the net improvement in health as the denominator [1]. For example, in falls prevention the ratio may be presented as the monetary cost per fall prevented, or a comparison of healthcare costs per fall-related injury between intervention and control groups.
	May be used to compare the cost-effectiveness of implementing a novel ICT solution in a falls service compared to usual practice e.g. exergaming versus standard exercise programme. May also be used to compare relative costs and effectiveness of different falls-related technologies e.g. different personal alarms systems.
	• Widely used in healthcare • Easily interpreted due to the simple ratio structure of results • Clear recommendations on how to report cost-effectiveness analyses in healthcare exist [2]
	• Possible confusion during analysis as to what constitutes a health care cost/saving, or a health improvement/decline • Assumptions made to estimate costs and outcome may be inaccurate • Ignores non-health-related costs and effects e.g. environmental impacts, effects on productivity
	1. Russell LB, Gold MR, Siegel JE, Daniels N, Weinstein MC for the Panel on Cost-Effectiveness in Health and Medicine. The role of cost-effectiveness analysis in health and medicine, JAMA, 1996 276, 1172-77. 2. Weinstein MC, Siegel JE, Gold MR, Kamlet MS & Russell LB. Recommendations of the panel on cost-effectiveness in health and medicine', JAMA, 1996, 276(15), 1253-58.

Method	Cost-benefit analysis
	Cost-benefit analysis may be used to perform an economic evaluation of a strategy designed to improve health. It differs from cost-effectiveness analysis in that the benefits are considered in monetary terms, rather than in terms of health outcome units [3].
	Where benefits can be determined in monetary terms (e.g. net reduction in fall-related medical costs), cost-benefit analysis can be used to compare novel ICT strategies to usual care. Return on investment can also be calculated as the extent to which benefits exceed implementation costs, expressed as a percentage [2]
	• Allows benefits to be considered in terms of direct and indirect costs • Highly relevant to third-party payers e.g. health care funders, health insurance companies, industry, as results reflect return on investments [2]
	• For health-related interventions, it may be difficult to measure benefits in monetary terms [2] • An accurate cost-benefit analysis requires all direct costs/savings (e.g. medical, allied health, pharmaceutical, long-term care) and indirect costs/savings (e.g. disability, pain, loss of productivity) to be considered, which can be challenging in practice
	1. Beard J, Rowell D, Scott D et al. Economic analysis of a community-based falls prevention program, Public Health, 2006, 120(8), 742-51. 2. Carande-Kulis V, Stevens JA, Florence CS et al. A cost–benefit analysis of three older adult fall prevention interventions, Journal of Safety Research, 2015, 52(0), 65-70. 3. Davis JC, Robertson MC, Comans T & Scuffham PA. Guidelines for conducting and reporting economic evaluation of fall prevention strategies, Osteoporosis International, 2011, 22(9), 2449-59.

Method	Cost-of-illness analysis
	Cost-of-illness analysis is a method of evaluating – in monetary terms – the economic burden that a health condition places on society. These costs are usually considered in terms of direct costs (e.g. consumption of healthcare and related resources) and losses of productivity.
	Used as descriptive studies to identify conditions with high expenditure and use of resources. Can therefore by used to develop healthcare pathways based on costs of service utilisation, and to support healthcare management decision-making and policy development.
	• Widely used and recognised to facilitate decision-making in health policy development [1] • Effective for identifying the main cost components and their influences over total costs of a health condition • May be useful for comparing variability in costs between clinical subgroups e.g. costs of falls in community-dwelling older adults versus those in residential care
	• Does not evaluate the effects of interventions/technologies • Identifies level of expenditure, but not necessarily indicative of inefficiency and/or waste • Not effective in including intangible costs e.g. patients' pain, caregiver burden
	The usefulness of cost-of-illness analysis has been highly debated by health economists for a number of years, with many suggesting that specific purposes and varying methodological approaches are required too.
	1. Byford S, Torgerson DJ & Raftery J. Cost of illness studies, BMJ, 2000, 320(7245), 1,335. 2. Tarricone R. Cost-of-illness analysis: What room in health economics?, Health Policy, 2006, 77(1), 51-63.

8.3 General Assessment Methods

Method	World Café
	A 'World Café' is a special kind of a workshop for conducting large group discussions which encourages participants to share opinions and discuss ideas openly. The structure is as follows: 1. A large group is split into small groups e.g. 5-6 people 2. The groups are given time to discuss specific questions/topics 3. The groups summarise their opinions in written statements on posters/boards 4. All participants are given time to read and consider these statements 5. Participants rate their levels of agreement with statements, often by placing coloured stickers on the posters/boards, to provide a general level of agreement for the group with each statement
	May facilitate expert group discussions on specific topics.
	• Achieves open and creative discussions • Useful when a diverse range of participants are present in a large group • Allows all participants to reflect on statements • Provides concrete data on levels of agreement among all participants in a group
	• Lack of anonymity – participants may be less willing to express disagreement in an open environment • Results reflect overall group opinions/agreement – important, valid opinions may be overlooked in favour of more popular statements, depending on the individuals present
	1. World Cafés utilised in E-NO FALLS Work Package 1 to facilitate expert group discussions (see D1.1 for descriptions and D1.3 for results). 2. Information on methods, research etc. available at: http://www.theworldcafe.com/

Method	Focus Group
	A focus group study is a special kind of a workshop and involves organised groups of participants from a specific target population (usually 6 to 10 people per group) gathering together to express their opinions and experiences in relation to a specific topic. A moderator may guide the discussion to varying extents using structured questions and prompts. Audio and/or video recordings of the discussions are made, then transcribed and analysed to identify the main themes that have emerged. Multiple focus groups may be conducted according to the sampling requirements of a particular study.
	• Useful to collect participants' attitudes, feelings, beliefs, experiences and reactions to a specific topic, product, service etc. e.g. end-user experiences of using a falls detection device [2] • May be used to develop questionnaires/in-depth interviews • Can be used in their own right or to complement other methods (e.g. quantitative methods, interviews)
	• Produces a large amount of rich data in a short time • Specific attitudes, opinions etc. can be explored in great depth using the moderators questioning and prompts • Explores multiple views and allows group interactions (useful to explore the degree of consensus on a topic)
	• Since small groups from specific populations are chosen to participate, the data may not be widely generalizable. • Negative group dynamic effects and confrontations are possible • May be time and cost intensive (selective recruitment process, payment/incentives for attendance, moderators plus note-takers required to attend, data transcription and analysis).
	• Aside from the moderator, additional researchers are required to attend the focus group for note-taking purposes e.g. to document non-verbal behaviour, group dynamics, emergent themes).
	1. Barbour RS. Making sense of focus groups, Medical Education, 2005, 39(7), 742-750. 2. Williams V, Victor CR & McCrindle R. It is always on your mind: experiences and perceptions of falling of older people and their careers and the potential of a mobile falls detection device, Curr Gerontol, 2013, Geriatr Res, 2013, 2950-73.

Method	Interview
	The word interview comes from Latin and middle French and means to “see between” or “see each other”. Generally, interview means a private meeting between people (the interviewer and the interviewee) when questions are asked and answered, to obtain information, qualities, attitudes, wishes etc. Form the interviewee.
	To collect experience-based information directly by the user/patient, to collect data for a survey, to collect qualitative and quantitative data for several investigation scopes.
	• Best way to have an accurate and thorough communication of ideas • Question order could be controlled/ can make sure that all the questions will be answered. • Interview process is spontaneous (interviewees don't always have the time to think about their responses) • High rate of survey completion • Can explore answers with respondents and assist respondents with unfamiliar words or questions. • Able to get more qualitative data
	• Inefficient either when collecting straight numeric data is needed; asking respondents to fill out a form may be more appropriate. • Not suitable if respondents are unwilling to cooperate (e.g. may mess up your results). • Difficult to reach certain populations • Expensive and time consuming (lots of resources, e.g. for large-scale phone interviews) • Some may feel reluctant to share personal information or beliefs • Need trained interviewers • Must find a suitable place to conduct interview • Interviewer bias (verbal or nonverbal)
	There are many types of interviews that an organization can arrange. It depends on the objectives of taking the interview. Some important types of interviews are stated below: Personal interviews, Evaluation interviews, Persuasive interviews, Structured/Unstructured interviews, Counselling interviews, Disciplinary interviews, Stress interviews Public interviews, Informal or conversational interview, General interview guide approach, Standardized or open-ended interview, Closed or fixed-response interview
	1. http://thebusinesscommunication.com/what-is-interview-types-of-interviews/ 2. http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/conduct-interviews/main

Method	Survey/ Questionnaire
	A survey is a data gathering method that is utilized to collect, analyse and interpret the views of a group of people from a target population. The methodology is guided by principles of statistics from the moment of creating a sample, or a group of people to represent a population, up to the time of the survey results' analysis and interpretation: simple polls regarding political beliefs, opinions regarding a new product versus another. The method is proven to be an effective technique to gather necessary information for the advancement of science and technology. Surveys can be divided into two broad categories: the questionnaire and the interview. Questionnaires are usually paper-and-pencil instruments that the respondent completes. Interviews are completed by the interviewer based on the respondent says. Sometimes, it's hard to tell the difference between a questionnaire and an interview. For instance, some people think that questionnaires always ask short closed-ended questions while interviews always ask broad open-ended ones. But you will see questionnaires with open-ended questions (although they do tend to be shorter than in interviews) and there will often be a series of closed-ended questions asked in an interview.
	Survey research has changed dramatically in the last ten years due to new technologies (e.g. callcenters, computerized kiosks in public areas, online surveys). They are widely used in various fields of research, such as sociology, marketing research, politics and psychology.
	• Tends to be a reliable/ consistent method of inquiry because of standardization (same questions for all participants), when survey/ questionnaire design has well-constructed question • Surveys are versatile and used by all kinds of people in all kinds of professions. • Cost-effective, Generalizable, Reliable
	• Poorly phrased questions could be interpreted differently by participants (reduction of reliability) • Pre-tests about phrasing/ understanding the questions are necessary to reduce drawbacks • Cannot be changed during running (e.g. because of poorly phrased question) as they are not comparable (inflexible) • Validity: Survey questions are standardized and it is not possible to ask anything other than very general questions that a broad range of people will understand. Cannot represent complex opinions.
	1. http://www.opia.psu.edu/sites/default/files/insights014.pdf 2. http://cdn2.hubspot.net/hub/58820/docs/rl_methods_wp_four_methods.pdf