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Institute for Collaborative
Research on Ageing

Prof Chris Todd
School of Health Sciences

Digital technologies to support older people in the community to prevent falls

www.profound.eu.com www.fallsprevention.eu
www.preventit.eu www.eufallsfest.eu

Disclosure of interests : Funded by EC

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Plan

- Falls
- Digital technologies for fall:
  - Prediction
  - Assessment
  - Detection
  - Prevention

MIRA Exergame RCT

FARSEEING

ProFouND
Prevention of Falls Network for Dissemination

PreventIT

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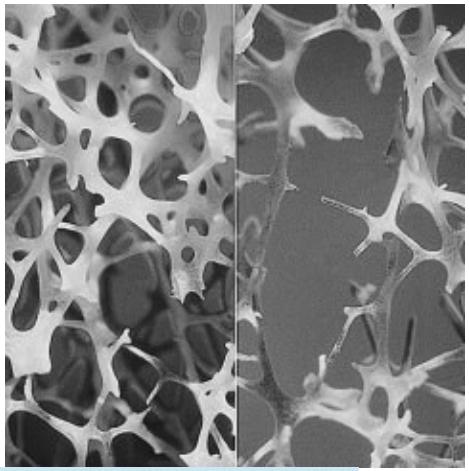
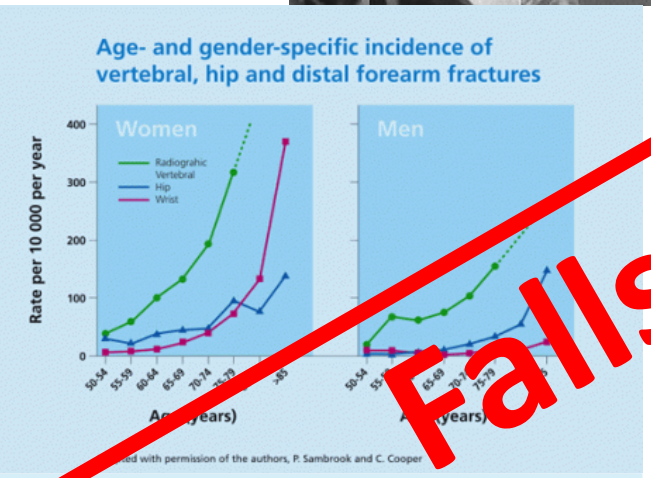
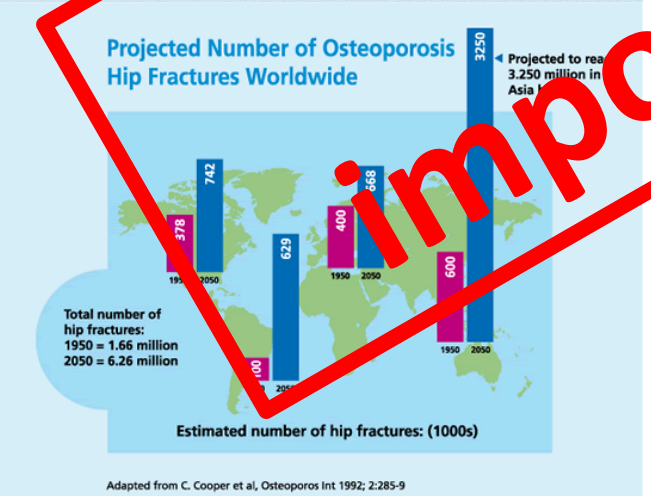
www.iofbonehealth.org







30-40% community dwelling

>65yrs fall in year

- 40-60% no injury
- 30-5[illegible]% minor injury
- 5-6% major injury (excluding fracture)
- 5% fractures
- 1% hip fractures

Falls most serious frequent home accident

50% hospital admissions for injury due to fall

History of falls a major predictor future fall

Falls are a big & important problem !

Masud, Morris *Age & Ageing* 2001; 30-S4 3-7
Rubenstein. *Age & Ageing*; 2006; 35-S2; ii37-41

Consequences of falls

- Age UK say NHS cost £4.6 million/day (£1.7billion/year)
- Non-fracture injury
- Peripheral fractures
- Hip fractures
  - Expensive for health services, patients & families
    - Money, morbidity, mortality and suffering
    - 20% die within 90 days
    - 50% survivors do not regain mobility
- Psychological and social consequences
  - Disability
    - Admission to long term care
    - Loss of independence
  - Falling most common fear of older people
    - More common than fear of crime or financial fear
    - Leads to activity restriction, medication use

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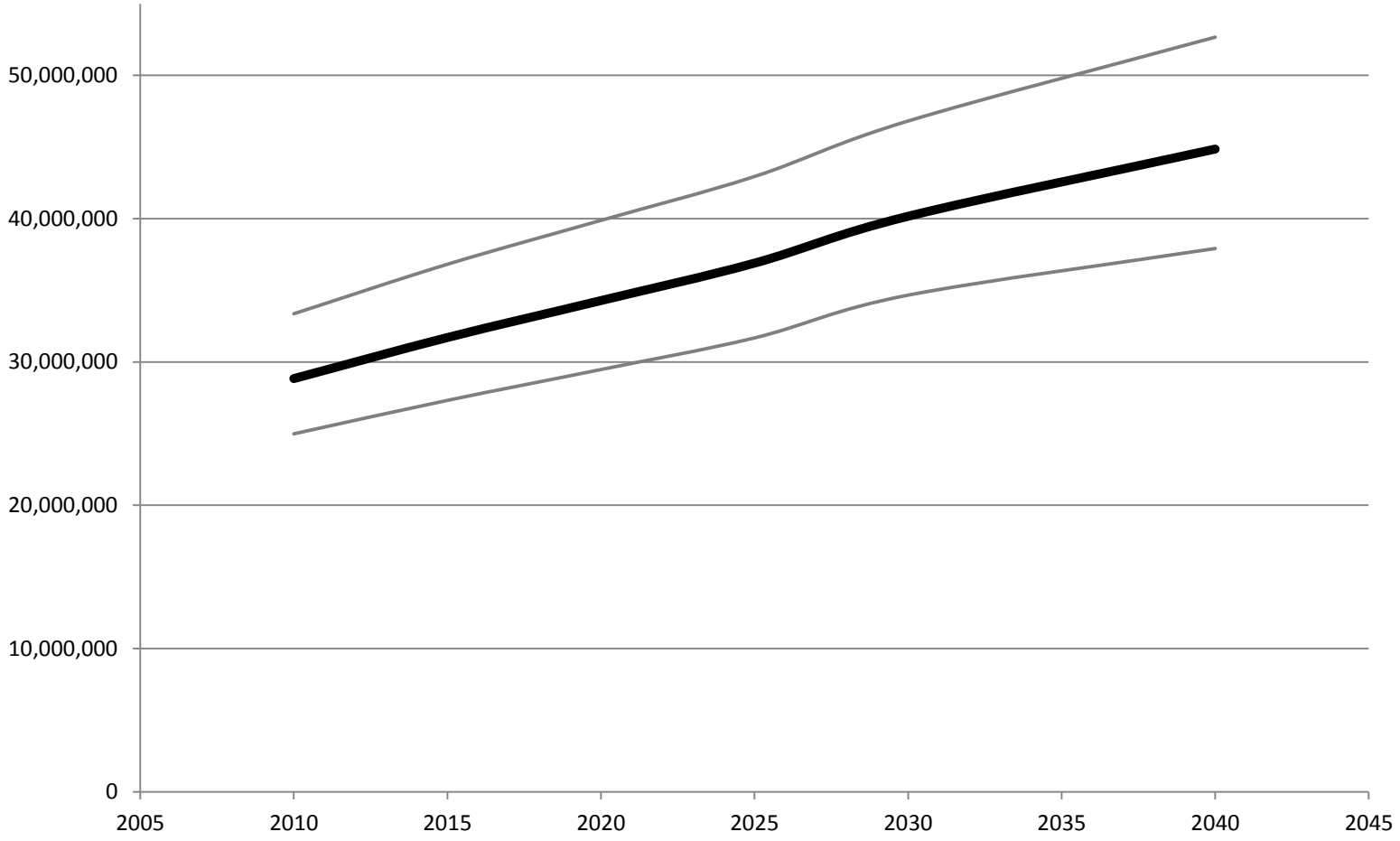
EU28 Falls amongst community dwelling older people (60 and above) 2015-2040 (estimate; 95% CIs) men & women



Todd et al 2016 unpublished data reported to EC

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Risk factors[1] for falls amongst community dwelling older people

Sociodemographic risk factors	Falling OR (95% CIs)	Recurrent falling OR (95% CIs)
Age (per increment 5-year)	1.12 (1.07-1.17)	1.12 (1.07-1.18)
Sex (female vs male)	1.30 (1.18-1.41)	1.34 (1.12-1.60)
Living conditions (alone vs not alone)	1.33 (1.21-1.45)	1.25 (1.10-1.43)
Ethnicity (Black/Black British vs White)	1.64 (1.34-2.01	
Psychological risk factors		
Cognitive impairment (yes vs no)	2.24 (1.25-4.03)	3.65 (1.71-7.79
Depression (yes vs no)	1.63 (1.36–1.94)	1.86 (1.45–2.38)
Fear of falling (yes vs no)	1.55 (1.14–2.09)	2.51 (1.78–3.54)
Self-reported health status (poor vs good)	1.50 (1.15–1.96)	1.82 (1.26–2.61)

[1] adjusted in multivariate analyses

Becker C, Woo J, Todd C. Falls *Oxford Textbook of Geriatric Medicine* 2018

adapted from Deandrea et al, 2010

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Risk factors[1] for falls amongst community dwelling older people

Medical conditions	Falling OR (95% CIs)	Recurrent falling OR (95% CIs)
Comorbidity (per increment of 1 condition)	1.23 (1.16–1.30)	1.48 (1.25–1.74)
Parkinson disease (yes vs no)	2.71 (1.08–6.84)	2.84 (1.77–4.58)
Dizziness & vertigo (yes vs no)	1.80 (1.39–2.33)	2.28 (1.90–2.75)
History of stroke (yes vs no)	1.61 (1.31–1.98)	1.79 (1.51–2.13)
Rheumatic disease (yes vs no)	1.47 (1.28–1.70)	1.57 (1.42–1.73)
Urinary incontinence (yes vs no)	1.40 (1.26–1.57)	1.67 (1.45–1.92)
Pain (yes vs no)	1.39 (1.19–1.62)	1.60 (1.44–1.78)
Hypotension (yes vs no) [2]	1.24 (0.90–1.71)	1.31 (0.95–1.81)
Diabetes (yes vs no)	1.19 (1.08–1.31)	1.28 (1.09–1.50)
Body mass index (low vs intermediate/high)	1.17 (0.93–1.46)	1.03 (0.86–1.23)

Becker C, Woo J, Todd C. Falls *Oxford Textbook of Geriatric Medicine* 2018
adapted from Deandrea et al, 2010

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Risk factors[1] for falls amongst community dwelling older people

Medication use	Falling OR (95% CIs)	Recurrent falling OR (95% CIs)
Number of medications (per increment of 1 drug)	1.06 (1.04–1.08)	1.06 (1.04–1.08)
Use of anti-epileptics (use vs no use)	1.88 (1.02–3.49)	2.68 (1.83–3.92)
Use of sedatives (use vs no use)	1.38 (1.15–1.66)	1.53 (1.34-1.75)
Use of anti-hypertensives (use vs no use)	1.25 (1.06–1.48)	1.23 (1.05–1.44)
Mobility and sensory issues		
History of falls (yes vs no)	2.77 (2.37-3.25)	3.46 (2.85-4.22)
Walking aid use (yes vs no)	2.18 (1.79-2.65)	3.09 (2.10-4.53)
Gait problems (yes vs no)	2.06 (1.82–2.33)	2.16 (1.47–3.19)
Physical disability (yes vs no)	1.56 (1.22-1.99)	2.42 (1.80-3.26)
Vision impairment (yes vs. no)	1.35 (1.18–1.54)	1.60 (1.28–2.00)
Hearing impairment (yes vs. no)	1.21 (1.05–1.39)	1.53 (1.33–1.76)
Physical activity (limitation vs no limitation)	1.20 (1.04–1.38)	NA

Becker C, Woo J, Todd C. Falls *Oxford Textbook of Geriatric Medicine* 2018
adapted from Deandrea et al, 2010

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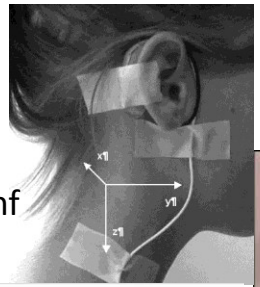
FARSEEING Taxonomy of Technologies:

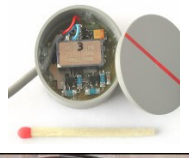
Body fixed/worn

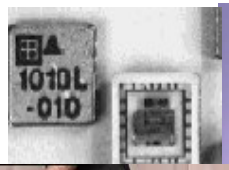
Ambient

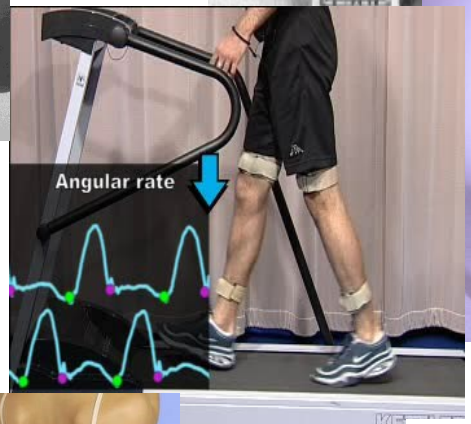
Portable

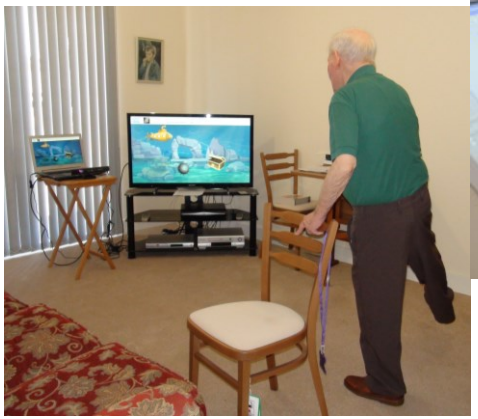


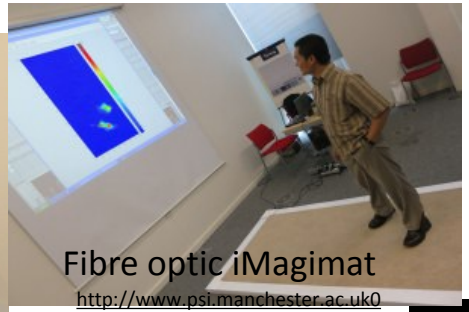
Boulton et al 2016 J Biomed Inf



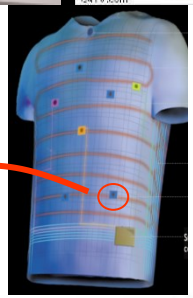


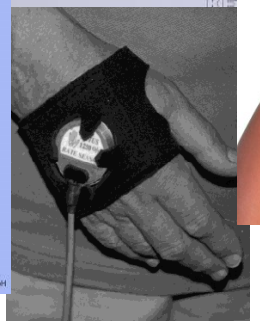


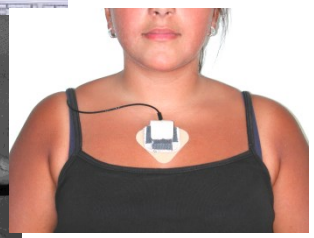




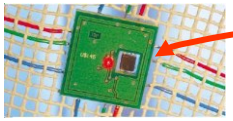
Fibre optic iMagimat
http://www.psi.manchester.ac.uk0

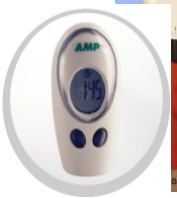


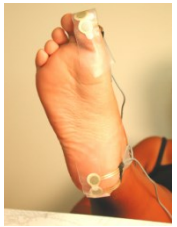




PreventIT

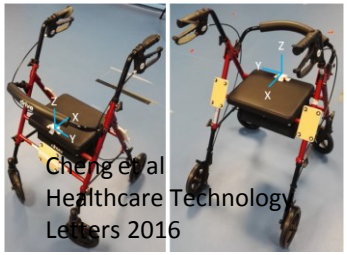




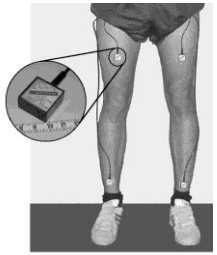


Samsung Galaxy J5, 2016

Sony Smartwatch 3



Cheng et al
Healthcare Technology Letters 2016



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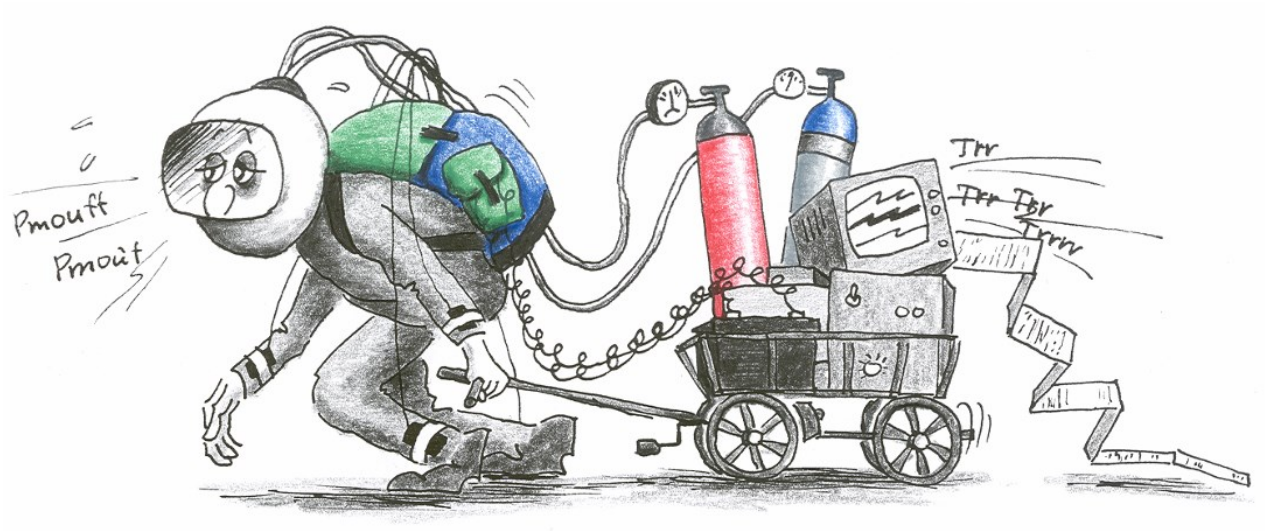

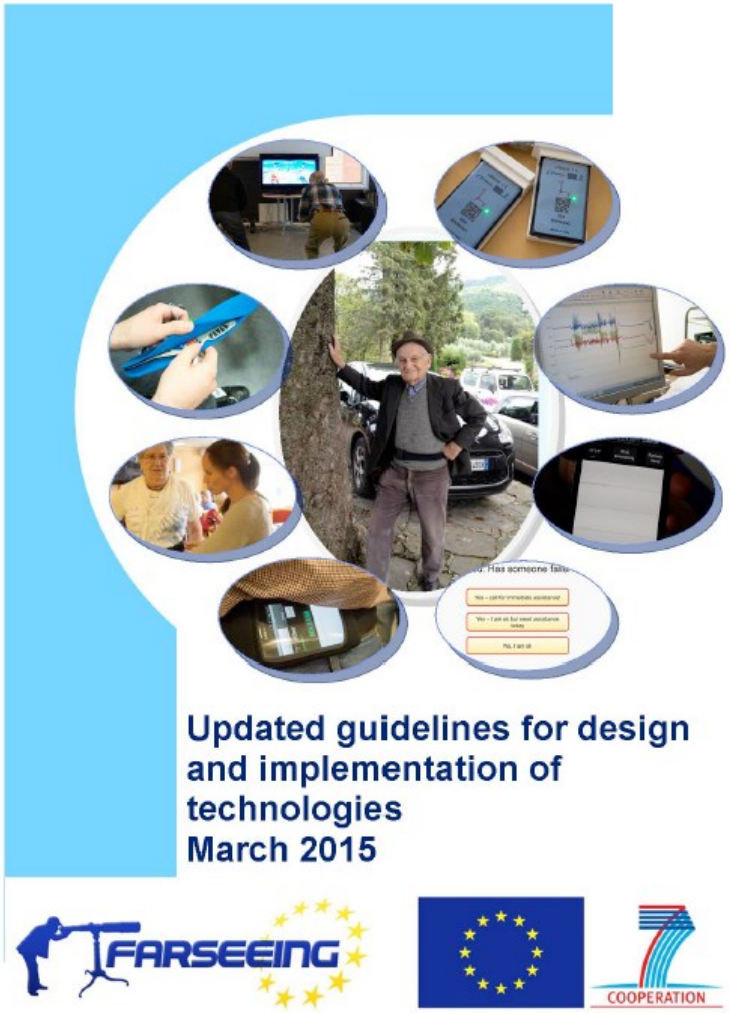

Intrinsic factors:
attitudes around control, independence, perceived need/requirements for safety

Extrinsic factors:
usability, feedback gained, cost

The project is co-funded by the European Community under the Information and Communication Technologies (ICT) theme of the Seventh Framework Programme (FP7/2007-2013). Grant Agreement n°288940.

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Video capture of the circumstances of falls in elderly people
Robinovitch S et al The Lancet 2013
DOI: http://dx.doi.org/10.1016/S0140-6736(12)61263-X

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Steve Robinovitch real life falls

Video capture of real-life falls in LTC

- 270 digital video cameras in common areas of 2 long-term care (LTC) facilities (with 522 collective residents)
- fall incidence report triggers video collection
- between 2007-2015, analyzed 1376 falls in 426 residents
- access to medical records: 826 falls in 211 fallers
- consent to share for education: 800 falls in 183 fallers

(Robinovitch et al Lancet 2013)

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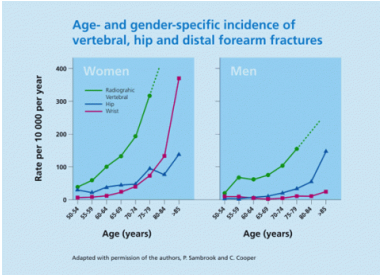
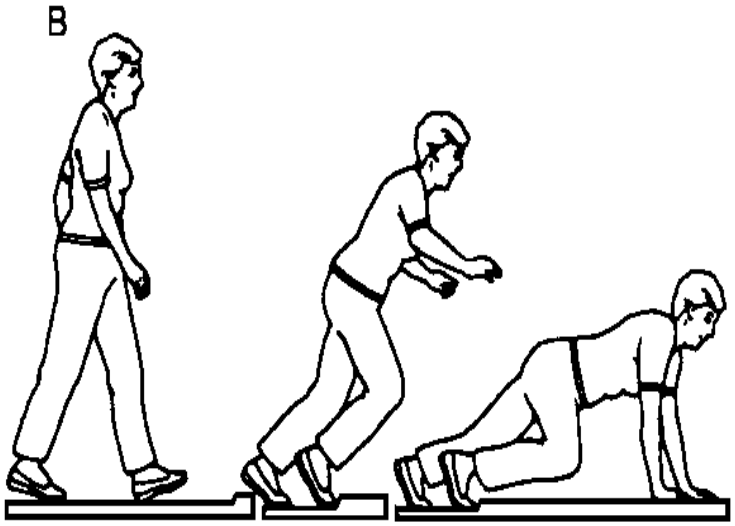
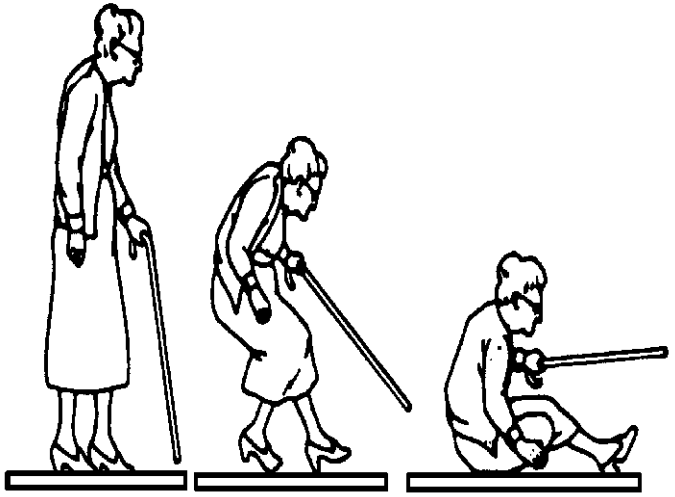
Cummings S, Nevitt M. A hypothesis: the causes of hip fractures. J Gerontol 1989







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Prediction of falls risk

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[1] adjusted in multivariate analyses

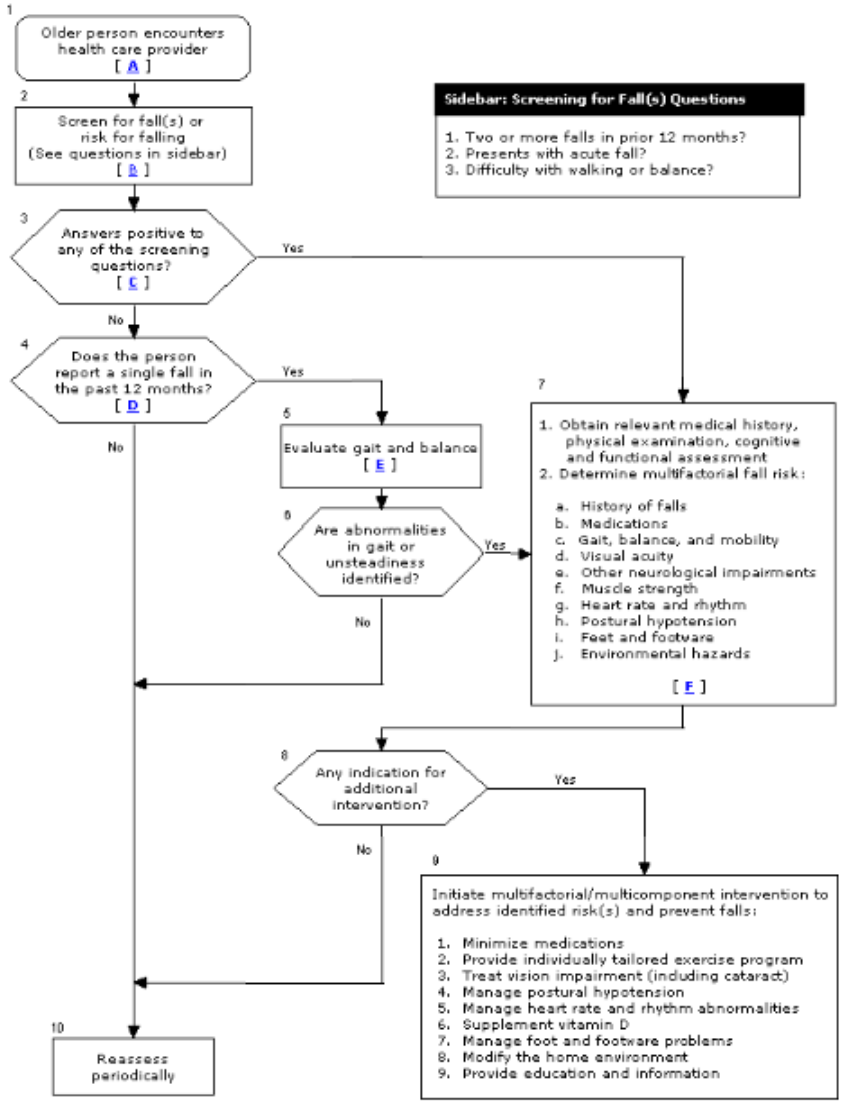
Becker C, Woo J, Todd C. Falls *Oxford Textbook of Geriatric Medicine* 2018

adapted from Deandrea et al, 2010

Prevention of Falls in Older Persons

AGS/BGS Clinical Practice Guideline

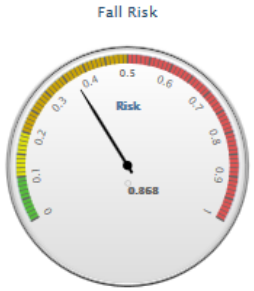
[x] = Annotation link (Click to see recommendations)



FRAT-up
Fall Risk Assessment Tool

Home | Run an assessment | Info | Login

Current risk of the subject: 0.368



http://ffrat.farseeingresearch.eu/

Health profile of the subject:

Does the subject live alone?	○ Yes	◉ No	○ Use prevalence	CESD:		☑ Use prevalence
Dizziness or unsteadiness last year?	○ Yes	○ No	◉ Use prevalence	Number of drugs used by the subject:	4	☐ Use prevalence
History of previous falls?	◉ Yes	○ No	○ Use prevalence	Visual stereognosis:		☑ Use prevalence
Does the subject use antihypertensives?	○ Yes	◉ No	○ Use prevalence	Contrast sensitivity?:		☑ Use prevalence
Is the subject female?	○ Yes	◉ No	○ Use prevalence	Age:	94	☐ Use prevalence
Does the subject suffer Parkinson?	○ Yes	◉ No	○ Use prevalence	How does the subject feel:	4	☐ Use prevalence
Does the subject use a walking aid?	○ Yes	◉ No	○ Use prevalence	Number of ADL disabilities (0-6):	1	☐ Use prevalence
Fear of falling (Deshpande)?	○ Yes	◉ No	○ Use prevalence	Hearing impairment?:	2	☐ Use prevalence
Does the subject use antiepileptics?	○ Yes	◉ No	○ Use prevalence	physical activity level:	2	☐ Use prevalence
Urinary incontinence last year?	○ Yes	◉ No	○ Use prevalence	Visual acuity (3 meter):		☑ Use prevalence
Does the subject suffer any pain?	◉ Yes	○ No	○ Use prevalence	Revised Walking Subscore:		☑ Use prevalence
Does the subject use sedatives?	○ Yes	◉ No	○ Use prevalence	MMSE score:		☑ Use prevalence
History of previous strokes?	○ Yes	◉ No	○ Use prevalence	Subject's number of IADL:		☑ Use prevalence
Diabetes blood glucose 126?	○ Yes	◉ No	○ Use prevalence			
Does the subject suffer rheumatic disease?	○ Yes	◉ No	○ Use prevalence			

Run the assessment! | Generate a report (.pdf)

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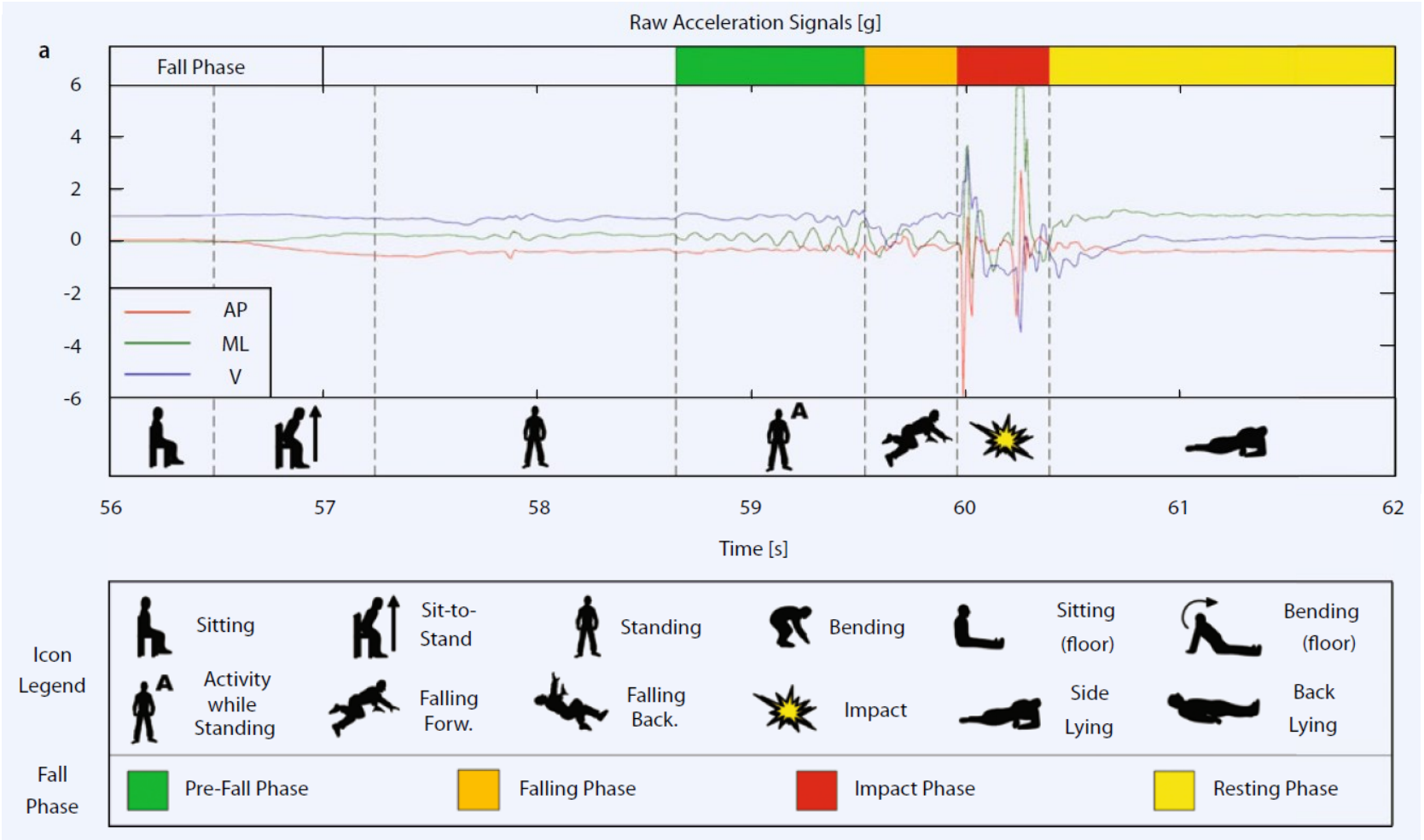
Can sensors improve prediction of falls ?



Becker C, et al. *Z Gerontol Geriatr* 2012

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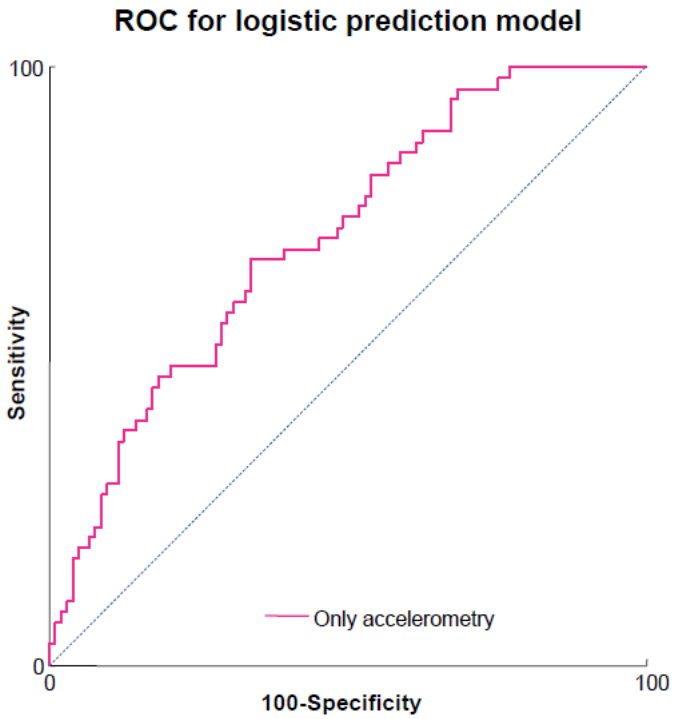
Predictors accelerometry

- local divergence exponent AP
- intensity VT
- number of steps
- duration of lying
- intensity VT x number of steps



- AUC 0.71

(van Schooten et al., J. Gerontol 2015)

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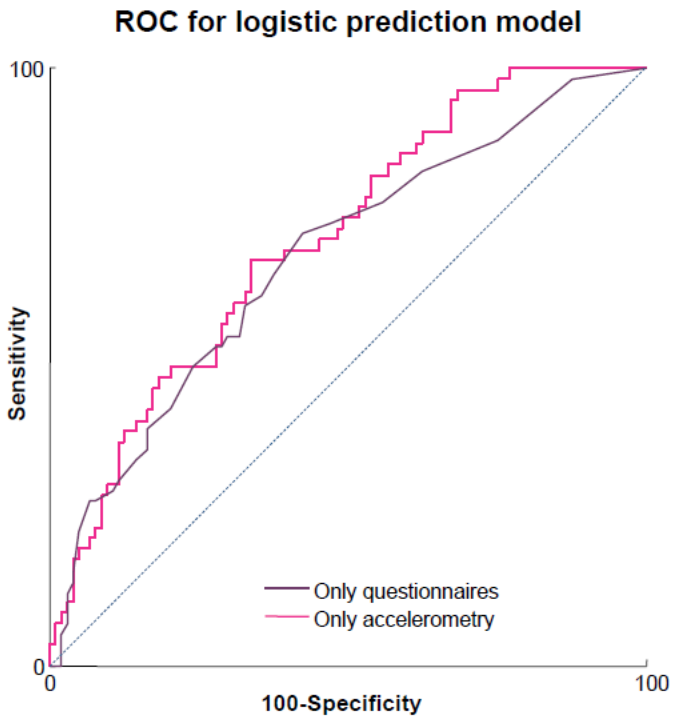
Predictors from questionnaires

- 6-month history of falls
- geriatric depression scale



- AUC 0.68

(van Schooten et al., J. Gerontol 2015)

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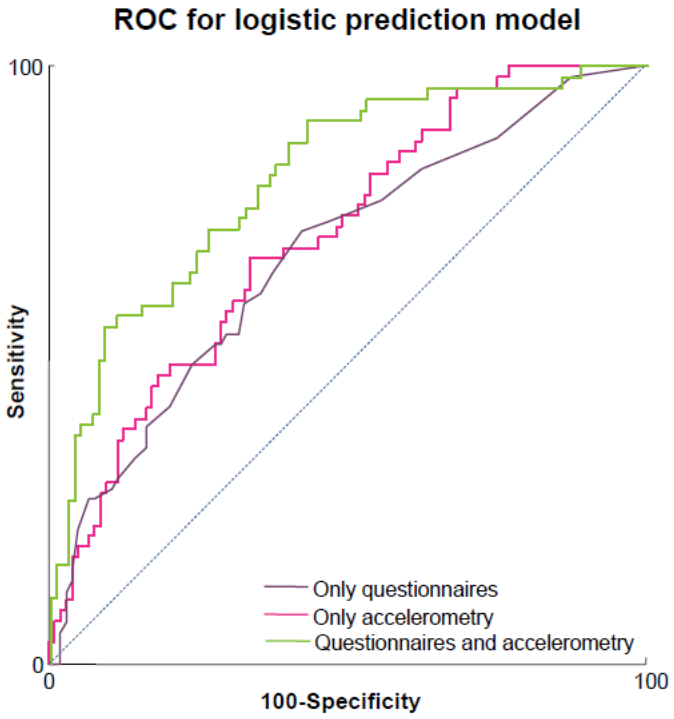
Added value of accelerometry

- 6-month history of falls
- local divergence exponent AP
- intensity VT
- number of strides
- geriatric depression scale
- smoothness ML
- sample entropy VT
- intensity VT x number of strides
- smoothness ML x number of strides

- AUC 0.82*



(van Schooten et al., J. Gerontol 2015)

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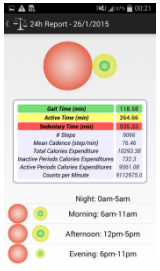
- Sensor data improves prediction of fall risk over traditional risk questions

- In a few years real life gait assessment could become part of clinical routines to identify specific deficits



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PreventIT Functional Tests

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Assessment of falls

Fall no.: RBK1964-01
Setting: geriatric rehabilitation

Signal file: F_RBK1964-01-2014-06-13-15-24-33.mat

Personal characteristics
Gender: female Age: 87 yrs Height: 163 cm Weight: 52 kg

Sensor characteristics
Device: uSense Location: Thigh

Sensor type(s): acc, gyro, mag Unit(s): m/s², °/s, µT

Sample rate: 100 Hz

Fall report
Fall time reported: 13.06.2014 15:30:00 Fall time signal: 13.06.2014 15:24:33

At the end of the group therapy (walking training) subject wanted to sit down on a achair because of dizziness. While turning around to sit down, she lost balance and fell on the left side on the ground. She tried to hold on to the rollator handles but missed them.

Witnessed: unknown Assistive device: unknown

Reported pre-fall activity: standing/turning Reported fall direction: unknown

Indoor/outdoor: Indoor Place of fall: unknown

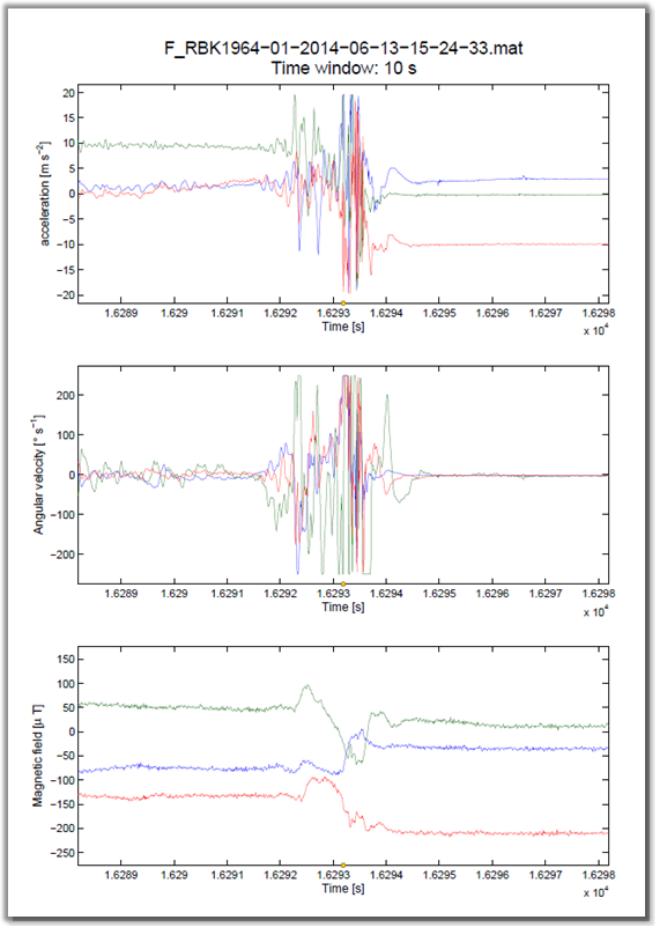
Multiple impact: unknown Fall on: floor

Got up without help: unknown

Injury: No Injury classification: no

Injury location: no Injury description: no

Adopted measures: none



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A multiphase fall model

Z Gerontol Geriat 2012 · 45:707–715
DOI 10.1007/s00391-012-0403-6
Received: 27 July 2012
Revised: 3 September 2012
Accepted: 6 September 2012
Published online: 25 November 2012

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[1] Department of Clinical Gerontology, Robert Bosch Hospital, Stuttgart
[2] Department of Electronics, Computer Science and Systems, University of Bologna
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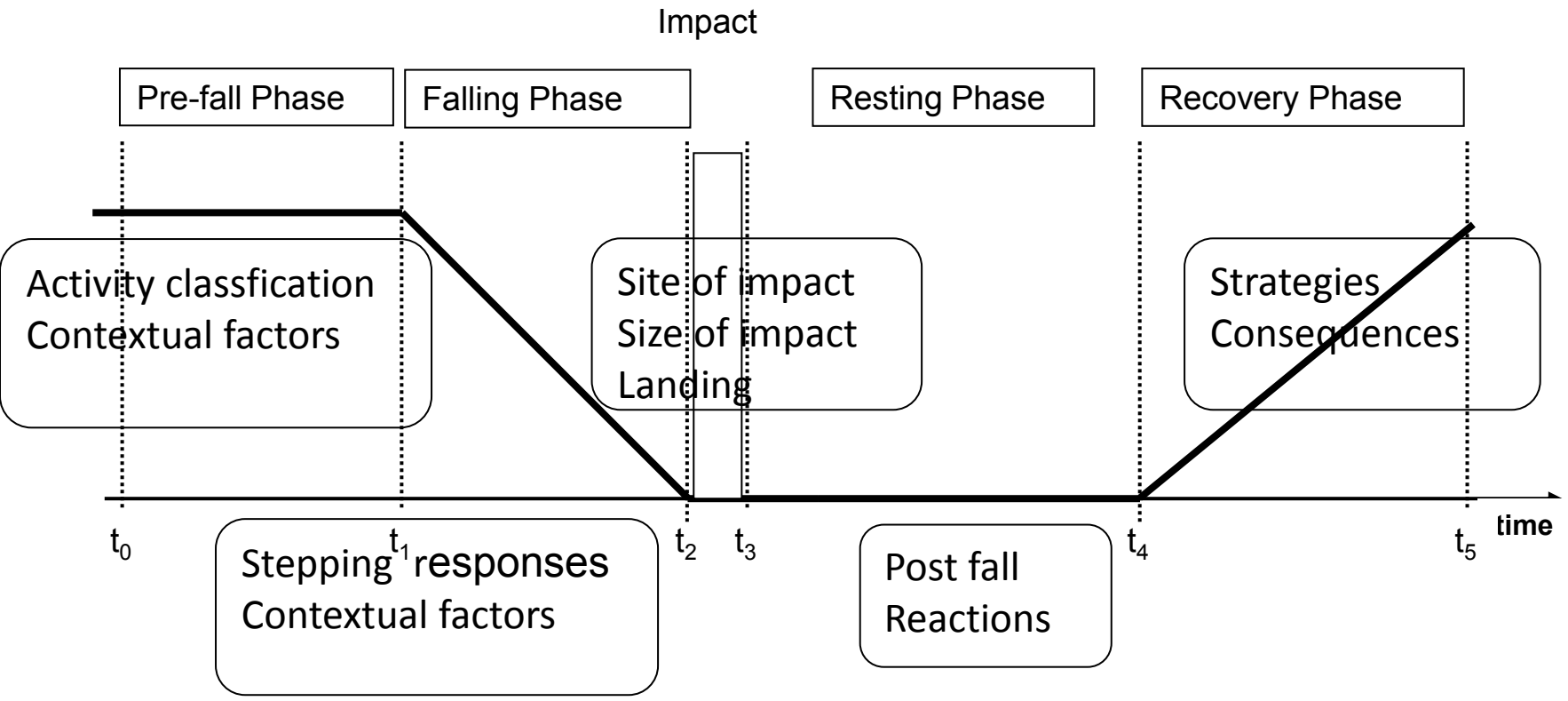
[9] ASF-Azienda Sanitaria di Firenze, Florence
[10] School of Population Health, University of Auckland
[11] Institute of Epidemiology and Medical Biometry, Ulm University

Proposal for a multiphase fall model based on real-world fall recordings with body-fixed sensors



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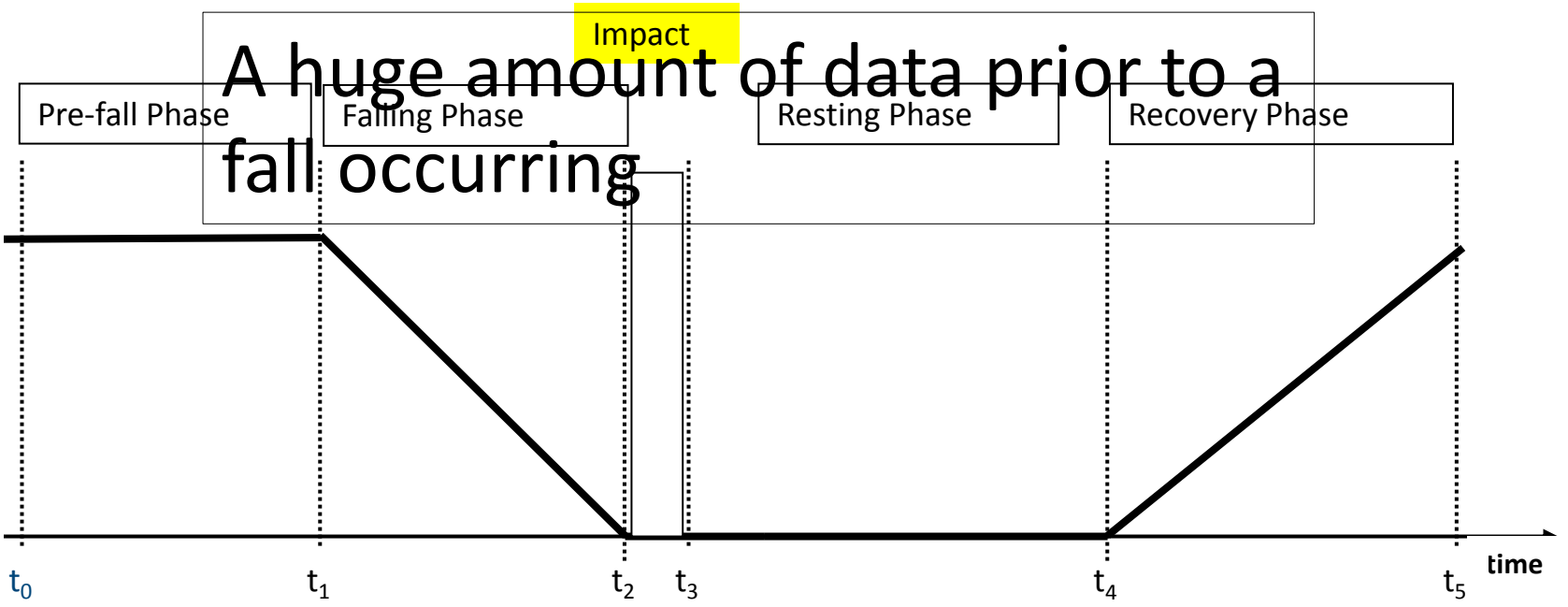
A multiphase fall model



A huge amount of data prior to a fall occurring

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Proposal for a multiphase fall model based on real-world fall recordings with body-fixed sensors

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Fall detection

Alarms

- >1/5 fall alarms used when appropriate

- Fleming et al *BMJ* 2008;337;a2227

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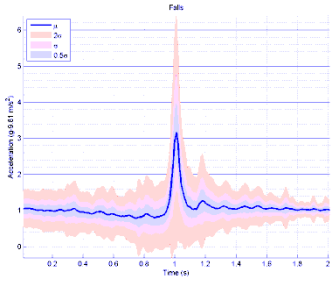
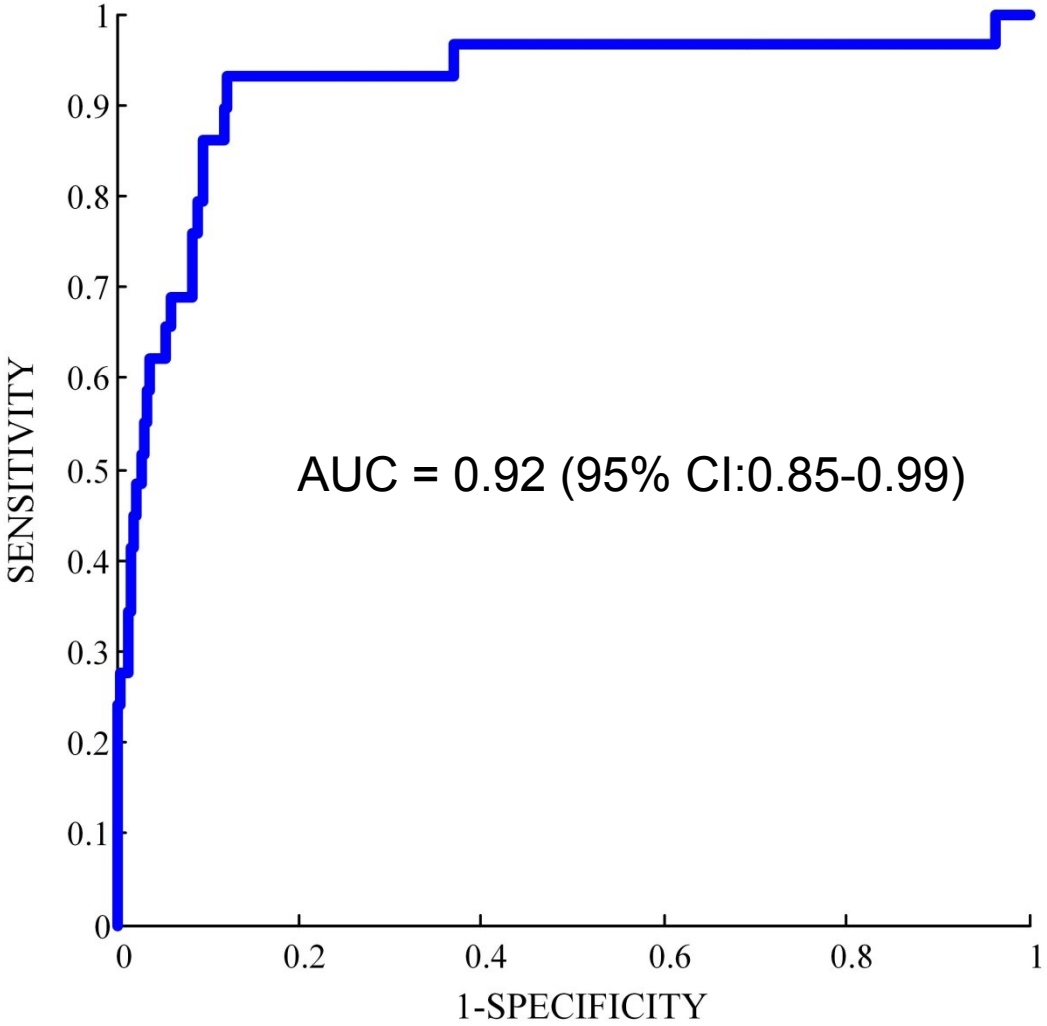
Wavelet based fall detection





Palmerini L et al. A wavelet-based approach to fall detection [Sensors 2015]

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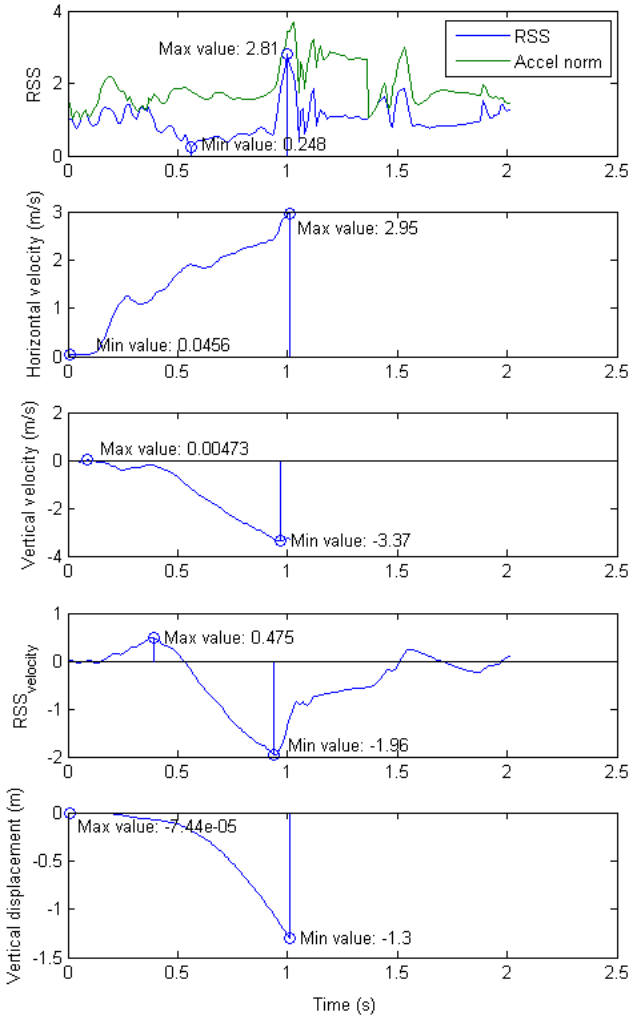
Detection: vertical and horizontal velocity



- Maximum PPV:
  - Sensitivity: 0.91
  - Specificity: 0.99
  - PPV: 0.78

Bourke A et al. Real-world fall temporal and kinematic variables for fall detection algorithm development for the L5 location. ICAMPAM 2015

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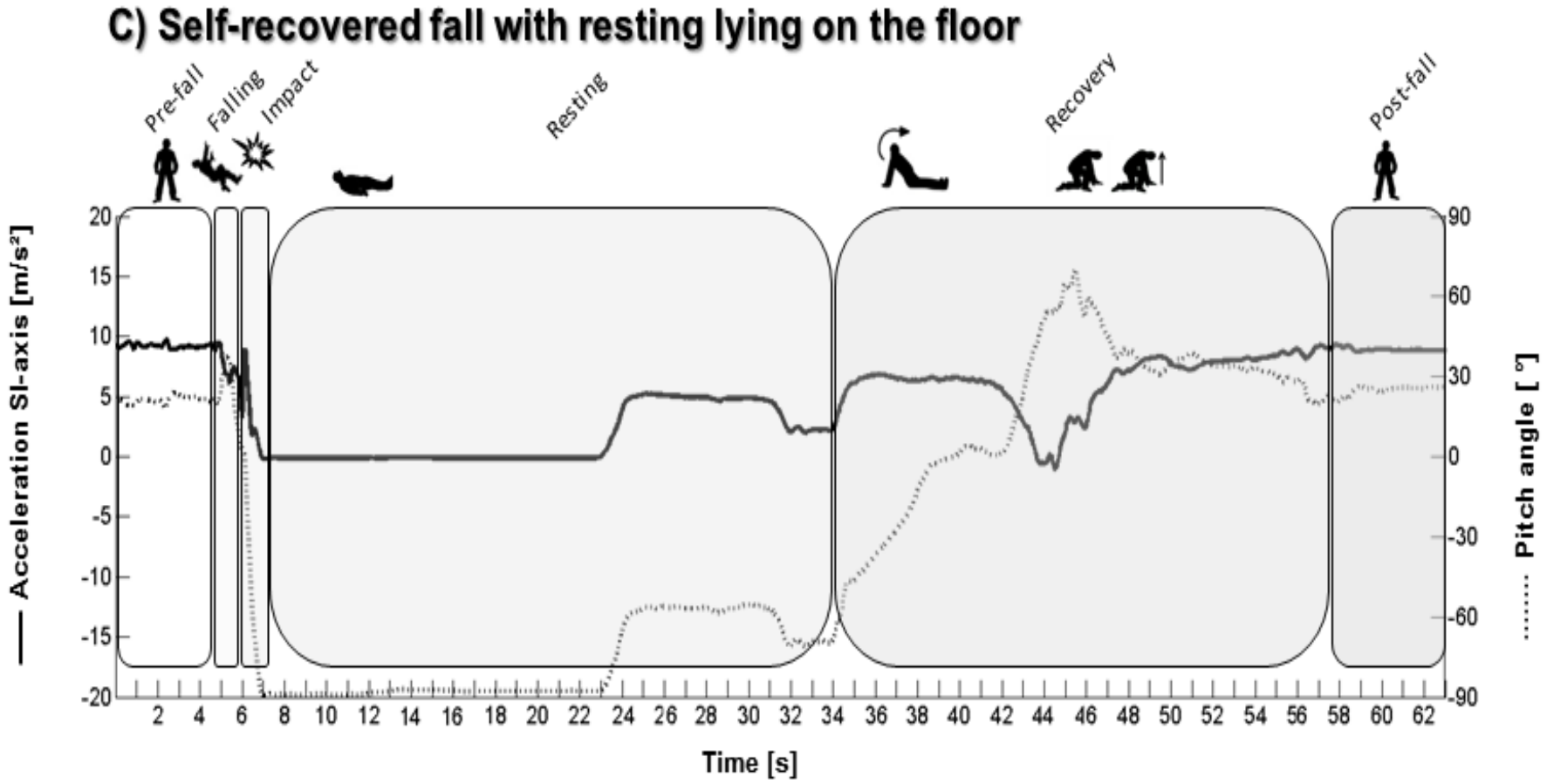
Non-injurious fall detection



The subject was cleaning the floor and fell backwards while turning around. After resting on the floor for a short time, the fall was recovered from lying, over an intermediate position by righting up to standing.

Schwickert L et al 2017

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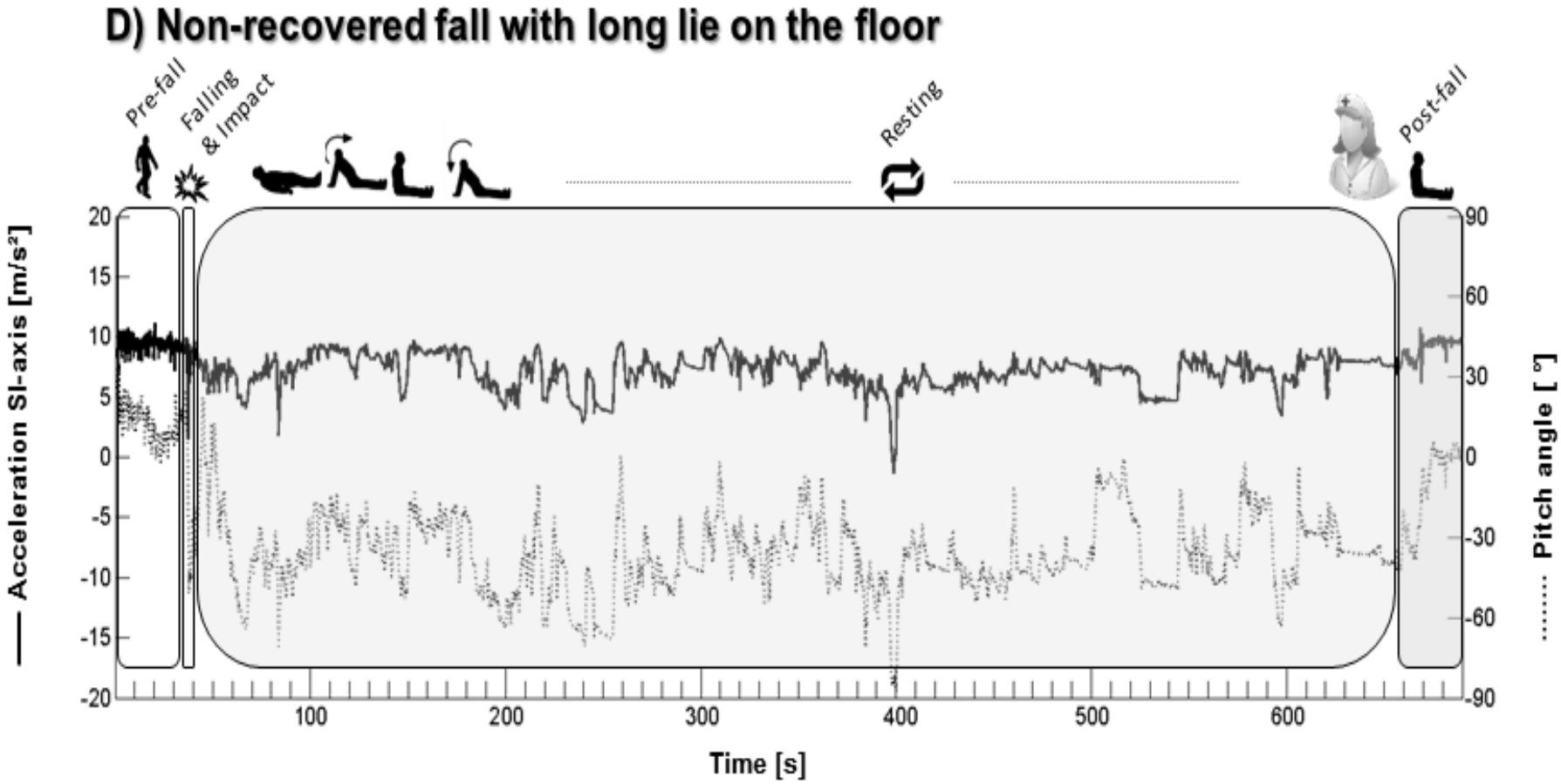
Injurious fall detection



The subject slipped and fell in front of the toilet in a hospital room. After resting on the floor and trying to stand up unsuccessfully multiple times for several minutes, the subject received help from a nurse to get up and sit on the bed.

Schwickert L et al 2017

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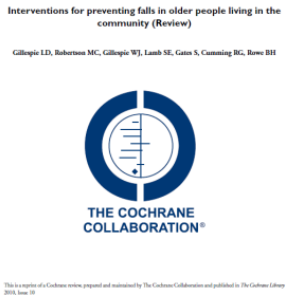
Fall detection

- Sensitivity and specificity getting better
- Automated fall alarms with option to cancel
- Service model that accepts false positives

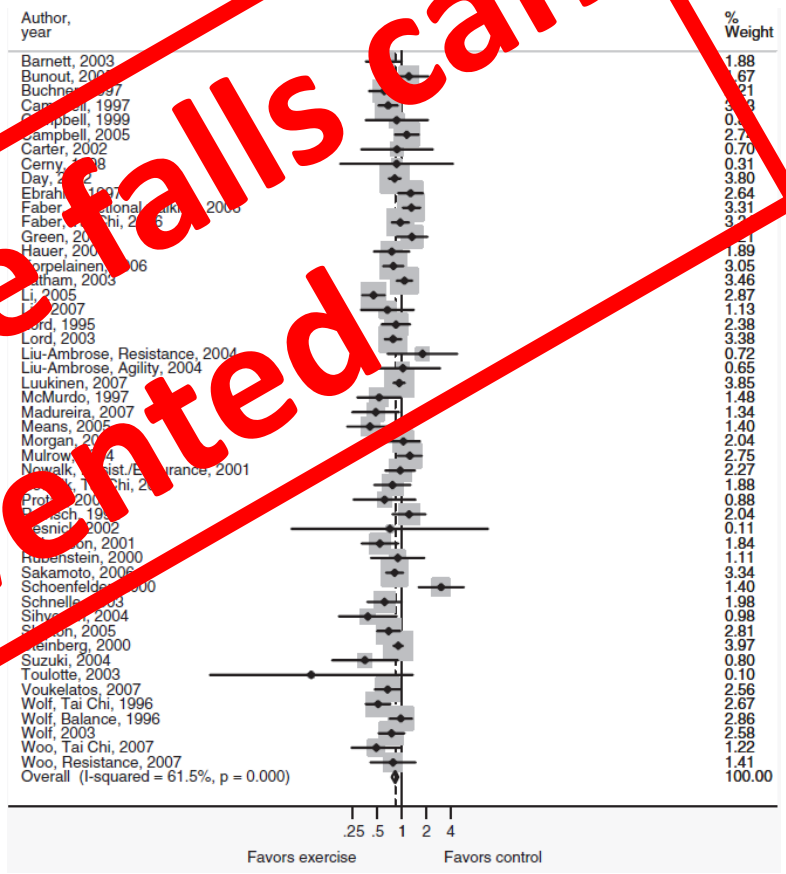
- For research paradoxically still depend on self report to confirm falls
  - Needs more work

Falls can be prevented!

Gillespie et al 2012
159 trials
79193 participants



- *Multiple-component group exercise*
  - *RaR 0.71 [0.63-0.82] RR 0.85 [0.76-0.96]*
- Multiple-component home-based exercise
  - RaR 0.68 [0.58-0.80] RR 0.78 [0.64-0.94]
- Tai Chi
  - RaR 0.72 [0.52-1.0] RR 0.[illegible] [0.57-0.87]
- Multifactorial intervention individual risk assessment
  - RaR 0.76 [0.67-0.86] RR 0.93 [0.86-1.02]
- Vitamin D
  - RaR 1.00 [0.90-1.11] RR 0.96 [0.89-1.03] NB low Vit D
- Home safety interventions by OT
  - RaR 0.69 [0.55-0.86] RR 0.79 [0.69-0.90]



44 trials 9,603 participants

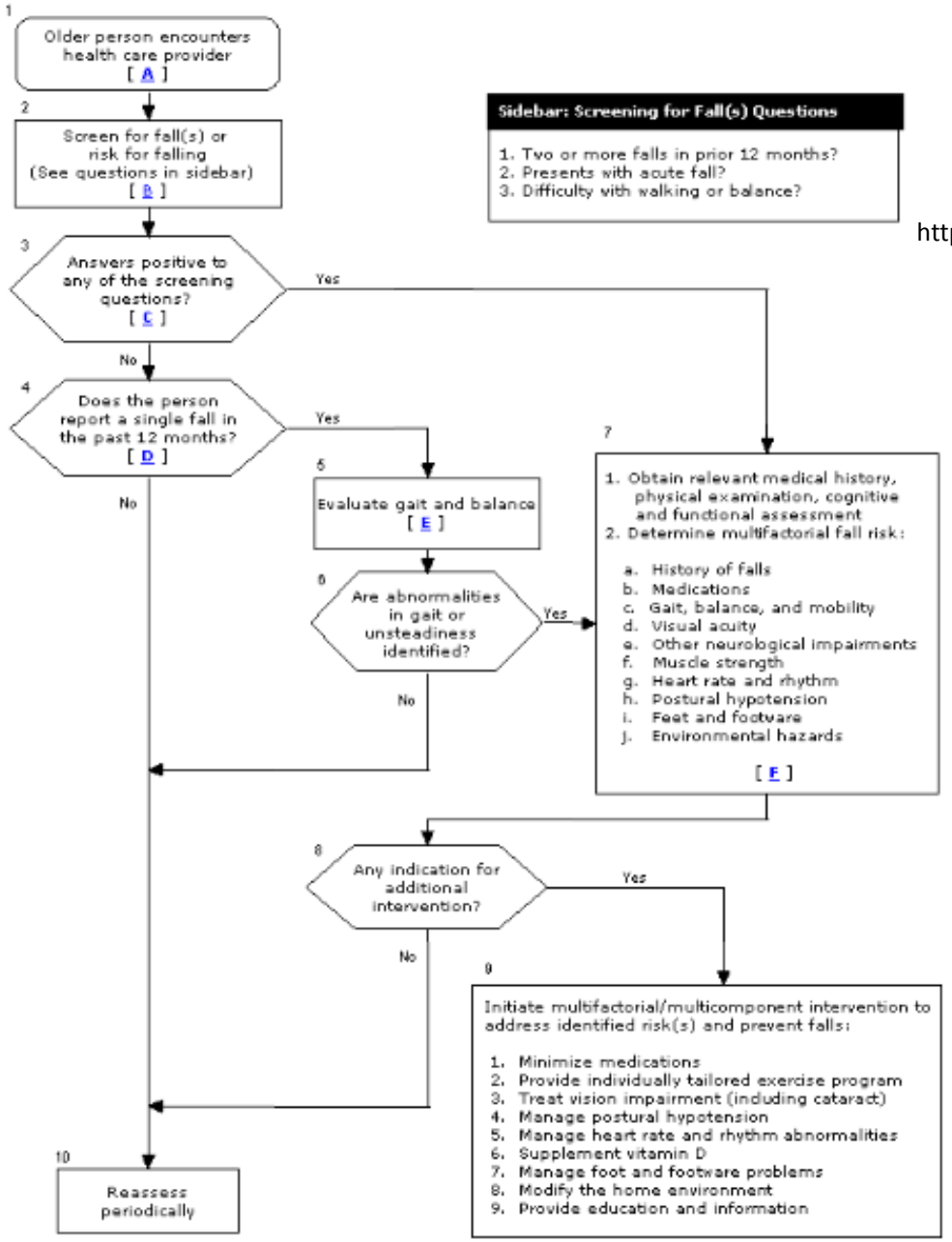
RR=0.83 (95%CI 0.75-0.91)

(High Dose & Challenging RR=0.58 (95%CI0.48–0.69)
Sherrington et al JAGS 2008

Good evidence falls can be prevented

AGS/BGS Clinical practice guideline

http://www.medcats.com/FALLS/frameset.htm



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ProFouND Falls Prevention *App*

Robert-Bosch-Krankenhaus

DEMOKRITOS
NATIONAL CENTER FOR SCIENTIFIC RESEARCH

Test website version
Android/iOS version under development
Future versions to use novel inputs
from sensors etc.

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Last Name | Search

Choose Patient

	Last Name	First Name	Gender	Country	City	Birth Year	Comments		
☰	Joe	Bloggs	Male	United Kingdom	Aberdeen	1910	This is hard work	✎	🗑

1 Showing 1 to 1 of 1 patients

+ Add New Patient

Available Questionnaires

Thank you for entering you patients and choosing one for consulting! First you have to select the "falls scenario", i. e. how many falls your patient has had in the last 12 months. Please use the following definition: A fall is "an unexpected event in which the participant comes to rest on the ground, floor or lower level" (Lamb et al. 2005)*.

No fall in the last 12 months ⇨ Choose "No Fall"
One fall in the last 12 months ⇨ Choose "One Fall"
Two or more falls in the last 12 months ⇨ Choose "Multiple Falls"
At least one fall with a fracture in the last 12 months ⇨ Choose "Injurious Fall(s)

After you have chosen the "falls scenario" you have to answer all questions being displayed. On the left side you see the questions you have to ask your patient. On the right side you have to choose the answer the patient had given.

No Fall	One Fall
Multiple Falls	Injurious Fall(s)

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ProFouND
Prevention of Falls Network for Dissemination
APPLICATION

ChrisTodd
Edit Profile
Logout

Available Patients

+ Add new record

Last Name: Search

Choose Patient

First Name	Last Name	Date of Birth	Gender	Country	City
Arthur	Brown	17.11.1934	Male	UK	London
James	Todd	11.11.1921	Male	UK	London

James Todd - Questionnaire History

Questionnaire	Date
No data available!	

Winston	Smith	01.01.1948	Male	UK	Manchester

1 Showing 1 to 3 of 3 records

Available Questionnaires

- No Fall
- One Fall
- Multiple Falls
- **Injurious Fall(s)**

Injurious Fall(s)

When was the patient's last appointment with an ophthalmologist or optometrist? ≤ 12 months

Test Up And Go: Patient has no abnormalities in transfer, standing or gait

Medication:
- ☐ 4 or more different medication
- ☐ Medications acting on Central Nervous System

Date of Fracture:
- ☐ Within the last 5 years

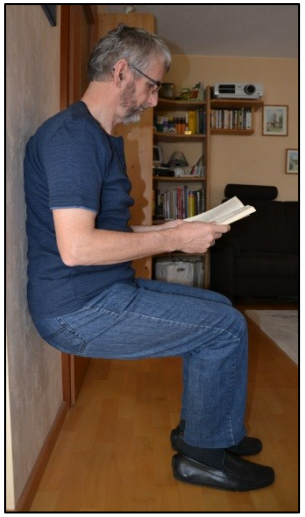
Submit

Motivating 60-70 year olds to be more active using smart technology: The PreventIT project.

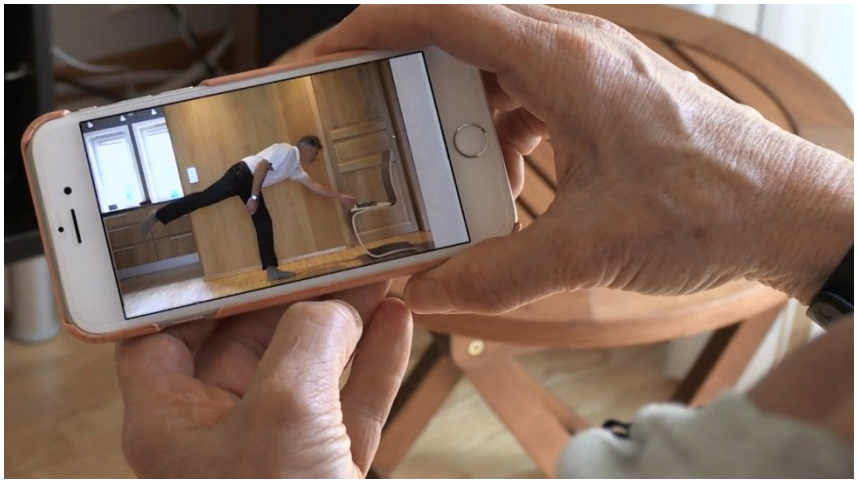
Lis Boulton, Helen Hawley-Hague, David French,
Fan Yang, Jane McDermott, Chris Todd,
University of Manchester

The LiFE Concept

- Many opportunities to improve strength and balance throughout the day.
- Look for opportunities to make life more challenging, not to make it easier!
- Principles: decrease the base of support, load the muscles, move more and sit less.



PreventIT Online



https://www.youtube.com/watch?v=upAfGHbNvdU

The eLiFE system

- Android smartphone – sensors and application
- Android smartwatch – sensors and application for notifications.

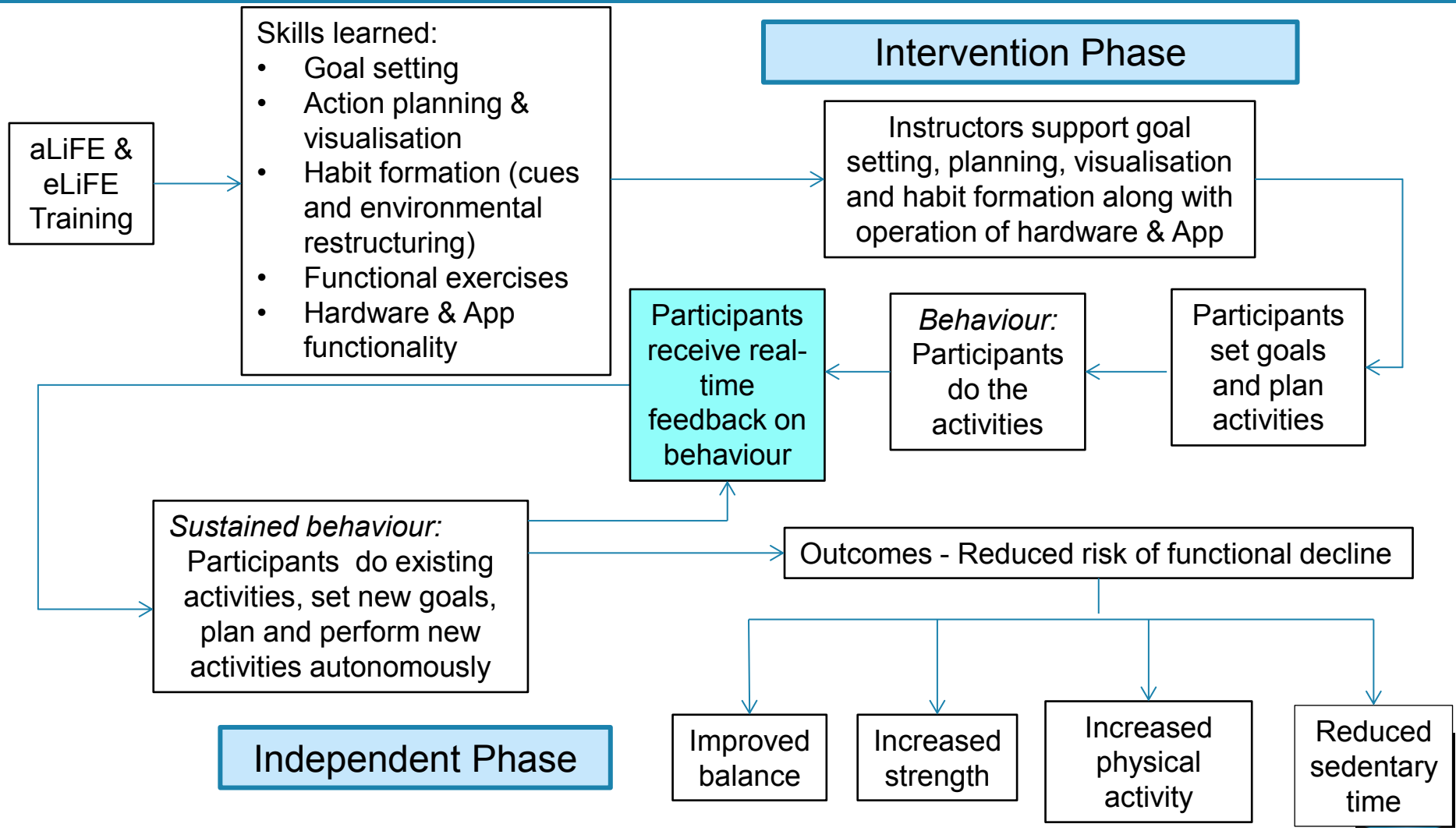
Samsung Galaxy J5, 2016

Sony Smartwatch 3

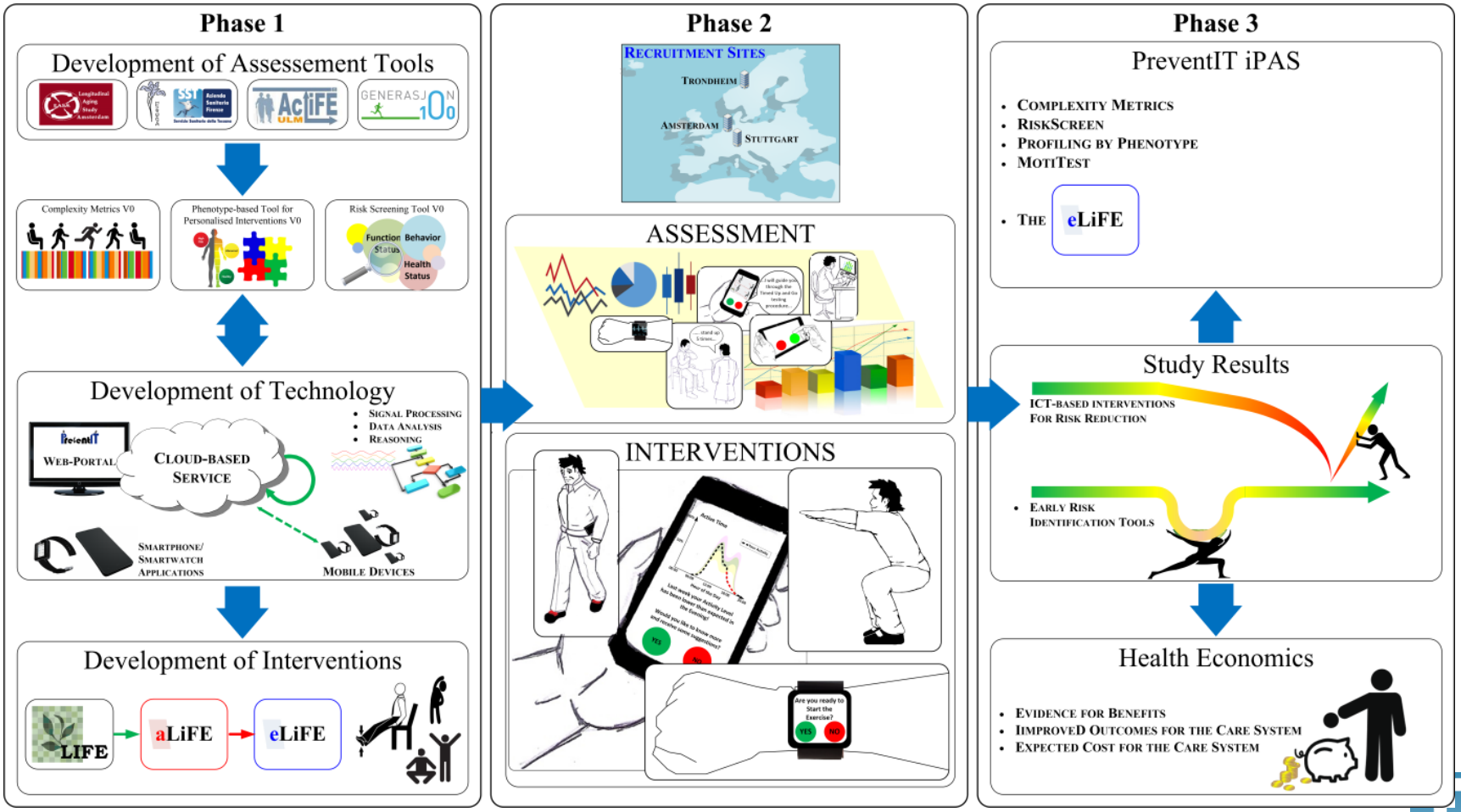
Developing the motivational strategy

- Social Cognitive Theories (HAPA)
- Habit Formation Theory
- Michie's Taxonomy of Behaviour Change Techniques
- All elements mapped onto behaviour change constructs & techniques
- 1322 motivational messages written & mapped to theory
- All translated into Dutch, German and Norwegian!
- 10% back-translated into English

The eLiFE Behavioural Model – how will the intervention work?



How far have we got?

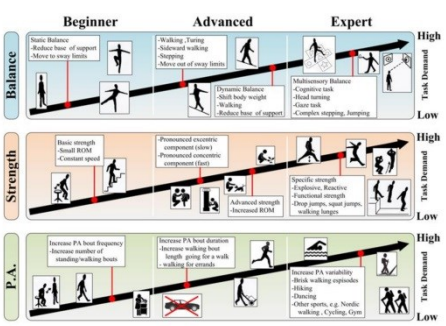


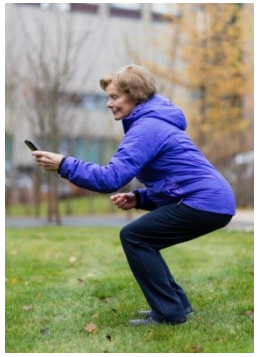
How far have we got?

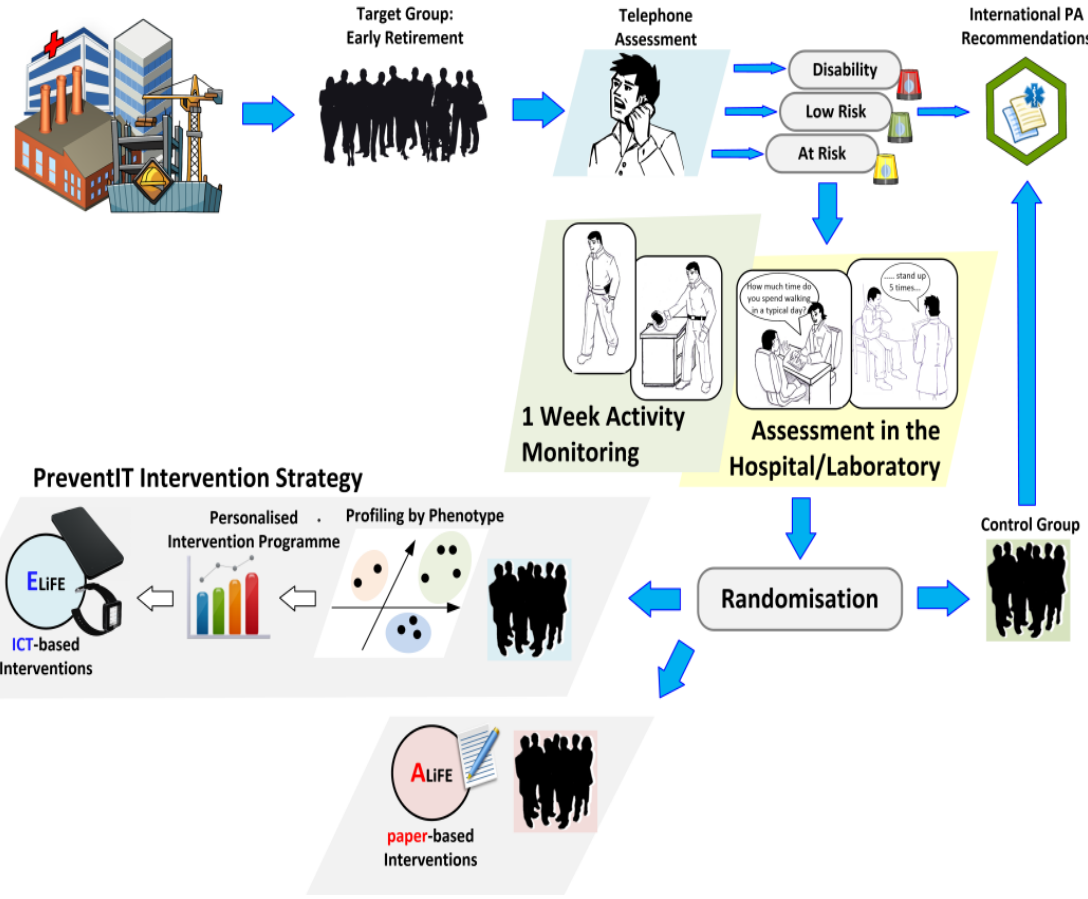
Pilot 1
aLiFE

Pilot 2
eLiFE

Feasibility RCT

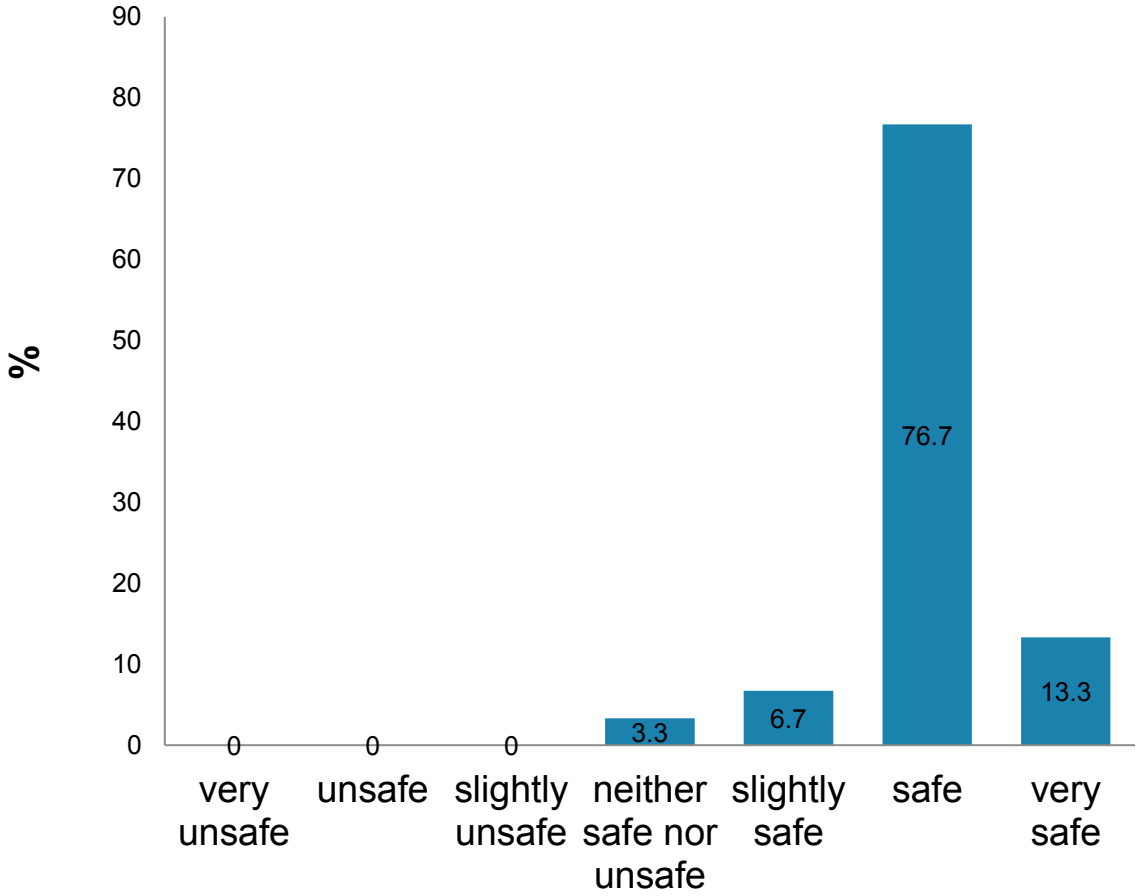




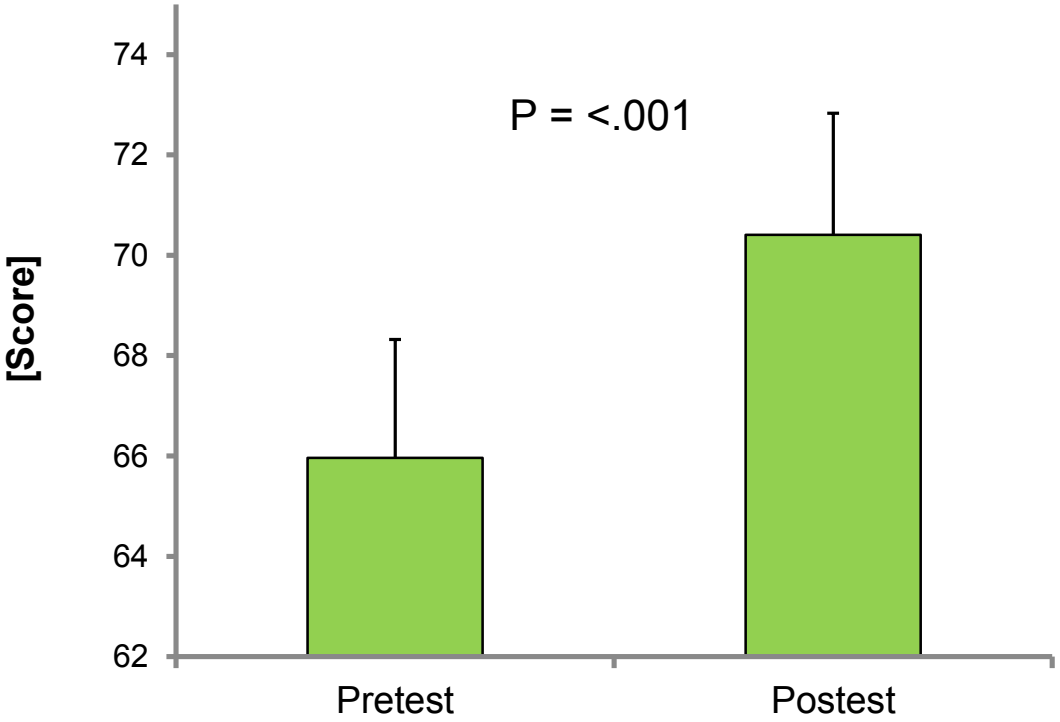


Safety

Did you feel safe when you performed the aLiFE activities?



Pre-post changes
Community Balance Mobility Score



A multi-centre, cluster randomised controlled trial comparing falls prevention Exergames with standard care for community-dwelling older adults living in assisted living facilities.

Emma Stanmore, Dawn Skelton, Chris Todd

Exergames

Cluster Randomised Trial

CE
APPROVED

Recruitment

18 Sheltered Housing facilities

12 Manchester, 6 Glasgow

137 pts consented, 31 ineligible

106 completed baseline assessments

Control Group

Standard care

Physio assessment

OTAGO exercise advice

Falls prevention information and leaflet

Intervention Group

MIRA

Falls prevention tailored exergames

3x per week for 12 weeks plus

standard care

Plus 3 months follow up on falls

CLINICAL ASSESSMENT

Lower limb muscle strength (TUG),
Balance (Berg),
Cognition (ACEIII),
Mood (GDS),
Medication,
PMH
(surgery, joint replacements, fractures
& co-morbidities)

QUESTIONNAIRE ASSESSMENT

History of falls/injuries,
FRAT,
Short FES-I (fear of falling)
VAS pain & fatigue,
Health status (EQ-5D),
Vision,
Usability (SUS),
Physical activity (PASE)
Demographics

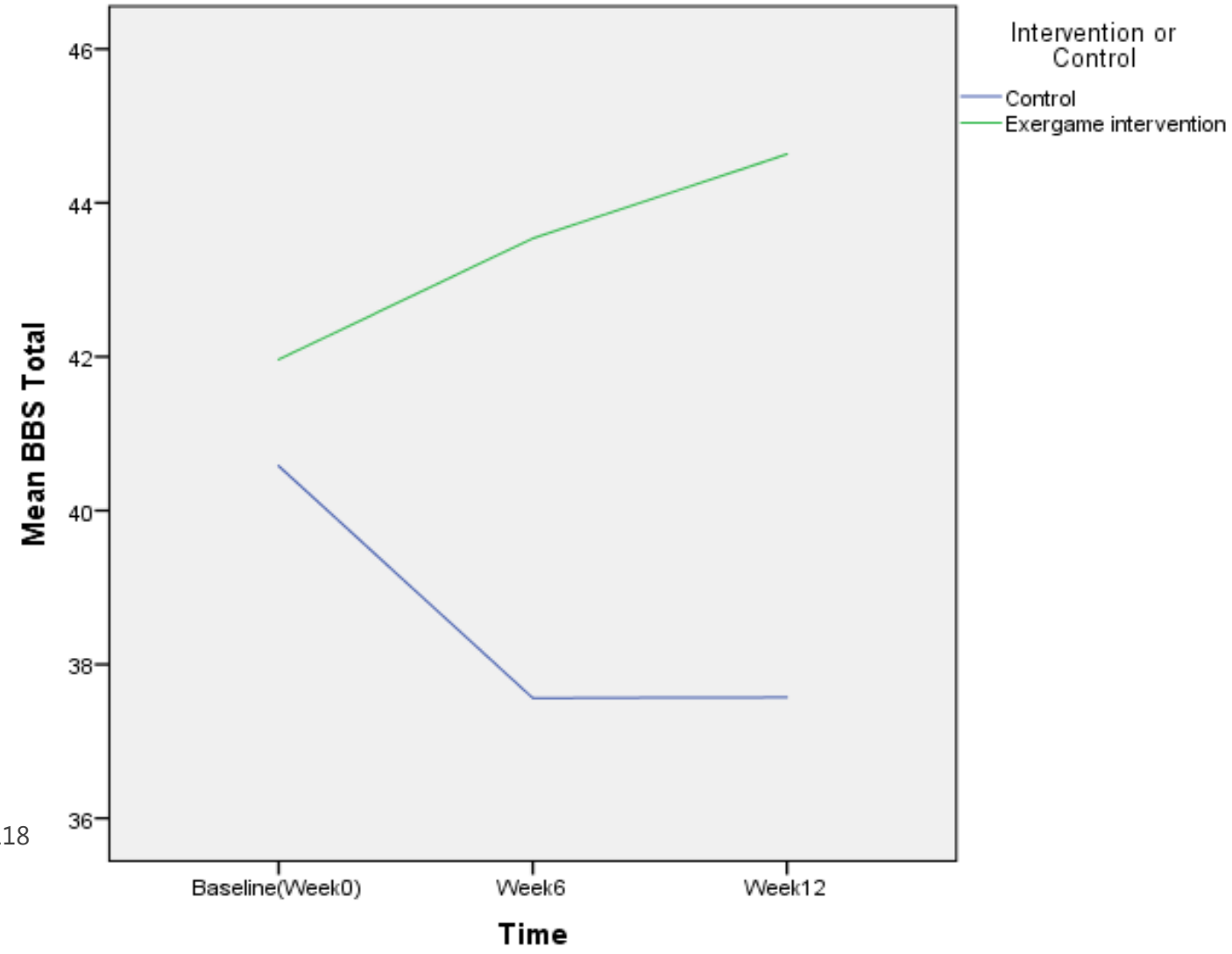
Plus 3 months follow up on falls

Demographics

Baseline (N=106)	CONTROL (n=50)	EXERGAMES (n=56)
Gender		
Females N (%)	38 (76.0)	45 (80.4)
Males N (%)	12 (24.0)	11 (19.6)
Age		
Mean	77.8	77.9
SD	10.2	8.9
Range	58 to 101	58 to 96

Nearly all White British

Primary outcome: Balance



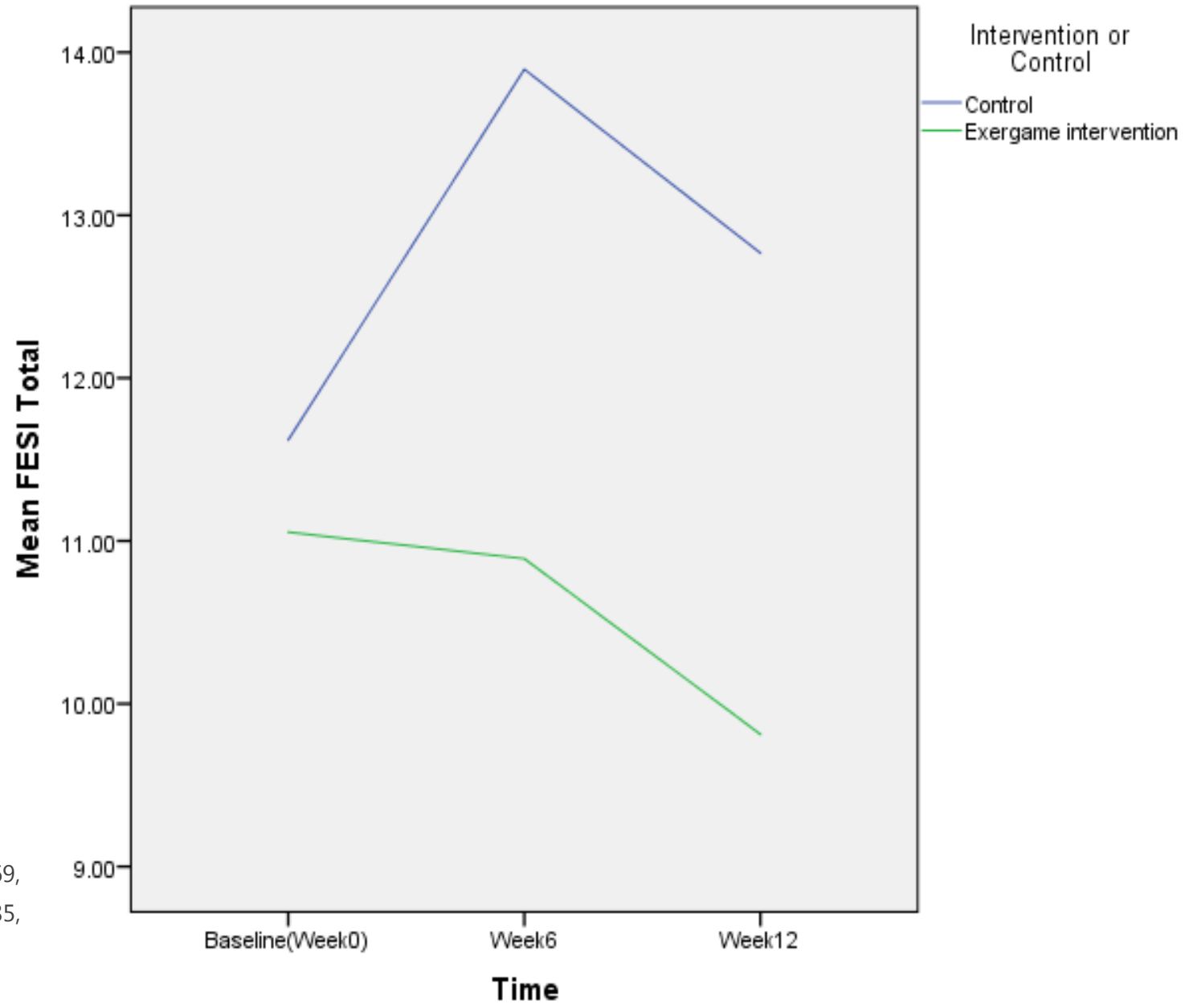
Berg Balance Scale

mean increase in BBS 6.18 (95% CI 2.38 to 9.97) (p=0.003).

ITT analysis

(N=106)

Secondary outcome: FES-I : fear of falling



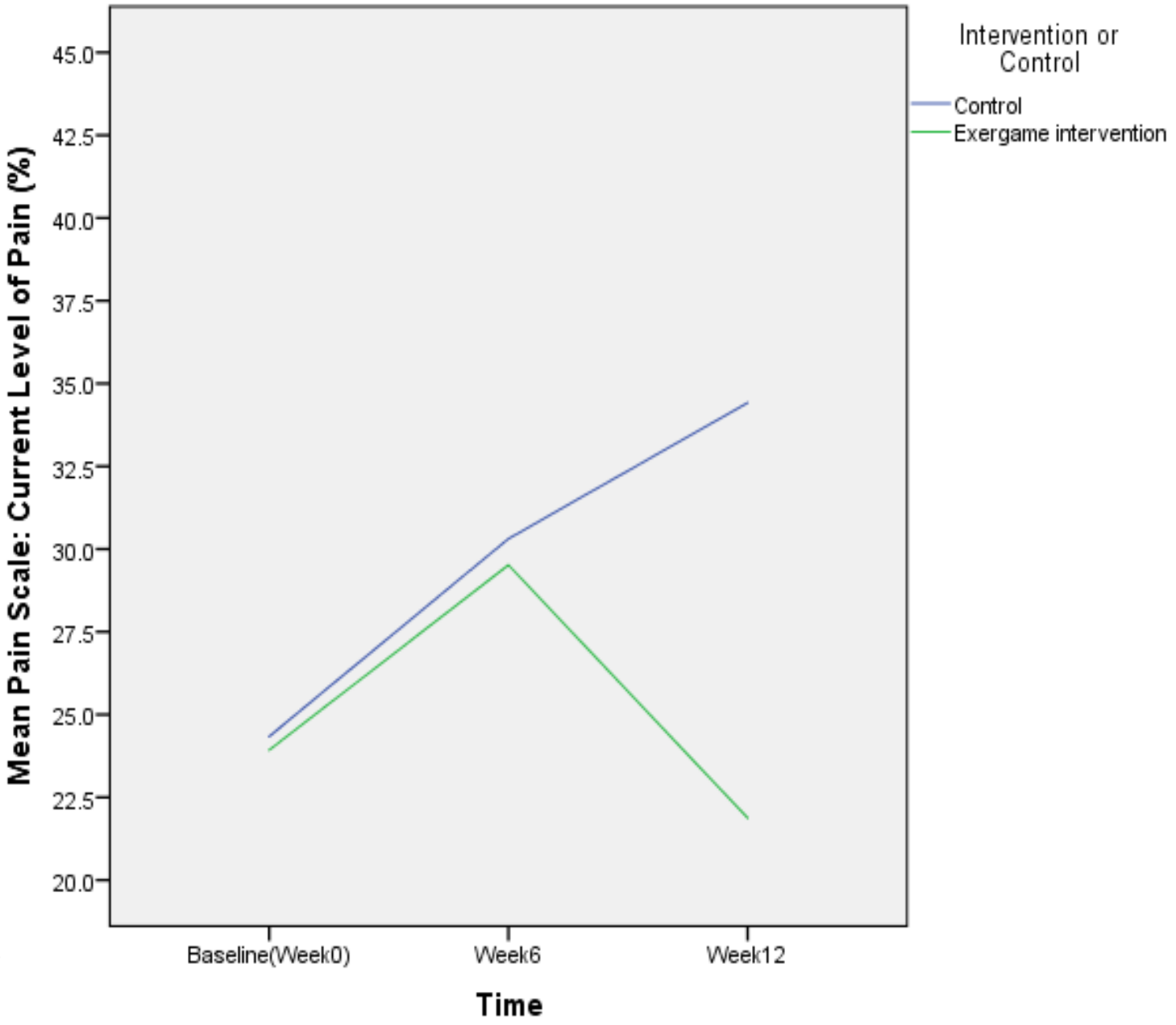
Fear of falling

Effect estimate=-2.69,

95% CI: -4.52 to -0.85,

(p= 0.007)

Secondary outcome: Pain



Pain Scale

Effect estimate=-12.07,

95% CI: -22.31 to -1.83,

(p=0.024)

Also better outcomes for the Exergames groups' participants for:

Cognition

Fatigue

Geriatric Depression Scale

Functional status/lower limb strength (TUG)

Adherence, attrition and adverse events

Mean Exergame sessions over 12 weeks = 24.85 out of 36 sessions

Only 14% attrition.

No reported adverse events.

Qualitative Results

- Focus groups & Interview.

- **Positive physical, mental & social outcomes noted by users & therapists**

- Physical: improvements in ADLs.
- Mental: improvements perceived ‘sharper mind, improved mood’.
- Social: ‘friendships, support, laughter, social cohesion, less isolated’.
- Exergames enjoyed, variety of preferences
  - no one size fits all.
- Continual therapist feedback for technical improvements.
- **Participants requested MIRA exergames to continue.**

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