Prof Chris Todd
School of Health Sciences

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


Disclosure of interests: Funded by EC
Plan

• Falls

• Digital technologies for fall:
  – Prediction
  – Assessment
  – Detection
  – Prevention

MIRA Exergame RCT
30-40% community dwelling >65yrs fall in year
- 40-60% no injury
- 30-50% minor injury
- 3-6% 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

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 (£1.7 billion/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
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Todd et al 2016 unpublished data reported to EC
## Risk factors for falls amongst community dwelling older people

<table>
<thead>
<tr>
<th>Sociodemographic risk factors</th>
<th>Falling OR (95% CIs)</th>
<th>Recurrent falling OR (95% CIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per increment 5-year)</td>
<td>1.12 (1.07-1.17)</td>
<td>1.12 (1.07-1.18)</td>
</tr>
<tr>
<td>Sex (female vs male)</td>
<td>1.30 (1.18-1.41)</td>
<td>1.34 (1.12-1.60)</td>
</tr>
<tr>
<td>Living conditions (alone vs not alone)</td>
<td>1.33 (1.21-1.45)</td>
<td>1.25 (1.10-1.43)</td>
</tr>
<tr>
<td>Ethnicity (Black/Black British vs White)</td>
<td>1.64 (1.34-2.01)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Psychological risk factors</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive impairment (yes vs no)</td>
<td>2.24 (1.25-4.03)</td>
<td>3.65 (1.71-7.79)</td>
</tr>
<tr>
<td>Depression (yes vs no)</td>
<td>1.63 (1.36–1.94)</td>
<td>1.86 (1.45–2.38)</td>
</tr>
<tr>
<td>Fear of falling (yes vs no)</td>
<td>1.55 (1.14–2.09)</td>
<td>2.51 (1.78–3.54)</td>
</tr>
<tr>
<td>Self-reported health status (poor vs good)</td>
<td>1.50 (1.15–1.96)</td>
<td>1.82 (1.26–2.61)</td>
</tr>
</tbody>
</table>

1 adjusted in multivariate analyses

Becker C, Woo J, Todd C. Falls Oxford Textbook of Geriatric Medicine 2018
adapted from Deandrea et al, 2010
## Risk factors for falls amongst community dwelling older people

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

Becker C, Woo J, Todd C. Falls Oxford Textbook of Geriatric Medicine 2018
adapted from Deandrea et al, 2010
<table>
<thead>
<tr>
<th>Medication use</th>
<th>Falling OR (95% CIs)</th>
<th>Recurrent falling OR (95% CIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of medications (per increment of 1 drug)</td>
<td>1.06 (1.04–1.08)</td>
<td>1.06 (1.04–1.08)</td>
</tr>
<tr>
<td>Use of anti-epileptics (use vs no use)</td>
<td>1.88 (1.02–3.49)</td>
<td>2.68 (1.83–3.92)</td>
</tr>
<tr>
<td>Use of sedatives (use vs no use)</td>
<td>1.38 (1.15–1.66)</td>
<td>1.53 (1.34–1.75)</td>
</tr>
<tr>
<td>Use of anti-hypertensives (use vs no use)</td>
<td>1.25 (1.06–1.48)</td>
<td>1.23 (1.05–1.44)</td>
</tr>
<tr>
<td>Mobility and sensory issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of falls (yes vs no)</td>
<td><strong>2.77 (2.37–3.25)</strong></td>
<td>3.46 (2.85–4.22)</td>
</tr>
<tr>
<td>Walking aid use (yes vs no)</td>
<td>2.18 (1.79–2.65)</td>
<td><strong>3.09 (2.10–4.53)</strong></td>
</tr>
<tr>
<td>Gait problems (yes vs no)</td>
<td>2.06 (1.82–2.33)</td>
<td>2.16 (1.47–3.19)</td>
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<tr>
<td>Physical disability (yes vs no)</td>
<td>1.56 (1.22–1.99)</td>
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<td>Vision impairment (yes vs. no)</td>
<td>1.35 (1.18–1.54)</td>
<td>1.60 (1.28–2.00)</td>
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<tr>
<td>Hearing impairment (yes vs. no)</td>
<td>1.21 (1.05–1.39)</td>
<td>1.53 (1.33–1.76)</td>
</tr>
<tr>
<td>Physical activity (limitation vs no limitation)</td>
<td><strong>1.20 (1.04–1.38)</strong></td>
<td>NA</td>
</tr>
</tbody>
</table>

1 Risk factors for falls amongst community dwelling older people adapted from Deandrea et al, 2010.
FARSEEING Taxonomy of Technologies:

Body fixed/worn

Ambient

Portable

Boulton et al 2016 J Biomed Inf

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

PreventIT

Samsung Galaxy J5, 2016

Sony Smartwatch 3


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

Extrinsic factors:
usability, feedback gained, cost
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
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)
Prediction of falls risk
## Risk factors for falls amongst community dwelling older people

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### 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

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adapted from Deandrea et al, 2010
Prevention of Falls in Older Persons
AGS/BGS Clinical Practice Guideline

1. Older person encounters health care provider
   Yes
   2. Screen for fall(s) or risk for falling (See questions in sidebar)
   No
   3. Answer positive to any of the screening questions?
   Yes
   4. Does the person report a single fall in the past 12 months?
   No
   6. Evaluate gait and balance
      Yes
      5. Are abnormalities in gait or unsteadiness identified?
      No
      8. Any indication for additional intervention?
      Yes
      9. Initiate multifactorial/multicomponent intervention to address identified risk(s) and prevent falls:
      1. Minimize medications
      2. Provide individually tailored exercise program
      3. Treat vision impairment (including cataracts)
      4. Manage postural hypotension
      5. Manage heart rate and rhythm abnormalities
      6. Supplement vitamin D
      7. Manage foot and footwear problems
      8. Modify the home environment
      9. Provide education and information
   No

Sidebar: Screening for Fall(s) Questions
1. Two or more falls in prior 12 months?
2. Presents with acute fall?
3. Difficulty with walking or balance?

10. Reassess periodically

[ ] = Annotation link (Click to see recommendations)
Can sensors improve prediction of falls?

Predictors accelerometry

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

• AUC 0.71

ROC for logistic prediction model

(van Schooten et al., J. Gerontol 2015)
Predictors from questionnaires

- 6-month history of falls
- geriatric depression scale

• AUC 0.68

(van Schooten et al., J. Gerontol 2015)
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)
• 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
PreventIT Functional Tests

Hello John! Do you want to test yourself?

Please insert the mobile inside the case waist belt

Now remain seated and wait for me to say GO...

Very Well John! You have shown an improvement!

Find a seat...

...try to keep your back straight...  
...try to keep your arms crossed over your chest...
Assessment of falls

Fall no.: RBK1964-01
Setting: geriatric rehabilitation

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

Sensor characteristics
Device: uSense  Location: Thigh
Sensor type(s): acc, gyn, mag  Unit(s): m/s^2, 1/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 chair 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 radiator handles but missed them.

Witness: unknown  Assitive device: unknown
Reported pre-fall activity, standing/fatigue: Reported fall direction: unknown
Indoors/Outdoors: 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
A multiphase fall model

- **Pre-fall Phase**
- **Falling Phase**
- **Resting Phase**
- **Recovery Phase**

**Activity classification**
- Contextual factors

**Site of impact**
- Size of impact
- Landing

**Stepping responses**
- Contextual factors

**Post fall Reactions**

**Strategies Consequences**

**Contextual factors**
- Site of impact
- Size of impact
- Landing

**Stepping responses**
- Time points:
  - \( t_0 \)
  - \( t_1 \)
  - \( t_2 \)
  - \( t_3 \)
  - \( t_4 \)
  - \( t_5 \)
A multiphase fall model

A huge amount of data prior to a fall occurring
Fall detection

Alarms

• >1/5 fall alarms used when appropriate

• Fleming et al *BMJ* 2008;337:a2227
Wavelet based fall detection

AUC = 0.92 (95% CI: 0.85-0.99)

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

- **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 0.78 [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]

**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

Gillespie et al 2012
159 trials
79193 participants

44 trials 9,603 participants
AGS/BGS Clinical practice guideline

http://www.medcats.com/FALLS/frameset.htm
ProFouND Falls Prevention App

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

* Add new record

### Choose Patient

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Date of Birth</th>
<th>Gender</th>
<th>Country</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthur</td>
<td>Brown</td>
<td>17.11.1934</td>
<td>Male</td>
<td>UK</td>
<td>London</td>
</tr>
<tr>
<td>James</td>
<td>Todd</td>
<td>11.11.1921</td>
<td>Male</td>
<td>UK</td>
<td>London</td>
</tr>
</tbody>
</table>

### James Todd - Questionnaire History

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No data available!</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Date of Birth</th>
<th>Gender</th>
<th>Country</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winston</td>
<td>Smith</td>
<td>01.01.1948</td>
<td>Male</td>
<td>UK</td>
<td>Manchester</td>
</tr>
</tbody>
</table>

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

- [ ] No abnormalities in transfer, standing or gait

Medication

- [ ] 4 or more different medications
- [ ] 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.
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?

Skills learned:
- Goal setting
- Action planning & visualisation
- Habit formation (cues and environmental restructuring)
- Functional exercises
- Hardware & App functionality

Intervention Phase

Instructors support goal setting, planning, visualisation and habit formation along with operation of hardware & App

Participants set goals and plan activities

Participants do the activities

Behaviour: Participants receive real-time feedback on behaviour

Sustained behaviour: Participants do existing activities, set new goals, plan and perform new activities autonomously

Outcomes - Reduced risk of functional decline

Independent Phase

Improved balance

Increased strength

Increased physical activity

Reduced sedentary time
How far have we got?
How far have we got?

Pilot 1  
aLiFE

Pilot 2  
eLiFE

Feasibility RCT

PreventIT Intervention Strategy

ICT-based Interventions

Alife

paper-based Interventions

Randomisation

Assessment in the Hospital/Laboratory

1 Week Activity Monitoring

Telephone Assessment

Target Group: Early Retirement

International PA Recommendation

Disability

Low Risk

At Risk
Safety

Did you feel safe when you performed the aLiFE activities?
Pre-post changes
Community Balance Mobility Score

P = <.001
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

Recruitment

18 Sheltered Housing facilities
12 Manchester, 6 Glasgow
137 pts consented, 31 ineligible
106 completed baseline assessments
<table>
<thead>
<tr>
<th><strong>Control Group</strong></th>
<th><strong>Intervention Group</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard care</strong></td>
<td><strong>MIRA</strong></td>
</tr>
<tr>
<td>Physio assessment</td>
<td>Falls prevention tailored exergames</td>
</tr>
<tr>
<td>OTAGO exercise advice</td>
<td>3x per week for 12 weeks plus</td>
</tr>
<tr>
<td>Falls prevention information and</td>
<td>standard care</td>
</tr>
<tr>
<td>leaflet</td>
<td>Plus 3 months follow up on falls</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Gender</th>
<th>Baseline (N=106)</th>
<th>CONTROL (n=50)</th>
<th>EXERGAMES (n=56)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females N (%)</td>
<td>38 (76.0)</td>
<td>45 (80.4)</td>
<td></td>
</tr>
<tr>
<td>Males N (%)</td>
<td>12 (24.0)</td>
<td>11 (19.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>77.8</td>
<td>77.9</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>10.2</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>58 to 101</td>
<td>58 to 96</td>
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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
Secondary outcome: FES-I: fear of falling

Effect estimate = -2.69,
95% CI: -4.52 to -0.85,
(p = 0.007)
Secondary outcome: Pain

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.**
EU Falls Festival 2017

8th and 9th May
Amsterdam, Netherlands

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