Training voluntary and reactive stepping for fall prevention

Daina Sturnieks
Standing balance requires controlling the centre of mass (CoM) of the body so that it remains over the feet, often called the base of support (BoS).

COM motion towards the edge of the BOS causes instability

- Feet-in-place responses

- Stepping - to increase the BoS.
Protective Stepping

Stepping is often the critical (final) option by which to maintain balance and avoid a fall.

Inappropriate step responses are significantly more prevalent in older people.

Trips & Slips = 60%


Voluntary Stepping
Choice Stepping Reaction Time

<table>
<thead>
<tr>
<th></th>
<th>Fallers</th>
<th>Nonfallers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stepping choice reaction time, ms</td>
<td>1322 (331)**</td>
<td>1168 (203)</td>
</tr>
</tbody>
</table>

Table 4. Predictor Variables of CSRT and Their Beta Weights

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>Beta Weights</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traits B score</td>
<td>0.12</td>
<td>.450**</td>
</tr>
<tr>
<td>Quadriceps strength</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Simple reaction time</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Sway: eyes closed on foam</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Maximal balance range</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>.454</td>
</tr>
</tbody>
</table>
Choice Stepping Reaction Time

YOUNG

OLD LOW RISK

OLD HIGH RISK

decision stepping

75...68...61... 54...47...

Sturnieks et al. J Gerontol, 2008

Sturnieks et al. J Gerontol, 2008
Step training pilot trials

n=37, independent units of retirement village, 1hr/week, 8 weeks

Compared to control, the intervention group improved in measures of processing speed, visuo-spatial ability and concern about falling.

Schoene et al. Plos One, 2013

n=90, community dwelling, 1+hr/week, 16 weeks.

Schoene et al. Plos One, 2015
**smart step**

**step+cognitive training:** standing stepping + brain exercises

- balance challenging
- accurate stepping
- fast responses

- response inhibition
- selective attention
- visuospatial processing
- set shifting

**Cognitive training:**

- seated brain exercises

- response inhibition
- selective attention
- visuospatial processing
- set shifting
AIM: to determine the effects of cognitive and step+cognitive training, compared with a no-intervention control group, on preventing falls in older people.

i. compare effect sizes of step+-cognitive training on reducing falls

ii. examine the effects of step+cognitive and cognitive training on:
   a) physical function (i.e. balance, gait, mobility)
   b) cognitive function
   c) neural plasticity (i.e. changes in brain structure and function)

iii. calculate the cost effectiveness of delivering the interventions
smart±step

**Recruitment**

**Baseline Assessment (n=750)**

**Randomisation**

**Time 0**
- **step+cognitive** (n=250)
- **cognitive** (n=250)
- **control** (n=250)

**1 week later**
- **Home visit**: System installation & training
- **Home visit**: System installation & training
- **Phone call**: Falls information sent via post

**4 weeks later**
- **Home visit**
- **Home visit**
- **Phone call**

**6 months**
- **Blinded re-assessment (n=300)**

**12 months**
- **Falls follow-up completed**
Primary outcome
• Prospective fall events over 12 months

Secondary outcomes
• Balance
• Stepping performance and speed
• Gait and mobility
• Cognitive functions
• Neuroplasticity (n=105)
<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Recruitment ID</th>
<th>Device ID</th>
<th>Study Type</th>
<th>Last Active</th>
<th>Last Week (min)</th>
<th>Last Fortnight (min)</th>
<th>Last Month (min)</th>
<th>Compliant Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>473</td>
<td>508</td>
<td></td>
<td>Motor Cognitive</td>
<td>13-Nov-2018 08:52</td>
<td>99 minutes, 54 seconds</td>
<td>205 minutes, 30 seconds</td>
<td>567 minutes, 42 seconds</td>
<td>7 / 7</td>
</tr>
<tr>
<td>436</td>
<td>470</td>
<td></td>
<td>Motor Cognitive</td>
<td>16-Nov-2018 13:32</td>
<td>99 minutes, 44 seconds</td>
<td>193 minutes, 54 seconds</td>
<td>346 minutes, 4 seconds</td>
<td>12 / 14</td>
</tr>
<tr>
<td>530</td>
<td>575</td>
<td></td>
<td>Motor Cognitive</td>
<td>17-Nov-2018 15:31</td>
<td>99 minutes, 2 seconds</td>
<td>163 minutes, 23 seconds</td>
<td></td>
<td>1 / 2</td>
</tr>
<tr>
<td>348</td>
<td>378</td>
<td></td>
<td>Motor Cognitive</td>
<td>15-Nov-2018 18:39</td>
<td>99 minutes, 17 seconds</td>
<td>247 minutes, 27 seconds</td>
<td>562 minutes, 12 seconds</td>
<td>25 / 28</td>
</tr>
<tr>
<td>532</td>
<td>568</td>
<td></td>
<td>Motor Cognitive</td>
<td>16-Nov-2018 09:41</td>
<td>98 minutes, 9 seconds</td>
<td>231 minutes, 33 seconds</td>
<td></td>
<td>2 / 3</td>
</tr>
<tr>
<td>260</td>
<td>278</td>
<td></td>
<td>Motor Cognitive</td>
<td>16-Nov-2018 19:01</td>
<td>97 minutes, 56 seconds</td>
<td>219 minutes, 19 seconds</td>
<td>332 minutes, 53 seconds</td>
<td>28 / 39</td>
</tr>
<tr>
<td>178</td>
<td>190</td>
<td></td>
<td>Motor Cognitive</td>
<td>16-Nov-2018 19:19</td>
<td>96 minutes, 32 seconds</td>
<td>220 minutes, 23 seconds</td>
<td>542 minutes, 11 seconds</td>
<td>38 / 45</td>
</tr>
<tr>
<td>201</td>
<td>213</td>
<td></td>
<td>Motor Cognitive</td>
<td>17-Nov-2018 13:04</td>
<td>96 minutes, 11 seconds</td>
<td>305 minutes, 15 seconds</td>
<td>710 minutes, 52 seconds</td>
<td>43 / 43</td>
</tr>
<tr>
<td>216</td>
<td>232</td>
<td></td>
<td>Motor Cognitive</td>
<td>17-Nov-2018 07:58</td>
<td>95 minutes, 40 seconds</td>
<td>225 minutes, 18 seconds</td>
<td>556 minutes, 8 seconds</td>
<td>39 / 41</td>
</tr>
<tr>
<td>473</td>
<td>508</td>
<td></td>
<td>Motor Cognitive</td>
<td>14-Nov-2018 16:07</td>
<td>59 minutes, 10 seconds</td>
<td>59 minutes, 10 seconds</td>
<td>106 minutes, 53 seconds</td>
<td>3 / 40</td>
</tr>
<tr>
<td>316</td>
<td>340</td>
<td></td>
<td>Motor Cognitive</td>
<td>17-Nov-2018 19:40</td>
<td>58 minutes, 45 seconds</td>
<td>101 minutes, 9 seconds</td>
<td>372 minutes, 51 seconds</td>
<td>18 / 32</td>
</tr>
</tbody>
</table>

Showing 1 to 50 of 353 entries (filtered from 547 total entries)
Step training in people with MS

- Falls are a significant problem in people with multiple sclerosis (MS): one in two people.
- Fallers having an average fall rate of 1.9 falls/month.
- Study of 200 community-dwelling participants with MS with 6-months of falls follow-up
  - Impaired balance control is the most important risk factor.
  - Other risk factors include poor stepping reaction time, impaired cognitive function.

Effects of a home-based step training programme on balance, stepping, cognition and functional performance in people with multiple sclerosis - a randomized controlled trial
Hoang, Phuc; Schoene, Daniel; Gandevia, Simon; Smith, Stuart; Lord, Stephen R.
Multiple Sclerosis Journal; London Vol. 22, Iss. 1, (Jan 2016): 94-103. DOI:10.1177/1352458515579442
Step training in people with MS

**AIM:** to investigate whether 6-months of step mat training can improve balance, cognition and risk of falling over 12 months in 500 people with MS.

Additional outcomes:
MS severity, mood, fatigue, sleep, gait, mobility, physical activity, sensorimotor function

[Link](http://www.neura.edu.au/clinical-trial/step-training-ms/)

ACTRN12616001053415
Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial

Dr Anat Mirelman PhD a, b, R, 8, Prof Lynn Rochester PhD a, Inbal Maidan PhD a, Silvia Del Din PhD a, Lisa Alcock PhD a, Freek Nieuwhof MS f, b, h, Prof Marcel Olde Rikkert MD f, k, j, Prof Bastiaan R Bloem MD k, h, Elisa Pelosi PhD a, Laura Avanzino MD a, j, Prof Giovanni Abbruzzese MD a, Kim Dockx MS g, Esther Bekkers MS a, Prof Nir Giladi MD a, b, h, Prof Alice Nieuwboer PhD a, Prof Jeffrey M Hausdorff PhD a, b, h
Reactive Stepping
Perturbation responses

Anterior Force threshold to step (N)

* p<0.001

- old n=108
- young n=14

Posterior Force threshold to step (N)

- non faller n=138
- faller n=106

p<0.05

Knee extension strength (β=0.330)
Body weight (β=-0.459)
ML sway (β=-0.208)
Ankle strength (β=0.207)
24.8%

Sturnieks et al. Gait Posture, 2012
Sturnieks et al. Plos One, 2013
Quantifying Trip Responses

- Biceps Femoris
- Semitendinosus
- Rectus Femoris
- Vastus Lateralis
- Gastroc. Medialis
- Soleus

Reaction time [ms]

Peak moment [Nm kg⁻¹]

Rate of moment generation [Nm s⁻¹ kg⁻¹]

*Pijnappels et al. Exp Brain Res 2005

*Pijnappels et al. Gait & Posture 2005
Quantifying Trip Responses

Pijnappels et al. Gait & Posture 2005
Perturbation Training

- Task-specific perturbation training - practicing the motor skill of avoiding a fall during conditions that mimic an actual fall
- Within a single session of repeated exposure to perturbations (slips, trips, platforms/treadmills) laboratory-induced falls can be significantly reduced among older adults.

Perturbation Training RCT

Randomisation (n=212)

n=109

Perturbation training – 47 walking trials with 24 slip trials

n=103

Control training – 10 walking trials with 1 slip trial

Time 0

12 months

Reassessment and falls follow-up completed for n=142

Pai et al. J Gerontol, 2014
Control group (single slip) were 2.3 times more likely to fall during the 12-month follow-up period (p < .05) than those who experienced the 24 repeated slips.

Pai et al. J Gerontol, 2014
Trip and Slip walkway
Trip and Slip walkway
**Slip and Trip training RCT**

**Aims:** To examine the effect of reactive step training (induced slips and trips) on balance recovery in older adults.

**Recruitment:** $n = 40$, healthy, active, independent living

**Pre-assessment**

**Randomization**

**Intervention ($n = 20$)**
- Trip and Slip training

**Control ($n = 20$)**
- Sham training

**Post-assessment**
Results | falls/slips and trip exposures

- **All falls**: $p = 0.005$
- **Slip falls**: $p = 0.029$
- **Trip falls**: $p = 0.090$

Rate of falls

- **Intervention**
- **Control**
Future applications

• Good evidence for trip and slip training for fall prevention

• Definitive trial needed

• Effectiveness in other populations
  • pilot studies in people with PD and people with MS.

• How can this be applied in the community?
## Step training conclusions

<table>
<thead>
<tr>
<th></th>
<th>Balance Training</th>
<th>Voluntary Step Training</th>
<th>Reactive Step Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement type</td>
<td>Volitional</td>
<td>Volitional</td>
<td>Reactive</td>
</tr>
<tr>
<td>Task-specificity</td>
<td>Low - Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Speed of movement</td>
<td>Slow - Moderate</td>
<td>Moderate</td>
<td>Fast</td>
</tr>
<tr>
<td>Stability range of activities</td>
<td>Within limit of stability</td>
<td>Within limit of stability</td>
<td>Outside limit of stability</td>
</tr>
<tr>
<td>Balance threat &amp; learning stimulus</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Minimum dose</td>
<td>High: 3+hours/wk, ongoing</td>
<td>High: 2+hours/wk, ongoing</td>
<td>Low: 1-3 hr sessions in 6mo</td>
</tr>
<tr>
<td>Additional benefits</td>
<td>Likely</td>
<td>Likely</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Evidence for fall prevention</td>
<td>Established (40% reduction)</td>
<td>Preliminary (50% reduction)</td>
<td>Preliminary (50% reduction)</td>
</tr>
</tbody>
</table>
NeuRA

neura.edu.au