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Decline in sensorimotor systems explains reduced falls self-efficacy

Mascha Pauelsen*, Irene Vikman, Viktor Johansson Strandkvist, Agneta Larsson, Ulrik Röijezon

Luleå University of Technology, Department of Health Sciences, Sweden

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ABSTRACT

Physical performance including balance tasks is one of the main factors explaining the variance in falls self-efficacy in older adults. Balance performance is often measured by use of gross assessment scales, which assess the result of integration of all systems involved in postural control. We aimed to investigate which measurements of postural control correlate to falls self-efficacy scores as measured by the FES-I instrument, and which sensory and motor systems best explain them.

A cross sectional study was designed, in which 45 older adults performed quiet stance and limits of stability trials during which their center of pressure (CoP) excursion was recorded. Falls self-efficacy was measured using the Falls Efficacy Scale – International. Eyesight, vestibular function, proprioception, reaction time and strength were also measured. Hierarchical orthogonal projection of latent structures was used to model FES-I with the CoP trials and then with the sensory and muscle function data.

Fes-I could be explained to 39%, with the eyes open trials and the limits of stability trials loading the heaviest. The base model could be explained to 40% using the sensory and muscle function data, with lower limb strength, leg proprioception, neck proprioception, reaction time and eyesight loading the heaviest.

1. Introduction

Human postural control acts in order to maintain orientation and equilibrium, i.e. balance. To create balance, the central nervous system integrates several modalities of sensory information – from visual, vestibular, and somatosensory receptors – and creates coordinated motor actions and reactions [Horak, 2006; Shumway-Cook, 2007]. This sensorimotor integration takes place in relation to the demands brought about by the motor task in progress and the environment in which it takes place.

Reduced falls self-efficacy is a form of fall-related concern and causes a dramatic decline in physical activity [Choi et al., 2017; Deshpande et al., 2008; WHO, 2002]. These concerns can develop before an actual fall ever happens [Davis et al., 2009; Maki, 1997; Yardley and Smith, 2002] and can be seen as both a cause and a consequence of falls [Lavedan et al., 2018]. It has been hypothesised that fall risk and fall-related concern are two separate consequences of decreased postural control [Hadjistavropoulos et al., 2011]. The latter was confirmed in our previous study showing that physical performance including balance tasks is one of the main factors explaining the variance in falls self-efficacy in older adults, as measured by the Falls Efficacy Scale – International (FES-I) [Pauelsen et al., 2017]. When balance performance is measured, this is often done by use of gross assessment scales, such as the Short Physical Performance Battery (SPPB) [Kapan et al., 2017; Pauelsen et al., 2017]. These types of measurements assess the result of integration of all systems involved in balancing. Therefore, they are a less suitable tool when it comes to understanding which parts of postural control most explain the existence of fall-related concerns. An understanding that could lead to more specific preventative interventions.

The use of a force plate offers more precise ways to look at balance, by measuring center of pressure (CoP) excursions during different tasks. One use of CoP is to look at postural sway, defined by Sheldon as “the constant small deviations from the vertical and their subsequent correction to which all human beings are subject when standing upright” [Sheldon, 1963]. Sway during quiet stance has been used to study postural control and balance [Qiu and Xiong, 2015]. Another way to use CoP, is by exploring its maximum amplitude during a limits of stability (LoS) test in which a person is challenged to lean as far away from their center as they can without losing stability or balance. It is a consistent and reliable measure of dynamic balance [Clark and Rose, 2001]. Conditions that have been known to affect balance – like age, or neurological morbidities – correlate with a reduced LoS [Faraldo-Garcia et al., 2016; Schieppati et al., 1994].

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* Corresponding author.
E-mail addresses: mascha.pauelsen@ltu.se (M. Pauelsen), irene.vikman@ltu.se (I. Vikman), viktor.johansson.strandkvist@ltu.se (V. Johansson Strandkvist), Agneta.larsson@ltu.se (A. Larsson), ulrik.roijezon@ltu.se (U. Röijezon).

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Both sway and LoS are a result of the different sensory and motor systems working together to create balance. By combining CoP measurements from different tasks with sensorimotor measurements, an explanatory model for the severity of FES-I might emerge.

This new knowledge about how fall-related concerns correlate to different aspects of postural control, could lead us forward in discovering how to improve health and maintain activity levels as a person ages. We therefore aimed to investigate a) which measurements of postural control correlate to falls self-efficacy scores as measured by the FES-I instrument, and b) which sensory and motor systems best explain them.

2. Methods

We carried out a cross sectional study in our movement science laboratory and analyzed predetermined postural control variables in relation to FES-I scores.

2.1. Sample

As this study is a deeper follow-up of an earlier study [Pauelsen et al., 2017], we recruited participants from within that study's sample. That original sample consisted of 153 participants out of 362 randomly selected older adults. Inclusion criteria for the original sample were: community living residents of *(left out for review)* Municipality aged 70 years or older. For the present study the following additional inclusion criteria were used: adequate vision to read 100 pt. large block letters, able to stand unassisted for 30 s or more, able to understand and process simple instructions. Out of 153 from the original sample, 126 were invited to be a part of this follow up study and 45 (36%) of those accepted.

2.2. Data collection

2.2.1. Falls self-efficacy

FES-I data from the previous study was used [Pauelsen et al., 2017]. Items guide the participant to assess how worried they are about falling while carrying out 17 specific activities at home, outdoors and socially. Assessment is done on a Likert scale of 1 (not worried) to 4 (very worried). The sum score ranges from 16 to 64.

2.2.2. Sensorimotor systems

The laboratory visit consisted of an extensive protocol including the following tests:

Bi-ocular vision acuity was screened with the help of an NFD vision chart. This chart is similar to the Snellen chart, but is used at 5 m instead of 6 and is scored using the decimal system instead of the 20/foot system; a score of 1,0 equals 20/20 (normal vision) and 0,5 equals 20/40 (worse vision). Vestibular function was tested with the help of Frenzel glasses. Both passive and active left to right rotation of the neck at different speeds as well as glancing left, right, up, and down was executed during which the occurrence of nystagmus was noted. To measure joint position sense (JPS) in the neck, the participants wore reflective markers in a room with a 3D camera system consisting of 8 cameras (Qualisys, sweden). While sitting with closed eyes, the participant was asked to find the neutral position in their neck. Then, the tester asked the participant to rotate their head to the left to approximately 45° and then reposition to their earlier marked neutral position. This rotating and repositioning was done 6 times per direction (left and right). The absolute error mean of six trials was used.

We assessed pressure sensibility around the ankles by using monofilaments of different stiffness on the lateral malleoli (increments: 0.4, 2, 4, 10, 300 g of linear pressure). Each monofilament – starting with the lightest – was tested 3 times on each malleolus until the participant felt the touch of the filament. JPS in the knee and foot were assessed with the use of a Biodex System 3 machine. The knee repositioning was done at 30° flexion from 90° and the ankle was repositioned to 5° dorsal flexion from 20° plantar flexion. The absolute error mean of three trials was used.

Maximum isometric strength of muscles in lower limb were also measured with the Biodex System 3, which measured the maximum torque in muscles around the hip joint – extension and abduction, the knee joint – flexion and extension, as well as the ankle – dorsal and plantar flexion. Maximum torque of three trials was used.

Participants performed a custom made reaction time test (RT) on the laboratory computer; at random time intervals, a visual and audio cue was produced at which the participant had to push a button as fast as possible. The average of five attempts was used.

2.2.3. Center of pressure (CoP)

Using a Kistler force plate, sampling at 3000 Hz, we measured CoP during quiet stance during four different trials of 30 s each: stable, or hard, surface with eyes open (SEO), hard surface with eyes closed (SEC), unstable, or soft, surface with eyes open (UEO), and soft surface with eyes closed (UEC). Foot placement was standardized by standing with the first metatarsal heads at a distance equal to 75% of the width between the anterior superior iliac spines. Rotational angle of the foot placement was self-chosen. Instructions were to stand up straight, look at the dot on the wall and stand as still as possible. For the eyes closed trials, we instructed the participants to first look at the dot on the wall and then close their eyes when they felt ready. When the participant closed their eyes, the tester made a mark in the measurement. Each trial lasted 30 s. We also used the force plate to measure the participant's limits of stability (LoS) by asking the participant to lean as far as possible in the anterio-posterior (AP) and medio-lateral (ML) directions without moving their feet, nor lifting toes or heels.

2.3. Calculation of outcome variables

We used MATLAB R2017a (MathWorks®, Massachusetts, USA) to generate the CoP trajectories and apply a lowpass butterworth filter with a cut-off at 10 Hz. Then we extracted several classical measures, which describe the participant's sway: AP and ML maximum amplitude, mean velocity, and 95% confidence ellipse of the total CoP signal. The ellipse is based on a principal component analysis of the CoP data points to establish the angle of the ellipse. Then, the smallest ellipse possible is drawn, still including 95% of all data points of the CoP trajectory. We also extracted the maximum AP and ML amplitude measurements for the LoS test.

2.4. Statistical analysis

To calculate the descriptive statistics, SPSS for Windows 24 (SPSS Inc., Chicago, Illinois, USA) was used. After which we used SIMCA 14.0 (Umetrics AB, Umeå, Sweden) to fit a hierarchical orthogonal projection to latent structures regression (O-PLS). O-PLS is a modification of the more classic – principal component based – partial least squares regression (PLS) and we used it to model explanatory abilities of our postural control measurements for FES-I, because the modelling technique allows for many collinear predictors [Eriksson et al., 1999]. The orthogonal modification made during an O-PLS removes the orthogonal – or non-correlated – information from the variability in X. This improves the interpretability of the model. Moreover, O-PLS can handle noisy data structures [Trygg and Wold, 2002]. In this hierarchical model, the base model shows (a) which measurements of postural control correlate to falls self-efficacy scores as measured by the FES-I instrument, and the top model shows (b) which sensory and motor systems best explain those measurements of postural control. In other words, the top model creates a new O-PLS regression with the sensory and motor variables as repressors to explain the model created in the base model (the loadings of that model become the Y values in the top model). The interpretation should be read as which sensory and motor