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Evaluation of stability of balance recovery from unpredictable perturbations through the compensatory arm and leg movements (CALM) scale

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Abstract

The scale for evaluation of compensatory arm and leg movements (CALM) was developed to evaluate balance stability recovery after unpredictable displacements of the support base in the mediolateral direction. The mediolateral perturbations are applied in three modes: rotation, translation or combined rotation-translation, to either side, in three platform peak velocities: 20º-20 cm/s (low), 30º-30cm/s (intermediate) or 0º-40 cm/s (high), keeping peak acceleration of $500^{o}/s^{2}$(cm/s^{2}) and displacement amplitude of 7^{o} (cm) constant across perturbations. The factors perturbation mode (3), direction (2) and velocity (3) of platform displacement are combined to generate 18 distinct stance perturbations. To create the context of unpredictability, perturbations are pseudorandomly sequenced. To become aware of the stance perturbations, participants watch a video demonstrating a person responding to the different platform perturbations included in the protocol. After video watching, subjects are warmed up for 5 min. with global movements. Initial feet positions are marked on the support base with adhesive tapes (5-cm width). Other adhesive tape marks are fixed 15 cm away from the outer border of the feet to either side, in parallel to the feet orientation. The initial participant's posture on the platform is keeping the Romberg's stance, with the feet oriented forward, touching each other, maintaining both arms relaxed hanging beside the trunk, and palms of the hands lightly touching the upper legs. Participants wear a safety harness supported by two ropes tied at the shoulders height with the other end attached overhead. The participant's aim across perturbations is to recover balance after support base displacements trying to maintain the initial body posture. Participants' responses are filmed from behind using a commercial digital camera (Sony), for off-line analysis based on the CALM scale.

Guidelines

Guidelines for application

The compensatory arm and leg movements (CALM) scale is to be applied for analysis of large reactive responses to unpredictable large-magnitude stance perturbations in the mediolateral direction. Its application should be associated with the instruction to try not to step in response to perturbations, and keeping the feet together (Romberg posture) while waiting for the upcoming perturbation. Arm and leg movements are rated separately. Consider the wider movement between the right and left arms for rating.

Arm movements

Score and **description**

(1) **Near fall (grasping).** Grasping one or both safety ropes.

(2) **Large amplitude.** Raising the elbow(s) above the shoulder height without the purpose of grasping the safety ropes.

(3) **Moderate amplitude.** Wide arm movements (larger than about 10 cm of sideward hand displacement), but raising the elbow(s) below the shoulder height.

(4) **Small amplitude.** Minor contact loss (up to about 10 cm) between the hand(s) and the leg(s).

(5) **Motionless.** Keeping the hands in contact with the legs while recovering body equilibrium.

Leg movements

Score and description

(1) **Near fall (grasping).** Grasping one or both safety ropes (or near support base), regardless of leg movements.

(2) **Multiple steps through large increment of the support base.** Changing the support base for balance recovery through two or more steps, regardless the stepping pattern, with total displacement larger than 15 cm.

(3) **Multiple steps through small increment of the support base.** Changing the support base for balance recovery through two or more steps, regardless the stepping pattern, with total displacement equal to or smaller than 15 cm.

(4) **Single step through large increment of the support base.** Balance recovery through a single step, regardless the stepping pattern, with stepping amplitude larger than 15 cm.

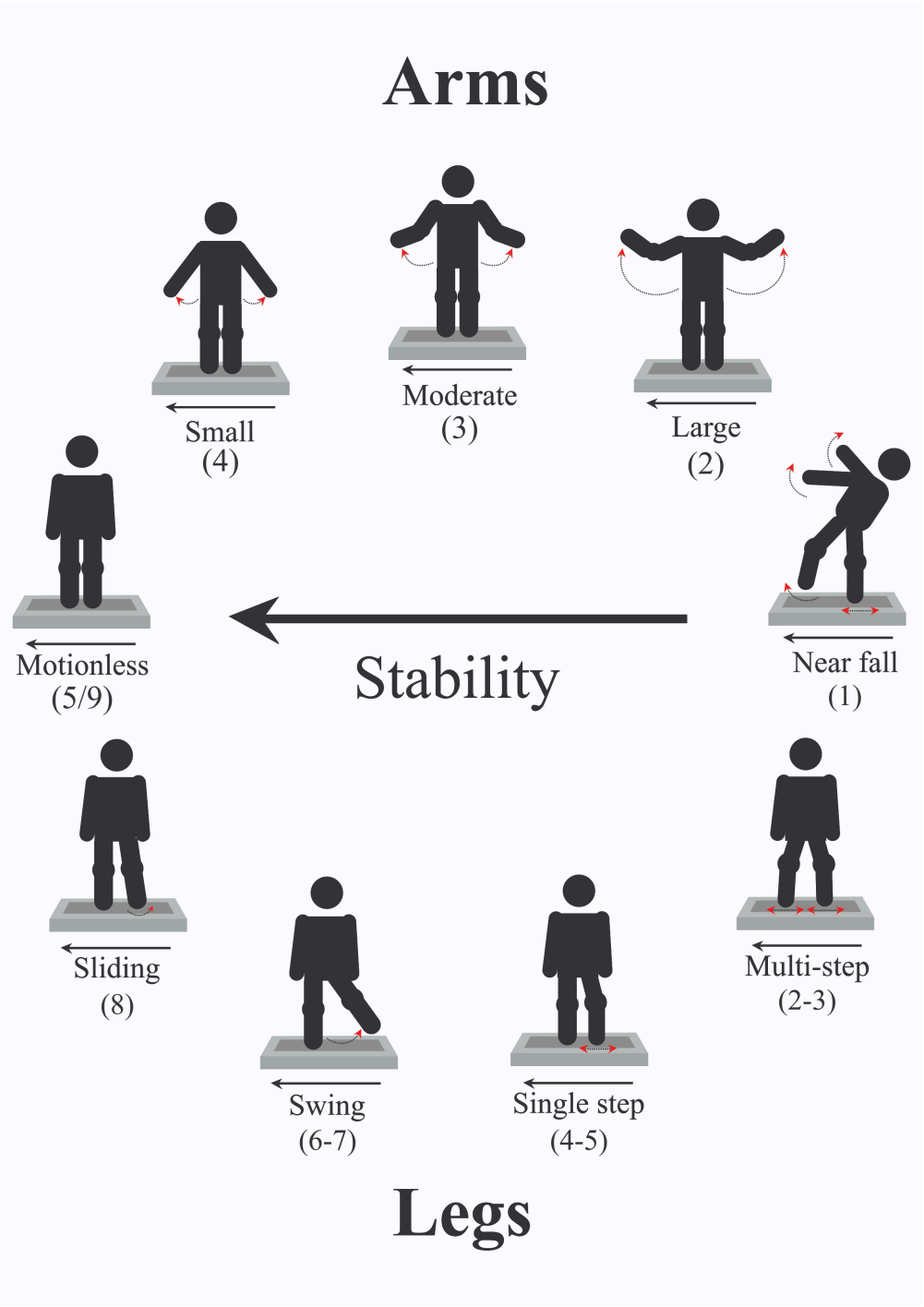
(5) **Single step through small increment of the support base.** Balance recovery through a single step, regardless the stepping pattern, with stepping amplitude equal to or smaller than 15 cm.

(6) **Leg swing with large amplitude**. Swinging one leg outward for counter-weighting lateral body leaning while supporting the whole body on the other leg, with movement amplitude larger than 15 cm.

(7) **Leg swing with small amplitude**. Swinging one leg outward for counter-weighting trunk movements while supporting the whole body on the other leg, with movement amplitude equal to or smaller than 15 cm.

(8) **Sliding.** Short one-foot or two-feet outward sliding over the support base (no feet-ground contact loss), not crossing the 5-cm mark on the platform, or short (few centimeters) one-foot rising.

(9) **Motionless.** Balance recovery keeping the feet in place.


Arms
Small
(4)
Moderate
(3)
Large
(2)
Motionless
(5/9)
Stability
Near fall
(1)
Sliding
(8)
Swing
(6-7)
Single step
(4-5)
Multi-step
(2-3)
Legs

Materials

Perturbations in both training and evaluation are applied automatically by means of a custom-made moveable platform controlled through a custom LabView computer interface (National Instruments).
Participants' responses are filmed using a commercial digital camera, for off-line analysis based on the CALM scale.

Troubleshooting

Safety warnings

To prevent falls, participants wear a safety harness supported by ropes tied at the shoulders height with the other end attached overhead.The safety harness shoud be adjusted so that it would support participants in the case of falls, but not providing any support while they stood on the platform before perturbation or during balance recovery without falls.

Preparation

1

Participants are warmed up for 5 min. with global movements. Given that balance perturbations are vigorous, possibly requiring fast movements of arms and legs, this is an important preparatoty step.

Instructions

2 (a) Firts, participants watch a video of a pearson responding to the balance perturbations to get acquainted with them. (b) Participant are informed that the task aim across perturbations is to recover balance after support base displacements trying to maintain the initial body posture. They are instructed that if they are unable to recover balance stability after a perturbation by keeping the initial posture, arm and leg movements can be used to recover a stable upright stance.
(c) Additionally, they are asked to refrain from grasping the safety ropes unless they are unable to recover balance using other resources, with this response being considered as near fall.

During the evaluation

3 (a) The initial participant's posture on the platform is keeping the Romberg's stance, with the feet oriented forward, touching each other, maintaining both arms relaxed hanging beside the trunk, and palms of the hands lightly touching the upper legs. The reduced ML support base is employed to impose a high challenge to balance recovery.
(b) Balance perturbations are applied while the participant is gazing at a frontal spot positioned at the eyes height.
(c) Perturbation trials are triggered randomly between 2-5 s following a verbal prompt, preventing temporal anticipation of the upcoming perturbation.
(d) To produce a context of perturbation unpredictability, randomized rotation, translation and combined rotation-translation of the support base is applied to either side in variable platform velocities.
(e) The support base is slowly returned to the initial position, before the ensuing balance perturbation.

Sequence of perturbations

4 The pseudo-random sequence of perturbation is the following:

1. Rotation; velocity 20º/s; to the right
2. Translation; velocity 20cm/s; to the right
3. Rotation; velocity 40º/s; to the left

4. Combined (rotation plus translation); velocity 20cm-20°/s; to the left
5. Combined (rotation plus translation); velocity 40cm-40°/s; to the right
6. Translation; velocity 30cm/s; to the right
7. Translation; velocity 40cm/s; to the left
8. Rotation; velocity 30°/s; to the right
9. Combined (rotation plus translation); velocity 30cm-30°/s; to the left
10. Rotation; velocity 20°/s; to the left
11. Translation; velocity 20cm/s; to the left
12. Rotation; velocity 40°/s; to the right
13. Combined (rotation plus translation); velocity 20cm-20°/s; to the right
14. Combined (rotation plus translation); velocity 40cm-40°/s; to the left
15. Translation; velocity 30cm/s; to the left
16. Translation; velocity 40cm/s; to the right
17. Rotation; velocity 30°/s; to the left

Combined (rotation plus translation); velocity 30cm-30°/s; to the right