Appendix A: Operation of EquiTest Device

The EquiTest device has been available commercially since 1986. This device performs a battery of tests: Sensory Organization Test, Motor Control Test, and Adaptation Test. It consists of a movable dual platform capable of anterior-posterior translation and rotation about the ankle joints in the sagittal plane. The dual platform is surrounded by a visual scene that can also rotate about the ankle joints. The EquiTest device quantifies the ground reaction force (the force exerted by the platform to each of the feet) using five force transducers. The two force plates are connected by a pin joint and supported by four force transducers mounted symmetrically on a supporting plate. These four transducers measure forces perpendicular to the force plate. A fifth transducer is mounted to the supporting plate directly beneath the pin joint for measuring shear force. The force transducers are sampled at 100 Hz. The sampled data are recorded as integer quantization levels in the following form (data from one of our subjects):

Table.
Number of Data Sample: 2000

DP	LF	RR	SH	LR	RF
1	319	108	0	110	314
2	319	106	0	110	314
3	318	106	0	110	314
… …					
1998	196	256	68	246	151
1999	197	256	68	247	151
2000	197	258	68	247	151

where DP means data point, LF and RF represent quantization levels from transducers mounted at left and right front, LR and RR represent quantization levels from transducers mounted at left and right rear, and SH represents the quantization level from the transducer at the pin that measures shear force. The resolution of the transducers is about 0.87 N between quantization levels. F_F and F_R in **Figure 2** of main paper are, respectively, the force values converted from LF + RF and LR + RR. F_H is the force value converted from SH. The device determines the center of pressure (COP) in the sagittal plane from the formula

$$\mathrm{COP} = \frac{(\mathrm{LF} + \mathrm{RF}) - (\mathrm{LR} + \mathrm{RR})}{\mathrm{LF} + \mathrm{RF} + \mathrm{LR} + \mathrm{RR}} \times 4.20 \quad \text{(inches)} \quad \text{.(A1)}$$

The center of mass (COM) at any particular moment is estimated with a one-sided moving average filter as

$$\mathrm{COM}(i) = \frac{1}{M}\sum_{j=1}^{M}\mathrm{COP}(i-j) \text{ .(A2)}$$

In this equation, i is the index of the COM data series, $\mathrm{COP}(i-j)$ $(j = 1, \cdots, M)$ are the COP values obtained with equation (A1) from the past M measurements of the transducers and M = 14 is the number of points used in the moving average.

The device then computes sway angle as

$$\theta = \arcsin\left(\frac{\mathrm{COM}}{0.5527 * H}\right) - 2.3^\circ \text{ ,(A3)}$$

where H is the height of the subject and 2.3° is the so called "forward lean" of the angle of the COM.

The sensory organization test (SOT) comprises six test conditions used to assess the vestibular, proprioceptive and visual aspects of balance. Participants stand on a computer-controlled platform within and facing a semicircular visual surround. For sway-referenced conditions, the movement of the surround or platform is referenced to the individual's sway. For example, in the sway-referenced surround condition, if the person sways forward, the surround also sways forward, reducing the degree to which the individual can use visual cues to perceive if he or she is no longer vertical. Participants are asked to stand quietly and steadily for three trials each of the following six conditions: (1) eyes open, surround and platform stable; (2) eyes closed, surround and platform stable; (3) eyes open, sway-referenced surround; (4) eyes open, sway-referenced platform; (5) eyes closed, sway-referenced platform; and (6) eyes open, sway-referenced surround and platform. An actuator controls the rotation of the base that supports the force transducers and the force plates. This rotation is proportional to the sway angle θ. An operator can set the proportional constant k, which is referred to as "gain," in the range of –1.0 ~ 2.0. The value of k is 0 when the platform is fixed.

The SOT equilibrium score (ES) is the angular difference between the calculated maximum anteroposterior displacement of the center of gravity and the subject's theoretical maximum sway of 12.5° expressed as a percentage for each trial. Equilibrium scores closer to 100 indicate better balance and those closer to zero worse. A fall counts as a zero for the trial.

$$\mathrm{ES} = \left(1 - \frac{\theta_{\max} - \theta_{\min}}{12.5^\circ}\right) \cdot 100\% \text{ (A4)}$$

The overall SOT equilibrium score is calculated by first averaging the three scores for each of conditions 1 and 2 and then adding these two averaged scores to the scores for each trial of Conditions 3 to 6 and dividing the total by 14. This weights the more difficult conditions (Conditions 3–6) more than the easy conditions (1 and 2) in the overall score.

The SOT Strategy Score (SS) is based on the peak-to-peak of the measured horizontal (shear) force normalized to a maximum of 25 pounds shown as

$$SS = \left(1 - \frac{sh_{max} - sh_{min}}{25}\right) \cdot 100\% \text{ .(A5)}$$

In this equation, sh is the shear force in pound converted from the measured SH. The Strategy Score is used to indicate the involvement of hip-sway in maintaining balance.