Development of an Integrated Sensorimotor Countermeasure Suite for Spaceflight Operations

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Introduction: Astronauts experience postflight disturbances in postural and locomotor control due to sensorimotor adaptation to the unique environment of spaceflight. These alterations might have adverse consequences if a rapid egress were required following a Mars landing or on return to Earth after a water landing. Currently, no operational countermeasure is targeted to mitigate postflight balance and locomotor dysfunction.

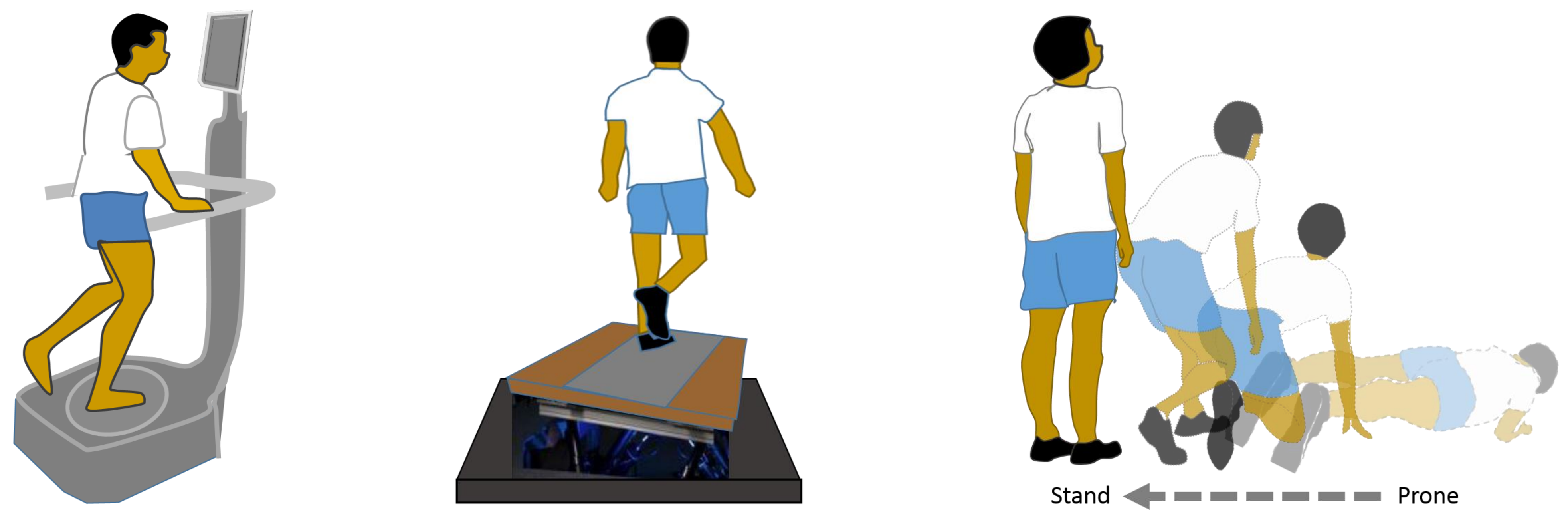
Goal : Develop and test a sensorimotor countermeasure suite comprised of preflight and inflight training designed to reduce post-landing balance and locomotor dysfunction.

Countermeasure Development

Aim 1: The countermeasure suite will be comprised of two integrated countermeasure approaches: 1) preflight sensorimotor adaptability training and 2) inflight posture training. We will use a phased-in approach in terms of countermeasure implementation. The preflight sensorimotor discordance training will be phased-in first on an initial set of subjects. The second group of subjects will be trained with both the preflight sensorimotor adaptability training and the inflight posture training. We will then be able to compare the efficacy of the sensorimotor adaptability training alone with that of a combined training protocol that includes both preflight adaptability training and the inflight posture training.

Phase 1

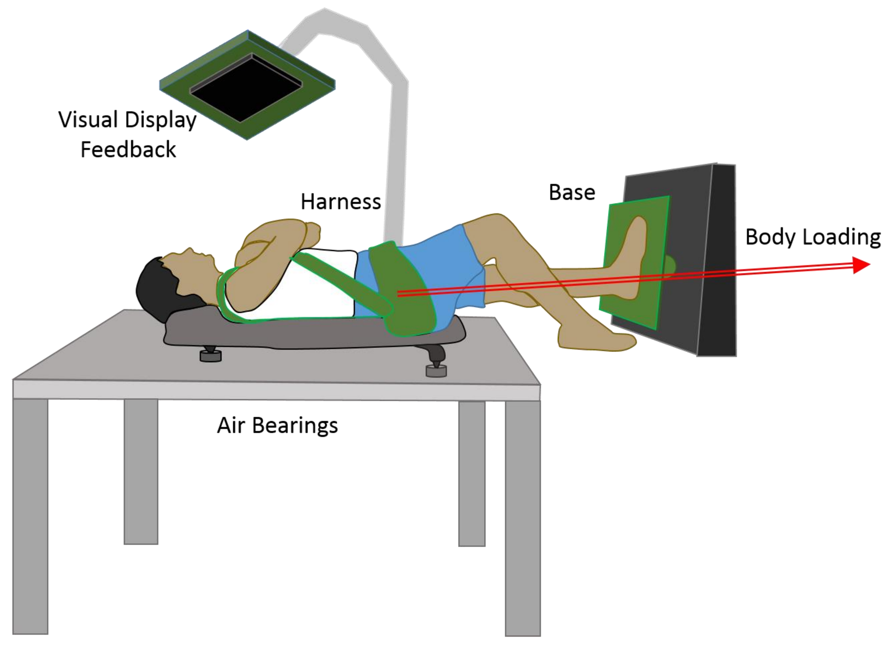
Preflight Sensorimotor Adaptability Training



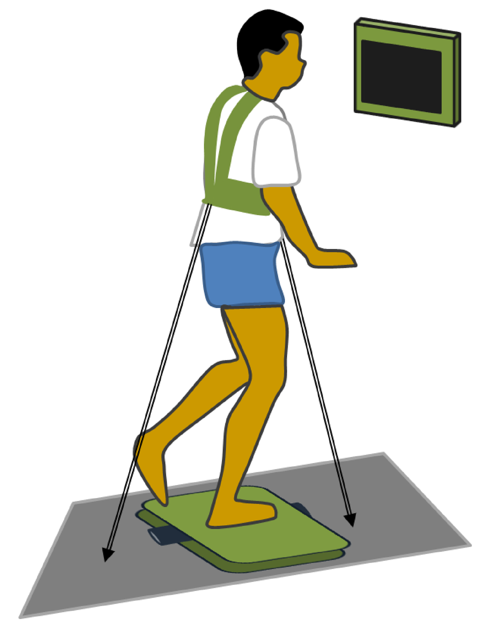
Preflight sensorimotor adaptability training is designed to improve one's general ability to adapt while experiencing challenging and conflicting novel sensory information, thus facilitating the dynamic re-weighting of multimodal sensory input. Subjects are trained by performing various posture and locomotion tasks while being exposed to different combinations of support surface movement, visual scene motion and vestibular disruption that challenges them to improve their ability to adapt to conflicting novel sensory information (Bloomberg et al., 2015).

Phase 2

Gravity Bed



Inflight Posture Training



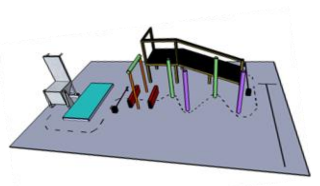
The gravity bed (Oddsson et. al., 2007) will serve as a 0g analog to develop and test Inflight Posture Training system for ISS. The inflight posture training component will serve to keep sensory integration pathways tuned to respond to upright balance challenges and coordinate the multiple degrees of freedom responsible for the maintenance of balance control. For the inflight posture training system subjects will be loaded axially toward their feet up to the equivalent of one full body weight in body-support loading and will be required to adjust their body orientation relative to a moveable platform under their feet.

Countermeasure Evaluation

Aim 2: Test the efficacy of the countermeasure suite to reduce post landing postural and locomotor dysfunction. To save on flight resources, the control data for this study will consist of results from astronauts who previously participated in the Functional Task Test (FTT) and Field Test (FT) experiments prior to the implementation of our countermeasure suite. We will use a sub-set of tests from the FTT and FT studies that showed the greatest changes in functional performance due to balance and locomotor alterations.

Functional Tests

Sit to Stand: Once given a command, subjects stand as quickly as possible and stand relaxed for 10 seconds.



Seat Egress and Walk: Subjects unbuckle a harness and complete an obstacle course starting from both an upright seated position and with the seat positioned with its back to the floor.

Recovery from Fall/Stand: Subjects lie face down on a foam surface for 10 seconds and then stand up as quickly as possible onto a force plate and remain standing for 3 minutes.

Object Translation: Subjects transfer three weights with handles (2.7 kg, 4.5 kg, 9 kg), individually, a distance of 2.4m and place them in a receptacle and then transfer the weights back to the initial receptacle.

Jump Down: Subjects jump down from a platform (30 cm height) onto a force plate to measure postural stability.

Balance Tests

Dynamic Posturography Test: Subjects maintain upright stance for several 20-second trials with eyes closed while standing on a sway-referenced base of support (with and without ± 20° head movements in the pitch plane).

Tandem Walk Test: Subjects attempt to walk 10 steps with the arms folded across the chest, while placing the feet in a tandem heel-to-toe position for each step. This is repeated three times with eyes closed and one time with eyes open for a total of 40 steps.

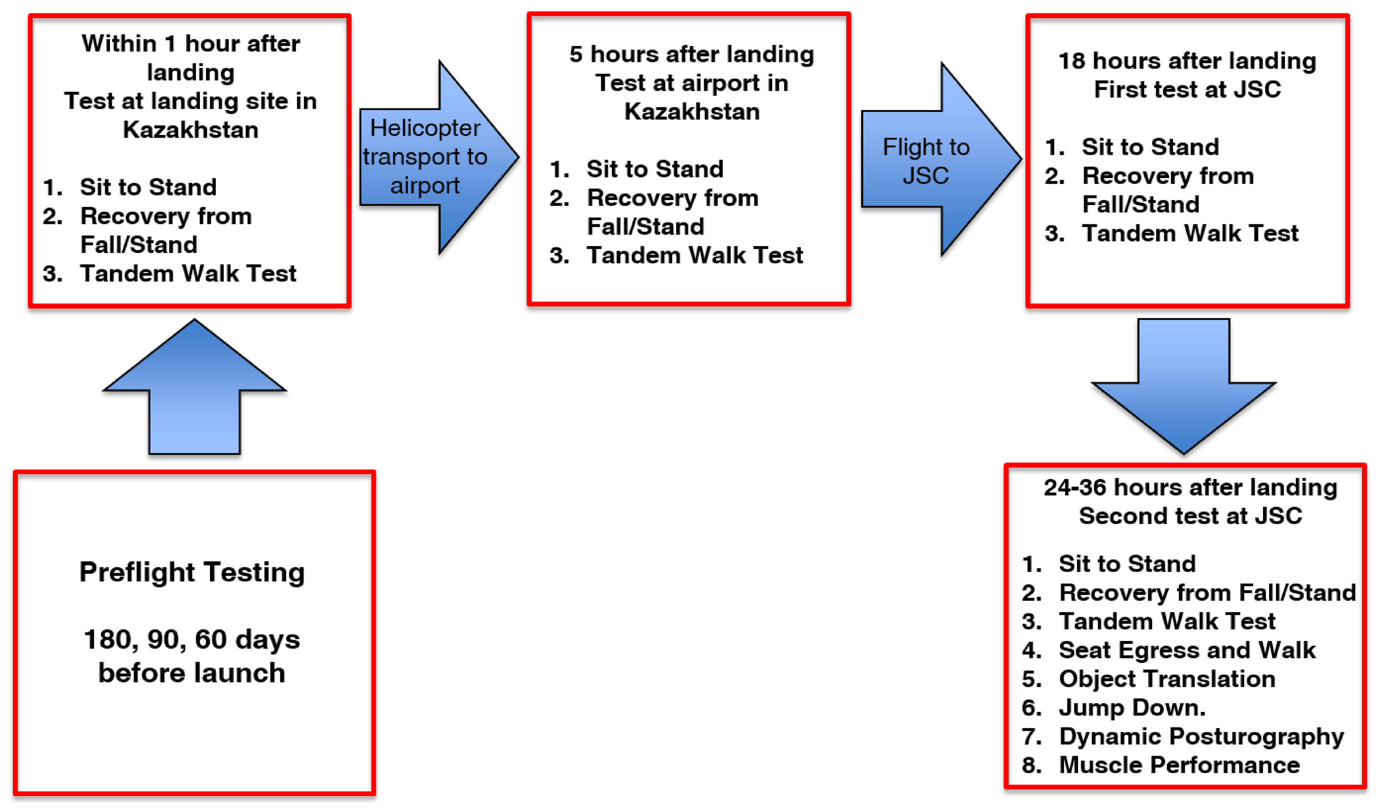
Muscle Performance Tests

Maximum Isometric Force: Subjects in leg press system push against a fixed force plate.

Power/Endurance: Subjects push a weight away as fast as possible (40% max force, 21 repetitions).

The primary purpose of these tests is to determine the contribution of muscle performance changes to alterations in functional and balance test outcomes.

Testing Schedule



References

Bloomberg JJ, Peters BT, Cohen HS and Mulavara AP. Enhancing astronaut performance using sensorimotor adaptability training. Front. Syst. Neurosci. 9:129.doi: 10.3389/fnsys.2015.00129. 2015.

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