FUNCTIONAL TASK TESTS IN PARTIAL GRAVITY DURING PARABOLIC FLIGHT

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BACKGROUND

Understanding how critical mission tasks are performed in partial gravity such as on the moon or Mars is necessary to define effective and comprehensive countermeasure strategies for preserving crew performance during exploration missions. We studied the performance of tasks such as standing, walking, and jumping during the partial gravity phases of parabolic flight. We hypothesized that the acute effects of partial gravity on vestibular, proprioceptive, and sensorimotor functions would negatively impact performance.

METHODS

Twelve subjects were tested over three flights of 30 parabolas each, including 10 parabolas at 0.25g, 10 parabolas at 0.5g, and 10 parabolas at 0.75g. Subjects also performed tests in 1g between parabolas. During the sit-to-stand with obstacle walk task, subjects rose from a seated position and walked as quickly as possible straight ahead towards a cone (4 m distance), walked around the cone making a 180° left turn, returned, and sat in the chair. On the way to and from the cone, subjects stepped over a 30 cm high obstacle. For the recovery from fall task, subjects lay prone for the pull-up phase and initial 10 sec of the parabola. Then they were asked to rise as quickly as possible and maintain a quiet stance for 10 sec. The tandem rail balance task involved standing with both feet on a 4.5 cm wide rail. The time ended when subjects either stepped off the rail or grabbed on to support straps. The jump down task started with the subjects standing on a 30 cm high platform, then the subjects were instructed to step off the platform, land with both feet simultaneously, and settle in a quiet stance. The cone of stability task involved subjects leaning about the ankles as far as they could in the anterior, posterior, and lateral directions without unfolding their arms or taking a step. The center of pressure distance between endpoints was calculated. Data were collected using inertial measurement units (Opal V2, APDM, Portland, OR) worn on the head and trunk, heart rate monitors (RS800CX, Polar, Kempele, Finland), and a force plate (Bertec, Columbus, OH).

RESULTS

Gravity level had a significant effect on performance, with the greatest changes from 1g tending to be at the 0.25g level (Table 1). Lower gravity levels were associated with increased times to complete the sit-to-stand obstacle walk task and the recovery from fall task, decreased change in heart rate during the recovery from fall task, decreased rail balance times, and increased cone of stability distance in the anterior-posterior direction.

Table 1. Functional task performance at different gravity levels during parabolic flight.

Measure	0.25g	0.5g	0.75g	1g	p-value
Sit-to-stand with obstacle walk time (sec)	9.8 ± 1.4*	7.2 ± 0.7	6.9 ± 0.8*	7.4 ± 0.9	<0.001
Recovery from fall time to settle (sec)	5.3 ± 0.9*	4.6 ± 0.8	4.2 ± 0.6	4.3 ± 0.7	0.002
Recovery from fall change in heart rate (bpm)	6.0 ± 7.3*	11.2 ± 6.5*	14.9 ± 4.9	15.9 ± 6.5	<0.001
Rail balance with eyes open time (sec)	2.7 ± 0.8*	4.8 ± 2.1	6.6 ± 4.7	8.4 ± 6.7	0.031
Rail balance with eyes closed time (sec)	1.6 ± 0.4*	2.1 ± 0.4	2.4 ± 0.6	2.6 ± 0.8	<0.001
Jump down time to settle (sec)	2.1 ± 0.4	1.9 ± 0.4	2.0 ± 0.3	1.8 ± 0.3	0.328
Cone of stability – anterior-posterior (cm)	20.8 ± 2.7*	18.8 ± 2.2	18.6 ± 1.7	17.9 ± 2.0	0.039
Cone of stability – lateral (cm)	26.8 ± 6.6	24.4 ± 2.1	23.0 ± 2.1	23.8 ± 2.3	0.215

p-value: one-way repeated measures analysis of variance; *Significant pairwise difference from 1g ($p<0.05$).

DISCUSSION

These data suggest that there is a dose-response relationship between gravity level and functional task performance. The largest changes in performance were expected at the lowest gravity level (0.25g) because subjects would no longer be able to use the gravitational reference for the perception of upright. Understanding the extent of performance deficits informs the risks and design of countermeasures for exploration spaceflight missions.

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