



Acute exposure to microgravity does not influence the H-reflex with or without whole body vibration and does not cause vibration-specific changes in muscular activity

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ABSTRACT

Purpose: Many potential countermeasures for muscle and bone loss caused by exposure to microgravity require an uncompromised stretch reflex system. This is especially true for whole body vibration (WBV), as the main source of the neuromuscular activity during WBV has been attributed to stretch reflexes. A priori, it cannot be assumed that reflexes and Ia afferent transmission in particular have the same characteristics in microgravity as in normal gravity (NG). Therefore, the purpose of the study was to compare Ia afferent transmission in microgravity and NG and to assess how microgravity affects muscle activity during WBV.

Methods: In 14 participants, electromyographic activity of four leg muscles as well as Hoffmann-reflexes were recorded during NG and microgravity induced by parabolic flights.

Results: The size of the Hoffmann-reflex was reduced during WBV, but did not differ during acute exposure to microgravity compared to NG. The influence of the gravity conditions on the electromyographic activity did not change depending on the vibration condition.

Conclusions: As far as the electromyographic activity of the recorded leg muscles is concerned, the effect of WBV is the same in microgravity as in NG. Moreover, Ia afferent transmission does not seem to be affected by acute exposure to microgravity when subjects are loaded with body weight and postural sway is minimized.

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1. Introduction

Muscle and bone loss are a major concern of manned spaceflight: it is estimated that astronauts lose 1–2% bone mass per month (Ohshima, 2010) and about 10% of muscle cross-sectional area after only 17 days of spaceflight (Adams et al., 2003; Tesch et al., 2005). Furthermore, the decrease in muscle and bone strength is normally higher than the loss of muscle and bone mass suggests: for instance, when taking into account changes in bone geometry, the decrease in bone strength may be twice as high as measurements of bone density or bone mineral content indicate (Keyak et al., 2009). Similarly, parameters related to muscle strength (e.g. maximal voluntary contraction or peak power) declined more after space flight than parameters related to muscle mass, e.g. cross-sectional area (Koryak, 2001; Fitts et al., 2010).

Ever since these problems became apparent, physical exercise has been used as a countermeasure for the degrading effects of microgravity. However, the training devices used for this purpose (treadmill, bicycle ergometer, resistance exercise devices iRED and aRED) were not able to prevent decreases of muscle and bone strength: recent studies showed that the cross-sectional area of soleus and gastrocnemius muscle fibers were reduced by up to 20% after 6 month on board the international space station (ISS), which entailed a reduction in maximal velocity and peak power of up to 55% (Fitts et al., 2010). The authors of a recent study examining the bone mineral density after 6 month of spaceflight also concluded that the exercises currently employed on board the ISS do not provide stimuli that are high enough to prevent bone loss (Cavanagh et al., 2010).

Two types of exercise that provide high stimuli for muscle and bone are reactive jumps (Ebben et al., 2010; Kramer et al., 2012) and whole body vibration (WBV). WBV was found to be effective for improving bone mineral content and density in subjects with Osteopenia (Lam et al., 2012), increase bone mineral density in postmenopausal women (von Stengel et al., 2011) and the elderly

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(Sitjà-Rabert et al., 2012), while also improving strength, power and balance (Petit et al., 2010; Sitjà-Rabert et al., 2012). Both types of exercise (WBV and reactive jumps) rely on Ia afferent input: reactive jumps require a high leg stiffness, which is thought to be greatly enhanced by the contribution of Ia afferent input (Gollhofer et al., 1992; Komi and Gollhofer, 1997), and the main source of the neuromuscular activity during WBV has been attributed to stretch reflexes (Cochrane et al., 2009; Ritzmann et al., 2010). Consequently, it has to be verified whether the stretch reflex system and the Ia afferent transmission in particular are altered in a microgravity environment before reactive jumps, WBV or any other exercise type relying on Ia afferent input can be considered as countermeasure for muscle and bone loss during space missions. However, results regarding the modulation of Ia afferent transmission due to microgravity are scarce and not very reliable due to the very small sample sizes of three (Miyoshi et al., 2003) or four (Nomura et al., 2001; Sato et al., 2001) subjects.

Therefore, the purpose of the study was to investigate (a) if acute exposure to microgravity changes the Ia afferent transmission, both during WBV and without WBV, and (b) if the – predominantly Ia afferent driven – leg muscle activity during WBV would differ between microgravity and normal gravity conditions. Based on preliminary studies examining the Hoffmann-reflex and the stretch reflex during previous parabolic flight campaigns, we hypothesized that Ia afferent transmission would not be affected by microgravity and that there would be no interaction effect between vibration and gravity level.

2. Methods

2.1. Subjects

Fourteen subjects (seven female, seven male) volunteered to participate in this study. All participants gave written informed consent to the experimental procedure, which was in accordance with the latest revision of the Declaration of Helsinki and approved by the ethics committee of the University of Freiburg and the French authorities responsible for the protection of persons participating in biomedical research (DEMEB of the AFSSAPS). The participants were healthy with no previous neurological irregularities or injuries of the lower extremity. Their mean ($\pm$ standard deviation) age, height and body mass were 28 ± 5 years, 175 ± 8 cm and 71 ± 12 kg, respectively.

2.2. Parabolic flights

The aircraft was a modified Airbus A300 Zero-G, operated by Novespace on behalf of the German Space Agency (DLR) during the 14th and 15th DLR parabolic flight campaigns. No participant except for one had previously participated in a parabolic flight campaign. All participants were given an injection of 0.7 ml of Scopamine 30 min before takeoff to prevent motion sickness. A typical flight lasted 3 h and comprised 31 parabolas. For the present study, data from a total of 175 parabolas were analyzed (10–15 per participant). The course of one parabola is illustrated in Fig. 1: after a countdown, the level normal-gravity (NG) flight changed to a climb flight which lasted 20 s and imposed a gravity level of 1.8 g (hypergravity, HG). The MG phase (22 s) was followed by a second HG phase, induced by the aircraft's descent and return to its normal flight level. The NG phase between two parabolas lasted between 1 and 8 min and was used for auxiliary procedures and to switch subjects.

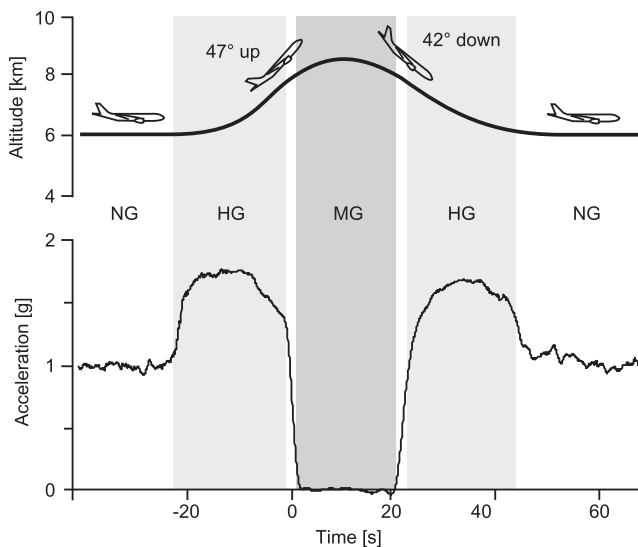


Fig. 1. Illustration of one parabola and the corresponding acceleration signal: after a countdown, the level flight (normal gravity, NG) becomes a steep climb flight, inducing approximately 20 s of hypergravity (HG), followed by approximately 22 s of microgravity (MG) and another HG phase before returning to a level NG flight again.

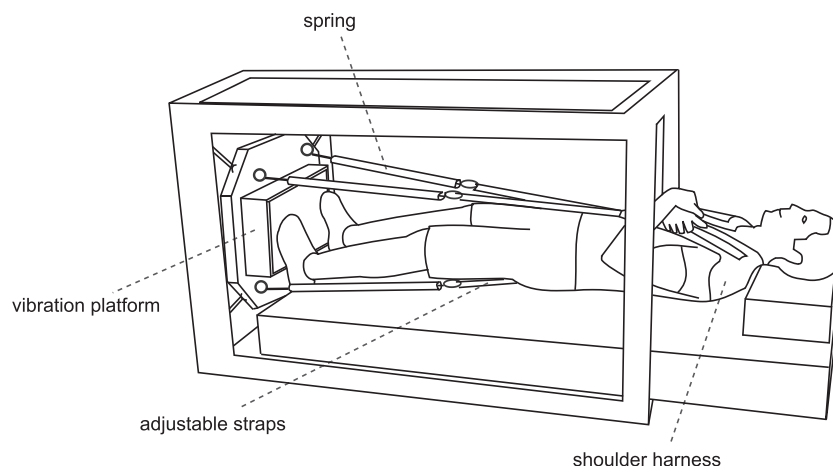


Fig. 2. The experimental setup: the subject is pulled towards the vibration platform by four springs via four adjustable straps. The straps are adjusted in a way that the springs exert a force that matches the subject's body weight. The subjects were instructed to assume a forefoot position with knees slightly bent (knee angle of 150°).

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