Available online at www.sciencedirect.com
ScienceDirect
PERGAMON
Acta Astronautica 60 (2007) 728–736
ACTA ASTRONAUTICA
www.elsevier.com/locate/actaastro

Effect of unloading on muscle volume with and without resistance training

Hiroshi Akima[a,*], Jun-ichi Ushiyama[b], Junjiro Kubo[c], Hideoki Fukuoka[d], Hiroaki Kanehisa[e], Tetsuo Fukunaga[f]

[a] *Research Center of Health, Physical Fitness and Sports, Nagoya University, 1 Furo, Chikusa, Nagoya, Aichi 464-8601, Japan*
[b] *Institute of Physical Education, Keio University, Hiyoshi 4-1-1, Kohoku, Yokohama, Kanagawa 223-8521, Japan*
[c] *Japan Institute of Sports Sciences, 3-15-1 Nishigaoka, Kita, Tokyo 115-0056, Japan*
[d] *Department of Maternal and Child Health, Faculty of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan*
[e] *Department of Life Science, Graduate School of Arts and Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro, Tokyo 153-8902, Japan*
[f] *Department of Sports Sciences, Waseda University, 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan*

Received 31 August 2005; received in revised form 19 July 2006; accepted 25 October 2006
Available online 15 December 2006

Abstract

The present study aimed to investigate the effect of resistance training on the volume of four muscle groups and/or 17 individual muscles of the human lower limb during 20 days of 6° head-down tilt bed rest. Twelve healthy men were divided into two groups: the resistance training group: BR-Tr ($n = 6$) and the control group: BR-Cont ($n = 6$). The volumes of the knee extensor, knee flexor, adductor, plantar flexor, and dorsiflexor muscle groups and their individual muscles were calculated. After the bed rest, the BR-Tr subjects showed no significant change in the volume in almost all tested muscles; in contrast, the volumes of the four muscle groups significantly decreased in the BR-Cont group (−12% to −8%). These results suggest that resistance training during bed rest can prevent the deteriorating of thigh muscles and calf muscles.

Keywords: Microgravity; Muscle volume; Unloading; Human

1. Introduction

Since the end of the 2000, astronauts from the United States and Russia have carried out a long stay in the International Space Station. It is well known that atrophy of the lower limbs occurs by exposure to unloading environment, such as short-duration spaceflight [1–4] and simulated models for spaceflight like bed rest [1,5–9] and unilateral lower limb suspension (ULLS) [10,11]. Unfortunately, no well-established physical training regimen for the prevention of muscle atrophy as a result of spaceflight or bed rest conditions has been determined yet.

Although it is generally accepted that resistance training is the most effective means of gaining strength and mass of skeletal muscles [12,13], limited data have been generated regarding changes in the volumes of muscle groups and their individual muscles in the lower limb as a result of resistance training during unloading. Previous attempts have been made to show the effect

* Corresponding author. Tel.: +81 52 789 3954; fax: +81 52 789 3957.
E-mail address: akima@nagoya-u.jp (H. Akima).

0094-5765/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.actaastro.2006.10.006

of resistance training on strength and/or morphological properties in skeletal muscles during bed rest [6,14–17]. For example, Germain et al. [16] and Bamman et al. [15] reported that muscle strength in the lower limbs could be maintained as a result of resistance training during 6° head-down tilt bed rest. Bamman et al. [14] demonstrated in eight volunteers that resistance training during bed rest reduced fiber area in the vastus lateralis muscles. Most of the previous studies including these reports were focused on a small muscle region of interest using biopsy technique and/or limited muscle groups such as the knee extensors (KE) and plantar flexors (PF); thus, no reports, as far as we know, have demonstrated that a resistance training regimen during unloading changes of the volumes of muscle groups and their individual muscles.

In this study, we tested the hypothesis that dynamic leg press training plus plantar flexion training during 20 days of bed rest may maintain the volume in the thigh and calf muscles, including the KE, knee flexor (KF), adductor (AD), PF and dorsiflexor muscle groups. This idea arose from the results of previous studies [5,6,15]. First, from these studies, we confirmed that dynamic leg press resistance training during 20 days of bed rest was effective preventing atrophy in the thigh muscles, i.e. the KE and KF muscle groups; however, no training effect was found in the PF muscle group [5]. Second, Bamman et al. [15] showed that plantar flexion resistance training is useful maintaining the muscle strength of the PF muscle group. From these studies, dynamic leg press plus plantar flexion resistance training during bed rest may be effective for the thigh and lower leg muscles. Therefore, the purposes of the present study are: (1) to determine the effect of dynamic leg press plus plantar flexion resistance training on the lower limb muscle groups and their individual muscles, (2) to determine the effect of unloading on atrophy of the thigh and lower leg muscle groups and their individual muscles based on magnetic resonance imaging (MRI). There are some limitations for calculation of muscle volume using MRI, e.g. effects of fluid shift and intramuscular fat and/or connective tissue. However, this methodology is the gold standard for measurement of muscle volume in human subjects [1,3,5,6,18], thus we used MRI in this study.

2. Materials and methods

2.1. Subjects

Twelve healthy men participated in this study after giving their informed consent to the experimental protocol, which had been approved by the ethical committee of the Faculty of Medicine, The University of Tokyo. These subjects were assigned to two groups, i.e. resistance training (BR-Tr: $n = 6$) and non-training during bed rest (BR-Cont: $n = 6$). The physical characteristics of the subjects were shown in Table 1.

Table 1
Physical characteristics of the subjects

	Pre	Post
BR-Tr		
Age (yr)	23.3 ± 4.9	–
Height (cm)	169.8 ± 6.4	170.0 ± 6.2
Weight (kg)	65.5 ± 17.1	65.0 ± 16.4
BR-Cont		
Age (yr)	22.7 ± 2.9	–
Height (cm)	169.6 ± 7.8	169.7 ± 7.9
Weight (kg)	67.3 ± 13.6	66.7 ± 13.2

Values are means and SD.

2.2. Bed rest procedure

Bed rest procedures used in this study have been already reported elsewhere [5,6,19,20]. Briefly, subjects remained in a 6° head-down tilt bed rest at all times throughout the bed rest period except for resistance training for BR-Tr, and did not permit any weight-bearing posture and any physical activities were restricted to a minimum for BR-Cont. During 20 days of bed rest, they used a movable bed when they transfer. The room temperature of the wards did not surpass 25 °C. All tests were conducted at least within 3 days after reambulation. This bed rest project was conducted from August to September in 2000, therefore all data in this study was not duplicate our previously studies [5,6].

2.3. Resistance training

Using a horizontal leg press training device (VR-4100, Cybex Corp., USA), both bilateral dynamic leg press resistance and plantar flexion exercises were performed 16 of the 20 days of the bed rest period. Resistance training consisted of one morning session (leg press training) and one afternoon session (plantar flexion training) per day. In the morning leg press training session, subjects performed five sets of 10 repetitions with a load corresponding to 70% of maximal isometric force (MIF) with a 1-min rest between sets with a horizontal posture. The angle of the hip, knee, and ankle joints were, respectively, positioned to approximately 110°, 90°, and 80° at the start of each action. During