Balance and Gait Analysis after 30 Days −6° Bed Rest: Influence of Lower-Body Negative-Pressure Sessions

PHILIPPE DUPUI, M.D., RICHARD MONTOYA, PH.D.,
MARIE-CLAUDE COSTES-SALON, M.D., ALEXANDRA
SÉVERAC, PH.D., and ANTONIO GÜELL, M.D.

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Five volunteers took part in −6° head-down bed-rest experiments for 30 d. In the first experiment, three subjects underwent several sessions of lower-body negative-pressure (LBNP) per day, with two others serving as controls. In the second, the LBNP group of the first experiment became the control and vice versa. Two experimental protocols analyzed the bed-rest-induced modifications of balance and gait and the efficiency of LBNP in counteracting these modifications. A kymographic method allowed the measurement of walking parameters. Anteroposterior and lateral sways were successively studied with both a force platform (static condition) and a rocking platform (dynamic condition). The tests were performed 2 d before the bed-rest period, and over the 1st, 3rd and 4th days of the recovery period. When the subjects were controls, bed rest decreased step length, walking velocity, and balance stability. LBNP completely counteracted the bed-rest-induced modifications of gait and static balance and of dynamic balance for the lateral sway. As LBNP was ineffective in counteracting the modifications of the anteroposterior sway, dynamic balance deficiency was independent of the beneficial effect of LBNP on the decreased orthostatic tolerance induced by −6° head-down bed rest. The results indicate that head-down bed rest, like spaceflight, induces certain sensorimotor changes involved in the decrease of gait and balance performance.

When people are exposed to microgravity, the sensorimotor programs which have evolved on Earth are not appropriate for spatial orientation and motion. Microgravity induces recalibration of the sensorimotor systems (23,24,29,30). The adaptive state developed during spaceflights is equally inappropriate for a one-g environment and leads to maladjusted perceptual and sensorimotor reactions during entry and landing (1), and subsequent postural and gait alterations (1,4,5,15,23,24,29,30).

During spaceflight or immediately after the landing, the effects of microgravity on static and dynamic posture have been examined by several authors with different methods; i.e., performance on balance rails (23,24,29,30) and electromyographic activity from the major antigravity and weight-bearing muscles of the lower limbs (1,4,5,16,23,24,28). It has been shown that microgravity 1) reduces the necessity for postural reflexes in major leg muscles (24); 2) induces a reinterpretation of the otolithic input (23); 3) reduces static and dynamic postural input from the proprioceptive system (29); and 4) reduces tonus in extensor muscles (4,5). These modifications of sensorimotor control induce postflight postural instability that persists for several days (1,16,17,24). However, a quantitative study has never been conducted on spatial and temporal gait characteristics in returning spaceflight crewmembers.

The methodological difficulties of studying equilibrium and gait during or after spaceflights have led some authors to analyze their modifications during or after simulation of microgravity. Two studies of dynamic balance modifications (6,18) and one of gait modifications (6) have been realized using anti-orthostatic (−6°) bed rest as simulation of microgravity. This technique is the most widely used analog for microgravity because it reproduces many physiological changes that are very similar to those observed in space; e.g., redistribution of body fluids and body mass, muscle atrophy and bone demineralization (21).

Two long-duration (30 d) head-down (−6°) bed-rest experiments to simulate microgravity were organized to assess efficiency of periodical lower-body negative-pressure (LBNP) sessions on the cardiovascular adap-

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From the Laboratoire de Neurophysiologie, URA CNRS 649, Faculté de Médecine, Université Paul-Sabatier, 31062 Toulouse CEDEX, France (P. Dupui, R. Montoya, M.-C. Costes-Salon, A. Séverac), and MEDES, Hôtel Dieu-St. Jacques, 31052 Toulouse CEDEX, France (A. Güell).

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Address reprint requests to: Philippe Dupui, M.D., Laboratoire de Neurophysiologie, Faculté de Médecine, 133 route de Narbonne, 31062 Toulouse CEDEX, France.

tation syndrome. The opportunity was taken to accomplish the following: 1) to study the bed-rest-induced modifications of balance and gait with original methods in order to complete previous investigations (6); and 2) to evaluate the efficiency of periodical LBNP sessions during bed rest in counteracting the deleterious effects of simulated microgravity on balance and gait.

MATERIALS AND METHODS

Two bed-rest studies were performed at an interval of 1 year, with the participation of the same volunteers after the agreement of the French National Ethics Committee: the first, in November–December 1987 and the second in September–October 1988. The duration of each experiment was 42 d, including successively an ambulatory period (7 d), a −6° head-down bed-rest period (30 d), and a recovery period (5 d).

Subjects

Five healthy male volunteers (age ranging from 28 to 36 years) took part in this study. In the first bed-rest period, three subjects were submitted to periodical LBNP sessions (subjects A, B, and C) and the two others (D, E) served as controls. One year later, during the second bed-rest period, the three subjects (A, B, C) having undergone LBNP in 1987 made up the control group in 1988 and the 1987 control group (D, E) became the 1988 LBNP group.

−6° Head-Down Bed Rest

During the 30 d of bed rest, the subjects were placed in the −6° head-down position; they were not allowed to raise their heads from the plane of the bed (even for urination or defecation) but they could perform lateral movements and roll from side to side. The subject selected his recumbent (dorsal, ventral, or lateral) position and the time spent in each position. From the bed to the LBNP box and into the LBNP box, the subject remained head-down.

LBNP Sessions

Three 20-min LBNP sessions per day (10 a.m., 2 p.m., and 6 p.m.) at −28 mm Hg for the first 3 weeks of the bed rest were followed by four daily sessions (9 a.m., 12 a.m., 2 p.m., and 6 p.m.) for the first 4 d of the last week, culminating in six daily sessions (9 a.m., 12 a.m., 2 p.m., 5 p.m., 8 p.m., and 10 p.m.) during the last 3 d. Therefore, each subject was subjected to a total of 1–2 h • d^{-1} of LBNP during bed rest. The value of −28 mm Hg was chosen so as to avoid the occurrence of petechia or varicose veins. During the LBNP sessions, the subject remained head-down with soles of the feet against a foot board; unfortunately, the pressure exerted by the feet during the −28 mm Hg pressure session was not measured.

Gait Analysis

A kymographic method allowed the measurement of the simultaneous horizontal displacements of both feet along a 6-m walkway (3). Recordings of longitudinal displacement of both feet were performed by linking each foot to a length-voltage transducer (potentiometer) by means of wires. The subject wore disposable plastic slippers fitted over the bare feet with straps. The slippers were connected to the transducer by a wire fastened to the head of the second metatarsal. The movement transmitted to the transducer was reduced by winding the wire around a 16-strand pulley-block. The length of the displacements of each foot versus time was measured by the potentiometer output. The variations were recorded on an electrostatic paper chart and a microcomputer stored and processed the signals. The spatial and temporal gait parameters of the right and the left foot were processed by the microcomputer from several successive walk cycles. The parameters measured were the stride and the step length (m) as well as the cycle, the stance, the swing, and the double support durations (s). From these lengths and durations several parameters were calculated: the total cadence (strides • min^{-1}) and the walking speed (m • min^{-1}). To present the temporal organization of the walking cycles clearly, some of the temporal parameters were expressed as a percentage of cycle duration. The subject was instructed to start on the preferred foot first and reach the end of the 6 m walkway, walking with a steady rhythm of gait. For all subjects, data were collected from the first trial, owing to a tight schedule for the other examinations.

Balance Analysis

Balance function was tested both in static and dynamic conditions.

Static balance (orthostatic position on a fixed base): Static balance was tested by a force moment platform (PL) that was attached to a fixed base (B) by means of a hinge joint (HJ) and an elastic element (E) (Fig 1). The hinge joint and the elastic element acted as a dynamometer. A potentiometer fixed on the hinge joint allowed analysis of the horizontal displacements of the subject's foot pressure-center. This indicated the oscillations of the subject's center of gravity. Postural stability was measured by the sum, in millimeters, of the absolute values of the horizontal displacements of the foot pressure-center sampled at 1 KHz during 25.6 s.

Dynamic balance (upright position on a rocking base): The subjects were examined while standing on a seesaw platform (Fig. 1) derived from the platforms of Freeman et al. (11) and Dietz et al. (8). The seesaw, consisting of a platform with a cylindrical curved base (weight, 2 kg; height with the platform horizontal, 6 cm; radius of base curvature, 55 cm), was in contact with the ground along a generatrix of the cylinder (pivot). Because the center of gravity of the system (subject and

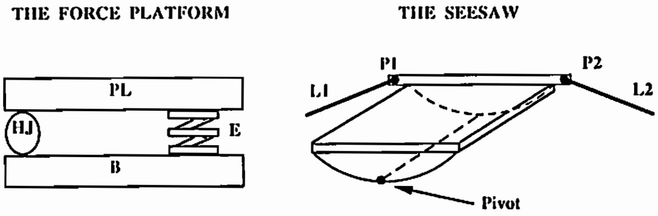


Fig. 1. (Left) The force platform (PL, platform; B, support base; HJ, hinge joint; E, Elastic element). (Right) The seesaw platform (P1 and P2, potentiometers; L1 and L2, levers).

platform) was above the center of rotation of the seesaw, the system was unstable and no resonance frequency obtained. Angular tilting of the platform supporting the subject was monitored by means of two potentiometers (P_1 and P_2) fixed on the platform. Levers (L_1 and L_2) were fixed to each potentiometer shaft, the other end laying on a smooth floor. The seesaw platform made the subject unable to stand still. He needed to continuously adapt his posture in order to keep balance. From the potentiometer output, a microcomputer calculated the total linear displacement of the pivot; i.e., the sum in millimeters of the absolute values of each elementary horizontal displacement of the pivot on the ground over 25.6 s. This parameter gave an assessment of the dynamic balance performance (2).

Balance analysis protocol: The force moment platform and the seesaw platform allowed either anteroposterior or lateral sways to be recorded according to the position of the subject on the platform. Table I summarizes a balance recording session and shows the chronological order of the tests and their experimental conditions (anteroposterior and lateral swaying; eyes open and eyes closed). In order to conform to the schedule of the other examinations, we were limited to only one test run per subject session. The duration of the subject's transfer from the force platform to the seesaw was about 3 min and from the anteroposterior to lateral position, about 2 min. During the eyes-open tests, the subject looked at an eye-level target on a wall approximately 3 m in front of him. During dynamic balance tests, the subject was instructed to try to hold the seesaw as horizontal as possible.

General Protocol

The experimental procedure began by gait analysis (total duration, about 5 min) and continued with balance analysis (total duration, about 10 min). The five subjects underwent two practice sessions during the ambulatory period to become familiar with the procedure of gait and balance examinations. They were tested 2 d before (pre-bed-rest) bed rest and during the recovery period after the 30-d of −6° head-down bed rest: on the 1st day of getting up, 30 min after the orthostatic tolerance testing of cardiovascular parameters (recovery 1, R_1); on the 3rd day (recovery 3, R_3); and on the 4th day (recovery 4, R_4). At R_1, immediately after bed rest, upright tilting of the subject was performed to evaluate the cardiovascular deconditioning (control subjects) or to test the efficiency of LBNP as a prophylactic measure of the orthostatic intolerance (LBNP subjects) (12). The tilt test was stopped after 60 min of +60° body position or earlier in the event of giddiness or fainting. After the tilt test, the subject remained seated on a wheelchair for 30 min to become progressively used to the vertical position without requiring much activity of the lower-limb muscles.

TABLE I. THE BALANCE ANALYSIS PROTOCOL.

Platform	Sways	Eyes	Duration (s)
Force Platform	Anteroposterior	Open	25.6
		Closed	25.6
	Lateral	Open	25.6
		Closed	25.6
Seesaw Platform	Anteroposterior	Open	25.6
		Closed	25.6
	Frontal	Open	25.6
		Closed	25.6

Statistical Analysis

A two-way analysis of variance (ANOVA) with repeated measurements was used to study the influence of −6° head-down bed rest on balance and gait parameters and the efficacy of the LBNP sessions on the deleterious effects of the bed rest on these parameters. The two factors were the LBNP sessions (two levels: with and without LBNP) and the periods of the measurements (four levels: base, R_1, R_3 and R_4). Post hoc testing was accomplished with Scheffé's test. For all statistical analyses, the level of $p = 0.05$ denoted significance.

RESULTS

Gait Parameters

The values (mean and S.D.) of spatial and temporal gait parameters measured with and without LBNP at the four periods of the experiment are indicated in Table II. The effects of 30 d −6° head-down bed rest and the efficiency of the LBNP sessions as countermeasure were analyzed with respect to spatial and temporal gait parameters. Fig. 2 shows the effects of bed rest and of LBNP sessions on the walking speed, stride length, and cycle duration. To illustrate the modifications between pre-bed-rest and recovery periods, the recovery values were expressed as percentages of the pre-bed-rest values of each walking parameter.

Pre-Bed-Rest Performance

For all subjects and all parameters, there was no significant difference between pre-bed-rest values from year to year.

Changes of Gait Parameters After Head-Down Bed Rest

The global analysis of variance showed that bed rest significantly disturbed ($p < 0.05$) certain gait parameters. On the first day of recovery (R_1), the walking speed was significantly ($p < 0.05$) decreased by about 6% with respect to the pre-bed-rest value (Fig. 2). This resulted from a 6% decrease ($p < 0.05$) in stride and step length with no significant change in cycle duration. On the 4th day of recovery (R_4) the lengths returned to their pre-bed-rest values, whereas cycle duration was increased by 5%; this increase could be related to the muscular pains (stiffness), especially in the quadriceps, that three of the five subjects felt.

Effects of LBNP Sessions on Walking

The global analysis of variance showed that LBNP sessions corrected the effects of the head-down bed rest on the stride and step lengths and consequently on the walking speed (Fig. 2, closed circles).

TABLE II. GAIT PARAMETERS {MEAN (S.D.)} MEASURED WITHOUT AND WITH LBNP BEFORE (PRE-BED-REST) AND AFTER (R_1, R_3, R_4) BED REST.

Parameter	Without LBNP				With LBNP			
	Pre-bed-rest	R_1	R_3	R_4	Pre-bed-rest	R_1	R_3	R_4
Walking Speed (m/min)	114 (7)	106 (11)*	108 (10)*	110 (7)	109 (4)	107 (6)	112 (9)	115 (7)
Stride Length (m)	1.75 (0.11)	1.64 (0.18)*	1.72 (0.21)	1.78 (0.09)	1.75 (0.05)	1.69 (0.12)	1.77 (0.11)	1.80 (0.07)
Step length (m)	0.88 (0.06)	0.82 (0.09)*	0.87 (0.10)	0.89 (0.05)	0.87 (0.03)	0.85 (0.05)	0.88 (0.05)	0.90 (0.04)
Cycle Duration (s)	0.92 (0.03)	0.93 (0.06)	0.96 (0.06)	0.97 (0.04)*	0.96 (0.03)	0.96 (0.03)	0.95 (0.03)	0.94 (0.02)
Cadence (Cycles/min)	130 (5)	129 (9)	126 (9)	125 (6)	126 (6)	126 (14)	127 (11)	128 (6)
Stance Duration (s)	0.55 (0.02)	0.55 (0.05)	0.56 (0.04)	0.57 (0.03)	0.57 (0.02)	0.57 (0.02)	0.56 (0.05)	0.56 (0.03)
vs. Cycle Duration (%)	57.9 (1.56)	59.0 (0.61)	58.7 (1.01)	58.9 (1.08)	59.2 (1.15)	59.0 (1.17)	58.9 (0.89)	59.8 (0.76)
Swing Duration (s)	0.38 (0.02)	0.38 (0.02)	0.40 (0.02)	0.40 (0.02)	0.40 (0.02)	0.39 (0.02)	0.40 (0.03)	0.39 (0.02)
vs. Cycle Duration (%)	42.1 (1.56)	41.0 (0.61)	41.3 (1.01)	41.1 (1.08)	40.8 (1.15)	41.0 (1.17)	41.1 (0.89)	40.2 (0.76)
Double Support Duration (s)	0.08 (0.01)	0.08 (0.01)	0.08 (0.01)	0.09 (0.01)	0.08 (0.01)	0.09 (0.02)	0.08 (0.01)	0.09 (0.01)
vs. Cycle Duration (%)	8.7 (0.9)	8.7 (1.0)	8.6 (1.1)	9.1 (0.5)	8.6 (1.0)	9.4 (1.7)	8.5 (1.3)	9.1 (1.3)

Data were tested for significance using a two-way analysis of variance with repeated measures; Post hoc testing was accomplished with Scheffé's test.

* Post-bed-rest value differs significantly ($p < 0.05$) from pre-bed-rest value.

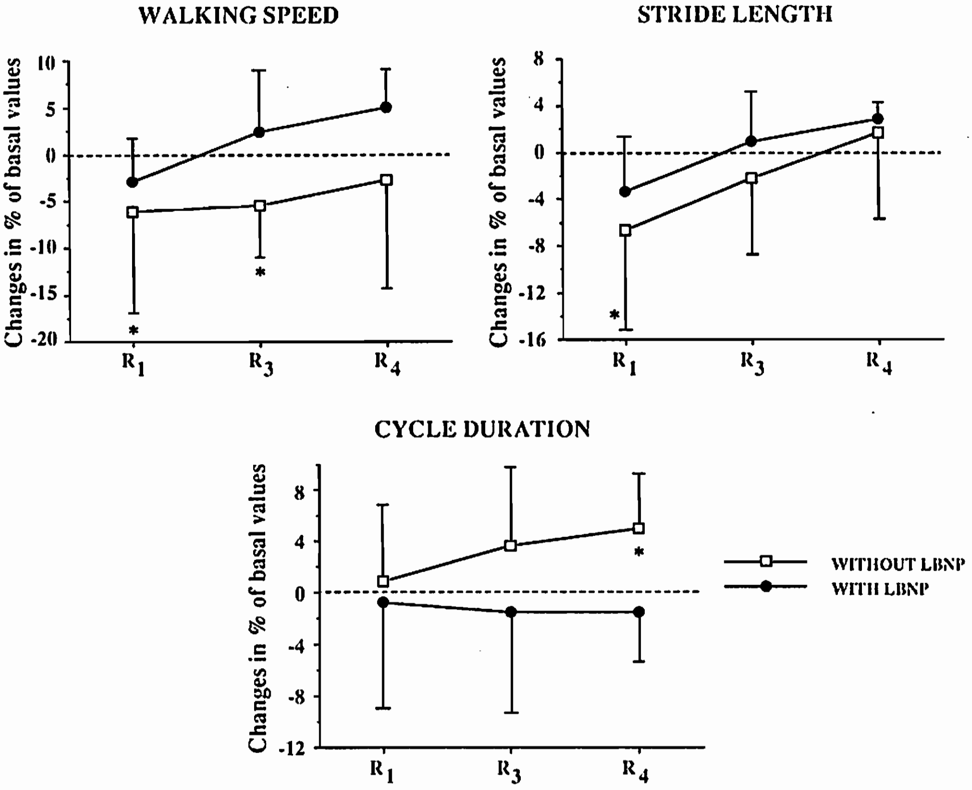


Fig. 2. Recovery (R1, R3, R4) of walking speed (top left), stride length (top right) and cycle duration (bottom) measured with and without LBNP. The recovery changes are expressed in percentage of pre-bed-rest values (mean ± S.D.). *Recovery values differ significantly ($p < 0.05$) from pre-bed-rest values.

Balance Parameters

Table III contains the results of the static and dynamic balance examinations. The balance parameters were measured during anteroposterior and lateral sways, both eyes open and eyes closed, before and after bed rest, and without and with LBNP. The results are illustrated in Fig. 3.

Pre-Bed-Rest Performances

The pre-bed rest data indicate that four subjects were within the range of postural equilibrium performance typically exhibited by young healthy subjects (2). Subject E exhibited some difficulties in maintaining balance in dynamic conditions with eyes closed. This abnormality could explain, in this test condition, the large standard deviations of the balance parameter mean values; it did not interfere with the statistical interpretation of the results since the analysis of variance takes the repetition of measurements in the same subject into account. Moreover, for all subjects, there was no statistically significant difference between pre-bed-rest values from year to year.

Changes of Balance Parameter After Head-Down Bed Rest

Anteroposterior sway: An analysis of variance on static and dynamic balance parameters showed a significant difference ($p < 0.01$) according to the test day.

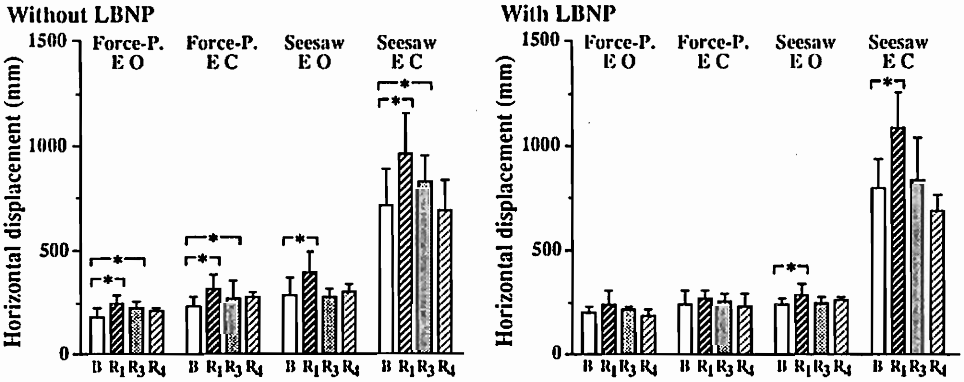
TABLE III. STATIC AND DYNAMIC BALANCE PARAMETERS {MEAN (S.D.)} MEASURED WITHOUT AND WITH LBNP BEFORE (PRE-BED-REST) AND AFTER (R_1, R_3, R_4) BED REST.

Sways	Balance Parameter	Eyes	Without LBNP Pre-bed-rest	Without LBNP R_1	Without LBNP R_3	Without LBNP R_4	With LBNP Pre-bed-rest	With LBNP R_1	With LBNP R_3	With LBNP R_4
Anteropost	Static	Open	178 (48)	249 (39)*	222 (35)*	205 (19)	201 (28)	241 (66)	218 (10)	182 (35)
		Closed	227 (49)	319 (66)*	270 (81)*	279 (20)	242 (68)	272 (37)	257 (34)	234 (58)
	Dynamic	Open	283 (86)	391 (103)*	279 (33)	297 (45)	241 (28)	284 (54)*	247 (33)	258 (21)
		Closed	713 (179)	959 (194)*	827 (127)*	689 (151)	797 (143)	1088 (164)*	839 (201)	689 (81)
Lateral	Static	Open	192 (70)	202 (44)	178 (75)	209 (28)	189 (60)	210 (29)	203 (20)	182 (38)
		Closed	186 (48)	295 (135)*	241 (110)	208 (41)	185 (40)	254 (47)	212 (62)	200 (45)
	Dynamic	Open	274 (51)	366 (49)*	315 (61)	299 (48)	309 (74)	334 (114)	291 (62)	318 (115)
		Closed	668 (206)	774 (139)*	645 (123)	739 (350)	868 (278)	808 (234)	768 (349)	621 (161)

Data were tested for significance using a two-way analysis of variance with repeated measures; Post hoc testing was accomplished with Scheffé's test.

* Post-bed-rest value differs significantly ($p < 0.05$) from pre-bed-rest value.

ANTEROPOSTERIOR SWAY



LATERAL SWAY

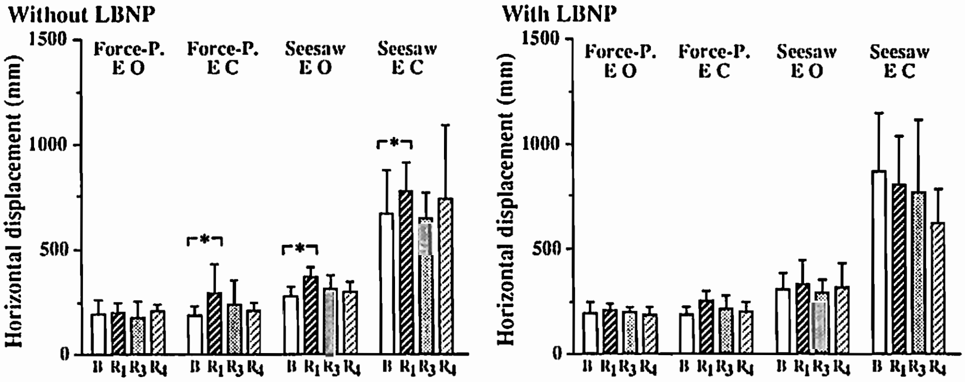


Fig. 3. Mean values and standard deviations of the static and dynamic balance parameters measured eyes open (EO) and eyes closed (EC) without LBNP (left) and with LBNP (right) during the pre-bed-rest period (B, before bed rest) and during the recovery period (R1, R3, R4). Anteroposterior sway (upper diagrams) and lateral sway (lower diagrams). *Recovery values differ significantly ($p <$ 0.05) from pre-bed-rest values.

After the end of bed rest and 30 min after reaching the vertical position (R_1), there was a significant increase ($p < 0.05$) in the balance parameters relative to pre-bed-rest values whether the subject had his eyes open or closed on the force platform or the seesaw. From the 3rd or 4th day of the recovery period, the parameters were not different to their pre-bed-rest values.

Lateral sway: This was less disturbed by bed rest than anteroposterior sway. Indeed, immediately after the end of bed rest (R_1), static balance parameters were significantly increased only when the subjects had their eyes closed, whereas dynamic balance parameters were increased in both eyes open or closed conditions. Parameters returned to pre-bed-rest values for the third recovery day (R_3).

Effects of LBNP Sessions on Balance

Anteroposterior sway: The LBNP sessions completely counteracted the bed-rest effects on static balance but they did not counteract the effects on dynamic balance. Since, at the end of bed rest (R_1), the balance parameters measured in the seesaw tests with eyes open or closed were significantly increased relative to pre-bed-rest values. However, the recovery of dynamic balance seemed to be slightly more rapid with LBNP than without it; i.e., from the 3rd day of the recovery period (R_3), the dynamic balance performances with eyes open or closed were not different from pre-bed-rest performances.

Lateral sway: In all cases (static and dynamic balance, eyes open or closed), LBNP sessions completely counteracted the deleterious effects of bed rest; i.e., under all the experimental circumstances, the R_1 values of the balance parameters were not statistically different from pre-bed-rest values.

DISCUSSION

Head-down bed rest is known to reproduce many of the physiological changes observed in space; i.e., redistribution of body fluids and body mass, decreases in plasma volume and red cell mass, bone demineralization, and muscular atrophy. Following bed rest, the subjects exhibited decreased orthostatic tolerance as well as balance and gait instability similar to those typically demonstrated by crewmembers returning from space (14,18,26). In contrast to the well known cardiovascular and hormonal responses to head-down bed rest, the changes in sensory input and motor output are not well defined. But many arguments and some experiments suggest that bed rest disturbs (albeit to a lesser extent than microgravity) the sensorimotor systems which are involved in muscular tonus and postural activity. These sensorimotor disturbances could explain part of the gait and balance perturbations occurring during the recovery period.

Drozdova and Nesterenko (9) reported visual and intraocular changes during a study of 100-d bed rest that they related to reduced cerebral blood circulation. Haines (13) found significant impairment in peripheral visual field sensitivity during a 30-min passive 70° head-up tilt administered immediately after 14 d of bed rest. If prolonged bed rest impairs visual sensitivity significantly, this impairment might contribute to post-bed-rest body-balance decrements.

During bed rest, data provided by the semicircular canals usually remain unchanged because the head movements which are allowed induce angular accelerations of the head. But the changes of the endolymphatic fluid pressure, attributable to cephalic fluid shifts accompanying head-down bed rest, are reported to alter the response properties of the vestibular receptors (18). The otolithic information about head position relative to the gravitational vector was preserved but the large anteroposterior linear accelerations which occur on walking (10) disappear during bed rest; there is probably a partial disuse of the macular perception of the linear acceleration.

During bed rest, gravity is still present, but head-to-foot loading of the body along its long axis is minimized, so the input from the cutaneous pressure receptors of the foot sole is decreased. These receptors, which contribute significantly to postural control in man (23), are then not being used.

The motor ability is also altered because bed rest induces muscular atrophy and an impairment of the proprioception of the antigravity muscles (26). During immobilization or in microgravity, the reduction of voluntary and reflex muscular activity contributed to a sensorimotor deconditioning of the muscular system (27). During bed rest, the antigravity muscles of the legs were the most affected, as shown by decreases in limb circumference and by reduced performance in tests of muscle strength or motor capabilities (26). Dietrick et al. (7), in a study of healthy individuals placed in body casts for 6–8 weeks, found that the muscles associated with locomotion suffered the greatest decrease in strength; i.e., the biceps femoris lost 6.6%, the tibialis anterior lost 13.3%, and the gastrocnemius-soleus group lost 20.8%. The strength of the back extensors and abdominal muscles did not decline. These strength changes were associated with loss of muscle mass, especially in distal muscles (thigh circumference decreased by 3.5% and calf circumference by 5.6%). Similar changes occurred during the Skylab flight (27).

The post-bed-rest-decreased orthostatic tolerance (25) might contribute to the gait and balance alterations, but to a lesser extent than sensorimotor disturbances since the subjects did not show any tendency to syncope or to presyncopal state (sweating, paleness, thirst) during either gait or balance testing. In addition, as the post-bed-rest decrease of dynamic balance performance mainly occurred during eyes closed tests and persisted despite the LBNP sessions in dynamic conditions for anteroposterior sway, the sensorimotor disturbances appeared as a non-negligible factor (in regard with hemodynamic factors) in the bed-rest-induced balance alterations. However, it was impossible to evaluate the relative importance of proprioceptor disuse, motor control disuse and muscle atrophy.

Anteroposterior sway was affected by head-down bed rest more than lateral sway, especially in dynamic conditions. This observation was consistent with bed-rest-induced sensorimotor disuse of distal limb muscles (7,27). Indeed, anteroposterior sway involves more distal muscle activity (particularly the ankle extensors and flexors) than proximal muscle activity (19,20). This observation emphasizes the interest of balance examination allowing distinct studies of anteroposterior and lateral sways to investigate the role of distal or proximal muscles in changes of balance performance.

This study confirms the results of previous bed-rest studies (6,14) which reported gait and balance abnormalities after 14 or 30 d head-down bed rest. The results of our study showed the beneficial action of the LBNP sessions on most of the deleterious effects of bed rest on gait and balance. LBNP sessions counteracted the decrease of the step lengths and of the walking speed and reduced the standard deviations of the mean of the gait parameters. When lateral sway was considered, LBNP sessions completely counteracted the bed-rest effects on balance in static and dynamic conditions. When anteroposterior sway was considered, LBNP sessions completely counteracted the bed-rest effects on static balance; in dynamic conditions, LBNP sessions were ineffective. This observation emphasizes the idea that bed-rest-induced sensorimotor disuse had greatest effect on the muscles that control the ankle.

For the same bed rest experiment, Güell et al. (12) showed the beneficial effect of LBNP as a prophylactic method to counteract the orthostatic intolerance induced by bed rest. The improvement, by LBNP sessions, of gait and balance performance during the recovery period could be attributable to higher orthostatic tolerance. Despite the LBNP sessions, the persistence of the decrease in dynamic balance performance after bed rest when anteroposterior sway was studied suggested that sensorimotor changes play a non-negligible role in bed-rest-induced gait and balance modifications; thus, the beneficial effect of LBNP did not exclusively result from a higher orthostatic tolerance. The LBNP sessions, able to increase the hydrostatic gradient between vessels and adjacent tissues in the lower limbs, could provoke a mechanical reactivation of muscle proprioceptors. However, during the LBNP sessions, the body is drawn footwards and the reappearance of a reaction force against the foot-board could reactivate the pressoceptors of the soles of the feet. The reactivation of the muscular proprioceptors and of the foot sole pressoceptors could prevent the disuse of the reflexes involved in postural control and could increase muscular tonus.

In conclusion, the study showed the beneficial effects of the LBNP sessions on most of the deleterious effects of bed rest on balance and gait. The effects of bed rest and LBNP should be confirmed later with a greater subject sample in order to decrease the variability of the post-bed-rest results. The results suggest the existence of possible links between cardiovascular and sensorimotor deconditioning and open new perspectives of basic research regarding inflight prophylaxis of sensorimotor disorders.

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