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EFFECTS OF VARIOUS KNEE-RAISING POSTURES IN A SUPINE POSITION ON SWELLING IN THE LOWER LEGS AND FEET IN ELDERLY WOMEN

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The present study examined the effects of different knee-raising postures in the supine position on swelling in the lower legs and feet of elderly women. Seven elderly women with no illness-related swelling maintained a supine position for 40 min on a bed under four knee-raising postures: downhill, raising the knees and further raising the feet; horizon, raising the knees with the lower legs in a horizontal position; mountain, raising the knees to a height above the feet; and control, stretching the knees without elevation of the feet. While maintaining a supine position, downhill and horizon conditions showed significant decreases in circumferences and increased bio-impedance at all measured positions of the calf and foot, compared to the control condition. In contrast, the mountain condition did not show decreases in all circumferences. No significant differences were found for heart rate, blood pressure or scores of subjective comfort in any body areas among the conditions. These results suggest that the downhill and horizon conditions have effects on lower leg swelling without causing additional discomfort or circulatory strain.

Key words: adjustable bed; swelling; elderly women; knee raising; circulatory strain

INTRODUCTION

In Japan, the population of elderly individuals in need of care is markedly increasing and most of them have been using an adjustable bed at homes and care institutions. In general, the adjustable bed has functions to raise the whole surface of the bed and/or just the back or knees of the user. In our previous study (Kuroda et al., 2008), about half of the elderly users of adjustable beds, particularly women, experienced symptoms of lower leg swelling due to factors such as surgical side effects and unknown causes. In addition, about 90% were trying to relieve swelling by raising the legs while in a supine position on the bed, which corresponded to one of major treatment for it (O'Brien et al., 2005; Bartholomew et al., 2005). To raise the lower legs, however, most were found to use cushions and pillows, rather than the knee-raising functions of the adjustable bed.

The adjustable bed for general use has two types of knee-raising functions. One type raises the knees to a height above those of the feet and hips (Mountain type). This function has been used to prevent the user's upper body sliding downward while using the back-raising function (Gatch, 1909). Another type raises both the knees and feet above the hips with the calves in a horizontal position (Horizon type). Since almost all adjustable beds can only allow one posture or the other, elderly users have to choose between the mountain and horizon types when installing the bed. On the other hand, the general recommendation is to raise the knees and then raise the feet higher than the heart and knees (Downhill type) to relieve swelling (Buetow, 1956; Kimura, 2006). This posture is considered to have greater and faster effects in relieving swelling of the lower legs, because the liquid in the

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calves and feet beyond the knees is easily drained with the aid of gravity. Clarification of the effects of these kinds of knee-raising postures on lower leg swelling would be useful for providing correct knowledge to users who suffer from leg swelling and to extend the functions of the adjustable bed.

The present study therefore examined the effects of different knee-raising postures, including downhill, horizon and mountain postures, in a supine position for an extended time on swelling in the lower legs and feet of elderly women.

METHODS

Participants

Participants comprised seven healthy women of age between 66 and 72. Physical characteristics of the participants are shown in Table 1. None of them had a history of cardiac-, metabolic- or illness-related swelling. Written informed consent was obtained before participation. This study was approved by the ethics committee of the Faculty of Design in Kyushu University (Approval No. 10).

Table 1. Physical characteristic of participants.

	Mean±SD	Range
Age (years)	68.6±1.8	66 - 72
Height (m)	1.52±2.3	1.49 - 1.56
Body mass (kg)	50.4±3.2	46.8 - 56.2
Circumference (mm) [a]		
Calf [b]	343±20	323 - 373
Foot [c]	223±10	213 - 239

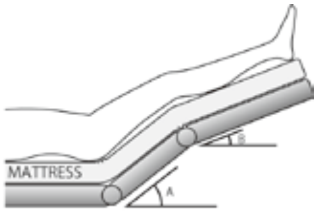
[a] Measured in the supine position.
[b] Measured at the position of maximal thickness.
[c] Instep circumference.

Knee-raising conditions

The participants performed three conditions of knee-raising (downhill, horizon, and mountain) and a control condition (no knee-raising) while lying supine on a bed (KA-513A; Paramount Bed, Japan) with a mattress (KE-523; Paramount Bed, Japan) (Figures 1 and 2). The downhill condition raised the knees and further raised the feet above the knees. The horizon condition raised the knees with the lower leg maintained horizontally. The mountain condition raised the knees to a height above the feet. The control condition stretched the knees and feet on the mattress without elevation. These postures were achieved using changes in the surface shape of the bed and blocks (Figure 2). Under the three conditions with knees raised, the thigh (Angle A) was fixed at an elevation of 22°, to ensure that the knees were above the level of heart in the supine position. In our preliminary experiments, if the angle of the thigh (Angle A) was >22°, some participants complained of pain in the lower trunk and discomfort in the downhill posture.

Procedures

Each participant visited our experimental building five times. On the first visit, we explained the procedures and purposes of the experiments, and then the participants were acclimatized to the procedures. From the second visit, experimental trials were performed at the same time on different days within a 2-week period. The experiments were undertaken in a climatic chamber at an ambient temperature of 27 °C with a relative humidity of 50%. During the experiments, participants wore a



Conditions	A (°)	B (°)
Downhill	22	7
Horizon	22	0
Mountain	22	-16
Control	0	0

Fig. 1. Experimental conditions for knee-raising posture.

Downhill Horizon Mountain Control

Fig. 2. Postures for each knee-raising posture.

shirt and shorts.

In each experimental trial, the participant first went to the toilet to empty their bladder, then assumed a sitting position with the knees bended for 40 min on the edge of the bed, followed by a sitting position with the knees outstretched using a back rest on the bed for 40 min. They drank 300 ml of water while sitting on the edge of the bed. These processes were used to maximize swelling of the lower limbs. Finally, the participant assumed a supine position in one of the four knee-raising postures for 40 min on the bed. The order of knee-raising conditions was counter-balanced.

Measurements

The circumferences of the right calf (at 3 positions) and foot (instep circumference), and bioelectrical impedance in the left calf (at 2 positions) and foot were measured at the beginning and every 5 min during the 40 min in the supine position. Before the sitting position, the measurement positions of the circumference were determined by the following procedures. First, we detected the position where the circumference of the calf was maximal, and determined the height of this position from the supratarsale fibulare, defined as L. Finally, we calculated the positions of L plus 25%×L (upper position) and L minus 25%×L (lower position). The instep circumference was measured around the cuneiform and cuboid bones distal to the heel. Before the experiment, we attached a measuring tape using a surgical tape so that the measuring tape stayed in place throughout the experiment. In addition, because the calves were in contact with the mattress, part of the mattress was cut to make space under the calves. Bioelectrical impedances at 50 kHz in the upper and lower half of the left calf and in the foot were monitored using a multi-frequency bioelectrical impedance instrument (MLT-30; Sekisui Chemical, Japan). An increase in impedance was considered to reflect a decrease in water volume in the areas between electrodes (Kushner, 1992; Thomas et al., 1992).

Heart rate was continuously recorded by using a heart rate monitor (MSC-2DX; Cateye, Japan). Blood pressure was measured in a supine position by using an automated blood pressure monitor (HEM-770A; Omron, Japan) at the beginning and every 10 min in the supine position. In addition, participants scored subjective comfort (0-7 points, from 0, “very uncomfortable” to 7, “very comfortable") in eight body areas (upper back, lower back, hip, thigh, knee, calf, ankle and heel) at 0, 20 and 40 min in each supine position.

Statistical analysis

A two-way (conditions × time) analysis of variance with repeated measures (ANOVA) was used to assess the effects of each condition on measured variables. Significant F-ratios were followed by the post-hoc test using Dunnet's procedure to make comparisons between the beginning and at different times during each position. Values of $p<0.05$ were considered significant.

RESULTS

Figure 3 presents the rates of change compared to the beginning of leg-raising for the circumferences during the 40 min maintaining the supine position. In all measured areas, ANOVA revealed significant effects of time and interactions between time and condition. While maintaining the supine position, downhill and horizon conditions showed significant decreases in the circumferences at all heights of the calf and in the foot. Under the control condition, the circumference at the lower position of the calf did not change significantly, although the other circumferences decreased significantly. In addition, the decreasing rates in the circumferences at the upper position of the calf was smaller in the control condition than in the downhill and horizon conditions (after excluding the mountain condition, ANOVA identified a significant interaction between time and condition). In contrast, the mountain condition did not show decreases in any circumferences.

Figure 4 indicates rates of change compared to the beginning of leg-raising for impedance. Although significant increases were seen at all measured areas, ANOVA revealed significant interactions between time and condition. At all measured areas, appearance of significant changes was slow in the mountain condition, compared with other conditions. At the lower area of the calf and foot, the downhill condition showed earlier appearance of a significant increase from the beginning, compared with the horizon condition.

Figures 5 and 6 illustrate changes in heart rate and mean blood pressure during the 40-min period of maintaining the supine position, respectively. No significant effects of time or interactions between time and condition were found for any measurement. Figure 7 presents changes in scores of subjective comfort at eight areas during the 40 min in a supine position. Although no significant differences were found at any areas, scores for the knees, calves, ankles and heels while keeping the supine position tended to be lower in the control condition than in any other conditions.

DISCUSSION

The knee-raising functions of adjustable beds are expected to have two main roles for their users. One is to prevent the upper body sliding downward and to maintain a preferable posture while using the back-raising function. The other is to relieve lower leg swelling due to disease and/or exposure of the lower legs under the gravity for long periods, as in the case of sitting in a wheelchair or on a bed. In recent adjustable beds for users in need of care, those allowing the mountain position have outnumbered those allowing the horizon position. Most previous studies focusing on the posture in bed have used adjustable beds with the mountain posture (Endo A, et al. 2005, Kubota and Yamamoto, 2008). The present study failed to demonstrate positive effects of the mountain posture on lower leg swelling, based on the circumferences of the calf and foot. With the mountain posture, the feet and calves are below the level of the knees. Liquid such as blood and lymphatic fluid in the calves and feet thus has to resist the gravity to pass in a heart direction through the knees. The mountain posture might thus be unsuitable for relieving the lower leg swelling on an adjustable bed,

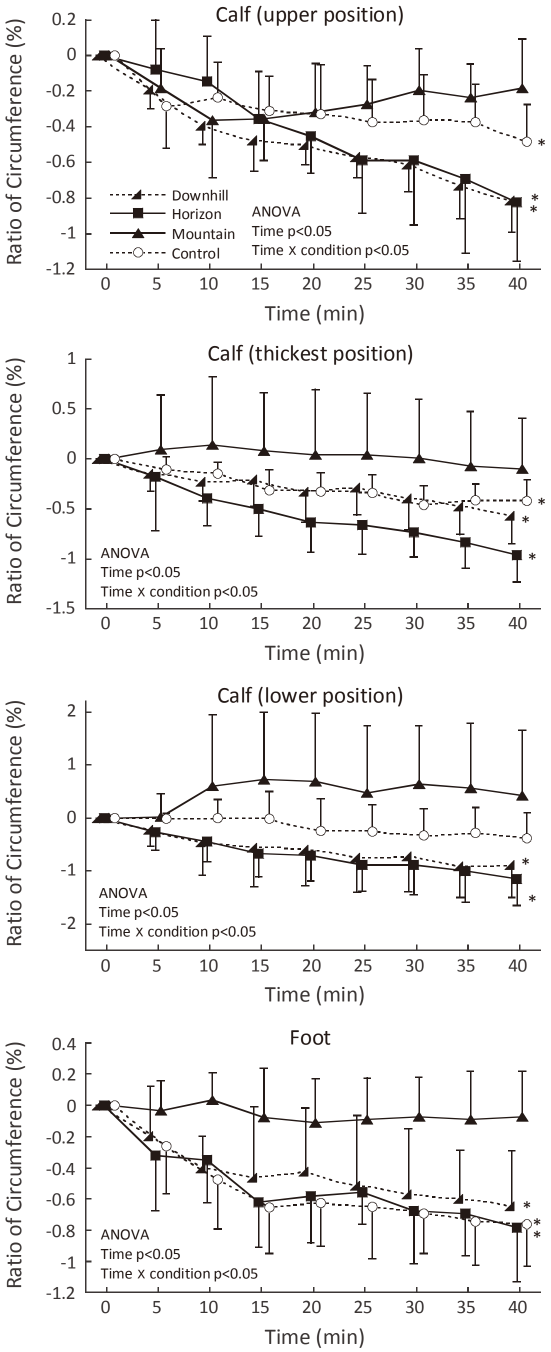


Fig. 3. Changes in the ratios of circumferences around the calf and foot during knee-raising.
* Significant differences between to the beginning (0 min) and the end (40 min) of leg-raising (p<0.05). Error bars represent the standard deviation.

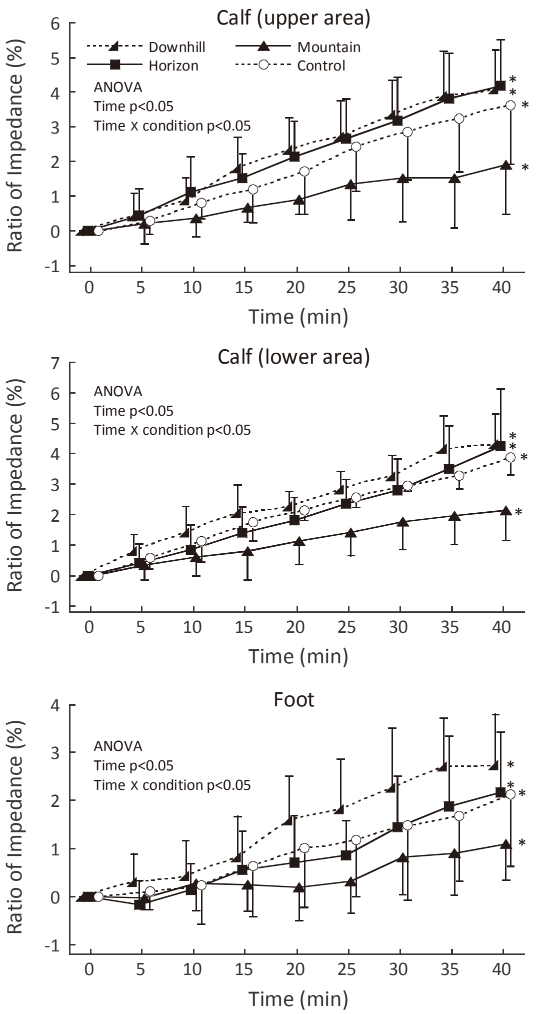


Fig. 4. Changes in the ratios of bio-electrical impedance during knee-raising.
* Significant differences compared to the beginning of leg-raising (0 min) (p<0.05). Error bars represent the standard deviation.

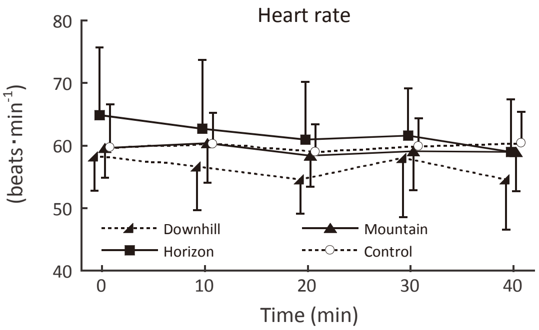


Fig. 5. Changes in the ratios of heart rate during knee-raising. Error bars represent the standard deviation.

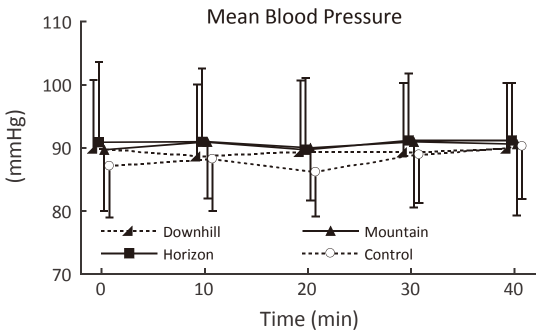


Fig. 6: Changes in the ratios of mean blood pressure during knee-raising. Error bars represent the standard deviation.

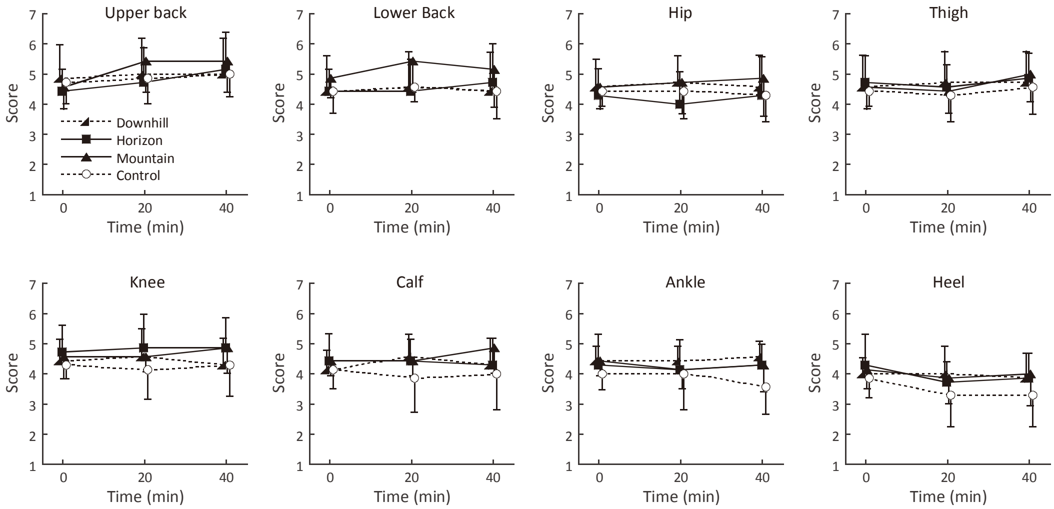


Fig. 7. Changes in scores of subjective comfort at body areas during knee-raising (Score 1: very uncomfortable - Score 7: very comfortable). Error bars represent the standard deviation.

although the position might allow maintenance of preferable postures.

In the horizon and downhill postures, significant changes were found for all measured circumferences and bio-impedance in the calf and foot. The control condition showed lower decreases in the two circumferences in the calf than the horizon and downhill conditions. On the other hand, our previous studies using a 40-min supine position in young and elderly women failed to find any difference in decreases in the circumferences of the calf and foot between horizon and control conditions (Kuroda et al., 2006a; Kuroda et al., 2006b). The findings of differences in the present study would be due to two strategies that were not adopted in the previous studies. The first is the addition of measurements above and below the position of maximal calf circumference, which revealed differences between the horizon and control conditions. The other is the inclusion of a period of sitting with the knees outstretched between prolonged chair sitting and lying supine for 40 min.

Both previous studies (Kuroda et al., 2006a; Kuroda et al., 2006b) and the present investigation succeeded in making the lower leg swell with prolonged chair sitting, confirmed by an increase of 3-5 mm in the calf circumference. Since the calves are perpendicular to the ground, fluid behaviours in the lower legs and feet are easily influenced by gravity. In our previous studies (Kuroda et al., 2006a; Kuroda et al., 2006b), the participants kept a supine position with various knee postures after prolonged sitting in a chair. Even a supine position without the knees raised showed marked reductions in leg swelling, because the lower legs were largely freed from the effects of gravity. We guessed that the dramatic posture change from a sitting position to a supine position inhibited the identification of differences in reduction effects on lower leg swelling between the conditions. In the present study, sitting with the knees outstretched was performed between sitting in a chair and lying supine. Sitting with knees outstretched can retain the swelling of the lower legs caused by sitting in a chair, and avoid dramatic changes in direction of the lower leg toward the supine position. Use of this sitting position with the knees outstretched might be the key to finding differences between horizon and control postures.

In both horizon and control postures, the direction of the calf was the same, that is, horizontal along the surface of the mattress. However, the height of the calf influenced the decrease in the calf circumferences. On the other hand, the angle of the thigh was the same in horizon and mountain postures in the present study. This suggests that to relieve lower leg swelling in a supine position without back-raising, the feet should be elevated at or above the level of the knees and the calves and the feet should be elevated above the upper body, that is, the level of the heart. Most elderly people in need of care use adjustable beds with a knee-raising function. However, most adjustable beds with a knee-raising function are limited to either the mountain posture or the horizon posture. Since the mountain posture is considered to have better effects in maintaining the position of the upper body using back-raising functions, beds that can achieve both types of leg-raising would be very useful for elderly users, particularly for those who suffer from lower leg swelling.

We hypothesized that the downhill posture has stronger effects for relieving lower leg swelling, compared with the horizon posture, because fluid in the calves and feet easily drains beyond the knees with the aid of gravity. However, the present study failed to find definitive evidence for this hypothesis, although impedance of the calf tended to increase faster with the downhill posture than with the horizon posture. In general, patients with lower leg swelling are recommended to adopt postures such as the downhill posture and adjust the height of the feet using aids such as pillows and cushions. The height of the feet in the downhill posture of the present study was 24 cm, and pillows or cushions were needed to achieve this posture. Future research should be focused on the minimum height of the feet needed to effectively relieve lower leg swelling under the downhill condition.

On the other hand, since the effect of knee-raising on lower leg swelling requires keeping the same posture for an extended period, we also measured circulatory strain and local pain. Postural changes are known to result in circulatory changes (Fichet and Cariou, 2009; Jabot et al., 2009). In the supine position, however, maintaining any of the leg-raising positions for 40 min did not result in any differences in blood pressure or heart rate compared to the position without legs raised. In addition, no leg-raising postures showed any significant reduction in comfort scores for any area compared to control conditions. Leg-raising postures instead tended to show improved comfort at the lower limbs, including the knees, calves, ankles and heels. Leg-raising in the supine position, as used in the present study, thus had no secondary effects on the participants.

Users of adjustable beds often use the back-raising function for long periods. In this posture, the legs are positioned lower than the heart, which would easily result in swelling of the legs. Accordingly, leg-raising such as the horizon and downhill postures would effectively reduce such swelling. However, the lower legs would remain below the level of the heart, even by using the leg-raising functions. This relationship between positions might cancel the effects of leg-raising. Examination of the effects of leg-raising in a sitting position by using the back-raising function of adjustable beds will be needed.

In conclusion, the downhill and horizon postures have greater effects on lower leg swelling without additional discomfort or circulatory strain, compared with control and mountain postures.

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