

*Original Article***Sacral skin blood flow rate changes during shoulder and ankle flexion and extension in healthy young adults**Toshiaki Sato, OTR, PhD,<sup>1</sup> Tomomi Hayasaka, OTR,<sup>2</sup> Kou Arata, OTR<sup>3</sup><sup>1</sup>Department of Occupational Therapy, Yamagata Prefectural University of Health Sciences, Yamagata, Japan<sup>2</sup>Department of Rehabilitation, Shinjo Tokushukai Hospital, Yamagata, Japan<sup>3</sup>Department of Rehabilitation, Tsuruoka Kyoritsu Rehabilitation Hospital, Yamagata, Japan**ABSTRACT**

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**Objective:** We investigated the changes in sacral skin blood flow during shoulder and ankle flexion and extension movements.

**Subjects and Methods:** The subjects were 18 healthy young adult men. Sacral skin blood flow rates were measured using a laser Doppler flow meter during active and passive movements of the shoulder and ankle. Analysis of variance with Tukey's multiple comparison test was used to compare the sacral skin blood flow rates before, during, and after movements.

**Results:** In terms of movement sites, shoulder movement significantly increased the sacral skin blood flow compared with ankle movement ( $p < 0.01$ ). For movement patterns, active movement (vs. passive movement) significantly increased the sacral skin blood flow compared with passive movement ( $p < 0.01$ ).

**Conclusion:** These results suggested that sacral skin blood flow rates varied according to the movement site and pattern.

**Key words:** healthy young adults, shoulder flexion and extension, ankle flexion and extension, sacral skin blood flow.

position over a long period of time, defective circulation develops in the region where the body touches the supporting surface, which may cause necrosis of the surrounding tissues. In terms of continuous stress time at the same site, 2–3 h is considered excessive. In addition, factors such as body weight add stress to the body and malnutrition may lead to decubitus ulcers [1]. Although decubitus ulcers can affect the skin across the whole body, they are highly prevalent in the sacral area (occurring in 50%–60% of patients [2]). Once decubitus ulcers occur, treatment usually takes a long time. Furthermore, a deteriorated decubitus ulcer can degrade the individual's general condition or may cause infection; such consequences either cause or contribute to the death of elderly people in many cases [3]. Therefore, it is important to prevent decubitus ulcers, especially in elderly individuals who face an increased risk.

A common approach to the prevention of decubitus ulcers is to change position every 2 h. In a previous study, Suzuki et al. [4] reported that patients with cranial nerve disorders, patients requiring bed rest, and patients without decubitus ulcers tended to have greater changes in skin blood flow compared to healthy persons, and the effects continued even after a position change. In addition, the effects tend to vary considerably among individuals. Shimizu et al. [5] reported that active movement is promoted to improve the blood flow during decubitus ulcer treatment in elderly people aged  $\geq 75$  years. A number of studies in the rehabilitation field have examined the prevention and improvement of decubitus ulcers achieved through positioning strategies [6,7] and physical therapy [8,9]. Although some relevant literature describes the examination of blood flow change by position change and decubitus treatment by active movement, there are no reports to date describing the tracking of blood flow changes by limb movement over time.

The purpose of this study was to assess whether the movement of limbs, particularly shoulder and ankle movement, caused sacral skin blood flow in a cohort of healthy young men. We considered the dynamic

**Introduction**

An important problem in today's society is the increasing number of older adults who are bedridden. When an individual is confined to bed in the same

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effects only on the skin in the sacral region for this study.

## Subjects and Methods

### 1. Subjects

The sample included 18 healthy young adult men with an average age of  $21.7 \pm 0.5$  years (21–32 years), average height of  $170.2 \pm 7.5$  cm (164–182 cm), and average weight of  $61.8 \pm 5.7$  kg (54–70 kg). All subjects were right-handed. The study purpose and experimental procedures were explained to the subjects, and informed written consent was obtained from the participants before enrollment.

### 2. Experimental device (Figure 1)

Sacral skin blood flow was measured by a laser Doppler blood flow meter (ALF21R; Advance Co. Ltd., Tokyo, Japan). The measurement site included the midpoint of the line between the right and left anterior superior iliac spines on the sacral area (Figure 1). The measurement outcome was tissue blood flow (flow). Electromyography was used to measure the muscle activity of flexion and extension of the shoulder (shoulder movement) and ankle (ankle movement). For the electromyography procedure, bipolar conduction by surface electrodes was selected. The measurement sites were the anterior and posterior bellies of the deltoid for shoulder movements and the tibialis anterior muscle and gastrocnemius muscle for ankle movements. Electrodes were placed along the running direction of muscle fibers at the middle of each muscle belly and at a distance of 2 cm between electrode centers. Ground electrodes placed on the right acromion to assess shoulder movements and on

the right internal condyle to assess ankle movements were used as indifferent electrodes. To monitor each shoulder and ankle movement, a digital video camera (NV-GS300; Panasonic Inc., Tokyo, Japan) was placed at the left side behind each participant.

Each analog waveform from the laser Doppler blood flow meter and electromyogram was obtained via A/D conversion to a simultaneous recording system (The Teraview; Gigatex Co. Ltd., Osaka, Japan) to create digital video pictures. Electrical signals [10] were synchronized for measurement.

### 3. Measurement outcomes (Figure. 2)

Measurement was conducted with the participants in the left lateral position. Using a portable measurement device for pressure and shear force (PREDIA-MEA, Molten Corp., Hiroshima, Japan), the results obtained were  $3.4 \pm 0.3$  (3.1–3.7) N and  $2.9 \pm 2.3$  (1.2–5.5) N during shoulder and ankle movements, respectively. To minimize the effects of shear force, the lateral position was selected.

Measurement movement variables included active and passive shoulder and ankle movements. The measurement order was random. Measurements were taken for 3 min and included the following: at-rest lateral position (as resting data), each movement, and after movement as convalescent data. The subjects were asked to rest for 1 min and then to start active movement when given the signal by the examiner. Passive movements were initiated upon verbal instructions. Every examiner was asked to finish or help finish the flexion/extension movements in 5 s. The range of joint motion was inferred from the movements the subjects were able to complete in all ranges of motion (Figure 2).

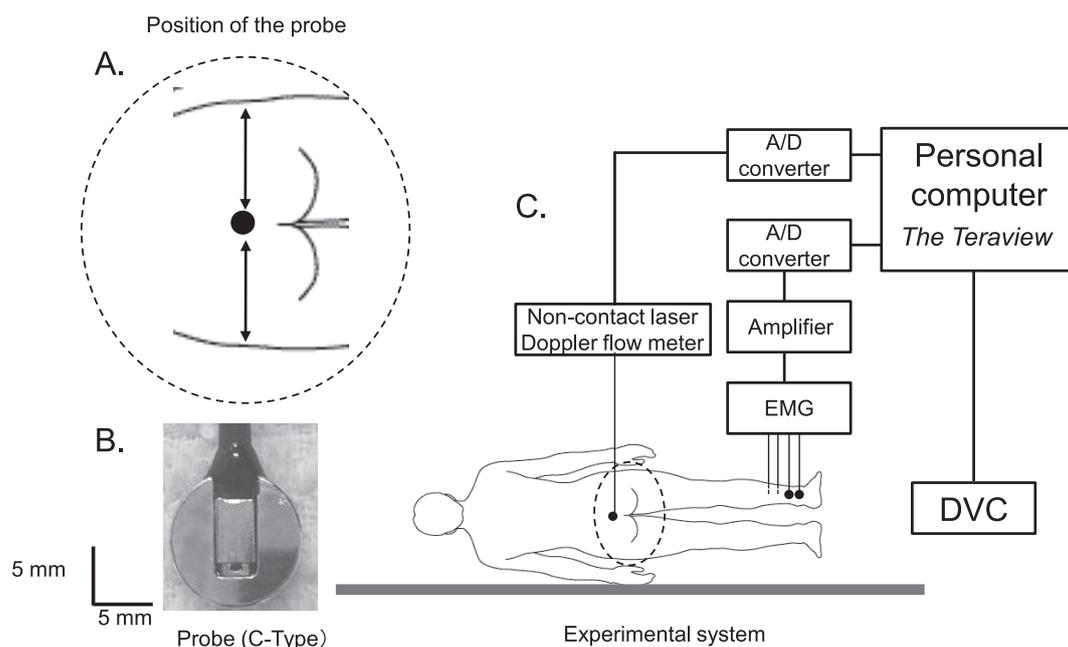
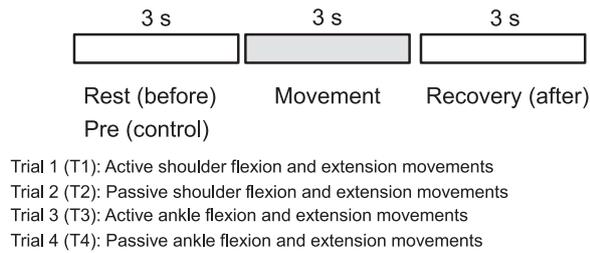


Figure 1. Illustration of the experimental setup.



**Figure 2.** Experimental protocol of each trial.

#### 4. Analysis method

The value of the sacral skin blood flow for 30 s in a 3-min period (90–120 s after start) in the at-rest lateral position before movement was 100%. The percentage of the average value of sacral skin blood flow for 30 s during each movement (90–120 s after start) and for 1 min after the movement finished was calculated and the sacral cutaneous blood flow in the at-rest lateral position (before movement) and rate of change were compared. For the sacral skin blood flow during each movement and the rate of change, a one-way analysis of variance and a multiple comparison technique (Tukey method) were used. Statistical significance was determined at a probability value of  $\leq 0.05$ .

#### Results

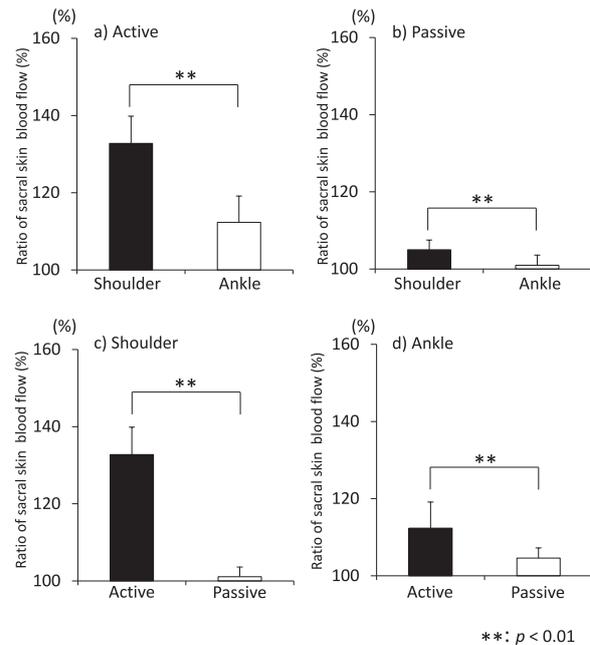
During active (Trial 1) and passive (Trial 2) shoulder movements, the sacral skin blood flow rate changes were  $132\% \pm 7.1\%$  (117.5–142.4) and  $104.6\% \pm 2.6\%$  (100.0–108.3), respectively. Likewise, during active (Trial 3) and passive (Trial 4) ankle movements, the sacral skin blood flow rate changes were  $112.3\% \pm 6.8\%$  (103.3–129.4) and  $101.1\% \pm 2.5\%$  (96.1–103.7), respectively.

##### 1. Comparison of sacral skin blood flow rate changes by movement site

Sacral skin blood flow rate changes during active shoulder movements were significantly higher than those during active ankle movements ( $p < 0.01$ ) (Figure 3-a). Furthermore, sacral skin blood flow rate changes during passive shoulder movements were significantly higher than those during passive ankle movements ( $p < 0.01$ ) (Figure 3-b).

##### 2. Comparison of sacral skin blood flow rate changes by movement pattern

Sacral skin blood flow rate changes during active shoulder movements were significantly higher than those during passive shoulder movements ( $p < 0.01$ ) (Figure 3-c). In addition, sacral skin blood flow rate changes during active ankle movements were significantly higher than those during passive ankle movements ( $p < 0.01$ ) (Figure 3-d).



**Figure 3.** Change of sacral skin blood flow by the difference of movement of site and pattern.

- Sacral skin blood flow in the shoulder and the ankle during active movements.
- Sacral skin blood flow in the shoulder and the ankle during passive movements.
- Sacral skin blood flow during active and passive shoulder movements.
- Sacral skin blood flow during active and passive ankle movements.

#### Discussion

##### 1. Effects of movement site on sacral skin blood flow

The present study findings showed that the sacral skin blood flow during active shoulder movement was significantly higher than that during active ankle movement. It is plausible that the enhanced blood flow is attributed to the difference in movement muscle mass related to active shoulder and ankle movements, along with the effects of sympathetic nerves involved in upper- and lower-limb movements. With regard to the movement muscle mass, the main muscles related to shoulder movements include the deltoids, pectoralis major, and latissimus dorsi muscles, two of which are trunk muscles and have a large surface area. However, the primary muscles related to active ankle movements include the tibialis anterior, gastrocnemius, and soleus muscles, which are confined to the lower limbs. Therefore, during active ankle movements, less muscle mass is involved compared to that in shoulder movements. From these results, it can be inferred that the increased mass of sacral blood flow during shoulder movements was greater than that during ankle movements, because of the difference in blood circulation volume that is attributable to muscle

pumping [11]. Furthermore, regarding the effects of sympathetic nerves in the movement of the extremities, earlier reports show that sympathetic nerves tend to play a larger role in upper-limb movement [12]. Our findings suggest that these factors contributed to the increased blood flow in this study.

## 2. Effects of movement pattern on sacral skin blood flow

The results of this study show that sacral skin blood flow during active movement was significantly higher than that during passive movement of both the shoulder and the ankle. These findings may be attributed to the difference between active and passive movements. For instance, unlike passive movement, active movement includes repeated contraction and relaxation of muscles. Consequently, the change in blood flow rate during active movement might be greater than that during passive movement, because the blood flow to skeletal muscles passes through capillaries that run across the muscle fibers and muscle activity is expected to exert great mechanical effects on blood vessels. The reason for this, in part, may be because of the activity of cholinergic adrenergic fibers, which increases active movement to dilate blood vessels and increase muscle blood flow [13].

This study provided changes in sacral skin blood flow due to joint movements of the extremities over time. In addition, the results show that the blood flow is characteristically greater in the shoulder than in the ankle, as well as during active movement compared with passive movement. Furthermore, the findings show that shoulder and ankle movements, even passive movements, increased the blood flow, suggesting that muscle pumping allows blood circulation to continue and to increase. This data suggests the effectiveness of range-of-motion exercises in efforts to alleviate decubitus ulcers.

Regarding limits and future prospects, because this study was conducted on healthy young men, it will be necessary to consider different effects related to differences in gender, age, and physical build. Future studies targeting various subjects might demonstrate that the range-of-motion exercises facilitated by occupational therapists leads not only to maintenance and improvement of fibers but also to the prevention and/or improvement of decubitus ulcers. In addition, by specifically focusing on blood flow changes according to the difference in velocity and repetition

times of joint movements, the results of this study can be applied to occupational therapy programs.

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