



Original Article

Effects of skin stretching without joint movement on skin extensibility of rats

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Abstract. [Purpose] This study examined the possibility of maintaining skin extensibility by stretching the skin involved in disuse joint contracture. [Subjects and Methods] The study was carried out using 18 male Wistar rats. The rats were randomly allocated to three groups. The control group received no intervention for the right ankle joint, the fixation group received one-week's fixation of the right ankle joint in maximum plantar-flexion with a cast, and the stretching group received continuous stretching of the skin over the Achilles tendon for 30 min once daily for one week with the cast removed during the skin stretching, but the joint was not moved. On the final day, skin extensibility of the skin from the posterior aspect of the ankle joint was determined using a tensile strength tester and a length-tension curve. [Results] Statistical analysis of the data revealed significant differences in the skin extensibility among the three groups. The stretching group showed significantly greater improvement of skin extensibility than the fixation group. [Conclusion] Skin stretching without moving the joint was demonstrated to be useful for maintaining skin extensibility.

Key words: Skin, Extensibility, Rat

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INTRODUCTION

Joint contracture tends to increase progressively in severity as the joint is kept immobile for a prolonged period of time under the influence of joint fixation or illness. It is therefore essential to suppress the onset of joint contracture. One type of joint contracture is acquired contracture, which develops after birth in the presence of some factors. Depending on the factors responsible, acquired joint contracture has been subdivided into cutaneous contracture, connective tissue contracture, myogenic contracture, neurogenic contracture, and arthrogenic contracture (contracture of joint origin)¹⁾. Of these types of joint contractures, cutaneous contracture is usually considered to develop from skin burns, injury, scarring, etc²⁾. Stretching of the affected skin in cases of burns has been used as a means of treating scar contracture. This therapy has been shown to be effective at improving the extensibility of scarred tissue³⁾ and expanding the area of the scarred tissue⁴⁾. These previous reports indicate the efficacy of skin stretching on cutaneous contracture arising from scarring.

It has also been shown that the skin is involved in disuse joint contracture arising from joint fixation or immobility⁵⁻⁷⁾. Our

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previous study demonstrated that 2 weeks of joint fixation reduced the extensibility of the overlying skin⁸). Joint movements are normally accompanied by stretching of tissues such as the skin and muscles; however, even in cases when a joint is impossible to move, the skin retains its capability to stretch without moving the joint. Maintaining the extensibility of the skin may potentially minimize the progression of joint contractures, even when the joints cannot be moved. However, no previous study has elucidated whether skin extensibility can be maintained by stretching the skin without performing any joint movement.

The present study was designed to examine the possibility of maintaining the skin extensibility through stretching of the involved skin in cases of disuse joint contracture.

SUBJECTS AND METHODS

The animals used in this experiment were 8-week-old female Wistar rats (n=18). The animals were housed in cages and given free access to food and water. The environment of the animal care room was maintained at a constant room temperature of 23 °C with an air conditioner, and day and night were artificially regulated by setting lights-on for 12 h and lights-off for 12 h each day. This animal experiment was conducted in accordance with the National Institute of Health (NIH) Guide for the Care and Use of Laboratory Animals, and the experiment was carried out with the approval of the Research Ethics Committee of the Prefectural University of Hiroshima.

The duration of the experiment was one week. Six rats were allocated to the control group, which received no intervention for the right ankle joint. Another 6 rats were allocated to the fixation group, in which the right ankle joint was fixed in maximum plantar-flexion with a cast for one week. The remaining 6 rats were allocated to the stretching group, which received fixation of the right ankle joint in maximum plantar-flexion with a cast, and stretching of the dorsal skin over the ankle joint once daily for 30 minutes with the cast removed during the skin stretching, which was performed without joint movement.

Joint immobilization was achieved by the method described by Ono et al. Pentobarbital (40 mg/kg) was injected intraperitoneally (i.p.), and under anesthesia the ankle joint was held in full plantar flexion and immobilized with a plaster cast from the thigh to the foot area⁹). In order to prevent the cast from breaking or falling off, it was covered with a stainless steel net. During the fixation period, close attention was paid to the onset of edema and cast loosening, and the cast was renewed as needed. In the stretching group, skin stretching was performed after removal of the net and the cast, under anesthesia induced by intraperitoneal injection of pentobarbital sodium (40 mg/kg, i.p.). During the stretching, the rats were placed in the lateral decubitus position, with the right ankle joint placed upwards and kept in maximum plantar-flexion to avoid ankle joint movement. Stretching was carried out using an unstretchable segment of tape which could be attached to the skin, so that only the skin could be stretched, without any motion of the joint. One tape was attached to each of the proximal and distal parts of the rat's right Achilles tendon. The skin was stretched along the major axis of the leg in both the proximal and distal directions. A stretching force equal to 0.3 N was applied with the use of a spring scale, following the method of a previous study¹⁰).

Skin extensibility was evaluated using a tensile strength testing machine (Autograph Tensile Tester model AG-50kNG, Shimadzu Corporation) on the last day of the experiment⁸). The skin sample for the test was obtained from over the Achilles tendon. During maximum plantar-flexion of the ankle joint, the skin was marked at 2 points: Point A, 3 mm distal to the heel; Point B, 10 mm proximal to Point A. The length of the skin sample between the distal end (5 mm distal to Point A) and the proximal end (5 mm proximal to Point B) was 20 mm and its width was 4 mm. Each rat was subsequently sacrificed by exsanguination via the abdominal aorta. Skin samples were immediately collected from each of the sacrificed rats. Holes were made at Points A and B of the skin sample, and an unstretchable stainless steel wire was inserted through the holes, followed by fixation of both ends of the wire on the tensile testing machine with the use of a clamp. The test start point of the sample was adjusted with calipers, so that the distance between the two points of wire insertion was 10 mm (the distance between the two marked points). The tensile strength test was conducted once on each skin sample, with the starting distance of the stretch set at 0 mm and the starting tension at 0 N. The extent to which the skin was stretched by the force of 0.3 N from the start point was measured as an indicator of the skin extensibility.

We used a software program to perform the statistical analysis. The non-parametric Kruskal-Wallis test was used to compare skin extensibility. The Steel-Dwass test was used for post-hoc comparison. A significant difference was concluded to exist at a probability value of less than 5% in all of the statistical tests.

RESULTS

The results of the skin extensibility test are shown in Table 1. Statistical analysis of the data revealed significant differences in the skin extensibility among the three groups. The skin extensibility was significantly lower in the fixation and stretching groups than in the control group. The stretching group had significantly higher skin extensibility than the fixation group.

DISCUSSION

This study examined whether or not skin stretching, without any joint motion, would allow skin extensibility to be maintained. Stretching is usually performed to cause the soft tissues to be stretched while moving the joint. The effects of

Table 1. The changes in skin extensibility

Group	Distension distance (mm)
Control	5.1 ± 0.7
Fixation	2.8 ± 0.4 *
Stretching	3.7 ± 0.4 *†

Values are mean ± SD.

*Significant decrease compared to the control group ($p < 0.05$)

†Significant increase compared to the fixation group ($p < 0.05$)

stretching have been evaluated in previous experimental studies^{11, 12}). In previous experiments using animals, the ankle joints of rats were fixed in maximum plantar-flexion with the use of a cast and the range of motion of the ankle joint was measured after repetition of once daily stretching of the plantar muscles originating in the ankle joint with the cast removed during stretching. In these experiments, continuous stretching (30 min/day) resulted in suppression of the onset of joint contracture¹³). In human experiments measurement of the passive torque after repeated stretching of the ankle joint in the direction of dorsiflexion (30 min/sess) showed there was a decrease in the passive torque in this direction¹⁴). In these past experiments, the efficacy of stretching while the joint was moved was manifested by improvement of the muscle extensibility, and the target of the stretching was the muscles. However, it has been reported that the tissues responsible for joint contracture are not confined to skeletal muscles, but include the skin as well⁵⁻⁷). As is the case with skeletal muscle, the skin can also be stretched by the motion of stretching while moving the joint. In cases where the joint is forced to be fixed with a cast, stretching of the skin without the joint moving at the same time is possible if a window is opened in a part of the cast. Skin is the only tissue which can be stretched without moving the joint. Therefore, unlike in previous studies, it was determined that in this study, the effects of stretching exercises targeting exclusively the skin would need to be examined by carrying out those exercises without joint movements to prevent them from exerting effects on the muscles.

The results of the present study indicate that skin stretching without joint motion can also maintain skin extensibility. Tissue expansion was previously reported as a method of stretching the skin without moving the joint. In the technique of tissue expansion, a capsule is inserted under the skin and gradually inflated to cause stretching of the skin and soft tissues¹⁵). Kabaker et al. used a tissue expander in male patients with scarring alopecia caused the skin of the hair-covered scalp to stretch and replace the skin of the area of hair loss¹⁶). Bauer et al. used a tissue expander in patients with nevus to stretch the skin of the inguinal and hypogastric regions, followed by use of the stretched skin to cover the nevus-affected area¹⁷). The results of these studies indicate that tissue expansion can improve skin elasticity through stretching of the skin. However, because tissue expansion involves surgical stress, it is never used to suppress the onset of disuse joint contracture. The present study is significant in that it revealed the efficacy of skin stretching on the body surface without movement of the joint.

The limitations of our study were as follows. The reported changes in skin area stretched by the tissue expansion technique include epidermal cell proliferation¹⁸), epidermal thickening¹⁹), dermal thinning²⁰), etc. The improvement in the skin extensibility observed in the present study, following stretching without simultaneous joint movement, seems to be explained by changes in the skin similar to those reported by previous studies. However, although morphological changes and biochemical changes should have been examined, these were beyond the scope of our study. As a result, these issues remain a matter of speculation. In the future, morphological and biochemical changes in the skin will need to be investigated after performing stretching exercises without joint movements.

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