J. Phys. Ther. Sci.
26: 11–13, 2014

Effect of Skin Resection on the Improvement of Joint Contractures in Rats

Atsushi Tasaka, MS, RPT[1)*], Takeya Ono, PhD, RPT[1)], Sadaaki Oki, PhD, MD[1)], Namiko Umei, PhD, RPT[2)], Hideki Ishikura, MS, RPT[1)], Kazuki Aihara, RPT[1)], Yuta Sato, RPT[1)], Akira Otsuka, PhD, RPT[1)], Norio Muto, PhD[1)]

[1)] *Graduate School of Comprehensive Scientific Research, Prefectural University of Hiroshima: 1-1 Gakuen Machi, Mihara City, Hiroshima 723-0053, Japan*

[2)] *Department of Physical Therapy, Faculty of Health and Welfare, Prefectural University of Hiroshima, Japan*

Abstract. [Purpose] The effect of skin resection on joint contracture was determined by comparing the first measurement of range of motion after cast removal and the second measurement after the skin resection. This study aimed to verify that both the joint movement during the measurement and skin affect range of motion. [Subjects] Twelve female Wistar rats were used. [Methods] The right hind limb ankle of each rat was immobilized in complete plantar flexion in a cast. In the resection group (n = 6), the skin of the right hind limb ankle was removed surgically, but not in the non-resection group (n = 6). In the resection group, the first measurement of the dorsiflexion angle was obtained after the cast was removed, and the second measurement was obtained after skin resection. In the non-resection group, both measurements of the dorsiflexion angle were obtained soon after the cast was removed. [Results] Compared with the non-resection group, the resection group showed a significant increase between the first and second measurements of range of motion. [Conclusion] These results show that range of motion is substantially affected by skin, in addition to joint movement, during measurement.

Key words: Joint contracture, Skin, Rat

(This article was submitted Jun. 11, 2013, and was accepted Jul. 22, 2013)

INTRODUCTION

Joint contracture occurs after a long period of fixation and/or immobilization due to fracture or impaired consciousness. Animal experiments have shown that joint contracture is affected by the skin. The influence of the skin on joint contracture has been determined in several studies based on the change in range of motion (ROM) between the first measurement after cast removal and the second measurement after skin resection[1–4)]. Studies investigating multiple measurements of ROM in joint contracture have reported that a single joint movement can improve the ROM[5, 6)]. Therefore, the authors of these previous studies suggested that joint contracture is influenced by both joint movement and skin incision. However, no studies have measured ROM twice without skin resection to determine the changes in ROM.

In the present study, our purpose was to determine the effect of the joint movement through ROM measurements performed twice after removal of the cast, and the effect of the skin when ROM was measured once after the cast removal and once again after skin resection of rats with plantar flexion contractures.

SUBJECTS AND METHODS

Twelve, 8-week-old female, Wistar rats with an initial body weight of 189.1 ± 5.3 g were used. The animals were housed in a temperature-controlled room at 23 °C with a 12-hour light-dark cycle. The rats were provided free access to standard rat food and water. The experiment was conducted in accordance with our university's guidelines for animal experimentation (No. 12 MA-003).

The duration of the experiment was 2 weeks. The rats were randomly divided into 2 groups. Under pentobarbital sodium anesthesia (40 mg/kg b.wt), the right ankle joint of each rat was immobilized in full plantar flexion in a cast from the toes to above the knee joint. In addition, the cast was covered with a stainless steel net to prevent breakage and falling. When the toes became edematous due to fixation, the cast was replaced. In the resection group (n = 6), the skin of the right ankle was removed surgically, but it was not removed in the non-resection group (n = 6).

Before the experiment and after 2 weeks, dorsiflexion of the ankle joint was measured. At the end of the immobilization period, the rats were sacrificed with pentobarbital sodium anesthesia (40 mg/kg b.wt), and blood was removed by cutting the abdominal aorta. In the resection group, the

*Corresponding author. Atsushi Tasaka (e-mail: p0824009fa@yahoo.co.jp)

Table 1. The changes in ROM of ankle dorsiflexion (in degrees)

Group	After two weeks		
	First measurement	Second measurement	First − second[b]
Resection (n=6)	113.1±9.9	103.9±11.5[a]	9.27±2.8
Non-resection (n=6)	105.7±4.7	102.1±3.8[a]	3.64±1.0

Values are means ± SD
a: significant decrease compared with first measurement (p<0.05)
b: significant difference between resection and non-resection group (p<0.01)

first measurement of the dorsiflexion angle was obtained after the cast was removed, followed by the second measurement after skin resection. The skin was resected from the lower leg to the heel. Skin resection was carefully done without affecting dorsiflexion of the ankle joint. In the non-resection group, both measurements of the dorsiflexion angle were obtained in the same manner after the cast was removed. When measuring dorsiflexion, the rat was positioned on its side with the hip and knee fixed in flexion. A force of 0.3 N was applied perpendicularly to the sole of the foot using a tension meter[7)] (KYOWA Co., LTS-1KA). A digital camera recorded the test from directly above the hind limb. Recorded videos were downloaded to a computer to extract still images of dorsiflexion at the moment of application of the 0.3 N force. The ROM of dorsiflexion was measured from the still images using computer software (ImageJ version 1.44p; USA). The ROM of dorsiflexion was defined as the angle obtained from a line parallel to the longitudinal axis of the fibula and a line parallel to the bottom of the heel to eliminate forefoot movement from the measurement. Higher ROM values indicated greater restriction of movement. Dorsiflexion was measured 3 times, and the mean value was used in the analysis.

The Wilcoxon test was used to compare the change in ROM between the first and second measurements. The Mann-Whitney U test was used to compare the differences in measurements between the two groups. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

The data of dorsiflexion ROM are shown in Table 1. There were no significant differences between the two groups before the experiment. The ROM measurements decreased significantly in both groups between the first and second measurements. Compared with the non-resection group, the resection group showed a significant increase in ROM between the first and second measurements.

DISCUSSION

Skin is one of the tissues involved in the occurrence of joint contracture[8)]. Skin contracture occurs after damage from burns or wounds, such as hypertrophic scarring due to damage beyond the basement membrane separating the epidermis and dermis[9)]. Contracture of the skin and soft tissue that occurs after joint immobilization has been investigated in previous animal experiments. In these studies, the cause and contribution rate of soft tissue contracture were clarified by measuring the ROM of the joints in general.

Ichihashi et al.[3)] fixed rats' knees in full flexion for 30 days and measured the ROM of knee extension after removal of the cast, and resection of the skin and muscles. They found an increase in ROM after resection of the skin and muscles. Okamoto et al.[4)] fixed rats in full plantar flexion for 1, 2, 4, 8, and 12 weeks and reported that the ROM of plantar flexion improved after cast removal and resection of the skin and muscles for all time periods of immobility. These previous studies indicate that skin affects contracture formation resulting from joint immobilization. In our study, joint contractures occurred in all rats after joint fixation. Several methods have been reported for establishing joint contracture by joint immobilization. The method of immobilization used in this study was carried out in accordance with that reported by Ono et al[10)]. Our results show that the ROM of dorsiflexion increased between the first and second measurements in both groups. This indicates that the ROM increase observed in the second measurement in the non-resection group may be due to the stretching of the skin, because the measurements were carried out using the same torque. Furthermore, the increased ROM in the second measurement in the resection group was considered to be the sum of the stretching effect from moving the joint during the measurements and the skin resection. The change in the ROM between the first and second measurements was greater in the resection group than in the non-resection group. The second ROM measurement in the resection group improved 9.27 ± 2.8 degrees from the first measurement, an improvement of approximately 12% of the full ROM limitation. In the non-resection group, the ROM improved 3.64 ± 1.0 degrees, an improvement of approximately 5% of the full ROM limitation. Therefore, we estimate the skin effect was approximately 7%, the result of subtracting the joint movement effect (5%) from the change in ROM (12%) in the resection group.

Skin contracture after burns and wounds is reported to be caused by excess proliferation of fibroblasts[11)], abnormal generation of collagen fibers[12)], and contraction of the wound[13)], followed by scar contracture. However, skin contracture due to joint immobilization has not previously been clarified. The results of our study and previous studies demonstrate that skin has a critical role in the formation and treatment of joint contracture, because we found that skin resection improved ROM after joint immobilization. Stretching of the skin by an open-window procedure[14, 15)] may be effective when immobilization treatment is used after fracture. In the future, it will be necessary to examine how the skin itself changes during joint immobilization.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI grant number 24500606.

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