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Laboratory Experiments for the Force and Load with Pseudo-Dynamic Test: Ex-vivo Study for the Manual Therapy

Background: Because of the lack of accurate values for applied forces in manual therapy, manual therapists relies on the magnitude of the individual's perception during applying the force. However, excessive loading maneuvers carry risks for patients.

Objective: To establish the relationship between the maximal force applied to swine skin with the specific region, sex, and baseline parameters of the subject.

Design: Ex-vivo Study and laboratory Experimental research

Methods: 3.5 kg of Korean pork sirloin that is a piece of swine was handled and it was set 3 dimensions; #A; #B; #C. Forty-seven participants who has no experience in physical therapy randomly carried out the experiment, indicated to push each place of the pressure spots with same posture and process under supervision from the instructor who has over 15 years of manual therapy, and we measured the pressure force in each time.

Results: The biggest pressure force was recorded in spot #A, and #B was represented after #C. Pressure on #A showed certain statistic relation with height ($r=.317$, $p<.05$) and weight ($r=.434$, $p<.01$); pressure on #B showed certain relation which has statistical meaning with only height ($r=.401$, $p<.01$); pressure on #C emerged to have statistic relationship with height ($r=.308$, $p<.05$)and weight ($r=.428$, $p<.01$). The age aspect revealed relation with pressure on #A, #B and #C, but that was not statistically significant.

Conclusions: It can be inferred that there is the most loss of pressure in the area where cartilage is like an island in the middle.

Key words: *Manipulation; Pressure force; Manual therapy*

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INTRODUCTION

Several approaches have been used in the rehabilitation field for relieving pain or set the body alignment, and one of the methods is manual therapy.[1] This is called a manipulation technique, and it is used by physical therapist many years to decrease pain and increase movement range for patients with musculoskeletal problems. In particular, the manipulation technique can be used when the joint mobility is significantly reduced, or when the improvement of the joint mobility after mobilization treatment is not satisfactory. Manipulation technique is controlling clients or objects to one's own physical advantage, often unfairly or dishonestly through applying excessive force in such a short time span and using this sequence repetitively before one's returning of elastic force. This kind of methodology might have some risks according to the fact that repeatedly applying forces above the threshold that the patient's body tissue can withstand manipulation.[2]

Some of the physical therapists or medical doctors have been put the manipulation into controversial issues that the conducting manipulation on the smallest, most extensive range of vertebrae of the spine might, in some instances, lead to disability or death. The frequent occurrence of such medical accidents is due to the lack of prior review of damage to

blood vessels and nerves around the neck, damage to the major ligaments of the neck, or the transfer of relatively excessive force to the neck.[3,4] It is strongly recommended to perform the test on the ligament and vascular compression before application.

However, the solution to the direct and intrinsic path, rather than the cursory method, would be the materialization of quantified data that the physical process of quantities such as force or weight, safety range of the force applied in manual therapy, is expressed in the number of units. Consideration of the appropriate and quantitative applied force to be used in manual treatment, one of the problems that have not been solved until now, is essential since the force applied in manual therapy depends entirely on the therapist's own perceived sensation, even the variation would be considered in force applied among eligible experienced therapists relatively high. Even if the technique acquired by the same therapist, applied to the same patient in grades (Ⅰ~Ⅳ), the forces on the connective tissue of the patient are not constant. Besides, it can be divided into techniques involve shear, longitudinal stretch extension, deep pressure compression, and unwinding twisting movements according to the direction and method of force.[2] There is a hypothesis. As a result, many researchers attempt to prevent other accidents by applying a safe range of force by measuring the force generated during manual therapy.

In general, since the 'mobilization' contains relatively small forces and slow movements, it is relatively safe compared to the 'manipulation technique', resulting in fewer side effects.[5] During therapy sessions, the force value was measured by attaching a load cell to the treatment table or attaching strain gauges (pressure sensors) on the skin or therapist's gloves.[6] However, these attempts may cause a damper effect when the load cell is attached to the treatment table, and the adhesive applied to the glove may have different characteristics, and thus, a correction factor for the error may still be presented. It is not very easy to verify because it is not defined fully yet. Before this concept is applied to the human body, laboratory clinical trials applied to connective tissues of similar nature should be preceded.

Therefore, in this study, the force activity when applying manual therapy using swine skin, which is suitable for omnidirectional experiment and measurement and most like human skin, is measured differently according to the thickness or distribution of dermal and muscle layer to predict the applied stress. Also, since this study is one of the earliest studies in the relevant field here in South Korea, the pressing force's effectiveness in terms of additional data acquisition was considered related to gender, human physical characteristics (height, weight, etc.), measurement location (back fat, muscle), and cartilage.

SUBJECTS AND METHODS

Subjects

Forty-seven participants aged from 21 to 29 years, 26 males and 21 females who had never been exposed to manual therapy or educated by physical therapists were recruited in this study; because manual therapy technic or experience could affect the experimental process. They were randomly allocated to the order. These participants made those sequences with equivalent position and posture for pressure of manual therapy (Table 1).

Table 1. Baseline characteristics of the participants

Gender	Participants (n = 47)
Female	26 (53.1%)
Male	21 (42.9%)
Median age (year)	25
Weight (kg)	68.62 ± 2.08
Height (cm)	168.69 ± 1.28

Data listed as mean ± SD.

Ex-vivo Materials

It is improper to repeated post-anterior movement on human body from untrained participants, we used pork sample for ethical obligation. 3.5 kg of Korean pork sirloin that is a piece of swine which is cut from the bottom and side parts of a pork's back was sampled and it was stored 298 K of temperature for each trial (Fig 1). It was 300 mm of length and 600 mm of thickness which is suitable practicing for manual therapy motion.

Outcome Measures and Experimental Procedures

For establishing the similarity to human body, we designated three of virtual pressure spots; #A was consisted of thick epithelium layer (20 mm), vessels with muscles, additional fat (13 mm) and few microvessels or cartilages (5 mm); #B contained thinner epithelium layer (10-12 mm), thin microvessels or cartilages (2-3 mm), vessels and muscles (18 mm); #C

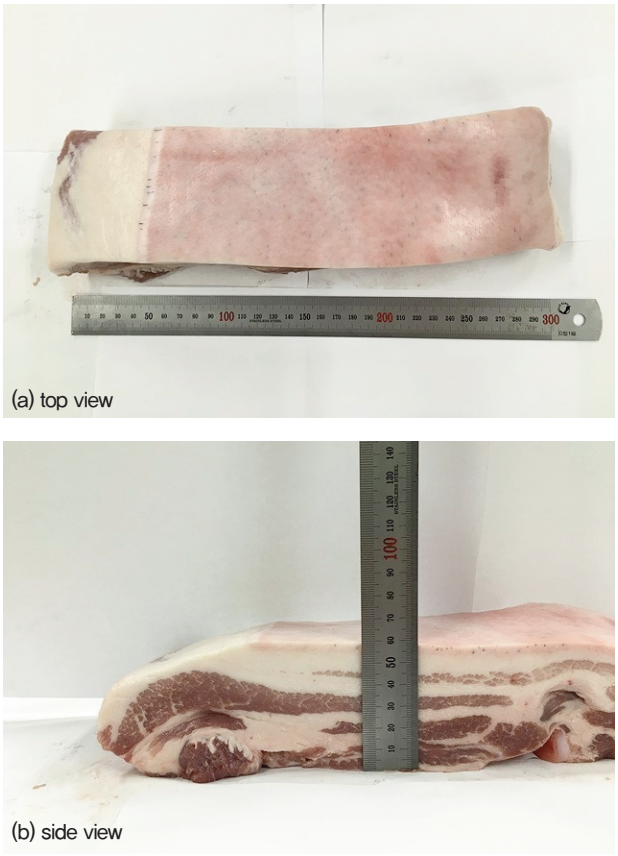

Fig. 1. Appearance of the sample

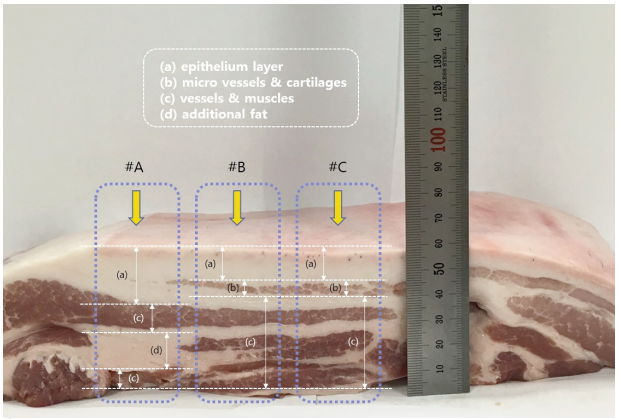

Fig. 2. Strain gauges and measurement points according to layer distribution.

had thinner epithelium layer (10 mm), thicker microvessels or cartilages (6–7 mm), vessels and muscles (25 mm).[7] These spots were 50 mm apart from each other and for conducting the experiment under various condition of the body (Fig. 2).

Ex-vivo trials were undertaken push the virtual pressure on the attached strain gauges (pressure sensors) with participants' own thumbs with other phalanges flexed. Arduino Uno R3 model (a micro-controller board based on the ATmega328) were used for collecting data from the strain gauges (Fig 3).

Forty-seven participants randomly carried out the experiment and were allowed to push each place of the pressure spots with same posture and process under supervision from the instructor who has over 15 year of manual therapy; the participants asked their upper arm straight, using their thumbs, and push the buttons with maximum power as biggest as they were possible. Raw pork meat was refrigerated at about 278 K. until the experiment, and experimented at room temperature about 303 K.

The primary outcomes were set to find out according to layer distribution which includes epithelium layer, vessels with muscles, additional fat, microvessels/cartilages vessels and muscles. Secondary results with height, weight, gender, age and other information were measured that is expected to be referenced for other studies.

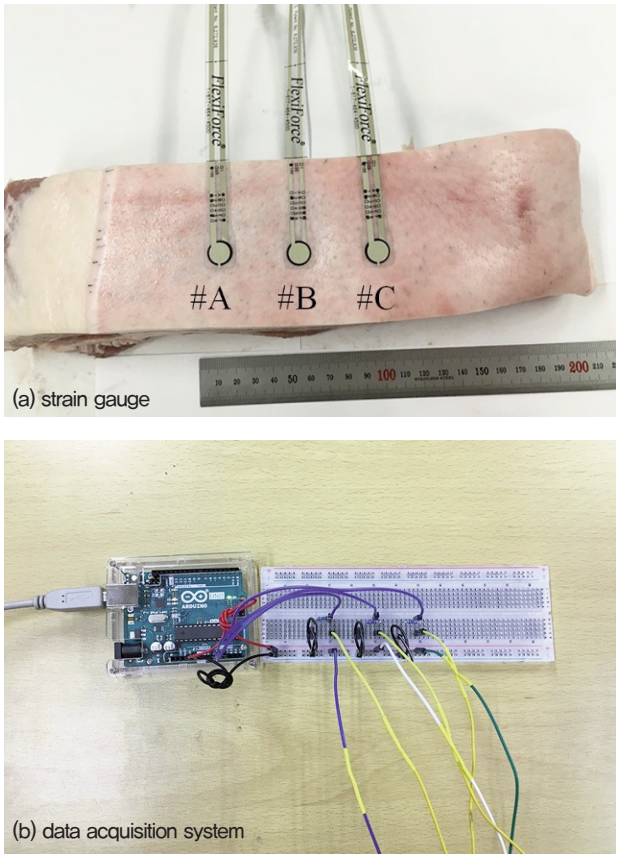

Fig. 3. Experimental setup

Data and Statistical Analysis

SPSS Statistics 21 software for Windows (IBM, Armonk, New York) was used for statistical analysis of all the results. Parametric statistical assessment was applied since the data were almost normally distributed, continuous variables and fulfilled homogeneity of statistical variances, an independent t-test and ANOVA (Analysis of Variance) were adopted to identify within-layer distribution differences, with α at .05. Pearson's correlation analysis for statistical works in between pressure, height, weight and age. post-hoc comparison was assessed by Bonferroni correction.

RESULTS

Primary Outcomes

The simple average scores according to each pressure location is distributed in Table 2. The biggest pressure force was recorded in spot #A, and #B was represented after #C. The force was lowest in thinner epithelium layer (10–12 mm), thin microvessels or cartilages (2–3 mm), vessels and muscles (18 mm).

Pressure on #A showed certain statistic relation with height (r=.317, p<.05) and weight (r=.434, p<.01); pressure on #B showed certain relation which has statistical meaning with only height (r=.401, p<.01); pressure on #C emerged to have statistic relationship with height (r=.308, p<.05) and weight (r=.428, p<.01). The age aspect revealed relation with pressure on #A, #B and #C, but that was not statistically significant.

Table 2. Overall pressure according to locations

	Pressure on #A	Pressure on #B	Pressure on #C
Pressure (pa) mean	37.787234	16.765957	36.765957

Secondary Outcomes

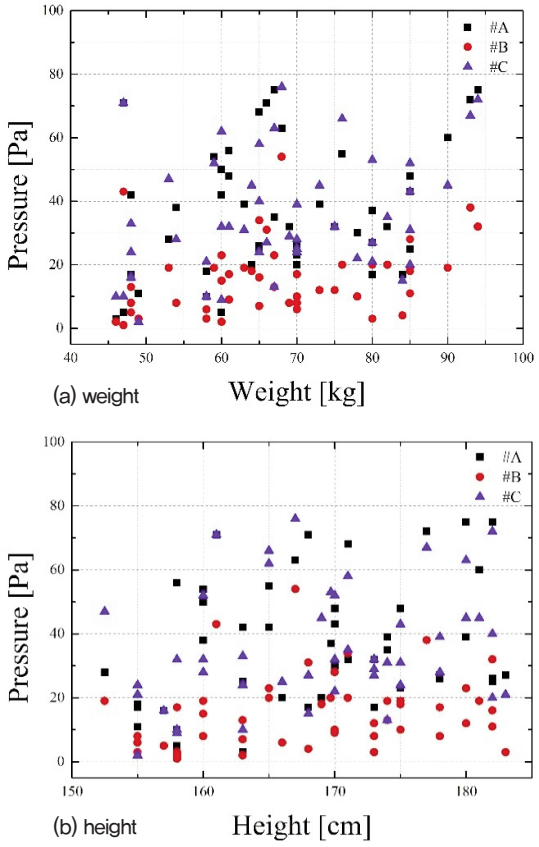

Fig. 4. Pressure distribution of the data according to weights and heights

Table 3. Correlation between variables

Variables	1. Pressure on #A	2. Pressure on #B	3. Pressure on #C	4. Height	5. Weight	6. Age
1. Pressure on #A	1					
2. Pressure on #B	.866**	1				
3. Pressure on #C	.836**	.884**	1			
4. Height	.317*	0.247	.308*	1		
5. Weight	.434**	.401**	.428**	.731**	1	
6. Age	0.088	0.139	0.067	0.140	0.176	1

#A: consisted of thick epithelium layer (20 mm), vessels with muscles, additional fat (13 mm) and few microvessels or cartilages (5 mm); #B: contained thinner epithelium layer (10–12 mm), thin microvessels or cartilages (2–3 mm), vessels and muscles (18 mm); #C: had thinner epithelium layer (10 mm), thicker microvessels or cartilages (6–7 mm), vessels and muscles (25 mm); *p<.05, **p<.01

Pressure according to weight and height

Whole pressure distribution according to weight and height is showed in figure 4. The simple average scores according to each pressure location was showed in Table 2 and the distribution chart results would similar from the original results; biggest pressure force was recorded in spot #A, and #B was represented after #C. Pressure #B was represented as contained thinner epithelium layer (10–12 mm), thin microvessels or cartilages (2–3 mm), vessels and muscles (18 mm) and the pressure force was the lowest distributed in this area.

Pressure according to weight based on genders

Pressure distribution according to weight based on genders is showed in figure 5. The original average scores according to each pressure location was already showed in Table 2 and the distribution chart results would similar from the original results; biggest pressure force was recorded in spot #A, and #B was represented after #C. Response tendency appears that the pressure force would increase following the weight on both genders.

Pressure according to height based on genders

Pressure distribution according heights based on genders is showed in figure 6. Like the original average scores, it denotes lowest pressure force was recorded in spot #B; as contained thinner epithelium layer (10–12 mm), thin microvessels or cartilages (2–3 mm), vessels and muscles (18 mm). Response tendency appears that the pressure force would increase following the height on both genders and this stands for gradual compare to previous pressure distribution according to weight based on genders.

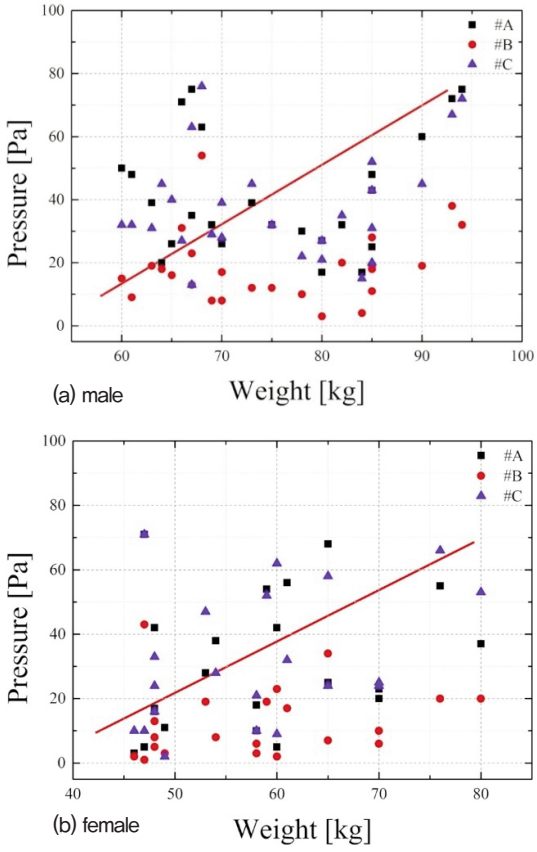

Fig. 5. Pressure distribution of according to weights based on genders

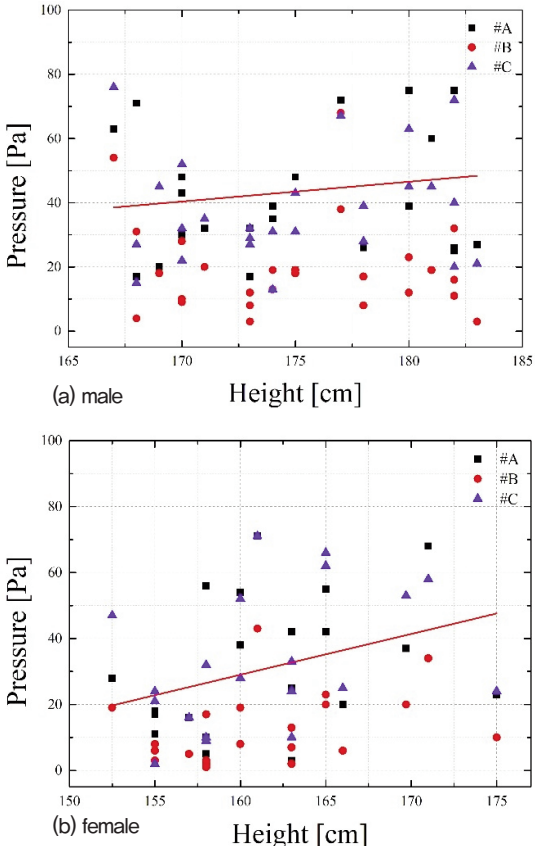

Fig. 6. Pressure distribution of according to heights based on genders

Ecumenic compressive stress appeal to gender

For systematic use of the data, we converted compressive stress owing to gender. The pressure force was applied to the human body might signify in accordance with subjects' body shape, gender and even pressure area, so it is needed to be probed by converting compressive stress under any circumstances (pressure/area). Compressive stress is a force that causes a material to deform to occupy a smaller volume. When a material is experiencing a compressive stress, it is said to be under compression. A high amount of compressive stress, such as tensile stress, leads to failure due to tension. A compressive stress causes a material to compress or shorten.

Area #A (consisted of thick epithelium layer (20 mm), vessels with muscles, additional fat (13 mm) and few microvessels or cartilages (5 mm)) denoted 556.68 mPa (0.56 Pa) in male and 391.08 mPa (0.39 Pa) in female, and this is 0.7-point different distribution tendency. Pressure point #B contained thinner epithelium layer (10-12 mm), thin microvessels or cartilages (2-3 mm), vessels and muscles (18 mm) showed 249.68 mPa(0.24 Pa) in male and 163.05 mPa (0.16 Pa) in female, and this is 0.65-point different distribution tendency. Point #C had thinner epithelium layer (10 mm), thicker microvessels or cartilages (6-7 mm), vessels and muscles (25 mm) and represented 509.55 mPa(0.50 Pa) in male and 410.19 mPa (0.41 Pa) in female, and this is 0.8-point different distribution tendency. Each proportion average point was 0.72 and this could be used as a correction constant.

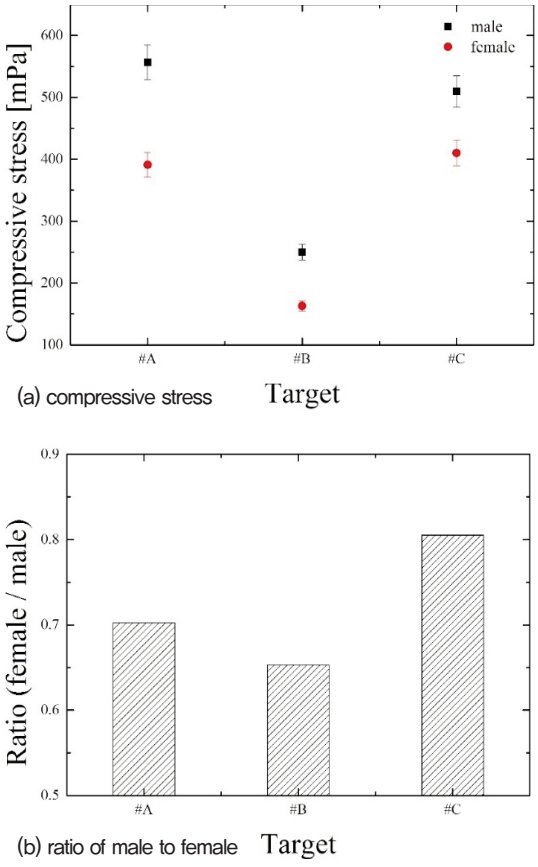

Fig. 7. Results of the ecumenic compressive stress appeal to gender

DISCUSSION

Manual therapy has been developed with a variety of concepts, styles, and goals, but it is the same that the therapist uses himself as a therapeutic tool to apply pressure on the patient or subject's body. Manual therapy has proven effective, but it is not a complete intervention. There have been reports of side effects and contraindications in clinical practice. The most essential of these is the unquantified pressing force, which is the limitation that different therapists use different magnitudes, directions, and ranges of motion when the same subject is given the same prescription. Even if a skilled therapist applies the same force or grade, the magnitude of the force can be very different. The need for quantification may be necessary as of the nature of the therapies that rely solely on the therapist's subjective judgment and eye-to-eye experience. Assume that patient's arm about 30 degrees shoulder flexed when a prescription is given to perform an upper limb articulation to lift the upper limb, the subject's condition is as if any therapist could perform the same procedure in a nearly approximate range using a goniometer or other digital goniometer. If you can identify the appropriate force or grade in the form of a number, it can contribute to communication between therapists and the specification of medical records. It can be a basis for accident litigation and is expected to be of great help in overcoming the above limitations.

In addition, the researchers foresaw that this study would provide a platform for the development of more advanced and advanced therapies.

The magnitude of the pressure change according to weight or height is sufficiently predictable and would have little meaning in scientific clinical study, but there is little data on related studies so far. In this study, results shown when pressed with the same force, pressure on A; The largest pressure distribution was found in the adipose area, pressure on C; Veins and muscle areas, pressure on B; The pressure

tended to decrease gradually in the order of co-existing microvascular and cartilage. As a result, it can be inferred that there is the most loss of pressure in the area where cartilage is like an island in the middle.

Load refers to external factors that attempt to deform materials and other materials (body and skin). If the material is assumed to be a body, a load acts on it, causing the load to propagate inside, creating an internal repulsive force that tries to resist the deformation, and the whole body tries to find an equilibrium. In this case, the numerical value expressed as the unit area of the force, propagated to all the points inside to cause deformation, may be defined as stress. It is assumed that all parts except bones of the body are elastic parts so that a load is applied to these parts and deformation occurs. The ideal result is considered when the force applied inside the body to induce deformation and the internal force to resist deformation are in equilibrium.

In the case of the load, the relatively low load in the situation of the female, higher in the male, suggesting that the amount of muscle and other environmental effects were caused by the continuous exercise or intensive physical daily activity. In addition, since women in this study usually perform aerobic exercise or cardio exercise which has a higher dynamic effect than muscular exercise, it is estimated that the pressing force is relatively low.

According to a study by Chaudhry et al. [1] the arm muscles (e.g. biceps) are viscoelastic, reported that deformation may occur after some degree or in about 60 sec. This results in a relatively short time of about 0.25 sec. in back part. This suggests that the incidence time duration of elasticity and the quantitative force pressure can be an advantage for the patient during the treatment. It is predicted that by using only elasticity of the muscle, the effect of lower muscle extension and stress can be seen through the repulsive force. It is reported that the difference in left and right muscle activity occurs about ±10% when applied to the erect spinal muscles.[8] In addition, studies on muscle tension abnormalities, twisting and repetitive movements, abnormal postures, and the like, such as fasciculation syndrome, have been reported.[9] Central paralysis, and cervical spine may be accompanied by pain with involuntary abnormal movements such as lateral bending, extension and torsion, and in various samples, the effect will be maximized.[10,11]

However, the application of the technique to muscle tension abnormality in the previous study report[12] could be very limited, such as the administration of botulinum toxin to control passive surface symptoms. Through this, in-depth research on each location and validation for different patients should be developed to cultivate active balance control ability of human body.

In addition, in this study, there are lack of this kind of cases, if the factors except the frequency treatment method are strictly controlled and performed after a long time, only subjective load and strength can be evaluated for symptoms, and quantitative biomechanical evaluation to be performed. However, the application of the technique to muscle tension abnormality in the previous study report[12] could be very limited, such as the administration of botulinum toxin to control passive surface symptoms. Through this, in-depth research on each location and validation for different patients should be developed to cultivate active balance control ability of human body.

CONCLUSION

The purpose of this study is to measure the pressure applied during manual therapy by using a strain gauge and to convert the applied stress through the value to obtain the raw data in actual application. Through the basic experimental method according to the previous study, the stain gauge was attached to the swine skin with flesh and the characteristics of the participants were analyzed. The results of the experiment with 47 non-majors in physical therapy were summarized as follows. 1) As a result of measuring the pressure load of the subject, it was not related to the height and the change of the load according to the weight was small but qualitatively increased. 2) In the section of 60-70 kg body weight, both men and women had relatively high loads, and after 70 kg, there was no significant changes. 3) At the #A point where the fat layer is the most, there is a difference in the ratio of men and women, which is estimated to be able to continuously apply a relatively high force. 4) By the converted stress of men and women, the average ratio of each position could be predicted, and it is estimated that the modification factor could be applied according to the characteristics of the manual therapy operator. The raw data of this study also suggests the magnitude of maximal force according to skin or muscle characteristics, and the proportion of adequate force according to gender, age and weight of healthy young people during manual therapy. In addition, further studies on the measurement of loads on the depth direction and various positions of the skin should be necessary.

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