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Effects of different bed heights on the physical burden of physiotherapists during manual therapy: an experimental study

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Abstract: This study aimed to determine the effect of physiotherapists' physical burden caused by different bed heights during manual therapy. Thirty-three male physiotherapists performed tasks simulating lumbar massage and passive hip abduction range-of-motion exercise (ROM) on the beds with low height (LH) and adjusted height (AH), with each task performed three times. The anterior inclination angle of the physiotherapist's trunk was measured, the surface electromyograms of the erector spinae and trapezius muscles were recorded, and perceived stress was assessed. The indexes obtained were statistically compared for different bed heights. Additionally, the lumbar disc compression force and flexion torque were estimated. The lumbar burden caused by the excessive bending and the biomechanical burden and perceived stress were stronger at LH than AH. In ROM tasks using the right hand, the muscle activity was lower at the left lumbar region at LH than at AH. At LH, the anterior inclination angle increased and the lumbar muscle activity declined as the number of tasks increased. The burden on the shoulders was not significantly different by bed heights. Our results showed that, when physiotherapists perform manual therapy, it is necessary to adjust the bed height to reduce physical burden and ensure higher quality of service.

Key words: Physiotherapist, Physical burden, Bed height, Manual therapy, Trunk anterior inclination angle, Surface electromyogram, Lumbar disc compression force, Lumbar flexion torque

Introduction

Work-related musculoskeletal disorders (WMSD) are a major problem common to many different occupations, including healthcare workers[1–3]. Physiotherapists have one of the highest rates of WMSD[4–6]. The most commonly affected body part is the lower back, followed by the upper limbs (including the neck, shoulders, hands, and fingers)[4, 7, 8]. Based on a longitudinal study, Campo *et al.*[8] estimate that the probability of the occurrence of WMSD in any body region during a one-yr period would be 20.7%. They list manual therapy maneuvers—such as soft tissue work, passive range of motion, and joint mobilization—as risk factors. Manual therapy has been identified as one

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of the major risk factors associated with the development of WMSD in physiotherapists[4, 7, 9–11]. These studies have confirmed that manual therapy is a matter of great interest.

Some studies have examined the relationship between physical burden and bed heights or working heights in manual patient handling tasks as nurses[12–14]. The use of adjustable beds in nursing practice can influence the working postures of personnel and reduce task demands[12]. Notably, compression and anterior/posterior shear loading at the L5/S1 level during sling and removal have been found to significantly decrease in magnitude as bed height increases[13]. Another study[14] reported that raising the bathtub decreased erector spinae muscle activity and intervertebral disc compression forces, while increasing trapezius muscle activity and shoulder moments, and increasing the burden on the shoulders and upper limbs. However, few studies explore the physical burden that occurs during manual therapy by physiotherapists. Only one study evaluated the lumbar flexion angle and the perceived stress, and provided an optimal anthropometric landmark for adjusting the bed height while manual tasks[15].

Beds used in physiotherapy include mat platforms, medical beds, and height-adjustable beds. For patients who use wheelchairs, the bed height is often adjusted to 45 cm, which is the typical seat height of wheelchairs in Japan. The height of mat platforms at hospitals and welfare facilities is also usually 45 cm. Previous studies in Japan have investigated the effects of bed heights and the presence or absence of a sheet in connection with the task of correcting the lying in a dorsal position at 47 cm (low) and at 85 cm (high)[16]. However, overseas studies regarding bed heights and working heights for manual patient handling tasks do not include any studies on the physical burden resulting from low beds of 45 cm or so. This study aimed to determine the effects of the difference between low and adjusted bed height to the physical burden on the lumbar region and the shoulders of physiotherapists during massage (no load) and ROM (load generated by a patient) techniques.

Subjects and Methods

Subjects

Thirty-five male physiotherapists working actually were recruited for this study. The subjects had 20–40 yr of age, the experience of less than 10 yr, body mass indexes (BMIs) of less than 25 kg/m^2, and none reported any lower back or upper limb pain that interfered with their routine daily activities.

This study was conducted in accordance with the Declaration of Helsinki and was by the ethical review committee for research involving human subjects of Bukkyo University (2019-34-B) and the ethical review committee of Shiga University of Medical Science (2020-095). The subjects each provided written informed consent.

Simulated patient

A volunteer, simulating a patient, participated in each task throughout the experimentation to maintain the workload to the subjects at a constant level. The simulated patient was a 25-yr-old male, 169.0-cm tall, weighing 68 kg (BMI=23.8 kg/m^2). The weight of the lower limb of the simulated patient was set to 17.2% of the body weight, using the lower-limb mass ratio of Ae *et al*[17]. The mass center was assumed to be at the center of the lower limbs, and the load on the load point was set to 1/2. This resulted in an estimated value of 5.8 kg.

Experimental protocol

The subjects performed a lower back massage task (Fig. 1) and a hip joint ROM task (Fig. 2) using a height-adjustable bed set the height at which they felt comfortable working (AH), and a low bed (LH) 45 cm from the ground.

During the massage task, the subject aligned his hands on the lower back region of the simulated patient who was lying in the prone position and performed a deep transverse friction massage on the lumbar paraspinal muscle groups for 30 s. During the ROM task, passive motion was applied to the simulated patient's right hip until the abduction end point was reached (in the extended position) with the patient lying in the supine position. This movement cycle was repeated five times. The subject then stood at the simulated patient's right side and fixed the pelvis with the left hand while the right hand grabbed the proximal part of the heel bone. The exercise tempo was paced to a metronome set at 74 BPM, and one movement cycle was completed in 8 beats. The subjects were mainly required to use their upper limbs. Under the condition at both bed heights, the subjects were instructed to uniform working method as following: the foot placement including the distance from the side edge of the bed, the knee extension positions, setting the distance between the feet at approximately the shoulder-width apart, performing the massage task using the same pressure force.

Evaluation indexes were surface electromyograms (sEMG), anterior inclination angle of the trunk, perceived stress, and massage pressure force. sEMG was measured

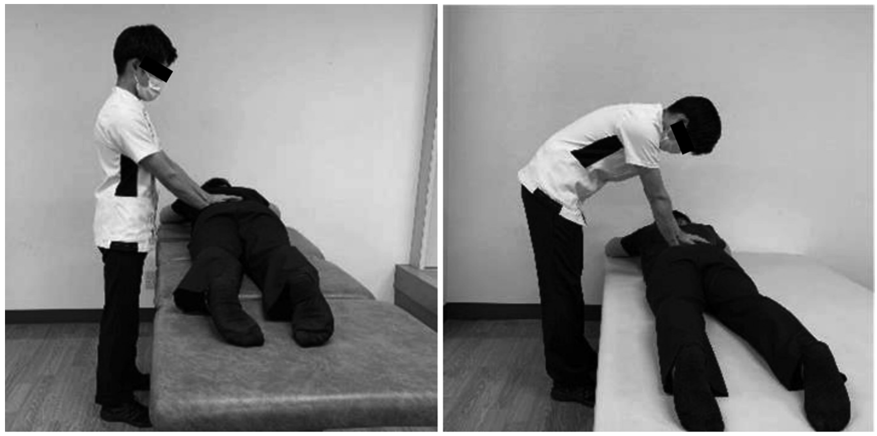

Fig. 1. Massage at adjusted height (left), at low height (right).

Fig. 2. Range-of-motion exercise at adjusted height (upper), at low height (lower); the starting limb position (left), the abduction end point (right).

at four sites (left and right upper trapezius muscles and lumbar paraspinal muscles). Pre-gelled bipolar electrodes (YS-01, Yuui-Koubou Ltd., Osaka, Japan) were applied parallel to the muscle fibers, after the sites on the skin had been shaved as necessary and cleaned with a 50% ethanol solution. Regarding the trapezius muscles, electrodes were placed 1 cm medial to the midpoint of the line connecting the seventh cervical spinous process and acromion. On the lower back, electrodes were placed in the area of the paraspinal muscle group at the level–L3–4. The electrodes had Ag/AgCl and were 5 mm diameter. The centers of the electrodes were placed 20 mm from each other. The electrodes were connected to the main recording unit of the EMG device (YS-BioMeas_RMS4G, Yuui-Koubou Ltd.) through a wire equipped with a built-in amplifier. The elicited EMG signals were amplified (×1,000) and filtered using a coupling capacitor, Butterworth low-pass filter, and notch filter (50–60 Hz). The pre-processed signals were converted to the root-mean-square (RMS) with 50 ms time constant using a built-in RMS-to-DC converter (AD737, Analog Devices Inc., Norwood, MA, USA). The full-wave rectified signals were digitized with 16-bit resolution and recorded at a sampling frequency of 50 samples/s. The EMG device had the following specs: 1 MΩ input impedance, 100 dB common-mode rejection ratio, 0.2 μV–2.5 mV actual gain range, and 8–1,000 Hz effective frequency range.

Acceleration on the subject's back surface was measured to determine the anterior inclination angle of the trunk. The acceleration sensor has a rectangular plane shape. The long axis and the axis perpendicular to the plane were assigned to the z-axis and x-axis, respectively. The subject wore a tight-fitting running shirt with an acceleration sensor embedded in the back of the shirt. The acceleration sensor was set along the z-axis, parallel to the vertical direction, at the level of the upper thoracic vertebrae. The main recording unit was connected to the acceleration sensor by a wire and recorded triaxial acceleration data at a sampling frequency of 5 samples/s. The values of the gravity acceleration vector decomposed into the z-axis and x-axis and were detected in the case of the subject's flexion. The ratio was computed by dividing the value in the z-axis by the gravitational acceleration. The inclination angle was obtained to plug the ratio into an arccosine function. A reference angle value was obtained in the upright standing position of each subject. An anterior inclination angle of the trunk was calculated by subtracting the reference value from the angle of the back, and the positive value was assumed at the subject bent forward.

Perceived stress in the neck/shoulder and the lower back of each subject was taken using the modified Borg scale (0 [no stress] to 10 [maximum stress]) by verbal answer immediately after the completion of each task. Pressure exerted during massage was measured using a sheet-like pressure sensor (PREDIA, Molten Corp., Hiroshima, Japan) attached to the palms of the subject's hand. The periodic peak pressure values in synchronization with the massaging rhythm were recorded.

Prior to the beginning of the experimental tasks, the subjects were asked to choose a comfortable bed height for the completion of the tasks using the height-adjustable bed. This bed height, which was specific to the preferences of each subject, was recorded by the experimenter as "easy-bed-height". The subjects performed warm-up exercises after the sensors had been placed, then underwent a training session during which they were instructed on how to perform both the massage and ROM tasks.

The subjects completed the massage and ROM tasks using both the AH and LH beds. Each task was performed three times, with a 1-minute rest period between each repetition. The order of the tasks was random, and the subjects had a 3-minute rest period between the massage and ROM tasks.

Data analysis

The subject data with massage pressure values that reached the upper limit of the sensor and perceived by the simulated patient as excessive, were excluded from the analysis.

The easy-working-height was the easy-bed-height chosen by each subject, plus the distance from this easy-bed-height to the back of the waist of the simulated patient in the prone position (16.7 cm) for the massage task; plus the distance from this easy-bed-height to the femoral greater trochanter of the simulated patient in the supine position (9.4 cm) for the ROM task.

Spinal compression and flexion torque values were estimated to evaluate lower back stress based on a biomechanical model. The spinal compression was calculated using BlessPro version 2.52[18], a workload assessment software. The mean height and weight of the all subjects were used, and the other postural parameters of one subject matching the mean body height of the all subjects, were used as representative values. The postural parameters that are the anterior inclination angle of the trunk, lower back bending angle and feet joint angles, were measured using side-view photographs of the work posture. The horizontal distance and height from the greater trochanter to the working point were measured using a tape measure. The lumbar flexion torque around the left-right axis passing through the L4–5 was estimated using the mean anterior inclination angle of the trunk measured in tasks performance, mean body height and weight of the all subjects. Other data that require to estimate were some segment lengths, segment masses, and locations of the center of each mass. Segment length data were referenced from anthropometric measurements contained in the 1997–1998 National Institute of Advanced Industrial Science and Technology database[19], and segment mass and the center of mass data were collected from a published database[17].

The mean RMS values of sEMG at the four measuring sites and the mean inclination angle of the trunk were calculated in each task performance period for each subject. A repeated measures two-way analysis of variance was used to compare the mean RMS and the mean inclination angle with the two factors of two bed-heights and three task repetitions. Mauchly's sphericity test was used to assess the data prior to the analyses, and the Greenhouse–Geisser correction was used as necessary. Multiple comparisons were conducted using Tukey's test. The Chi-square test or Fisher's exact test were used to compare the perceived stress between the different bed heights. The mean massage pressure was compared using the paired *t*-test. All statistical analyses were conducted using SPSS Statistics 27 (IBM SPSS, Inc., Tokyo, Japan). Statistical significance level was set at 0.05.

Results

The final analyses included data from 33 subjects, excluding 2 subjects.

The median age of the eligible subjects was 25 yr (range: 22–36 yr), and the median years of experience was 2 yr (0–9 yr). The body height (mean ± SD) was 170.6 ± 5.0 cm and the body weight was 64.6 ± 5.6 kg, resulting in a BMI of 22.2 ± 1.7 kg/m^2. The easy-working-height was 92.8 ± 6.6 cm (54.4% ± 3.4% of the body height) in the massage task and 90.0 ± 6.4 cm (52.8% ± 3.9% of the body height) in the ROM task.

Table 1 shows the estimated values of the biomechanical model. The estimated lumbar disc compression in the massage task was 807 N at AH and 1,687 N at LH. In the ROM task, when the starting limb position was at the farthest horizontal distance from the subject's center of gravity to the load point of the simulated patient's lower limb, the lumbar disc compression force was 1,789 N for AH and 2,987 N for LH conditions. The estimated lumbar flexion torque was 30.0 Nm at AH and 98.1 Nm at LH in the massage task and 52.5 Nm at AH and 122.7 Nm at LH in the ROM task.

Table 2 shows the results of the trunk inclination angle and the RMS values of sEMG at the four sites for AH and LH conditions. There was a significant interaction between two factors: bed height and task repetition, for the trunk inclination angle in the ROM task. The inclination angle increased in proportion to the times of repetitive task performed during the ROM task at LH. The inclination angle measured during the second task repetition was larger than that measured during the first repetition, and the inclination angle of the third repetition was greater than that during the first and second repetition. The RMS values of the both trapezius muscles did not differ significantly for either task between the AH and LH. The RMS values of the both paraspinal muscles were not significantly different between the AH and LH in the massage task. In the ROM task, the RMS values of the left paraspinal muscles were lower at LH than at AH, and were significantly lower with task repetition. There was a significant interaction between two factors for the RMS values of the right paraspinal muscles, and the RMS values measured during the third task was lower than that measured during the first task at LH.

Table 1. Disc compression force and flexion torque in lumbar

Task	Condition	Compression force[1] (N)	Torque[2] (Nm)
MAS	AH	807	30.0
	LH	1,687	98.1
ROM[3]	AH	1,789	52.5
	LH	2,987	122.7

MAS: Massage; ROM: Range-of-motion exercise; AH: Adjusting the height; LH: Low height.

[1]One of the subjects' postural parameters, matching the mean body height, was used as a representative value, and using the mean weight and height of 33 subjects.

[2]Using the mean weight and height of 33 subjects.

[3]The value at a starting limb position in ROM.

Perceived stress in the neck or shoulders was not significantly different between the AH and LH in the massage and ROM tasks (Table 3). The rate of the perceived stress score that was equal to or higher than three, was significantly higher at LH than at AH in the lower back. The mean massage pressure was significantly higher at LH (103.6 ± 39.9 mmHg) than at AH (86.1 ± 36.6 mmHg) (p<0.001).

Discussion

When we assessed the effect of bed height on the physical burden of physiotherapists, we found that the biomechanical load and perceived stress on the lower back increased due to the hyperflexion of the lower back in LH compared to AH. Notably, a significant difference in lumbar myoelectric potential was only observed in the ROM task. The burden on the shoulders related to myoelectric potential and perceived stress did not differ with differences in bed height.

The physical burden generated by the height of the work surface is affected by the worker's height and the

Table 2. Anterior inclination angle of the trunk and root-mean-square values of sEMG (n=33)

Task	Condition	Task repetition	Inclination angle (degree)		Myoelectric potential (μV_{rms})							
					Trapezius muscle				Paraspinal muscle			
					Left		Right		Left		Right	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MAS	AH	1st	16.8	8.5	3.1	3.9	4.4	5.0	8.9	6.0	8.3	5.0
		2nd	16.8	9.1	2.8	3.9	4.3	5.4	8.6	5.8	8.9	5.1
		3rd	16.8	9.6	3.2	4.5	4.4	5.2	8.9	6.4	8.6	5.1
		Mean	16.8	8.8	3.0	4.0	4.4	4.9	8.8	5.9	8.6	4.9
	LH	1st	73.2	8.7	4.0	4.9	5.2	4.2	9.8	8.3	8.5	6.8
		2nd	73.2	9.0	5.0	6.4	5.7	6.2	11.3	9.0	10.3	8.1
		3rd	73.8	9.1	5.2	6.7	5.0	5.2	10.4	9.3	9.0	8.2
		Mean	73.4	8.8	4.7	5.8	5.2	5.0	10.6	8.4	9.2	7.2
			p-value by multi-sample sphericity test or two-way repeated-measures ANOVA									
	Sphericity		0.013*		0.071		<0.001**		0.841		0.400	
	AH vs. LH		<0.001**		0.161		0.405		0.324		0.559	
	Task repetition		0.418		0.084		0.303		0.427		0.018*	
	Interaction		0.285		0.109		0.599		0.188		0.339	
ROM	AH	1st	25.0	10.0	10.4	7.1	43.9	19.8	28.6	10.1	13.6	9.2
		2nd	25.1	11.2	11.4	8.4	43.8	20.7	26.8	10.3	13.6	9.6
		3rd	25.1	11.2	11.9	9.0	43.0	19.2	26.1	10.4	14.0	9.7
		Mean	25.0	10.6	11.2	7.8	43.6	19.5	27.1	10.1	13.7	9.4
	LH	1st	79.7	8.1	13.4	13.2	39.3	17.7	16.9	10.8	11.9	10.4
		2nd	81.0†	8.5	14.6	13.6	39.2	18.6	14.7	9.8	10.6	10.5
		3rd	82.2†‡	8.1	14.9	13.6	38.7	17.9	13.3	9.8	10.1†	10.8
		Mean	81.0	8.1	14.3	13.1	39.1	17.8	15.0	10.0	10.8	10.4
			p-value by multi-sample sphericity test or two-way repeated-measures ANOVA									
	Sphericity		0.004**		0.208		0.030		0.010*		0.193	
	AH vs. LH		<0.001**		0.128		0.055		<0.001**		0.204	
	Task repetition		0.012*		0.040*		0.564		<0.001**		0.114	
	Interaction		0.005**		0.961		0.977		0.258		0.012*	

sEMG: surface electromyography; MAS: Massage; ROM: Range-of-motion exercise; AH: Adjusted height; LH: Low height; SD: standard deviation; ANOVA: analysis of variance.

**p*<0.05, ***p*<0.01 for multi-sample sphericity test or two-way repeated-measures ANOVA.

†*p*<0.05 for the comparison with 1st time by Tukey adjustment for multiple comparisons.

‡*p*<0.05 for the comparison with 2nd time by Tukey adjustment for multiple comparisons.

work content. If the work surface is too high, the worker's shoulders and upper arms must be raised, leading to an increased load on the neck and shoulders. If the work surface is too low, the worker's spinal column bends, placing an increased load on the lower back[20]. We compared the physical burden at two conditions: using the LH bed (45 cm) and the AH bed. We found that the easy-working-height at the AH bed was 90 cm or higher. This easy-working-height represented 54.4% of the subjects' body height for the massage task and that was 52.8% for the ROM task, which were similar to a previously reported optimal bathtub height of 57.7%[14] when children's nurses bathed a baby. These values almost correspond the height of the center of mass in adult male, 55.5%[21]. Taken together, these results suggest that using work surfaces closer to the physiotherapist's center of mass allow for a more stable posture.

The National Institute for Occupational Safety and Health recommends an L5/S1 disc compression limit of 3,400 N as a threshold value for lower back pain[22]. In a previous study, the L5/S1 disc compression fell significantly below 3,400 N during lifting tasks performed on a 90-cm-high work surface, while that was greater than 3,400 N during lifting tasks performed at 70 cm or less[23].

Table 3. Perceived stress (n=33)

Body part	Task condition	Number		*p*-value
		SS ≤2	SS ≥3	
Neck or shoulder				
	MAS-AH	32	1	§0.178
	MAS-LH	29	4	
	ROM-AH	22	11	0.211
	ROM-LH	17	16	
Lower back				
	MAS-AH	31	2	<0.001**
	MAS-LH	18	15	
	ROM-AH	24	9	0.003**
	ROM-LH	12	21	

SS: Stress score; MAS: Massage; ROM: Range-of-motion exercise; AH: Adjusted height; LH: Low height.
The rates of SS (≤2, ≥3) in neck or shoulder, and lower back are compared between two conditions (AH, LH) in each task.
**p*<0.05, ***p*<0.01 for χ^2 test.
§Using Fisher's exact test.

The results of the previous study are similar to those of the present study, in which the spinal compressions at AH for both task types were significantly less than 3,400 N, but were comparatively higher at LH for the ROM task involving hold of the simulated patient's leg. The workload assessment software used in this study was a static biomechanical model. Thus, the actual spinal compression force may be higher because of dynamic acceleration and muscle co-contraction[28]. Heavier patient's weight and magnitude of passive resistance may contribute to the physiotherapist's lumbar compression, increasing the risk of lower back pain.

In this study, a high biomechanical lower back load was observed in tasks performed at LH. The biomechanical load increased due to hyperflexion of the lower back, which can cause the prolapse of intervertebral discs and lumbar ligament injuries[24–26]. It has been reported that vocational and sport activities requiring lumbar hyperflexion or static lumbar flexion are associated with an increased risk of lower back injuries, including spasms and sprains[27]. Therefore, a height-adjustable bed should be used to reduce the workload of the physiotherapists.

In this study, the greater lumbar load at LH in the ROM task compared to AH was estimated from the biomechanical model. However, the myoelectric potentials of the lumbar region at LH had no significant difference for right side and was lower for left side. Waters *et al.*[28] indicated that large muscular forces were required in the contralateral lumbar muscles to maintain mechanical equilibrium, with the fifth lumbar vertebra and the first sacrum bone (L5/S1) lumbar disc as a fulcrum, for a load that was a combination of an external load on one side, a load on the arm and upper body, and dynamic muscle activity. In this study, the ROM task performed by holding the patient's lower limb with the subject's right hand was considered to involve greater muscle activity in the left lumbar region because of the load on the right upper limb. Hyperflexion at LH did not raise left lumbar myoelectric potential, which was considered because of a flexion-relaxation phenomenon initiated in the erector spinae and multifidus muscles at the 60° trunk flexion[29]. Jin *et al.*[30] described the interaction between the active tissues and passive tissues of the lumbar muscles by showing that in the 81° forward-stooping posture, the myoelectric potential of the erector spinae and multifidus muscles was lowered while the passive tissue moments of the lumbar region increased in comparison with shallower forward-stopping postures. Furthermore, the activity of the erector spinae muscle in the myoelectric potential linked with an excessive forward-stooping posture decreased or did not differ in comparison with shallower forward-stooping postures, whereas the myoelectric potential of the biceps femoris muscle was elevated[16, 30]. In other words, the mean anterior inclination angle was 81° in this study during the ROM task at LH, the excessive forward-stooping posture at LH may have led to a flexion-relaxation phenomenon and reduced active tissue activity of the erector spinae muscles, while raising the activity of the muscle of the posterior surface of the thigh in return.

In the ROM tasks on LH bed, the trunk anterior inclination angle increased with the number of tasks. Previous research has shown that a task in which the load point is above the waist mainly requires shoulder and arm muscles, but a task in which the load point is below the waist requires the movement of the entire body[22]. For this reason, the heavier the load, the lower the bed-height should be adjusted[15, 22]. In this study, instead of the bed being lowered, the forward-stooping posture was deepened as the number of tasks increased. This may have caused a flexion-relaxation phenomenon and increased the activity of the other muscles in return, and reduced the muscle activity in the lumbar region.

In this study, the generated massage pressure was higher at LH than at AH. High pressure values may have been measured due to an uneven application of pressure caused by the subject's unstable posture when working at LH. This indicates that the stooping posture required when working at LH results in a decrease in the technical quality of the manual therapy, suggesting that a stable posture is essential to ensure high-quality service, and can be achieved using an adjustable-height bed.

Weight loads, equipment conditions (such as the height of the work surface), and working posture play significant roles in the development of occupational lower back pain. Reducing the moment acting on the shoulders and lower back is essential for load reduction. In addition to the worker's height and weight, moment is associated with work posture, body load, horizontal distance between the worker and body load, height of the body load on the vertical axis, and the patient's passive resistance. Alperovitch-Najenson *et al*.[15] demonstrated that the third knuckle and radial styloid process of the wrist were the best landmarks for height when physiotherapists perform manual tasks. In nursing, it was determined that raising the bed to at least the nurse's knuckle height was necessary in order to avoid excessively increasing the lumbar spine load[13]. Kroemer and Grandjean[20], in the design of workplaces, stated that the height of the appropriate working surface for standing work was 10 to 15 cm below the elbow for light work and 15 to 40 cm below the elbow for heavy work involving a lot of muscle activity. The easy-working height for this present study was between the elbow and the knuckle, which was consistent with previous studies. Thus, bed-height adjustments can be used to reduce the burden on the lumbar region in manual therapy.

In this study, the burden on the shoulders did not differ depending on the bed height, but on the other hand, it considered that the presence or absence and size of the load greatly affected the burden on the shoulder. The burden on the shoulders may have been greater if a bed higher than the adjustable bed had been used[14], although this point was not evaluated this time. In other words, the beds used in this study may have been adjusted to a height that would not result in an excessive arm lift.

To reduce the burden on the shoulders, the horizontal distance between the load point and the worker should be reduced by using a drooping shoulder posture. Therefore, techniques and devices that help reduce workload have been reported, including the use of horizontal movements, which are unaffected by the force of gravity, and the use of the thighs and shoulders in place of the hands during upper and lower limb elevation exercises to reduce the load on the physiotherapist's neck and shoulders. Slings and sliding sheets can also be useful to reduce workload.

This study was conducted on healthy, adult physiotherapists. However, for ethical and safety reasons, the amount of work time in this study was shorter than the standard work time required in a real clinical setting, and rest periods were provided. In actual physical therapy, many of these patients, even light-weight elderly patients, suffer from contractures, pain, increased muscle tone, and rigidity. These symptoms are characterized by an extremely intense resistance to passive movements; therefore, the load of an actual patient is likely higher than that provided in this study (5.8 kg). While a single session of physical therapy lasts 20 min, multiple sessions are often required by patients with severe symptoms. Therefore, this study may underestimate the risk associated with load and work time. The results of this study can be also used to help reduce the physical burden of other healthcare workers.

The use of manual therapy techniques, including joint mobilization and manipulation, has been reported to be related to increased thumb symptoms[31], suggesting that the relationship between manual therapy techniques, such as massage and the load on the hands and fingers, requires further researches.

In conclusion, this study clarified the effects of the difference between low and adjusted bed height on the physical burden of physiotherapists during manual therapy. The biomechanical load and the perceived stress related to the lumbar region was higher at LH. There was no difference in muscle activity or perceived stress related to shoulders based on bed height. In a dynamic ROM task with a load on the right upper limb, the myoelectric potential of the left lumbar region was low at LH with a trunk anterior inclination angle exceeding 60°. In addition, because of an effect presumed to result from avoiding a burden on the muscle of the lumbar region, the myoelectric potential of the lumbar region declined while the trunk anterior inclination angle increased as the number of tasks increased.

Given the lack of education among physiotherapists on bed height adjustment in Japan, the results of this study can be used as evidence for the educational materials. They can also contribute to the reduction of physical burden as well as to help physiotherapists provide higher quality manual therapy.

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