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Original Article

Case Study

Original Article

Survey and Analysis of Cervical Rotation Joint Range of Motion Measurement Methods for Patients with Neck Diseases in Japan and Overseas –A Systematic Review–

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Abstract

[Purpose]

The purpose of this study was to investigate and analyze the methods for measuring the range of motion of cervical rotation joints with regards to studies on patients with cervical musculoskeletal diseases in Japan and overseas.

[Methods]

We searched PubMed, an electronic database, and the Ichushi-Web (last search date: March 11, 2024) for randomized controlled trials on cervical rotation range of motion, and extracted articles that included subjects with cervical musculoskeletal disorders. The content of the selected references was evaluated using the PEDro scale according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement, and the results were summarized according to PICO.

[Results]

Twenty references from PubMed and two from the Ichushi-Web were selected. Of the selected references, 16 were rated as high quality, 5 as moderate quality, and 1 as low quality. The CROM device was the most common measurement device.

[Conclusion]

One limitation of this study is that the results for range of motion of cervical rotation do not reflect differences in age and gender. In future studies, it is desirable to develop measurement instruments and methods that can be used in a wide range of research and clinical settings.

Keywords: cervical rotation, joint range of motion, systematic review

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I. Introduction

Neck pain and pain related to neck pain are major causes of disability worldwide[1]. In Japan, neck pain and shoulder stiffness are also prevalent across a wide range of ages[2]. According to the National Livelihood Basic Survey conducted by the Ministry of Health, Labour and Welfare, neck pain consistently ranks among the top complaints in terms of self-reported symptoms over the past decade, alongside lower back pain[3-5]. Neck pain is stated to be "neck pain with or without pain in one or both upper extremities."[6]. It is also defined in the anatomical field of neck pain, and evaluation and treatment of neck pain is an important matter in medical fields worldwide.

In joint motion impairment assessment[7], joints with multiple movements exhibit distinct differences in importance related to each specific motion. These movements are categorized into primary motion, reference motion, and other motion. Among these, primary motion refers to the most crucial actions preformed in daily activities. Typically, throughout the human body each joint is responsible for one primary motion. However, in the case of the neck, there are two primary motions: flexion-extension and rotation. When the range of motion for either of these is restricted to less than half, it results in residual motion impairment. The measurement of joint range of motion is used not only to evaluate disability but also to determine the effectiveness of treatment in various situations, and the joint range of motion indication and measurement method (hereafter referred to as "joint range of motion measurement method "[8] established by the Japanese Orthopaedic Association and the Japanese Society of Rehabilitation Medicine is widely used. Considered to be foundational knowledge in various medical fields, it is important that joint range of motion measurement methods be both practical and easy to understand, and therefore should be analyzed according to this purpose. According to a previous study[9] that surveyed and examined neck range of motion and cervical spine rotation in healthy subjects in Japan, goniometers and three-dimensional motion analysis and analyzers were utilized in more than half of the cases (36.8% and 28.9%, respectively), indicating the use of various measurement devices other than goniometers. However, we could find no literature on the measurement of cervical rotational joint range of motion in patients with cervical diseases. Therefore, we thought that it would be highly significant to investigate and analyze literature on patients with cervical diseases to clarify the measurement method and in turn provide new knowledge.

The purpose of this study was to conduct a qualitative systematic review of studies conducted in Japan and overseas on patients with cervical diseases and to investigate and analyze methods for measuring range of motion of the cervical rotation.

II. Method

1. Research Design

This study was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement[10], a guideline for reporting systematic reviews.

2. Selecting a Target Paper

A search formula including the keywords "cervical," "rotation," and "joint range of motion" was used to extract literature on randomized controlled trials (RCTs) of cervical rotation joint range of motion (Table 1).

The databases used for the literature search were PubMed and the Web version of the NPO Japan Medical Abstracts Society Ichushi-Web (hereafter referred to as Ichushi-Web) (last search date: March 11, 2024), and were collected by one independent person.

Inclusion criteria were as follows: 1) the study design was RCT, 2) the article was written in Japanese and English, 3) the full text was available, 4) the article was submitted during the 10-year period from 2014 to 2023, and 5) the article contained PICO elements in its text structure.

Exclusion criteria were: 1) reviews, opinions, letters, case reports, conference proceedings, and abstracts, 2) full text was not available, and 3) the subject was not a patient with cervical musculoskeletal disease.

The decision to include literature was made by three independent evaluators, all three of whom have experience with systematic reviews.

Primary screening was conducted based on the contents of the title and abstract in accordance with the inclusion/exclusion criteria. Secondary screening was conducted according to the inclusion/exclusion criteria, based on a careful reading of the full text and the inclusion/exclusion criteria, and inclusion of those with a description of patients with cervical musculoskeletal disorders in the text. When there was disagreement among the three participants, discussion was held until consensus was reached. The literatures were tabulated and visually displayed according to the PICO format.

3. Assessing the quality of the literature (risk of bias)

To confirm the quality of each reference, the "reliability" (or "internal validity") of the clinical trial and whether the trial contained appropriate statistical information were assessed by two independent raters using the PEDro scale[11]. Each of the following items was scored as 1 point, and the total score was 7/10 or higher for high, 5-6/10 for fair, and 4/10 or lower for poor.

1. Random allocation, 2. Concealed allocation, 3. Baseline comparability, 4. Blind assessors, 5. Blind subjects, 6. Blind therapists, 7. Adequate follow up, 8. Intention-to-treat analysis, 9. Between-group comparisons, 10. Point estimates and variability, Eligibility criteria（outside the score）

III. Result

1. Selected studies

An initial search identified 2037 references in PubMed and 242 references in Ichushi-Web. After a primary screening based on the inclusion criteria, 368 references in PubMed and 80 references on the Ichushi-Web were selected. Subsequently, those with descriptions of patients with cervical musculoskeletal disorders in addition to the primary screening items were selected as secondary screening items by full-text reading, and 20 PubMed articles, 2 articles on the Ichushi-Web, and a total of 22 articles[12-33] were extracted (Fig. 1, Table 2). In studies that involve cervical joint range of motion measurements and include patients with neck pain, we excluded literature where the purpose of joint range of motion assessment was the evaluation of cervical proprioception and represented the target position as joint angles[34].

Table1. Search Fomulas for Databease (Ichushi-Web,PubMed) Searches

PubMed	("cervic"[All Fields] OR "cervicals"[All Fields] OR "cervices"[All Fields] OR "neck"[MeSH Terms] OR "neck"[All Fields] OR "cervical"[All Fields]) AND ("rotate"[All Fields] OR "rotated"[All Fields] OR "rotates"[All Fields] OR "rotating"[All Fields] OR "rotation"[MeSH Terms] OR "rotation"[All Fields] OR "rotations"[All Fields] OR "rotational"[All Fields] OR "rotator"[All Fields] OR "rotators"[All Fields]) AND ("range of motion, articular"[MeSH Terms] OR ("range"[All Fields] AND "motion"[All Fields] AND "articular"[All Fields]) OR "articular range of motion"[All Fields] OR ("joint"[All Fields] AND "range"[All Fields] AND "motion"[All Fields]) OR "joint range of motion"[All Fields])
Ichushi-Web	(頸部/TH or 頸部/AL) and (回転/TH or 回旋/AL) and 可動域/AL

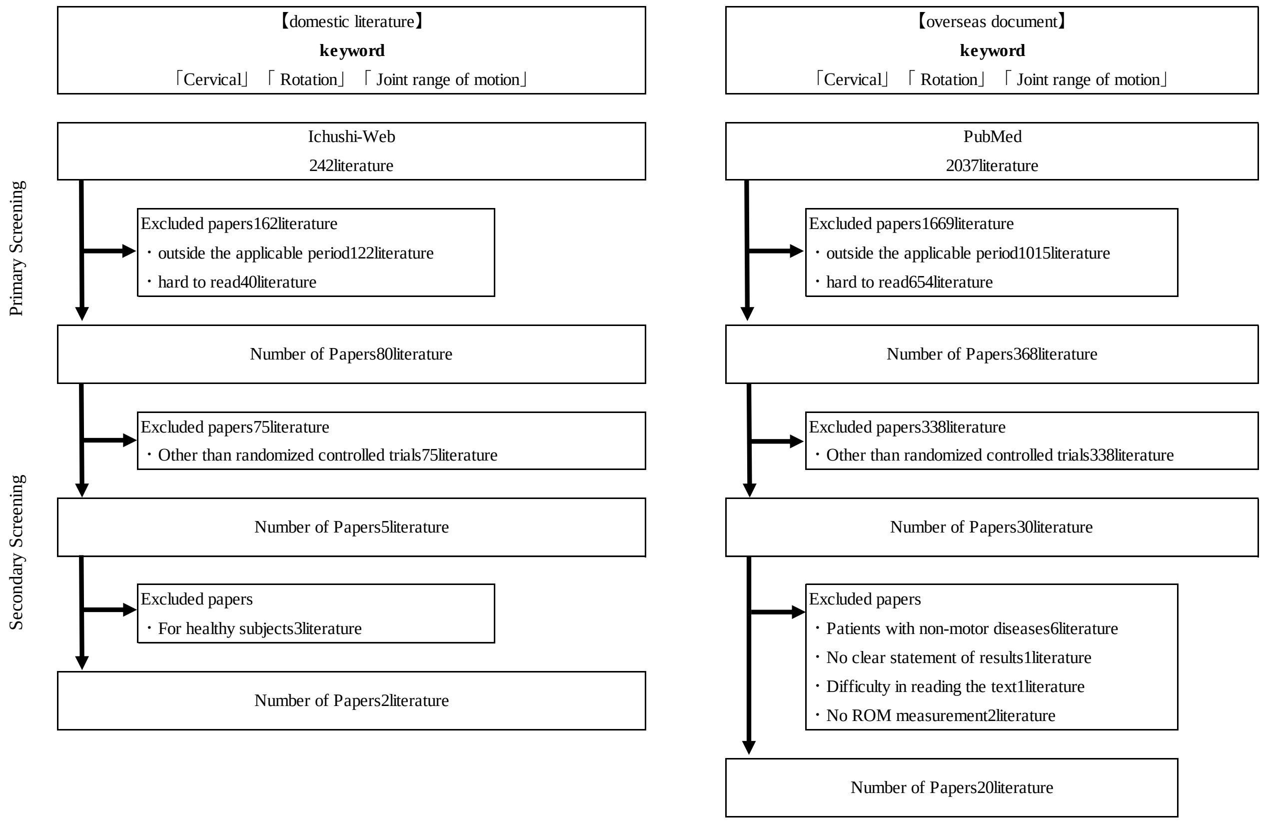

Figure1. Selected Paper

2. Quality of selected studies

The quality of 20 PubMed articles and 2 Ichushi-Web articles selected by the PEDro scale was evaluated and shown in Table (Table 3). The median total score was 7/10, with the lowest score being 3/10, and the highest score being 9/10. Sixteen of the selected references scored 7/10 or higher, indicating that the studies were of high quality. The remaining five were of moderate quality and one was of low quality. Random assignment, statistical group comparisons, point estimates and confidence intervals described in 100%, 95.4%, intention-to-treat analysis in 59.0%, blinding to the subject in 22.7%, and blinding to the treatment in 0%.

3. Time duration

In the 10-year period from 2014 to 2023, when the survey was conducted, the largest number of references was 5 in 2022 (Figure 2). In the five-year period from 2014 to 2018, 8 references (36.4%) were found, and in the five-year period from 2019 to 2023, 14 references (63.6%) were found.

4. Sample sizes

Sample sizes ranged from 20 to 134, for a total sample size of 1342 (Figure 3). The largest sample size ranged from 40 to 49, with 5 references.

5. Measuring instruments

The cervical range of motion (CROM) device (Performance Attainment Associates, MN, USA) (hereafter referred to as CROM device) was the most commonly used measurement device in 11 references (50.0%). This was followed by goniometers in 7 (31.8%), inclinometers in 3 (13.6%), and electromagnetic tracking systems in 1 (4.5%) (Table 4).

Table2. Characteristics of the Selected Studies

	First author, date	P	I	C	O
1	Omata J 2014	36 patients with neck pain	①Static Stretching10 times ②Static Stretching20 times ③Contract Stretching10 times ④Contract Stretching20 times	①,②,③,④ Before and after each intervention	No significant difference was found for ROM.
2	Oh SH 2016	Straight neck syndrome 20	①Sling stabilization exercise group ②Stretching exercise group	①,② Before and after each intervention	ROM improved before and after each intervention. There was no significant difference between ① and ②.
3	Joshi S 2020	42 patients with neck pain presenting with cervicothoracic junction dysfunction	①C7-T1 level Maitland mobilization group ②Mid-thoracic (T3-T6) manipulation group	①,② Before and after each intervention	ROM improved before and after each intervention. There was no significant difference between ① and ②.
4	Rodríguez-Sanz J 2020	58 patients with chronic neck pain	①Exercise group ②Manual therapy + Exercise group	①,② Before and after each intervention,After 3and6 months	There was significant improvement in ② after the intervention, 3 months, and 6 months. After both 3 and 6 months, there was a significant worsening in the less restrictive ①. There was a significant difference in ② compared to ① after the intervention, 3 months and 6 months.
5	Kang T 2022	41 patients with chronic neck pain	①Resistance exercise group ②Trapezius massage group	①,② Before and after each intervention	ROM improved before and after each intervention. Significant differences were found between ① and ②.
6	Rodríguez-Sanz J 2021	48 patients with chronic neck pain	①Exercise group ②Manual therapy+Exercise group	①,② Before and after each intervention	Significant improvement was observed in ② after the intervention. There was a significant difference in ② compared to ① after the intervention.
7	Seo J 2022	26 patients with chronic neck pain	①Active thoracic spine mobility exercise group ②Thoracic spine manipulation group	①,② Before and after each intervention	ROM improved before and after each intervention. There was a significant difference in right rotation for ① compared to ②.
8	Tejera DM 2020	44 patients with chronic neck pain	①Virtual reality treatment group ②Neck exercises group	①,② Before and after each intervention,After 1and3 months	There was improvement in ROM before and after each intervention and over time. There was no significant difference between ① and ②.
9	Srikrajang S 2023	28 patients with chronic neck pain	①Active scapular correction exercise group ②Control group	①,② Before and after each intervention	Significant improvement was observed in ① after the intervention. There was a significant difference in ① compared to ② after the intervention.
10	Abdel-Aziem AA 2022	55 patients with chronic neck pain	①Deep neck flexor group ②McKenzie group ③Control group	①,②,③	Significant differences were found in ③ compared to ① and ②. There was also a significant difference in ① compared to ②.
11	Aranha MF 2015	72 patients with trigger points in the upper trapezius muscle	①Electroacupuncture group ②Acupuncture group ③SHAM group	①,②,③ Before and after each intervention	Significant differences were found in right rotation between ① and ②. Significant differences were found in ① and ② compared to ③.
12	Murillo C 2021	40 patients with neck pain	①Dry needling group ②SHAM group	①,② Before and after each intervention	There was significant improvement in both ① and ②. There was no significant difference between ① and ②.
13	Ay S 2017	73 patients with cervical myofascial pain syndrome	①Kinesio Taping group ②SHAM taping group	①,② Before and after each intervention	There was significant improvement in both ① and ②. There was no significant difference between ① and ②.
14	Anwar S 2022	68 patients with chronic neck pain	①Breathing reeducation group ②Routine physical therapy group	①,② Before and after each intervention,After 4 and 8 weeks	There was significant improvement in both ① and ②. There was no significant difference between ① and ②.
15	Lin TY 2015	60 patients with cervical spondylosis with term ligament calcification	①Rehabilitation group ②①+ESWT(guided by X-ray image)group ③①+ESWT(guided by musculoskeletal sonography)group	①,②,③ Before and after each intervention	Improvement was seen in both ①, ② and ③ . ② and ③ showed improvement compared to ①. ③ showed improvement compared to ②.
16	González-Rueda V 2020	78 patients with chronic neck pain	①Inhibitory suboccipital technique group ②Upper cervical translatoric mobilization group ③Control group	①,②,③ Before and after each intervention,After 3 months	In left rotation, there was a significant increase in part of ①. There was no significant difference between ① and ② and ③ .
17	Noguera-Iturbe Y 2019	134 patients with trigger points in the upper trapezius muscle	①Kinesio Taping group ②SHAM group	①,② Before and after each intervention	No significant differences were found in both ① and ②. No significant differences were found in both ① and ②.
18	Siddiqui M 2022	80 patients with neck pain	①Autogenic inhibition technique group ②Reciprocal Inhibition technique group	①,② Before and after each intervention	Improvement was seen in both ① and ②. Compared to ②, ① was significantly improved.
19	Arjona Retamal JJ 2021	96 patients with chronic neck pain	①Manual suboccipital inhibition technique group ②Instrumental suboccipital inhibition group ③②+Upper cervical manipulation technique group	①,②,③ Before and after each intervention	Improvement was seen in both ①, ② and ③ . No significant differences were found in ①, ②, and ③ .
20	Calvo-Lobo C 2018	105 patients with cervicobrachial pain	①Median nerve neural mobilization group ②Cervical lateral glide group ③Oral ibuprofen group	①,②,③ Before and after each intervention,6 weeks later	Improvement was seen in both ①, ② and ③ . No significant differences were found in ①, ②, and ③ .
21	Rudolfsson T 2014	108 patients with chronic neck pain	①Neck coordination exercise group ②Strength training group ③Massage treatment group	①,②,③ Before and after each intervention,6 weeks later	② improved significantly. No significant difference was found between ① and ③ .
22	Park KD 2018	30 patients with myofascial pain syndrome in the upper trapezius muscle	①High-energy ESWT group ②Low-energy ESWT group	①,② Before and after each intervention	Improvement was seen in both ① and ②, with a significant increase in rotation to the healthy side. There was no significant difference between ① and ②.

ESWT:extracorporeal shock wave therapy

Table3. Quality of Selected Studies

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ⅰ	Random allocation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅱ	Concealed allocation	N	N	Y	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y
Ⅲ	Baseline comparability	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅳ	Blind assessors	N	N	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅴ	Blind subjects	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	Y	N	Y	N	N	Y
Ⅵ	Blind therapists	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Ⅶ	Adequate follow up	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y
Ⅷ	Intention-to-treat analysis	Y	N	N	Y	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	N	Y	N	N
Ⅸ	Between-group comparisons	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅹ	Point estimates and variability	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Eligibility criteria(outside the score)	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	total amount	5/10	3/10	7/10	8/10	5/10	8/10	6/10	8/10	8/10	5/10	6/10	8/10	7/10	8/10	7/10	7/10	9/10	8/10	8/10	7/10	6/10	8/10
	Research Quality	F	P	H	H	F	H	F	H	H	F	H	H	H	H	H	H	H	H	H	H	F	H

Y:Meets the criteria

N:Criteria not met

Ⅰ:Random allocation	Subjects were randomly allocated to groups
Ⅱ:Concealed allocation	Allocation was concealed
Ⅲ:Baseline comparability	The groups were similar at baseline regarding the most important prognostic indicators
Ⅳ:Blind assessors	There was blinding of all assessors who measured at least one key outcome
Ⅴ:Blind subjects	There was blinding of all subjects
Ⅵ:Blind therapists	There was blinding of all therapists who administered the therapy
Ⅶ:Adequate follow up	Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups
Ⅷ:Intention-to-treat analysis	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"
Ⅸ:Between-group comparisons	The results of between-group statistical comparisons are reported for at least one key outcome
Ⅹ:Point estimates and variability	The study provides both point measures and measures of variability for at least one key outcome
Eligibility criteria(outside the score)	Eligibility criteria were specified

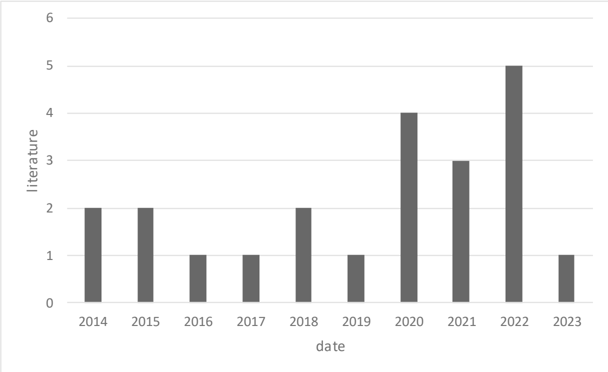

Figure2. Selected Literature (Number of papers and Year of Publication)

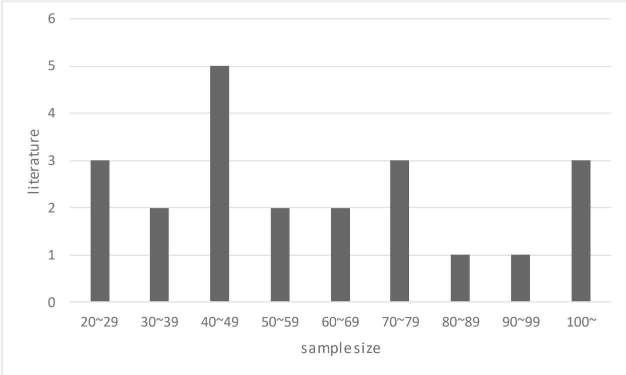

Figure3. Number of Research Subjects

Table4. Measuring instruments

Measuring instruments	literature	%
CROM Device	11	50.0%
goniometer	7	31.8%
angle meter	3	13.6%
Electromagnetic Tracking System	1	4.5%

IV. Discussion

The purpose of this study was to conduct a qualitative systematic review of studies in patients with neck disorders in Japan and abroad, and to investigate and analyze methods for measuring range of motion of the cervical rotation. Twenty-two references were selected through primary and secondary screening according to inclusion and exclusion criteria.

CROM devices were the most commonly used instruments, accounting for half of the total, because of their excellent intra- and inter-rater reliability[35]. The second most commonly used instrument was a goniometer, which is inexpensive, readily available, portable, and easy to use[35]. The electromagnetic tracking system, which uses magnetic sensors to measure position in three dimensions, produced the fewest results. The measurement of joint range of motion in cervical rotation requires consideration of the advantages and disadvantages of the measurement devices themselves, as they are employed according to the purpose of the measurement. The CROM device used most frequently in this study, which specializes in measuring joint range of motion in the neck, has excellent intra- and inter-examiner reliability, but requires instruction and practice for proper use, may not be easily accessible[35], can cause discomfort when being worn during measurement, and a limited starting posture during measurement[36] are some of the device's disadvantages. The second most common joint range of motion measurement method uses a goniometer to measure joint range of motion. While goniometers are inexpensive, easy to use and have the advantage of being used not only for measuring the neck but also for other joints, their disadvantage is that intra-examiner reliability is superior to inter-examiner reliability and the same examiner should perform the measurement[36]. Although 3D motion analyzers are available in various types, such as optical, mechanical, and magnetic, and are capable of continuous and detailed evaluation of various types of movements, their disadvantages are that they require time for measurement and analysis[36], are expensive, and are bound to a limited measurement environment[9]. In a previous study[9] on healthy subjects, 28.9% of the subjects used 3D movement analysis/analysis devices, while only 4.5% of the patients used such devices in the present study. This indicates that 3D motion analysis devices are not realistic as measurement devices in hospitals and other facilities that provide intervention and treatment to patients.

The quality of the 22 included RCTs was evaluated using the PEDro scale. 16 of the 22 studies were of high quality (72.7% of the total). However, while an increase in the range of motion of the cervical rotator joints was observed, several studies found no significant difference. This confirms that studies of high quality with high scores on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful[37]. The percentages for each evaluation item showed a similar trend to the PEDro statistics (updated February 7, 2022)[38]. Random assignment, statistical group comparisons, point estimates and confidence intervals were described in most of the literature, and intention-to-treat analysis and blinding of subjects were performed in a small percentage of the studies, with no blinding of treatment subjects. Blinding of treatment subjects was performed in only 2% of the PEDro statistics, and it is not unusual to find 0% blinding of treatment subjects, not only in the present study but also in previous studies[39-42]. It is easy to imagine that the intervention by treatment makes blinding to the therapist difficult, but blinding to the therapist is an important issue to improve the quality of RCTs in future clinical research.

Of the 22 references included in this study, only one was an RCT conducted in Japanese. This may reflect the low level of interest in and awareness of the range of motion of the cervical rotation in Japan. It is well known that range of motion of the cervical rotation is very important in daily life activities but evidence has not yet been established, and this is a research field that requires future development.

A limitation of this study is that the range of motion of the cervical rotation does not reflect the results of age and gender differences. It is known that joint range of motion decreases with age and that women tend to have a wider range of motion than men. However, RCTs are not studies that seek differences in age or gender, as they are interventions for diseases. Another limitation of the review process is that only existing instruments were used in this study, and no new instruments or methods were found, as literature on healthy subjects was used as an exclusion criterion. Although it was shown that each measurement device can be used for various purposes in research and clinical practice, the shortcomings of each device have not been overcome, and it is desirable to develop measurement devices and methods that can be used in a wide range of research and clinical practice in future studies.

Conflict of interest

There are no conflicts of interest or research funding to disclose in this study.

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Original Article

Effects of Various Treatments on Trigger Points on Joint Range of Motion –A Systematic Review–

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Abstract

[Purpose]

To clarify the effects of various trigger point treatments on joint range of motion and the potential of joint range of motion measurement as an evaluation method to determine the effectiveness of treatment in a qualitative systematic review.

[Methods]

We searched PubMed, an electronic database, and the NPO Japan Medical Abstracts Society Ichushi - Web for randomized controlled trials on trigger points, and extracted those that mentioned joint range of motion in the text (Last search date: December 7, 2023).

The PRISMA statement was followed, and the selected literature was qualitatively evaluated according to the PEDro scale. The results are summarized in a table according to PICO.

[Results]

Thirteen articles were extracted from PubMed and three articles from the Ichushi - Web. Of the selected articles, 12 were rated as high, 2 as fair, and 2 as poor. The most common site of interest was the neck, suggesting that various treatment methods for trigger points can affect joint range of motion.

[Conclusion]

Although we were unable to determine a clear range of improvement or statistically significant differences, the finding that various treatment methods for trigger points affect joint range of motion suggests that joint range of motion measurement can be used to determine the effectiveness of trigger points.

Keywords: Trigger Point, Joint Range of Motion, Systematic Review

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I. Introduction

A Comprehensive Survey of Living Conditions (2022) showed that among both men and women who had subjective indications of illness and/or injury, low back pain and stiff shoulders, in that order, were the most common symptoms[1]. It has been suggested that the cause of back pain may originate from spinal structures such as ligaments, intervertebral joints, vertebral bodies, intervertebral discs, and muscles and fascia[2]. In the case of stiff shoulders, the name of the symptom is derived from the state of muscle tension[3].

Thus, while many people in Japan complain of low back pain and stiff shoulders as subjective symptoms, the clinical causes of such issues are often numerous and diverse, making it difficult for therapists to decide on an appropriate treatment strategy.

In recent years, treatment practices employing various methods of manual therapy for trigger points (hereafter referred to as "TrP"), which are effective for myofascial pain syndrome (hereafter referred to as "MPS"), have attracted widespread attention[4], and back pain and stiff shoulders treatment with MPS as one of the causes, are noware being performed.

TrP is defined as a painful mass or induration at a site of tension within a muscle. There are two types of TrP: active TrP, which is the site causing the symptoms of patient complaints, and latent TrP, which has characteristics such as cord-like induration but does not cause the symptoms of patient complaintst[5]. The two types of TrPs are said to be characterized by the presence of scattered pain and cord-like induration, reproducible pain caused by pressure (associated pain), and the fact that the cause of the pain cannot be explained by the results of the neurological examination.

The former includes bony, intra-articular structural, muscular, and periarticular soft tissue factors and structural factors, while the latter states that defensive muscle contraction causes joint range of motion limitation[6]. The latter includes defensive muscle contraction that causes joint range of motion limitation. Needless to say, TrP is characterized by pain, which can be an indirect factor in the above, and there are many reports that indicate that treatment for TrP affects joint range of motion. On the other hand, there have not been enough studies on the effects of various treatment methods on the range of motion of joints.

The purpose of this study was to determine, in a qualitative systematic review, the effects of various treatments for TrP on joint range of motion and the potential of joint range of motion measurement as an evaluation method to determine the effectiveness of treatment.

II. Subjects and Method

1. Study Design

This study was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (hereafter referred to as " PRISMA ") statement[7], a guideline for reporting systematic reviews.

2. Selection of Target Literature

A search formula for "trigger point" was used to select references from randomized controlled trials (hereafter referred to as " RCT ") on trigger points (Table 1). The databases used for the literature search were PubMed and the NPO Japan Medical Abstracts Society Ichushi-Web (hereafter referred to as " Ichushi-Web "), and were collected by two independent persons (last search date: December 7, 2023).

Inclusion criteria were as follows: 1) Study Design

Table 1. Search Formula

Ichushi-web	(トリガーポイント/TH or トリガーポイント/AL)
PubMed	"trigger points"[MeSH Terms]OR("trigger"[All fields]AND"points"[All Fields])OR"trigger points"[All Fields]OR("trigger"[All Fields]AND "point"[All Fields])OR"trigger point"[All Fields]

was RCT, 2) The article was written in both Japanese and English, 3) The full text was available, 4) The article was submitted during the 10-year period from 2013 to 2022, and 5) The article contained PICO elements in its text structure.

Exclusion criteria were: 1) Reviews, opinions, letters, case reports, conference proceedings, and abstracts; 2) Articles for which the full text was not available; and 3) Articles for which there were non-human subjects. The decision on which literature to include was made by three independent evaluators, all of whom had experience with systematic reviews.

Primary screening was performed based on the contents of the title and abstract in accordance with the inclusion and exclusion criteria. Secondary screening was conducted based on the inclusion/exclusion criteria, and the inclusion of articles with descriptions of joint range of motion in the text that was determined in addition to the primary screening. When there was disagreement among the three researchers, discussion was held until consensus was reached. The extracted references were summarized in a table in PICO format.

3. Assessment of Risk of Bias

To confirm the quality of each literature, bias risk was assessed by two independent raters using the PEDro scale[8], which evaluates the "reliability" (or "internal validity") of a clinical trial and whether the trial contains appropriate statistical information. The risk of bias was assessed by two independent raters using the following items, with each item scoring 1 point, and a total score of 7/10 or higher being low, 5-6/10 being fair, and 4/10 or lower being high. 1. Random allocation, 2. Concealed allocation, 3. Baseline comparability, 4. Blind assessors, 5. Blind subjects, 6. Blind therapists, 7. Adequate follow up, 8. Intention-to-treat analysis, 9. Between-group comparisons, 10. Point estimates and variability.

III. Result

1. Extracted Articles

An initial search identified 8,147 articles in PubMed and 1,139 articles in Ichushi-Web. Primary screening was conducted based on the inclusion criteria, and 119 articles in PubMed and 16 articles in Ichushi-Web were selected. After that, as a secondary screening, those with descriptions of joint range of motion in addition to the primary screening items were extracted by full-text reading, and those without PICO elements were excluded, in total13 PubMed articles were selected[9-21] and 3 editions of the Ichushi-Web [22-24] were extracted (Fig. 1 and Table 2).

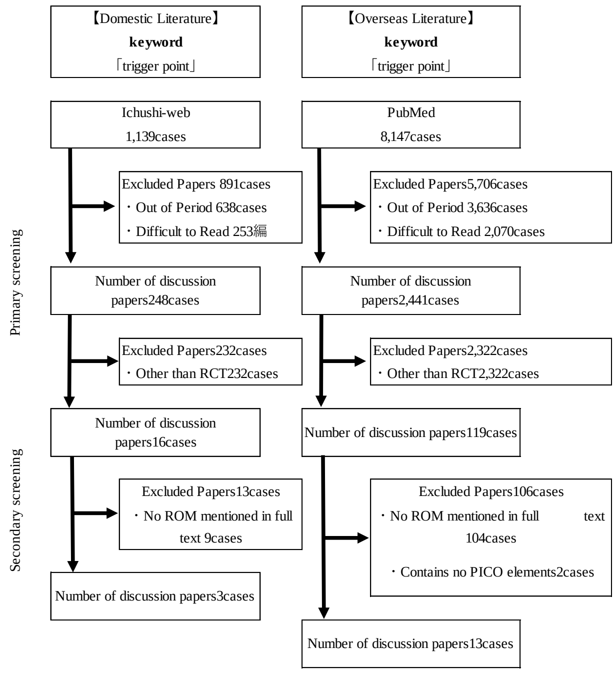

Figure1. Selected Paper

2. Quality of Selected Studies

Thirteen PubMed articles and three Ichushi-Web selected by the PEDro scale were evaluated for research quality. Twelve of the selected articles scored 7/10 or higher, indicating that the studies were of high quality. Two articles were rated as fair-quality studies with a score of 6/10, and two articles were rated as poor-quality studies with a score of 4/10(Table 3).

Table 2. Selected Paper(PICO Format)

	First Author, Age	P	I	C	O
1	Alayat Mohamed Salaheldein 2022	A total of 50 patients with MTrPs in the upper trapezius muscle participated in the study.	①Laser＋PPRT(progressive pressure release technique) ＋Exercises ②Placebo Laser＋PPRT(progressive pressure release technique)＋ Exercises	①and②	Significant improvement in cervical ROM (all directions) was observed.
2	Wamontree Phanida 2015	Sixty patients who were diagnosed as having upper back pain	①Massage group with Willai Massage Stick(TM)＋Stretch ② Ibuprofen administration＋Stretch	①and②	Statistically significant differences in all outcomes except cervical rotation.
3	Bae Youngsook 2014	30 subjects with TrP in the sternocleidomastoid muscle.	① KT attached ② No intervention	①and②	TMJ ROM increased significantly..
4	Álvarez SD 2022	80 subjects with TrP of the midline muscles in patients with nonspecific low back pain.	①DN ②Ischemic Trigger Point Compression	①and②	There were no statistically significant differences between groups, pre- and post-intervention.
5	Danazumi MS 2021	48 subjects with leg or buttock pain in patients with chronic pisiform muscle syndrome.	① Integrated Neuromuscular Inhibition Technique (INIT) ② Positional Release Technique	①and②	The INIT group significantly improved in all outcomes compared to the PRT group.
6	Velázquez-Saornil J 2017	44 subjects with at least one TrP in the ipsilateral quadriceps vastus medialis in the subacute phase after unilateral surgical reconstruction of a complete ACL tear.	①TrPDN＋Rehabilitation, ②Rehabilitation	①and②	Significant effect on ROM and functional improvement were observed .
7	Wendt M 2020	60 subjects with TrPs in the upper trapezius muscle.	①Muscle Energy Technique ＋Trigger Point Therapy (TPT) ② Muscle Energy Technique ③Trigger Point Therapy (TPT)	①and②and③	Statistically significant differences were found between measurements taken before, immediately after, and one day after treatment in the cervical spine.The combination of MET + TPT showed the greatest impact on increasing the range of motion in all cervical spine .
8	Chang WH 2021	100 subjects with cervical myofascial pain syndrome	①Classical Acupoints ②TrP	①and②	Some cervical ROM improved immediately in the TriT group. Trigger point therapy was also effective in improving ipsilateral flexion and rotation ROM.
9	Ceylan CM 2022	60 participants with myofascial pain syndrome in patients with nonspecific neck pain.	①Exercises ②KT	Before and after intervention	ROM improved in the KT group, but there was no difference in ROM improvement between the exercise group and the KT group.The KT group received exercise therapy in addition to KT, and the improvement in ROM was due to the exercise therapy.
10	Nasb M 2020	24 subjects with nonspecific chronic neck pain and TrP in the upper trapezius muscle.	①Dry cupping ② Ischemic compression ③①＋②	①and②and③	Flexion, extension, and lateral flexion were improved in all groups.The CT and ICT groups showed statistically significant improvement in some exercises, but there were no significant differences between the three treatment groups.
11	Castro-Sanchez AM 2017	Sixty-four subjects with TrP in the vastus medialis, iliopsoas, multifidus, and quadratus lumborum muscles in patients with fibromyalgia syndrome.	①DN ②Control	Effects of Dry Needling	ROM increased after both treatments. However, there was no statistically significant difference between the two groups.
12	Noguera-Iturbe Y 2019	134 subjects with TrP in the upper trapezius muscle.	①KT ②Control	KT	There was no difference in active ROM between the latent and active MTrP groups. There were no significant differences in any of the between-group comparisons.
13	Boonruab J 2021	Forty-six subjects with clinically diagnosed myofascial pain syndrome in the upper trapezius muscle.	①traditional Thai massage (CTTM) ② Thai hermit exercises(THE)	①and②	Cervical spine ROM was significantly increased in both the CTTM and THE groups.Comparison between groups showed no different effects between CTTM and THE, indicating that both increased range of motion.
14	Aranha MF 2015	60 subjects with TrP in the upper trapezius muscle in patients with neck pain.	①Electroacupuncture ②Acupuncture ③Counterfeit acupuncture needle	①and②and③	After treatment, a significant increase in right rotation was observed in the EAC group, a significant increase in right lateral flexion and right rotation was observed in the AC group, and no change was observed in the SHAM group. For follow-up evaluation, only the increase in right lateral flexion in the AC group was maintained.
15	Arjona Retamal JJ 2021	96 patients with chronic neck pain.	①Manual suboccipital inhibition technique (MSIT) ②instrumental suboccipital inhibition (INYBI) ③ INYBI＋Upper Cervical Manipulation Technique (INYBI＋UCMT)	①and②and③	The three groups showed significant improvement in all outcome measures except flexion/extension ROM, with a significant improvement in the time factor.There were no differences between groups.
16	Diego IMA 2019	24 subjects with TrP in the upper trapezius muscle in myofascial chronic neck pain.	①High frequency ②Placebo	①and②	MCRRF and placebo did not significantly improve cervical ROM except for right rotation. No differences were observed between groups.

KT:Kinesio Tape　TrP:Trigger Point　US:UltraSound　DN:Dry Needling　ROM:Range of Motion

Table 3.　PEDro Scale

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ⅰ	Random allocation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅱ	Concealed allocation	N	N	N	N	Y	Y	N	Y	N	N	Y	N	Y	N	Y	Y
Ⅲ	Baseline comparability	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅳ	Blind assessors	Y	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y
Ⅴ	Blind subjects	Y	N	N	N	N	N	Y	N	N	N	N	Y	N	Y	Y	Y
Ⅵ	Blind therapists	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y
Ⅶ	Adequate follow up	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Ⅷ	Intention-to-treat analysis	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y
Ⅸ	Between-group comparisons	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ⅹ	Point estimates and variability	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
	Eligibility criteria(点数外)	N	Y	N	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y
	合計Score	7/10	7/10	4/10	7/10	7/10	8/10	6/10	7/10	4/10	7/10	7/10	8/10	6/10	6/10	8/10	9/10
	研究の質Quality	Hight	Hight	Poor	Hight	Hight	Hight	Fair	Hight	Poor	Hight	Hight	Hight	Hight	Fair	Hight	Hight

Y:Meets the criteria

N:Criteria not met

Ⅰ:Random allocation	Subjects were randomly allocated to groups
Ⅱ:Concealed allocation	Allocation was concealed
Ⅲ:Baseline comparability	The groups were similar at baseline regarding the most important prognostic indicators
Ⅳ:Blind assessors	There was blinding of all therapists who administered the therapy
Ⅴ:Blind subjects	There was blinding of all subjects
Ⅵ:Blind therapists	There was blinding of all therapists who administered the therapy
Ⅶ:Adequate follow up	Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups
Ⅷ:Intention-to-treat analysis	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"
Ⅸ:Between-group comparisons	The results of between-group statistical comparisons are reported for at least one key outcome
Ⅹ:Point estimates and variability	The study provides both point measures and measures of variability for at least one key outcome
Eligibility criteria	Eligibility criteria were specified

3. Target Site

Eleven reports on the neck, two reports on the thoracolumbar region, one report on the hip joint, one report on the knee joint, and one report on the temporomandibular joint were followed up for intervention and joint range of motion measurement.

4. Effects of Various Treatment Methods for Trigger Points on Joint Range of Motion

Two Laser Therapy, three Kinesio Taping (hereafter referred to as " KT "), three Dry Needling (hereafter referred to as "DN"), five Manual Therapy, one Massage Stick, one Electroacupuncture, and one Radiofrequency Therapy were used as intervention methods for trigger points.

Fourteen of the 16 interventions increased the range of motion of the joints, but there was no significant difference in 8 of the interventions between groups. In 2 cases, there were no significant differences between the intervention groups before and after the intervention.

IV. Discussion

The purpose of this study was to clarify through a qualitative systematic review the effects of various treatment methods for TrP on joint range of motion and the possibility of measuring joint range of motion as an evaluation method for determining treatment efficacy.

Considering the research results, the initial keyword search for extracted articles yielded 8,147 PubMed articles and 1,139 Ichushi-Web, but after screening, the number of articles was reduced to 13 PubMed articles and 3 Ichushi-Web. We believe the reason for such a large decrease in the number of publications was due to the fact that there were few RCTs, and were only case reports and short reports. In addition, this study was limited to the 10 years from 2013 to 2022 in order to investigate recent research trends, which can also be a major factor in the decrease of the number of documents. In addition, in the quality evaluation using the PEDro scale, 12 studies were of high, 2 studies were of fair, and 2 studies were of poor quality. There were many articles that did not meet the criteria, and of particular note were 14 articles for VI Blind therapists that failed to meet the criteria standard. It is said that only 2% of studies meet the criteria for blinding of therapists in the PEDro statistics[25], and in this study as well, blinding of therapists in clinical trials is important for implementing interventions. It was suggested that this would be extremely difficult because the person conducting the test must be in a situation where they do not know the subject's intervention.

Regarding the target areas, there were 11 cases on the neck, 2 cases on the thoracolumbar region, 1 case on the hip joint, 1 case on the knee joint, and 1 case on the temporomandibular joint. From the above, the majority of the target areas for TrP were the neck. Based on the extracted literature, TrPs are said to occur most often in the shoulder girdle and neck, and among them, the trapezius muscle, is the most common site of MPS[12]. The reason for this could be due in part to its relative easiness.

The treatments for TrP included Laser Therapy in 2 cases, KT in 3 cases, DN in 3 cases, Manual Therapy in 5 cases, Massage Stick in 1 case, Electroacupuncture in 1 case, and Radiofrequency Therapy in 1 case. A wide range of methods were used, from highly specialized methods such as DN and Electroacupuncture that require a limited intervention environment, to methods that could be performed by the patient themself, such as KT and Massage Sticks. TrP is said to be a painful mass or induration at the site of intramuscular tension, and it has been suggested that external stimulation can be implemented as a treatment method depending on the skill of the interventionist and the environment. Regarding the effects of various treatment methods for TrP on joint range of motion, 14 out of 16 articles stated that an increase was observed, but there were also cases where there was no significant difference, and statistically there was no significant difference in joint range of motion. It has become clear that it is difficult to judge whether it is effective in increasing the number of patients. Although the above suggests that TrP affects joint range of motion, there was no clear evidence that various treatments for TrP statistically contributed to improving joint range of motion limitations. On the other hand, it has been revealed that TrP affects joint range of motion, suggesting that joint range of motion measurement can be used to determine the effectiveness of TrP.

One limitationOne of this study was that it was not possible to clearly report thereport contribution of TrP to improving joint range of motion. Even in the literature where improvements were seen, the specific extent of improvement could not be clarified.In addition, with the time limit we set as a period of only 10 years and research to be limited limited to include PICO elements from the RCT research, we experienced a significant decrease in the number of documents available andavaibable fewer results for various treatment methods.
In the future, we hope that clinical research will produce statistical results on the effects of various treatment methods for TrP on joint range of motion, and that joint range of motion measurements will contribute to the objective evaluation of effects in patients with TrP.

Conflict of interest

There are no conflicts of interest or research funding to disclose in this study.

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Original Article

Aerobic energy release decreases under hypoxia during intense identical constant-load exercise

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Abstract

[Purpose]

We aimed to clarify the effects of hypoxia on metabolic kinetics during short-duration constant-load exercise at identical intensities.

[Methods]

Eleven highly trained male track sprint cyclists (age, 22.2 ± 1.3 years) performed 65–70-s exhaustive identical constant-load bicycle exercise (558 ± 23 W) under normoxia (fraction of inspired oxygen, 20.9%) and hypoxia (fraction of inspired oxygen, 14.4%). Pulmonary oxygen uptake was measured using the breath-by-breath method. The blood lactate concentration was also measured post-exercise.

[Results]

The pulmonary oxygen uptake showed similar changes during the initial 20 s of exercise under both conditions. Thereafter, until the end of exercise, the pulmonary oxygen uptake was significantly lower under hypoxia than under normoxia. The pulmonary oxygen uptake plateaued after the initial 40 s of exercise under both conditions. Hypoxia reduced accumulated oxygen uptake during exercise (–12.8 ± 1.8%). The peak blood lactate concentration after the exercise was significantly higher under hypoxia than under normoxia (normoxia: 13.4 ± 0.5 mM, hypoxia: 15.6 ± 0.4 mM).

[Conclusion]

Hypoxia reduces aerobic energy release after the initial 20 s of identical constant-load exercises, suggesting a compensatory increase in anaerobic energy release, which results from glycolysis.

Keywords: hypoxia, intense identical constant-load exercise, anaerobic energy release

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I. Introduction

Altitude (or hypoxic) training is performed to improve endurance. Recently, athletes participating in relatively short-duration sporting events also perform altitude or hypoxic training to improve their anaerobic performance. Previous studies have investigated the physiological effects of altitude training on endurance (aerobic) performance using parameters such as hematological changes[1, 2, 3], maximal oxygen uptake[4], and blood lactate (BLa) concentration during submaximal exercise at identical work load[3]. However, the physiological effects of altitude (or hypoxic) training on anaerobic performance have not been adequately clarified.

Pulmonary oxygen uptake ($\dot{V}O_2$) during exercise at identical submaximal workloads does not differ between exercise under normoxic and hypoxic conditions[5, 6, 7]. Therefore, the oxygen cost of identical-load exercises is constant, regardless of the oxygen conditions during exercise.

In contrast, aerobic energy release is lower under hypoxia than under normoxia, despite the lack of difference in mechanical performance between these two conditions in short-duration all-out exercises of ≤ 60 s[6, 8]. Therefore, the decrease in aerobic energy release and the compensatory increase in anaerobic energy release under hypoxia compared with that under normoxia would result in the maintenance of exercise performance in short-duration high-intensity exercise[6, 8]. Maldonado-Rodriguez et al.[9] reported that hypoxic conditions elicited significantly greater physiological strain (rating perceived exertion: RPE, heart rate: HR, BLa) compared with that under normoxic conditions. Their results suggested that the sprint training protocol under hypoxic conditions might induce more positive training adaptations, in terms of increasing RPE, HR, and BLa without decreasing power output, compared to those with sprint training under normoxic conditions. In addition, a single session of sprint interval exercise (3 × 30-s sprints) under hypoxia caused a greater decrease in muscle glycogen content compared with the same exercise under normoxia without interfering with power output[10]. Therefore, short-duration exercise at high intensity under hypoxia is considered to elicit a large amount of anaerobic energy release with glycolytic energy compared with that under normoxia.

It is reported that hypoxia significantly slowed the response of $\dot{V}O_2$ at the onset of exercise at submaximal identical intensity compared to normoxia[4, 11, 12]. However, the differences in metabolic kinetics during short-duration exhaustive, identical constant-load exercise under normoxia and hypoxia remain unclear. If aerobic energy release is lower under hypoxia than under normoxia during short-duration exhaustive, identical constant-load exercise, this difference is observed in parameters such as the speed of the $\dot{V}O_2$ response and/or the degree of change in $\dot{V}O_2$ during exercise. Therefore, this study aimed to clarify the effect of hypoxia on metabolic kinetics during short-duration exhaustive, identical constant-load exercise. We used an exercise protocol practiced by Japanese sprint track cyclists for training. Clarifying the kinetics of metabolism during intense constant-load exercise is expected to be useful for the effective hypoxic training in sprint events.

II. Method

Eleven highly trained male sprint track cyclists volunteered to participate in this study. The participants' physical characteristics were as follows: age, 22.2 ± 1.3 years; height, 171.4 ± 1.2 cm; and body mass, 72.1 ± 4.4 kg, maximal oxygen uptake ($\dot{V}O_{2max}$), 4.73 ± 0.24 $L \cdot min^{-1}$ (65.6 ± 3.2 $ml \cdot kg^{-1} \cdot min^{-1}$). Of these, six were national team track cyclists in Japan. The remaining five cyclists were college students who had undergone sprint training. All the participants were fully informed of the purpose, procedures, potential benefits, and possible risks of participating in this study. We did not conduct the experiment when participants reported feeling unwell. We also carefully monitored the participants and immediately stopped the experiment if we observed that they were not feeling well. This study was approved by the Ethical Committee for the Protection of Human Subjects of the Japan Institute of Sports Sciences, and written informed consent was obtained from all the participants.

Each participant participated in two sessions: an exercise test under normoxia and an exercise test under hypoxia. The tests were performed in the same experimental room (hypoxic training room at the Japan Institute of Sports Sciences) at the same room temperature (21ºC). The inspiratory O_2 fractions (F_IO_2) used in this study were 20.9% (normoxia) and 14.4% (hypoxia, equivalent to a simulated altitude of 3,000 m)[10, 11, 13, 14, 15], and the O_2 concentration in the room air was adjusted accordingly. The participants performed the two tests on separate days, and the order of the tests was randomized. The two tests were performed at least 7 days apart. The participants were instructed to refrain from strenuous exercise the day preceding each test and maintain a similar diet.

The participants warmed up using two prescribed exercise protocols starting 40 min prior to the exercise test. The warm-up exercises were performed outside the experimental room. The participants performed bicycle exercise at 200 W for 10 min while maintaining their pedal cadence at 100 rpm. They rested for 2–3 min and then rode the bicycle at the same absolute intensity as that in the exercise test for 20 s. The work rate of this second exercise was 558 ± 23 W. The participants were instructed to maintain their pedal cadence at 100 rpm. After the warm-up exercises, the participants entered the experimental room and were instructed to rest for 10 min. They were then instructed to ride a bicycle ergometer, and the position, the mask for pulmonary gas measurement, and a pulse oximeter for measuring arterial oxygen saturation (SpO_2) were set for each participant. Thereafter, the participants assumed a sitting position on the bicycle ergometer for > 3 min, and the exercise test was initiated after the SpO_2 and pulmonary gas values stabilized.

The participants exercised using an electrically braked cycle ergometer (Excalibur Sport, Lode, Groningen, The Netherlands). The bike setup (saddle height and reach) for each participant was recorded and reproduced for each subsequent test. The test load for each participant was set at the maximal load that could be maintained for 65–70 s based on preliminary tests. As a rule, the test load of the first preliminary test trial was set at body mass (kg) × 8 W for the national team cyclists and at body mass (kg) × 7.5 W for the college student cyclists. This exercise intensity was set based on the exercise protocols practiced by Japanese sprint track cyclists for training. As appropriate, we arranged the test load for each participant based on preliminary test trials so that the participant reached exhaustion between 65 and 70 s. The absolute test load was the same under normoxic and hypoxic conditions. Prior to the experiment, we conducted trials to confirm the maximal intensity at which the participants could exercise for 65–70 s; the performance did not differ under either condition. The exercise load for this test was 558 ± 23 W. The participants performed the exercise until exhaustion under both conditions. They were instructed to maintain a pedal cadence of 100 rpm. Exhaustion was determined when the cadence fell below 95 rpm. The cadence was recorded throughout the exercise tests. All participants reached exhaustion between 65 and 70 s under both conditions.

Pulmonary gas exchange variables were measured during the pre-exercise rest period and throughout the exercise period using a breath-by-breath gas analysis system equipped with open-circuit auto O_2 and CO_2 analyzers and a hot-wire flow meter (AE300S; Minato Medical Science, Japan). The data were used to calculate $\dot{V}O_2$, carbon dioxide output, and minute ventilation ($\dot{V}_E$). Before the experiments, the flow sensor was calibrated with a known volume of room air at several mean flow rates, and the gas analyzers were calibrated using commercially available gases with known O_2 and CO_2concentrations (Sumitomo Seika Chemicals Co., Ltd., Japan). The gas analyzer was calibrated before each test using two standard gases (20.73% O_2 and 0.00% CO_2; 10.10% O_2 and 5.02% CO_2).

The breath-by-breath data were converted to second-by-second data using linear interpolation and time aligned to the start of the test. The first 15 s of data were removed to account for the cardio-dynamic phase[16]. The $\dot{V}O_2$ response of the exercise was modeled using a monoexponential formula with a time delay[12]:

$\dot{V}O_2 (t) = \dot{V}O_2\text{baseline} + \text{amplitude} (1-e^{-(t-TD)/\tau})$

where $\dot{V}O_2$ (t) is the $\dot{V}O_2$ at any time t, $\dot{V}O_2$ baseline is the $\dot{V}O_2$ before the onset of the exercise, amplitude is the final value to which $\dot{V}O_2$ projects, TD is the time delay, and τ is the time constant describing the rate at which $\dot{V}O_2$ rises towards the final value.

After the exercise, blood was withdrawn from the participant's fingertip to measure the BLa concentration. The blood was sampled 3, 5, 7, and 10 min after exercise. The volume of each blood sampling was 20 μl. BLa concentration was determined using an automated lactate analyzer (Biosen S_Line, EKF Diagnostic, Germany).

SpO_2 was measured through pulse oximetry (OLV-3100; Nihon Kohden, Japan) at the second or third finger. SpO_2 was monitored continuously from the pre-exercise resting phase until the end of exercise.

Statistical analysis was performed using SPSS Statistics (Version 23, IBM Corporation, New York, USA). Data are presented as means ± standard deviations. Breath-by-breath gas exchange variables and SpO_2 were averaged for 60 s during the pre-exercise rest period, and these parameters were averaged every 5 s during exercise. Pulmonary gas exchange variables during exercise were used for up to 65 s, at which time all participants could perform the exercise. Time-course changes in each parameter were tested using repeated-measures analysis of variance and Tukey's post-hoc test. The values for each condition (normoxia and hypoxia) at the same time points were compared using paired *t*-tests. In addition, the accumulated oxygen uptake and peak BLa concentration after exercise under both conditions were compared using paired *t*-tests. Statistical significance was set at $p < 0.05$.

III. Result

After the start of the exercise, the $\dot{V}O_2$ during the two conditions showed similar changes for up to 20 s. Thereafter, the $\dot{V}O_2$ under hypoxia was significantly lower than that under normoxia ($p < 0.05$, Fig. 1).

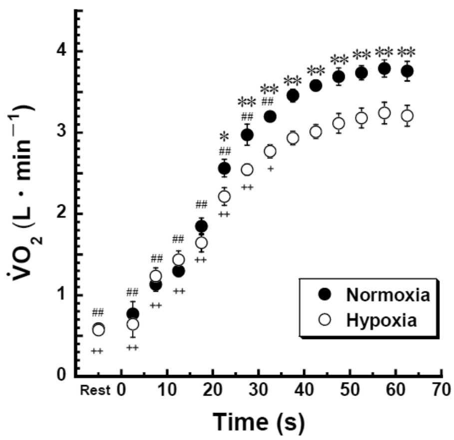

Figure 1. Kinetics of pulmonary oxygen uptake (VO_2) during the 65–70-s exhaustive identical constant-load exercise under normoxia (●) and hypoxia (○).
*$p < 0.05$, **$p < 0.01$, significant difference between normoxia and hypoxia
##$p < 0.01$, significant difference from the last 5 s of exercise under normoxia
+$p < 0.05$, ++$p < 0.01$, significant difference from the last 5 s of exercise under hypoxia

After the first 40 s of exercise, there was no statistical difference in the $\dot{V}O_2$ recorded from that time until the end of exercise under both conditions. Thereafter, there was no change in $\dot{V}O_2$ between the two conditions with the exercise duration. The $\tau\dot{V}O_2$ of the 2 conditions were not different (normoxia: 22.2 ± 0.7 s, hypoxia: 22.1 ± 0.8 s). The accumulated oxygen uptake during exercise under hypoxia was lower than that under normoxia (normoxia: 2.98 ± 0.07 L, hypoxia: 2.60 ± 0.08 L, $p < 0.01$, Fig. 2).

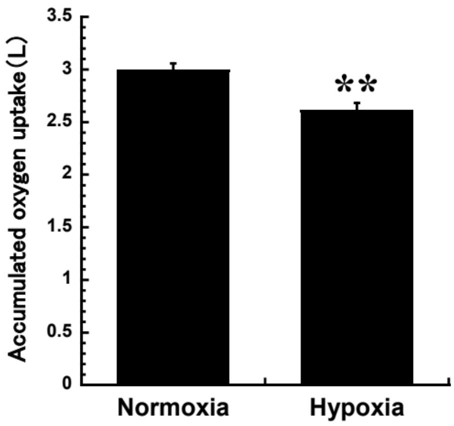

Figure 2. Accumulated oxygen uptake during the 65–70-s exhaustive identical constant-load exercise under normoxia and hypoxia.
**$p < 0.01$, significant differences between normoxia and hypoxia

Under both conditions, $\dot{V}_E$ increased with the exercise duration until the end of the exercise. During exercise, the $\dot{V}_E$ from 0 to 25 s of exercise under both conditions was similar. Thereafter, $\dot{V}_E$ under hypoxia was significantly higher than that under normoxia ($p < 0.01$, Fig. 3).

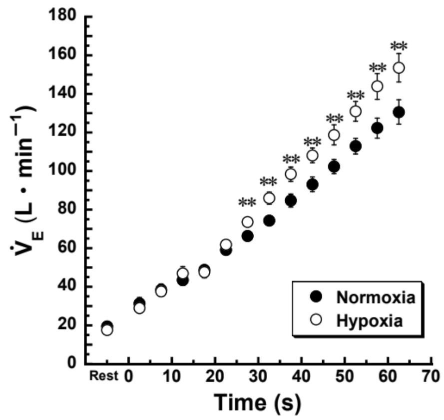

Figure 3. Kinetics of minute ventilation ($\dot{V}_E$) during the 65–70-s exhaustive identical constant-load exercise under normoxia (●) and hypoxia (○).
**$p < 0.01$, significant differences between normoxia and hypoxia

The peak BLa concentration after the exercise was significantly higher under hypoxia than under normoxia (normoxia: 13.4 ± 0.5 mM, hypoxia: 15.6 ± 0.4 mM, $p < 0.01$, Fig. 4).

The SpO_2 from the pre-exercise resting period to the end of exercise was significantly lower under hypoxia than under normoxia (pre-exercise resting period: normoxia, 98.0 ± 0.3%; hypoxia, 89.0 ± 0.9%; end of exercise: normoxia, 93.0 ± 1.5%; hypoxia, 79.6 ± 1.7%, $p < 0.01$).

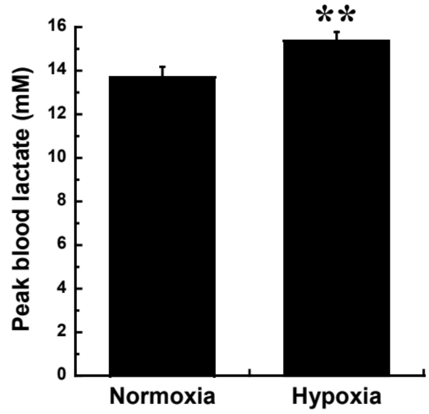

Figure 4. Peak blood lactate concentration after the 65–70-s exhaustive identical constant-load exercise under normoxia and hypoxia.
**$p < 0.01$, significant differences between normoxia and hypoxia

IV. Discussion

The major finding of this study was that $\dot{V}O_2$ during intense, identical constant-load exercise was lower after the first 20 s of exercise when the participants exercised under hypoxia than under normoxia. The $\tau\dot{V}O_2$ and the time at which the $\dot{V}O_2$ attained a plateau were the same in both conditions. After the first 40 s of exercise, there was no further increase in $\dot{V}O_2$ until exhaustion under either condition, although $\dot{V}_E$ continuously increased until exhaustion. Moreover, $\dot{V}_E$ was higher under hypoxic conditions than under normoxic conditions. In addition, the peak BLa concentration after exercise was higher under hypoxic conditions than under normoxic conditions. These results suggest that to compensate for the decrease in aerobic energy release, there is an increase in anaerobic energy release under hypoxic conditions after the first 20 s of identical-load exercise. Furthermore, differences in aerobic energy release did not occur because of differences in the speed of $\dot{V}O_2$ response.

As the $\dot{V}O_2$ of submaximal identical-load exercise is constant regardless of normoxia and hypoxia[5, 6, 7], the oxygen cost of identical-load exercise is believed to be constant, regardless of the oxygen concentration of the inspired air. However, Wolfel et al.[7] found that leg oxygen consumption during submaximal identical-load bicycle exercise was lower under hypoxia than during exercise at sea level (barometric pressure 751 Torr), despite identical pulmonary $\dot{V}O_2$. This reduced leg oxygen consumption may reflect increased pulmonary $\dot{V}O_2$ by either non-exercising muscle beds or, more likely, the respiratory muscles, as the work of breathing during hypoxia is greater than that at sea level[7, 17].

Previously, a reduction in arterial O_2 concentration induced by a lower inspired gas concentration slowed the adaptation of $\dot{V}O_2$ at the onset of submaximal exercise[4, 11, 12]. However, in the present study, The $\tau\dot{V}O_2$ and the timing of the no further increase in $\dot{V}O_2$ after the start of exercise was the same under both normoxia and hypoxia (40 s after the start of exercise). Therefore, we found that the difference in aerobic energy release during short-duration, intense, identical constant-load exercise between the two conditions was not due to the speed of the response in oxidative metabolism at the onset of the exercise. This seems to be a specific response to short-duration intense exercises.

In the present study, $\dot{V}_E$ was higher under hypoxia than under normoxia after the first 25 s of exercise. Moreover, the difference in $\dot{V}_E$ continuously increased until the end of exercise, whereas $\dot{V}O_2$ at the same time was significantly lower under hypoxia than under normoxia. Pulmonary $\dot{V}O_2$ includes not only the oxygen consumption of exercising leg muscles, but also that of non-exercising muscles and the respiratory muscles[18]. Respiratory muscle oxygen consumption increased with $\dot{V}_E$[18, 19]. Therefore, respiratory muscle oxygen consumption during exercise appears to be higher under hypoxic conditions than under normoxic conditions. Considering the difference in the respiratory muscle oxygen consumption, it seems that the difference in the leg muscle oxygen consumption during exercise between the 2 conditions used in this study was larger than the difference of $\dot{V}O_2$.

The $\dot{V}O_2$ response has been reported to show significant reduction in the slope of $\dot{V}O_2$ and work rate ($ml \cdot min^{-1} \cdot W^{-1}$) during incremental exercise under hypoxia[14, 20]. Murphy et al.[14] interpreted this as a progressive inability to adjust the oxygen supply to meet the metabolic demand with increasing exercise intensity. In the present study, a greater degree of inability to adjust the oxygen supply to meet metabolic demands occurred because of the considerably high exercise intensity, resulting in an increase in anaerobic energy release during exercise under hypoxia.

In this study, the peak BLa concentration after exercise was higher under hypoxia than under normoxia. Hypoxia stimulates muscle glycogenolysis, glycolysis, and lactate production[21]. Lactate accumulation is associated with glycolysis[22]. The most significant source of anaerobic ATP production during intense activities lasting longer than 10–20 s is glycolysis[22]. In the present study, a lower $\dot{V}O_2$ under hypoxia than under normoxia was observed after the first 20 s until the end of exercise. Therefore, the results of the BLa concentration and $\dot{V}O_2$ kinetics in the present study suggest that the energy source of the increased anaerobic energy release compensating for the decreased aerobic energy release under hypoxia was mainly from glycolysis.

Weyand et al.[6] examined the effects of hypoxia on aerobic and anaerobic metabolism during all-out sprint running at various velocities (exhausting at 15–180 s). They reported that the running speed was largely unaffected by hypoxic reduction in aerobic power during all-out runs of ≤ 60 s, suggesting that rates of anaerobic energy release sufficiently increased to fully compensate for the aerobic energy lost during hypoxic sprints of up to 60 s. Ogura et al.[8] reported lower aerobic energy release and higher anaerobic energy release under hypoxia than under normoxia during the late 20-s phase of the 40-s Wingate test, whereas there were no differences in the mean power output of the Wingate test among different F_IO_2 conditions. Although exercise intensity decreased with exercise duration in these previous studies (all-out sprint running at various velocities (exhausting at 15–180 s) [6], 40-s Wingate test (maximal effort pedaling from the onset of the exercise)[8], whereas it was constant throughout the exercise in the present study, their findings are consistent with our findings that hypoxia causes a decrease in aerobic energy release without affecting the mechanical performance during short-duration exercise. It is considered that the metabolic rates are determined by the rates of ATP hydrolysis at the cross-bridge level[6]. Previously, it has been assumed that the rates of ATP hydrolysis are the same during exercise at the same mechanical work regardless of F_IO_2, because $\dot{V}O_2$ during exercise at submaximal intensity is not different under normoxia and hypoxia[5, 7]. In contrast, in the present study, $\dot{V}O_2$ was lower under hypoxia than under normoxia, despite the same mechanical work exercise in both conditions. This suggests that in the intense exercise performed in this study, the same mechanical work exercises were performed under hypoxia as under normoxia with increased anaerobic energy release. If the metabolic rates under normoxic and hypoxic conditions are determined by the rates of ATP hydrolysis at the cross-bridge level, the matching ATP resynthesis rates are provided by the flexible rates of aerobic and anaerobic energy release.

Studies on sprint training in hypoxic environments have reported the effects of repetitive sprint training on exercise performance[15, 23]. Sprint repetition is expected to improve performance in several ball game sports (e.g., soccer, rugby, and basketball). However, the knowledge of short-duration, high-intensity exercise training in hypoxic environments is insufficient to improve performance during timed events (e.g., athletics, swimming, track cycling, and speed skating) that last from a few tens of seconds to 1–2 min.

The exercise protocol used in this study was used by Japanese sprint track cyclists for training, with the aim of improving their performance, especially in the 1-km time trial of track cycling for approximately 1 min. During altitude training, the absolute training intensity (mechanical stimulus) often falls below that of exercises performed at sea level. However, mechanical performance does not change during high-intensity, short-duration exercises performed under hypoxia[6, 8, 24]. The results of our study suggest that anaerobic energy release is greater under hypoxic conditions than under normoxic conditions during 65–70 s of exhaustive constant-load exercise at identical loads. Therefore, short-duration high-intensity training under hypoxia is effective for improving anaerobic performance in terms of maintaining mechanical stimuli similar to those under normoxia and increasing anaerobic energy release. In future, we aim to examine the effects of long-term training in normoxic and hypoxic environments for high-intensity constant-load exercise, which requires approximately 1 min to complete, on skeletal muscle energy metabolism.

A limitation of this study is that the actual energy metabolism of leg muscle during exercise could not be measured. Therefore, it is not possible to accurately determine leg muscle oxygen consumption or anaerobic energy release. The next study is to examine muscle energy metabolism under normoxic and hypoxic conditions with high time resolution (e.g., 31phosphorus magnetic resonance spectroscopy and near-infrared spectroscopy) during approximately 1 minute exhausting intense constant-load exercise.

V. Conclusion

Aerobic energy release after the initial 20 s during the 65–70-s exhaustive identical constant load exercise is lower under hypoxia than under normoxia. Furthermore, the $\tau\dot{V}O_2$ at the onset of exercise and the time at which the $\dot{V}O_2$ attained a plateau were the same in both conditions. Therefore, this difference in aerobic energy release does not occur because of differences in the speed of $\dot{V}O_2$ response. The reduction in aerobic energy release during identical-load exercises under hypoxia suggests an alternative compensatory increase in anaerobic energy release.

Conflict of interest

The authors declare no conflicts of interest.

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Case Study

A Case Study of Mechanical Diagnosis and Therapy (MDT) A case study of Manual Shift Correction (MSC) for acute low back pain with lateral shift

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Abstract

[Purpose]

The purpose of this study was to investigate the effects of Manual Shift Correction (MSC) and MDT exercises on the management of acute low back pain with lateral shift using Mechanical Diagnosis and Therapy (MDT).

[Methods]

A woman in her 30s developed acute lower back pain 4 days before presenting with a left lateral shift. After performing three sets of MSC, an MDT technique, the subject performed self-exercises such as side gliding in standing (SGIG) and extension in lying (EIL) using a wall once every three hours for five–six times. After one set of MSC, the distal symptoms converged in the lumbar region, and lumbar pain was reduced. After three sets of MSC, the patient was able to apply equal weight to both legs, and both the walking speed and gait improved.

[Results]

Although MDT can cause short-term pain, the patient's symptoms improved with repetitive movements.

[Conclusion]

Utilization of these management techniques may help break the cycle of pain caused by excessive avoidance of pain.

Keywords: Mechanical Diagnosis and Therapy, acute low back pain, lateral shift

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I. Introduction

Lower back pain is the most common complaint in both men and women in Japan[1]. Until recently, 85% of low back pain patients with LBP were considered to have nonspecific low back pain, meaning that the cause of the pain was unclear[2,3]. In a recent report conducted on low back pain patients in Yamaguchi Prefecture, it was found that 78% of cases can be accurately diagnosed using a combination of neurological, physical, and imaging findings[4]. However, even if imaging abnormalities are found, they are often insufficient in explaining clinical symptoms[5]. Even in cases where the cause can be identified, there is no uniform classification or intervention for lower back pain, except for diseases that are amenable to surgery, where there are various approaches to lower back pain.

The Mechanical Diagnosis and Therapy (MDT) is a method of analyzing low back pain by classifying it into categories. MDT evaluates and classifies pain based on the mechanical stimulation. The MDT is characterized by the evaluation of how baseline (BL) symptoms are changed by mechanical stimuli. This classification includes Derangement syndrome, Dysfunction syndrome, Postural syndrome, and others. Derangement syndrome is a condition in which symptoms and findings change in a short time and within a short period of time due to mechanical stimuli such as posture and movement, and most nonspecific low back pain fall under this classification[6,7].

In this case, the symptoms of acute lower back pain with lateral shift improved in a short time using the MDT approach.

II. Method

1. Patient Information

A woman in her thirties who worked at home on a personal computer spending her working hours in a sitting position in chair. She goes to the gym twice a week and exercises for approximately one hour using a training machine. Four days prior to her visit, while bending down to get out of her car, she felt severe pain from her lower back to the back of her right thigh and was unable to move. After the initial occurrence of pain she was slowly able to move, but gradually a left shift occurred. She visited our hospital when her symptoms had not improved after four days. When she visited our treatment center, she experienced persistent pain from the lumbar region to the posterior aspect of the right thigh. She could only slightly flex her trunk over time but could not extend it. She was unable to return her left shift to the midline position by herself and could not place any weight on her right leg. The patient's posture was tilted slightly forward. Pain in the lumbar region and posterior aspect of the right thigh increased, particularly with trunk extension and loading of the right leg. While chair sitting posture was a contributing factor in reducing pain, the pain increased when the patient stood up from the chair, and it took some time to perform any movement thereafter. As previously mentioned, achieving a normal gait was difficult because of her inability to apply weight to the right leg. However, the patient was able to walk at a slower pace. The patient also had a history of herniation between the 4th and 5th lumbar vertebrae.

2. Findings

Shifting in MDT is considered as follows: The direction in which both shoulders are shifted relative to the pelvis is described as right shift, and left shift respectively. Furthermore, a posture in which the upper trunk shifts to the opposite side of a symptom, such as leg pain, is described as contralateral shift, while a posture in which the upper trunk shifts to the same side as the symptom is described as ipsilateral shift. Empirically, contralateral shift is more common than ipsilateral shift (Figure 1).

Figure 1. Shift concept in MDT

Criteria suggesting that a lateral shift is associated with symptoms include the following: (1) the upper trunk is clearly shifted to one side, (2) the shift is approximately concurrent with the onset of symptoms, (3) the patient is unable to correct the shift on his/her own, or (4) the patient is unable to maintain the corrected state even if he/she can correct it on his/her own (5) intensity of symptoms change after correction, and (6) distribution of symptoms change after correction. If the patient is able to correct themself but is unable to maintain the corrected state, he/she is a likely candidate for manual shift correction (MCS) in MDT[8].

The patient has a posterior pelvic tilt, lumbar kyphosis, a slightly anterior trunk tilt, and a left shift and contralateral shift. Neurological findings such as sensory examination and tendon reflexes were normal. Although acute back pain recurred several times, it has never been prolonged, as in the present case, and the previous acute back pain had healed gradually within a few days. This was the first time that a lateral shift occurred to the extent that it was externally noticeable. The patient wakes up frequently at night because of pain and has difficulty sleeping. We interviewed the patient to rule out red flags; however, no information was obtained to suggest any serious pathology.

Dysfunction syndrome, in which pain is induced only in the final range of motion, and postural syndrome, in which pain is induced by continuously maintaining the same posture, were excluded. Baseline (BL) was defined as pain during right-foot loading and walking.

3. MSC Method

The therapist pushed the patient’s upper torso, including rib cage, toward the opposite side with their shoulder just above the patient's elbow (above the clavicle), and pulled the entire pelvis toward the therapist with both hands on the opposite pelvic region. By simultaneously pushing and pulling while correcting the shift so that the movement becomes that of a side glide, the therapist also aimed to ensure that the patient's weight was evenly distributed on both feet. Side glide is an MDT exercise in which both shoulders are kept horizontal, and the pelvis is moved to the left and right[8]. The side glide was preformed gradually with a small amplitude, where during this maneuver it was held for a moment before slightly relaxing. The exercises were then performed with a small amplitude, and when the side glide was performed, the exercises were held a little and relaxed a little. This process was repeated rhythmically as the correction progresses. If symptoms did not improve, the holding time was extended. The correction was performed by side gliding to the contralateral side up to the end range, which is a point of emphasis in the exercise stress test in MDT because the significance of the exercise becomes clear when the patient moves to the end range, the final range of motion[8]. When the patient reaches the end range of the side glide to the opposite side, the patient is slightly relaxed. This allows the patient to extend while maintaining slight overcorrection. The patient performed the extension while the therapist maintained an overcorrected position. The patient and therapist worked together to allow the patient to extend the end range. The therapist may change the position of both feet as needed to allow the patient to extend the end range. When the patient was fully extended, the therapist held the patient for a moment and then returned to the original positioning. The procedure of MSC is to gradually aim for end range while rhythmically repeating the procedure as many times as necessary[8)].

The subject was pushed to the end range, and in that position, the maximum possible extension for the subject was performed three times. The therapist was careful not to inhibit extension movement while maintaining lateral overcorrection (Figure 2).

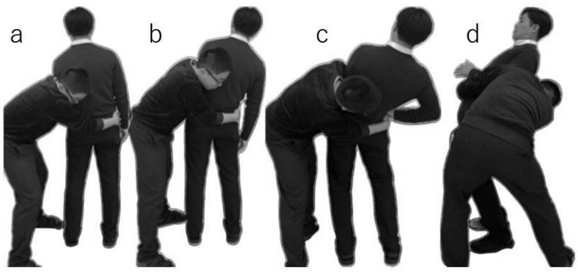

Figure 2. MSC Method
a: The therapist's left clavicle is placed on the patient's left upper arm and the trunk is pushed contralaterally while the therapist's hands pull in the contralateral pelvis.
b: Side glide contralaterally to the end range and relax slightly after reaching the end range.
c: Extend the patient while maintaining a slight overcorrection (posterior)
d: Extend the patient while maintaining a slight overcorrection (lateral)

The home exercises included right-side gliding in standing (SGIS) and extension in lying (EIL) using a wall.

The method of SGIS

The patient stood with the non-symptomatic side against the wall and leaned against the wall with the elbow flexed on the wall side. Both feet were placed at an appropriate distance from each other, and the hand on the opposite side of the wall was used to push the pelvis toward the wall. Push in as far as possible with end range(Figure 3).

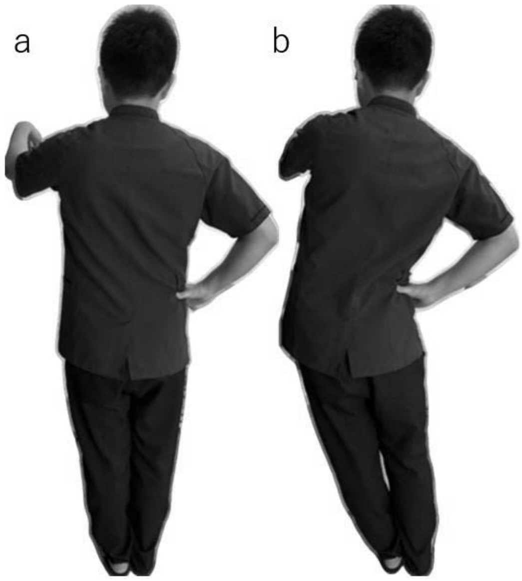

Figure 3. How to perform SGIS using a wall: The pelvis is pulled toward the wall by pushing in with the hand opposite to the wall side.
a: upright position b: side glide position
c: upright position d: side glide position
a: upright position b: side glide position

The method of EIL

In the supine position, hands are placed under shoulders and the spine is extended by extending the elbows while keeping the lower back and limbs relaxed. The lumbar region can be further extend through deep exhalation (overpressure). After waking up the next day, the lateral shift and lumbar pain were more severe than those immediately after the treatment, but improvement was observed by performing a set of 5-6 right SGIGs using the wall once every 3 hours. The patient was instructed to perform one set of EIL 5-6 times once every 3 hours from the point when the lateral shift completely disappeared and the pain from the posterior right thigh to the right lumbar region became median.

Three days after the MSC, both the lateral shift and lumbar pain disappeared, and the patient had no difficulties in daily activities (Figure 4).

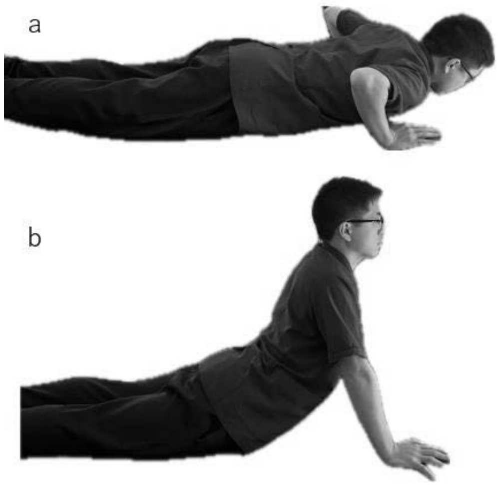

Figure 4. Method of EIL: Lying on the stomach with hands under the shoulders, the lumbar region and lower extremities are kept relaxed, and the elbows are extended to extend the spine. a: supine position b: extended position

4. Ethical Considerations

In accordance with the Declaration of Helsinki, the subject of this case report was informed orally and in writing about the protection of his/her personal information and publication, and their consent was obtained.

III. Results

During MSC, the patient's lumbar pain increased up to the mid-position during pushing, but the pain decreased significantly beyond the mid-position, and at the same time, the resistance sensation also decreased. After three extensions, the patient experienced anxiety and pain in the lumbar region when the practitioner gradually relaxed the lateral force from the pushed-in posture.

After the first set of MSC, the patient was able to apply a load to the right leg, and the lateral shift slightly returned to the midline. As for pain, a phenomenon called centralization, in which pain in the posterior aspect of the right thigh moved to the central region, was observed. Centralization has been reported as a good prognostic sign[9].

Since the MSC showed a reduction in right foot load and symptoms during walking in a short time, we judged that Directional Preference (DP) was detected and classified it as a Derangement of the MDT classification. After the third set of MSC, the patient was able to apply equal weight to both legs, and both gait and walking speed improved.

Photographs before and after the third MSC are shown in Figure 5.

Figure 5. Standing posture before and after MSC

IV. Discussion

The ultimate goal of MDT is to enable patients to manage their pain independently. Classification and evaluation are performed for this purpose, and MSC is one of the methods to achieve this goal. We believe that MDT is an effective method for patients to independently manage their pain on a daily basis. In the present case, the symptoms of acute lower back pain with lateral shift of the trunk were significantly reduced in a short time by the use of MSC, an MDT technique. The symptoms were also remitted by home exercises, such as SGIS, wall use, and EIL.

The phenomenon of movement paradox, in which pain is reduced with repetition of exercise, was observed[10], although it caused some pain during MSC and home exercise SGIS. Some reports suggest that pain management is useful in the short term[11]. It is thought that the use of such management will help break the vicious cycle of pain, in which excessive avoidance of pain leads to the transition to chronic pain.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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