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Are improvements in symptoms associated with changes in lumbopelvic posture in patients with posterior derangement using Mechanical Diagnosis and Therapy?

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Abstract.
BACKGROUND: Mechanical Diagnosis and Therapy (MDT) manages low back pain (LBP) with subgroup classifications. For a subgroup of the posterior derangement syndrome, postural education limiting lumbar flexion is included. However, it is not known if habitual posture in this subgroup actually changes through MDT management because of technical difficulties in monitoring habitual lumbopelvic posture. However, a wearable device, "LUMOback", which can evaluate the proportion of time with a neutral lumbopelvic posture (posture score), has now become available.
OBJECTIVE: To preliminarily investigate whether the posture score changes through the course of MDT management.
METHODS: Primary inclusion criterion was LBP with the posterior derangement syndrome. Primary outcome measure was the posture score during one week. The posture score was assessed one week before and six weeks after the initial MDT management, which included extension exercises and postural education.
RESULTS: All participants ($n = 8$) reported a successful treatment effect after the 6-week MDT intervention; however, there was no specific trend in the posture score (Friedman test: $p = 0.277$).
CONCLUSIONS: This study found evidence that the proportion of time with a neutral lumbopelvic posture during daily living, the posture score, which was measured with the LUMOback, did not systematically change with MDT management.

Keywords: Exercise therapy, low back pain, physical therapy modalities, posture, wearable electronic devices

1. Introduction

Low back pain (LBP) results in an enormous economic and healthcare burden throughout the world, and is often recurrent or prolonged [1]. A possible risk factor for the development of LBP is an awkward posture, such as slouched posture, especially when this is combined with prolonged sitting [2]. Therefore, slouched posture combined with time spent sitting could be associated with LBP. A recent study with a wearable device, the LUMOback, was done to understand lumbopelvic posture during actual daily life which indicated that individuals with LBP had less time with a neutral lumbopelvic posture than individuals without LBP [3].

According to the literature, Mechanical Diagnosis and Therapy (MDT), or the McKenzie approach, is one of the most commonly used physical therapy approaches for the management of LBP [4–7]. MDT

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is an evidence-based approach as a previous study found that certified MDT practitioners adhered more to evidence-based guidelines on the management of patients with LBP than physical therapists in general [8]. MDT uses classification subgroups to guide management strategies, which are identified through comprehensive evaluations using mechanical loading. The main subgroup is the derangement syndrome, which has a direction of mechanical loading to improve symptoms and function, called the directional preference (DP) [9], regardless of structural abnormalities. The derangement subgroup with DP of extension (posterior derangement syndrome) is the most common in people with LBP (52%) [10]. The management strategy for the posterior derangement syndrome includes increasing mechanical loading in the direction of lumbar extension with exercises and decreasing mechanical loading in the direction of lumbar flexion with postural correction [9]. Postural correction includes reduction of dynamic and static activities with lumbar flexion, for example, repeated forward bending and slouched sitting. To avoid slouched sitting and to maintain a neutral lumbopelvic posture, as in neutral standing, patients are instructed to use a lumbar roll during sitting.

MDT puts an emphasis on patient education and in fact patient's attitude towards self-management increases over the course of an episode of MDT management [11]. Postural education is an important component for patients with the posterior derangement syndrome. However, it is not known if the usual lumbopelvic posture actually changes in patients through the course of MDT management because of technical difficulties to actually monitor typical lumbopelvic posture. Recently, a wearable device, "LUMOback" (Lumo Bodytech Inc., Mountain View, CA, USA), has become available at a reasonable price. It is known that test-retest reliability for measuring the proportion of time with a neutral lumbopelvic posture during a day, known as posture score, is acceptable with the LUMOback, and that the posture score is different between individuals with and without LBP [3]. Therefore, using the LUMOback, it is possible to investigate if the usual lumbopelvic posture actually changes through MDT management in patients with posterior derangement syndrome.

The aim of this study was to investigate whether habitual lumbopelvic posture changes through the course of MDT management using the LUMOback. It was hypothesized that the proportion of time with a neutral lumbopelvic posture would increase with the MDT management, in association with a reduction of LBP.

2. Methods

2.1. Design

This preliminary study was a single-center quasi-experimental design. LUMOback data, habitual lumbopelvic posture and time spent sitting, were collected one week before and six weeks after the initial MDT evaluation. Other outcomes were assessed one week before the initial MDT evaluation (baseline), and three and six weeks after the initial MDT evaluation (3- and 6-week time points). All participants provided written consent before data collection. The study design was approved by the institutional research ethics committee and participants provided written consent before data collection. This study was pre-registered in the trial registration (UMIN000042285).

2.2. Participants

Participants were recruited via advertising in a local orthopedic clinic. Inclusion criteria of participants were: 1) $\geqslant$ 18 years of age, 2) LBP symptoms with referral from an orthopedic surgeon to physical therapy for exercise therapy and manual therapy techniques, 3) using a smartphone, 4) waiting for the initial MDT evaluation for more than one week. Exclusion criteria were: 1) not having posterior derangement syndrome, 2) not having DP of extension, and 3) a prior history of surgery.

Priori sample size estimation was undertaken to collect complete data from 10 participants as this has been recommended for a pilot study [12]. Making a liberal assumption of 33% loss of participants over the course of 6-weeks MDT, it was decided to obtain pre-treatment data on habitual posture and time spent sitting from 15 participants.

2.3. Intervention

All assessments and treatments including identifying MDT classification for subgroups were undertaken by the first author (HT), who had completed the MDT credentialing exam and the diploma clinical training, which is the highest level of training in the MDT program. The reliability for MDT classification for back pain has been established in credentialed MDT therapists [13,14]. The MDT management [9] (20–40 minutes) was undertaken up to a maximum of twice a week in the orthopedic clinic [11]. Detailed MDT evaluations for classifications and its management are de-

scribed in the text book [9]; a brief outline is described below.

Confirmation of the posterior derangement syndrome was undertaken with: 1) provisional classification of the posterior derangement syndrome with the presence of centralization and/or symptomatic and functional improvements with mechanical loading of lumbar extension at the initial MDT evaluation, and 2) a continuation of symptomatic and functional improvements through follow-ups.

For participants with a provisional classification of the posterior derangement syndrome at the initial MDT evaluation, education for postural correction in sitting was undertaken using a McKenzie lumbar roll (The Original McKenzie® Lumbar Roll™, OPTP, Minneapolis, USA). The participants were asked to use the lumbar roll during sitting to maintain neutral lumbopelvic posture, as in neutral standing. Further, participants were asked to minimize activities with lumbar flexion. As home exercises, participants were instructed to undertake 10 or more repetitions of mechanical loading in the direction of lumbar extension every three hours using various forms of the exercise (Appendix 1). At each follow-up, all participants were interviewed about their exercise compliance, with at least three sets of 10 repetitions a day considered acceptable [15].

At follow-ups, trouble shooting in postural corrections and exercises including progression and adjustment of exercises were undertaken. Manual therapy techniques including exercises with therapist's overpressure and passive posterior-anterior joint mobilization were used when it was considered that recovery with the home exercise programme reached a plateau.

2.4. Outcome measures

The primary outcome measure was habitual lumbopelvic posture, which was examined using the LUMOback. The same setting of the LUMOback and instructions for the use of the LUMOback as the ones used in the reliability study were given to the participants, and thus detailed information about use of the LUMOback is presented there [3]. Briefly, participants wore the LUMOback at the level of L5-S1 during the day. Participants undertook the calibration in neutral standing when they first put on the LUMOback in the morning. Once it is calibrated, the LUMOback device can determine the angle of the pelvis relative to the calibrated angle. In the current study, the habitual lumbopelvic posture was examined with the average posture score, which is the proportion of time in a day with neutral pelvic posture relative to the time with a pelvic posture at a pre-determined threshold, 'very slouched' in the LUMOback setting, over a week. The threshold of 'very slouched' included $\geqslant 7^\circ$ posterior or $\geqslant 14^\circ$ anterior tilt of the pelvis relative to the calibrated angle in sitting and $\geqslant 8^\circ$ posterior or $\geqslant 12^\circ$ anterior tilt of the pelvis relative to the calibrated angle in standing. The average time spent sitting in a week was also calculated as a secondary outcome measure using the LUMOback. Adequate test-retest reliabilities of the posture score (Intraclass correlation coefficient [ICC] $= 0.82$) and time spent sitting (ICC $= 0.75$) averaged over a week have been established [3]. Furthermore, minimum detectable changes (MDCs) for the posture score and time spent sitting in individuals with LBP were 11.7% and 126.7 minutes respectively [3]. The LUMOback has a real-time feedback function to maintain a neutral posture, but this function was made inactive throughout the study.

Other secondary outcome measures were: 1) pain intensity, 2) magnitude of disability, 3) self-reporting functional limitations, 4) quality of life, 5) mobility and 6) self-reported overall improvement; for all of which validity and reliability have been established [16–22]. The secondary outcomes except time spent sitting during a week and the self-reported overall were assessed at the baseline and 3- and 6-week time points. The self-reported overall improvement was assessed at the 3- and 6-week time points only.

Pain intensity was assessed with the P4 [20], where a sum score of 0 indicates no pain and that of 40 indicates the highest possible pain level. Disability was assessed with the Oswestry Disability Index Japanese version (ODI) [19], where 0% indicates no disability and 100% indicates the greatest disability. Self-reported functional limitation was assessed with the Patient Specific Functional scale (PSFS) [23], where an average score of 0 indicates the maximum limitation and that of 10 indicates no limitation. Quality of life was assessed with the physical component summary score (PCS), indicating quality of life in physical aspects, and the mental component summary score (MCS), indicating quality of life in mental aspects, of the MOS 36-Item Short-Form Health Survey version 2-week [23]. The value of 50 indicates Japanese normal, and the greater the value is, the better the condition [24]. Mobility measures included the Figure Floor Distance (FFD) [22] and a Modified Schober's Test [21]. In the FFD, positive value indicates that the finger reaches above the floor and negative value in-

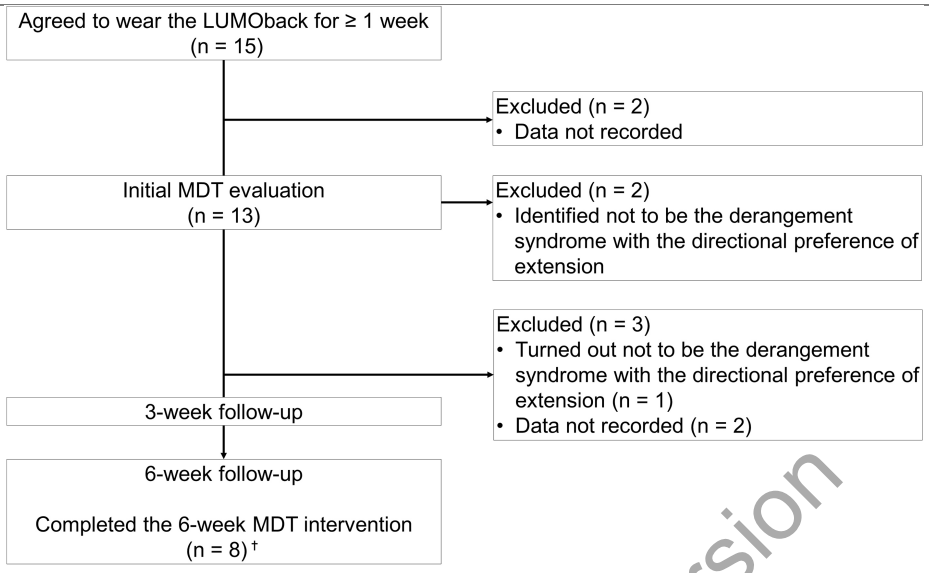

Fig. 1. Flow of the participants.

dicates that the finger reaches below the floor. In the Modified Schober's Test, the value of 15.0 cm indicates no movement of lumbar extension, and smaller values indicate grater lumbar extension range of motion in standing. The self-reporting overall improvement was assessed with a 7-point Global Rating of Change Scale (GRCS) (0 = worse than ever, 1 = much worsened, 2 = slightly worsened, 3 = no change, 4 = slightly improved, 5 = much improved, 6 = completely recovered) [25].

2.5. Statistics

SPSS version 21.0 (IBM Corporation, NY, USA) was used for statistical analyses and the level of statistical significance was set at 5%. Descriptive statistics were used to summarize characteristic of the participants and secondary outcomes.

Friedman test was used to investigate changes in the posture score and time spent sitting. Further, considering that the current study was a preliminary investigation, the posture score and time spent sitting were also analyzed quantitatively by plotting individual data. Data points that were greater than the MDCs at the baseline were highlighted.

Friedman test was used to investigate changes in the secondary outcomes except time spent sitting and the GRCS between the baseline and 3- and 6-week time points. Wilcoxon signed-rank test was then undertaken with Bonferroni corrections between the baseline and the 3- or 6-week time points as post-hoc analyses. Regarding the GRCS, the score of five or six was considered a successful response to treatment [25] and therefore the percentage of the participants with successful treatment was calculated.

3. Results

Figure 1 presents a flow of the participants. Recruitment of participants started in October 2016 and ended in March 2017. In addition to exclusion of five participants who turned out not to have the posterior derangement syndrome with DP of extension over a course of 6-weeks MDT management, LUMOback data were incomplete in four participants and they were also excluded from the analyses. Consequently, complete data of eight participants (four men and four women) were analyzed. The mean (SD) age was 31.4 (11.4) years. All participants had symptom duration of $>$ 3 months and the mean (SD) was 63.8 (42.1) months. Five participants had pain above the buttock and three also had referral to the lower limb. The mean (SD) treatment sessions from the baseline to the 3-week point were 3.1 (0.8) sessions and those from the baseline to the 6-week point were 5.3 (0.7) sessions. All participants reported acceptable compliance with prescribed exercises, with at least three sets of 10 repetitions a day.

Changes in the posture scores over the seven weeks are presented in Fig. 2 and those in time spent sitting are presented in Fig. 3. No statistically significant differences were detected in the posture score ($p = 0.277$)

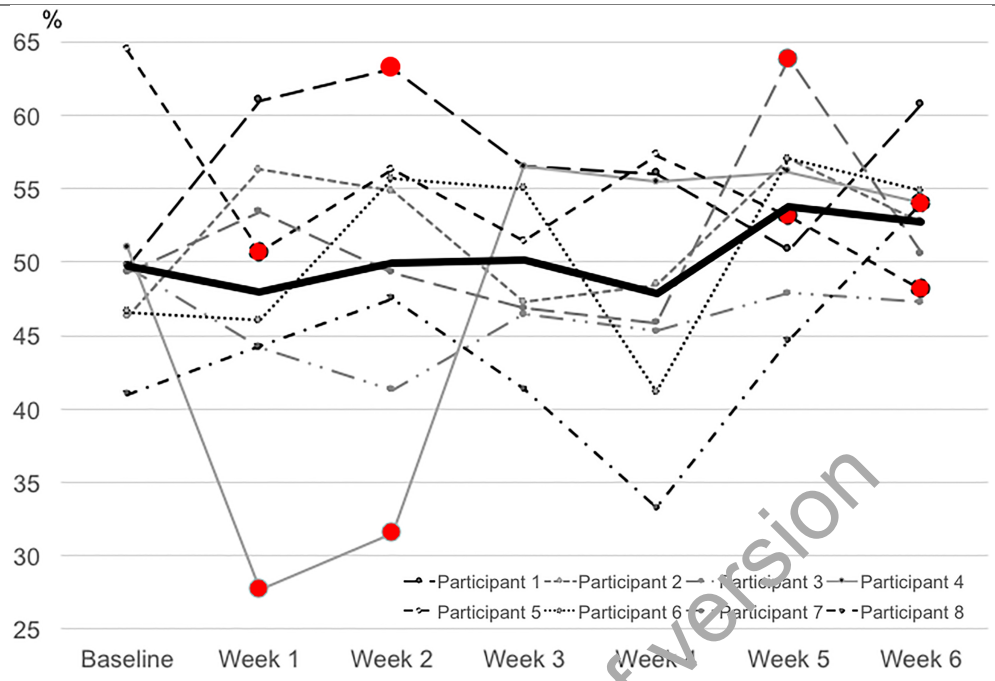

Fig. 2. Individuals' changes in the posture scores over the seven weeks. A vertical axis presents the posture score in percentage. A horizontal axis presents time, where the baseline means a week before the initial evaluation of Mechanical Diagnosis and Therapy. Big circles indicate the scores that changed greater and smaller than an established minimum detectable change (11.7%). A heavy black line indicates the mean of the eight participants.

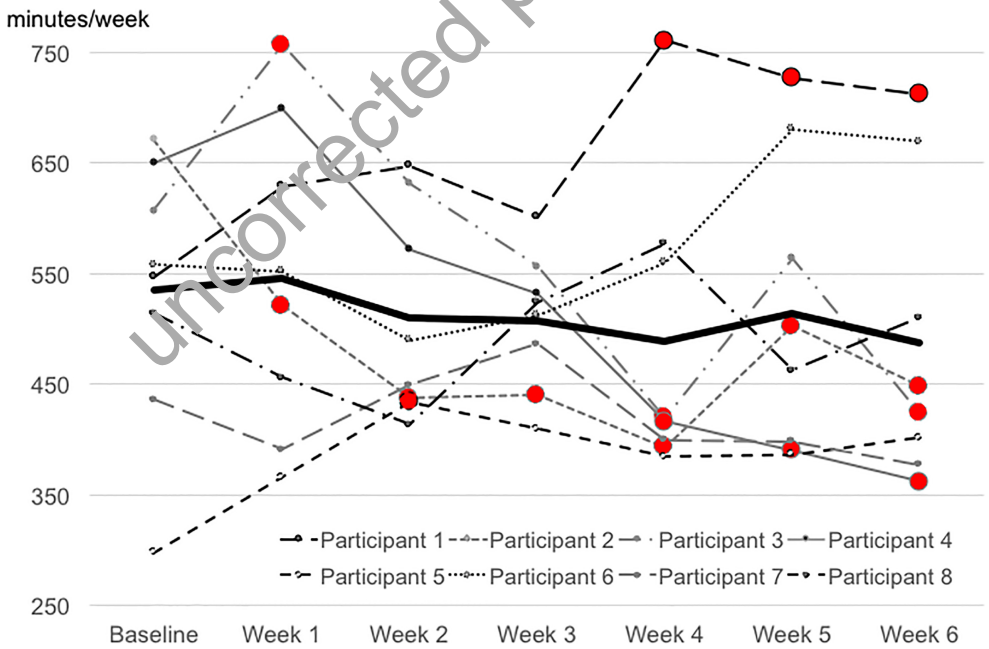

Fig. 3. Individuals' changes in time spent sitting over the seven weeks. A vertical axis presents time in minute. A horizontal axis presents time, where the baseline means a week before the initial evaluation of Mechanical Diagnosis and Therapy. Big circles indicate the scores that changed greater and smaller than an established minimum detectable change (126.7 minutes). A heavy black line indicates the mean of the eight participants.

Table 1
Mean (SD) of secondary outcome measures over the course of 6-week Mechanical Diagnosis and Therapy

	P4 (0-40)*	ODI (%)†	PSFS average (0–10)‡	PCS§	MCS§	FFD**	Ex¶
Baseline	9.6 (8.8)	17.7 (7.1)	4.6 (1.7)	50.0 (12.6)	47.3 (8.8)	7.2 (12.2)	11.9 (1.2)
3-week point	2.5 (1.6)	5.0 (4.2)	8.3 (1.3)	52.9 (5.2)	49.4 (7.4)	2.8 (10.2)	11.1 (1.1)
6-week point	0.9 (1.8)	2.9 (3.1)	9.5 (0.9)	59.7 (5.5)	53.3 (11.7)	0.0 (7.2)	11.3 (1.2)
p-value	0.001	0.002	0.001	0.072	0.197	0.011	0.043
p-value in the post-hoc analysis#							
Baseline vs 3-week point	0.028	0.012	0.018	0.674	0.484	0.069	0.025
Baseline vs 6-week point	0.011	0.018	0.012	0.161	0.263	0.05	0.141

Abbreviations: ODI, Oswestry Disability Index, PSFS; Patient Specific Functional Scale, PCS; SF-36 physical component summary score, MCS; SF-36 mental component summary score, FFD; Finger floor distance, Ex; lumbar extension range of motion measured with the Modified Schober's Test. *0 = no pain, 40 = the highest pain intensity. †Greater values indicate more severe disability. ‡0 = unable to perform activity, 10 = able to perform activity at the same level as before injury or problem. §50 = national average, greater values indicate a better condition. **Positive value indicates that the finger reaches above the floor and negative value indicates that the finger reaches below the floor. ¶Max = 15.0 cm, smaller values indicate grater lumbar extension range of motion in standing. #Statistical significance was < 0.025.

and time spent sitting ($p = 0.995$). It was not obvious that the posture score and/or time spent sitting changed greater than the MDCs between the baseline and one week after the initial MDT evaluation. It was also not obvious that the posture score and/or time spent sitting gradually changed greater than the MDCs over the course of the 6-weeks MDT management.

At the 3-week point, one participant reported the GRCS score of four and seven participants reported the GRCS score of five, showing 87.5% treatment success. At the 6-week point, two participants reported the GRCS score of five and five participants reported the GRCS score of six, showing 100% treatment success. Table 1 presents the secondary outcome measures at the baseline and 3- and 6-week points. The PCS and MCS scores did not change statistically. The mobility measures demonstrated statistically significant differences between the three time points but there was no statistically significant difference between the baseline and either 3- or 6-week point. The ODI and PSFS statistically improved from baseline at either 3- or 6-weeks and the P4 statistically improved from baseline at 6-weeks.

4. Discussion

The MDT management for the posterior derangement syndrome includes lumbar extension exercises and education for changing habitual posture to maintain neutral lumbopelvic posture during activities. However, it is not known if the usual lumbopelvic posture actually changes through the MDT management. Therefore, the habitual lumbopelvic posture for a week was monitored from one week before the initial MDT evaluation to seven weeks after the initial MDT evaluation with the posture score. It was hypothesized that the proportion of time with neutral lumbopelvic posture would increase with the MDT management, in association with a reduction of LBP. As expected, the participants' symptoms gradually recovered over the course of the 6-week MDT management. However, there was no specific trend of an increase in the posture score by initiating MDT management or through the management period. This disparity may indicate three possibilities. One possibility is that standard MDT management may not be effective enough to change participant's habitual posture and, if so, it may be possible that symptom improvement is facilitated when postural correction is enhanced with the use of LUMOback real-time feedback. A randomized controlled trial would be required to investigate this hypothesis. The other possibility is that the primary factor to improve symptoms was not postural change, but the exercises to produce adequate mechanical loading to the lumbar spine in the DP, considering the acceptable exercise compliance and gradual recovery of symptoms in the current study. The third possibility is associated with a possible limitation of the LUMOback, where the habitual lumbopelvic posture actually changed through MDT, but was not measurable with the LUMOback. As the posture score was different between individuals with and without LBP in a previous study [3], it was hypothesized that the posture score would change with symptom reduction through MDT management. However, the LUMOback is located at the L5-S1 level and the posture score decreases when there is $\geqslant 12^{\circ}$ anterior tilt of the pelvis relative to the angle in standing even though neutral lumbar lordosis is maintained, for example, with forward bending in standing. Studies with the use of a more comprehensive wearable measures than the LUMOback, which monitor lumbar motions relative to the pelvis, are required to understand

whether changing habitual lumbopelvic postures is associated with LBP.

There was also no specific trend of changes in time spent sitting by initiating MDT management or through the management period. This is not surprising because the current MDT management did not limit sitting itself. The link between prolonged sitting and LBP is ambivalent [1,2], but the current evidence lacks objective data of time spent sitting during daily living. The LUMOback cost is reasonable and it may be possible to collect very large amounts of data to conclude whether time spent sitting contributes to LBP.

According to the definition in the latest clinical practice guideline for LBP [26], all participants were classified with chronic LBP. There is no consensus on the effectiveness of MDT for chronic LBP compared with other interventions [27–30], but it is known that the derangement syndrome exists in a large subgroup of individuals with chronic LBP [28]. Furthermore, a subgroup of the derangement syndrome exists even in individuals with anatomical abnormalities such as lumbar spondylolysis [31]. The presence of DP is a positive prognostic factor and interventions using mechanical loading in the direction of DP are likely to be effective management strategies [32,33]. Thus, it is clinically important to investigate the possibility of the derangement syndrome regardless of chronic LBP or anatomical abnormalities.

4.1. Study limitations

The current study aimed to collect complete data from 10 participants. However, data from only eight participants were analyzed due to unexpected exclusion of four participants with incomplete LUMOback data. This indicates that further instructions of the use of the LUMOback and troubleshooting manuals are required in future studies to minimize the risk of incomplete LUMOback data. The sample size was smaller than the priori estimation and the sample size was small. However, there was no specific trend in either the posture score or time spent sitting by the participants over seven weeks and we believe that the conclusion in the current study would not change with a larger sample size. Further, two participants were excluded from the study because the posterior derangement syndrome was not identified and one participant was excluded as the provisional classification of posterior derangement syndrome changed in follow-ups. These exclusions are not surprising because posterior derangement syndrome is found in 52% in a previous study [10] and a concluding MDT subgroup sometimes is not identified in a single session [34].

The current preliminary investigation limited a 6-week follow-up and there may be an argument that the intervention for six weeks was not long enough to change habitual posture. However, five participants reported 'completely recovered' and two participants reported 'much improved' within six weeks and the duration of the intervention was considered adequate.

Finally, as stated above, the LUMOback might not have been so sensitive to detect changes in habitual lumbopelvic posture by initiating MDT management or through the management period. The posture score in the current study can be influenced by not only hyper lumbopelvic flexion but also hyper lumbopelvic extension accompanied with hyper posterior pelvic tilt. There is a possibility that participants maintain hyper lumbopelvic extension during activities. However, if so, there would have been a visible trend of reduction of the posture score through the MDT management and thus the conclusion in the current study would not change.

5. Conclusions

This study found preliminary evidence that the proportion of time with neutral lumbopelvic posture during daily living, which was measured with the LUMOback, did not systematically change with the MDT management. Symptom improvement, as recorded here, therefore cannot be due to any postural changes made by the patients.

Acknowledgments

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Conflict of interest

None to report.

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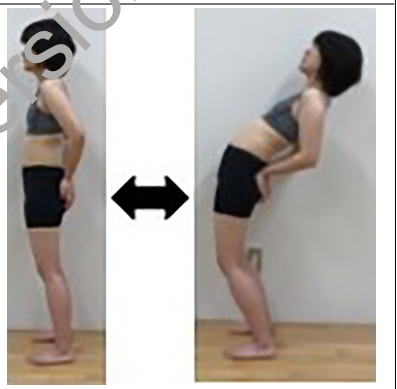
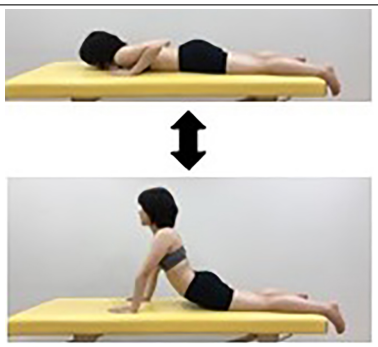
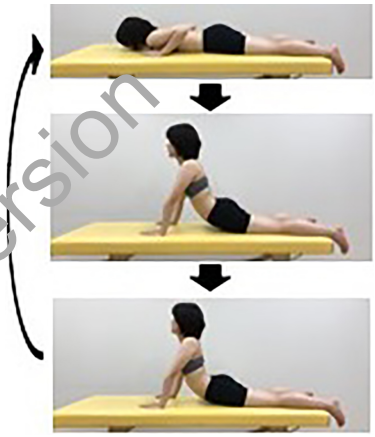
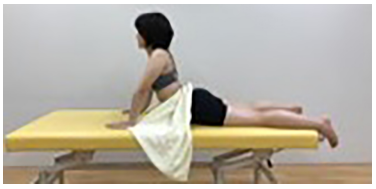
Appendix 1. Mechanical loading strategies in the direction of lumbar extension

Exercises	Description	Illustration
Extension in standing	Standing upright, the patient places the hands on the buttocks. The patient bends backward to their end-range with anterior pressure of the buttocks and with minimum knee bending, and returns to the starting position.	
Extension in standing with Sustained Natural Apophyseal Glide (SNAG) using fists	Standing upright, the patient places a fist with a support of the other hand under a spinal process, where pain reduces or centralizes. The patient apply pressure by the fist in the direction of the head. Then the patient bends backward to their end-range with minimum knee bending while maintaining the pressure in the direction of the head. Then, the patient returns to the starting position while maintaining the pressure in the direction of the head.	
Extension in standing with SNAG using a towel	Standing upright, the patient places an edge of a towel under a spinal process, where pain reduces or centralizes during extension with this technique. The patient apply pressure by pulling the towel in the direction of the head. Then the patient bends backward to their end-range with minimum knee bending while maintaining the pressure in the direction of the head. Then, the patient returns to the starting position while maintaining the pressure in the direction of the head.	

Exercises	Description	Illustration
Extension in lying	Prone laying, the patient places the hands at the (lower) level of the shoulder. The patient pushes-up the upper trunk to their end-range and returns to the starting position.	
Extension in lying with self-overpressure (sag)	Prone laying, the patient places the hands at the (lower) level of the shoulder. The patient push-up the upper trunk to their end-range and sags by breathing out and relaxing buttocks and lower limbs and then returns to the starting position.	
Extension in lying with self-overpressure with a towel	Prone laying, the patient places an edge of a towel under a spinal process, where pain reduces or centralizes during extension with this technique. The patient places the hands at the (lower) level of the shoulder and fixes the edges of the towel. The patient pushes-up the upper trunk and apply overpressure at their end-range and returns to the starting position.	
Extension in lying with overpressure with somebody's help	Prone laying, the patient places an edge of a towel under a spinal process, where pain reduces or centralizes during extension with this technique. An assistant stands up over the patient and fixes the edges of the towel. The patient places the hands at the (lower) level of the shoulder. The patient pushes-up the upper trunk and apply overpressure at their end-range and returns to the starting position.