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Original Article

Comparison of spinal column alignment and autonomic nervous activity using the intersegmental tenderness test in the segment above

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Abstract. [Purpose] The thoracolumbar supraspinous intersegmental tenderness test (ITT) in the segment above was performed to compare spinal alignment and autonomic activity in the presence or absence of pain. [Participants and Methods] Thirty young males were grouped into Th1–4 (Cardiopulmonary visceral nerves), Th5–9 (Large visceral nerve), and Th10–12 (Small visceral nerve) by ITT for the presence of pain. Measurements of the spinal alignment and autonomic function were performed. [Results] Those with ITT pain had a significantly lower range of motion in the sagittal plane at Th12, Th12–L1, and L2–3 and in the frontal plane at Th1–2, Th4–5, Th6–7, and L3–4 than those in the no pain group. On autonomic function tests, the pain group had significantly lower Total Power, LF (Low Frequency), and CVRR (Coefficient of variation of R-R interval). [Conclusion] In ITT, patients with pain at Th5–9 have a mixture of reduced sagittal tilt angle and autonomic hypofunction of the adjacent upper and lower thoracic to lumbar vertebrae.

Key words: Somatic dysfunction, Spinal alignment, Autonomic

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INTRODUCTION

Back pain is a general term for pains in the upper back and lower back that do not show any neurological changes or organic changes due to imaging findings[1)]. According to the 2016 National Lifestyle Survey, low back pain and stiff shoulders account for the first and second most common health problems for both males and females, and it is reported that disorders of motor function and visceral function increase with aging[2)]. Furthermore, patients with back pain are affected not only by pain but also economic loss due to their inability to work as well as ADL limitations, socio-economic problems, and deterioration of quality of life. Therefore, improvement of back pain and rehabilitation of patients are important issues in physical therapy[3, 4)].

ICD-9-CM (International Classification of Diseases) defines a pathological condition called “physical dysfunction” for disorders of motor function and visceral function related to back pain. Somatic dysfunction is “impairment or change in the structure of bones, joints, fascia, which are components related to somaticity, and related components of blood vessels, lymph,

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and nervous system"[5], and it is considered to apply when the symptoms appear in the back due to dysfunction of the spinal facet joints or diseases or dysfunction of internal organs[6]. Studies investigating the neurological mechanism of manipulation of the spinal column have also reported that back pain also affects reflex nerve output to both muscles and internal organs[7], so back pain might mix both motor dysfunction and visceral dysfunction. Regarding the relationship between back pain and motor dysfunction, it has been reported that patients with nonspecific low back pain have a smaller trunk lateral flexion ROM than healthy participants and that this is related to the laterality of erector spinae muscle activity[8]. In addition, it has been reported that degeneration of muscles, ligaments and facet joints induces pain due to continued spinal misalignment, causing deterioration of spinal mobility[9, 10], balance ability, walking ability[3] and QOL[4].

Some types of joint pain are considered back pain due to visceral diseases and dysfunction. The autonomic nervous system that controls visceral function has different organs based on the medullary level of the thoracolumbar sympathetic ganglia. Therefore, it has been clarified that referred pain due to dysfunction of internal organs occurs in a specific area on the back of the body[11, 12]. Regarding the relationship between associated pain and abnormalities in the autonomic nervous system, it has been reported that inhibition of the sympathetic nervous system leads to pain relief[13]. It has also been reported that increased muscle activity increases sympathetic nerve activity, resulting in decreased peripheral blood flow, decreased body surface temperature, and limited range of motion[14]. Therefore, it is necessary to pay attention not only to the motor function but also to the autonomic nerve function that controls the internal organs as a factor of back pain.

Dysfunction of the spinal intervertebral joints related to back pain is assessed by mechanical stress on the noncontractile tissues of the joint components, the joint capsule and ligaments, which induce pain[15]. The supraspinous intersegmental tenderness in the segment above test (ITT)[16] is a manual compression of the supraspinous ligament that crosses between the spinous processes and evaluates somatic dysfunction based on the presence or absence of pain. Therefore, the purpose of this study is to compare spinal alignment and autonomic nerve activity based on the pain by ITT, and to examine somatic dysfunction of the thoracolumbar spine from the viewpoint of motor function and neurophysiology.

PARTICIPANTS AND METHODS

This study was approved by the Ethical Review Committee of International University of Health and Welfare (18-Ifh-065). The participants were informed about the study in writing, and consent was obtained before the study was conducted. The participants were 30 young males (28.5 ± 5.1 years). Exclusion criteria were those who had or had a history of Locomotor (musculoskeletal) disorders of the spinal column or neurological disorders, or those who had a disease being treated and were taking medication. As a precaution, we instructed subjects to refrain from ingesting caffeine and alcohol within 24 hours of the test[17].

The items measured were the intersegmental tenderness in the segment above test (ITT), the sagittal spine inclination angle, and the electrocardiogram. The measurement procedure was as follows: (1) measurement of spinal alignment with the participant in a chair in the sitting position, (2) measurement of the electrocardiogram after resting for 20 minutes in a supine position on a bed, and (3) ITT with the participants in a prone position. (4) Statistical analysis: since the sympathetic ganglion of the spine has different effectors that control differently depending on the segment, the pain site of ITT is defined as Th1–4 (pain: A1, pain: B1), Th5–9 (pain: A2, pain: B2), Th10–12 (pain: A3, pain: B3). The experimental environment for ECG was soundproofed room and room temperature 27 °C. The time of measurement was around 17:00[18].

In the ITT test, the participants were placed in a prone position, and the supraspinous ligaments from Th1 to Th12 were manually pressed, and the cases where pain occurred were classified into group A, and the cases where pain did not occur were classified into group B. The ITT was judged to be painful when a sensor pad of the portable contact pressure measuring device Palm Q (Cape Co., Ltd., city, country) was placed at the pressing site of the participant and pressed to 200 mmHg, causing pain.

SpinalMouse® (Index, city, country), a spinal measurement analyzer, was used to measure spinal column alignment. In a previous study it was reported that the measurement of spinal alignment intraclass coefficients was 0.95 by using the SpinalMouse®[19]. In this study, in order to measure stable values, the subjects were asked to wear an open-back examination gown, and their posture was indicated. The participants were made to sit in a height-adjustable chair without a backrest in a sitting posture that included 90° hip/knee flexion[20]. They were instructed to keep their feet shoulder-width apart, arms at their sides, and face straight and horizontal toward the wall[20]. The examiner, a therapist with more than 10 years of clinical experience, palpated the spine and marked each spinous process. The measurement wheel was then moved slowly along the spine, and measurements were taken from Th1 to S3. The data of L3 was used. The index of spinal alignment was the sagittal plane tilt angle of each spine, and the average of three measurements was used as the representative value.

The electrocardiogram was measured using a portable heart rate variability measuring device, Check My Heart (manufactured by TRYTECH, city, country), and the RR interval was recorded at a sampling frequency of 250 Hz. The participants were instructed to perform the forearm supination in the supine position on the bed, after the researcher grounded the disposable electrode on the proximal ventral side of the forearm, and then set the respiratory rate to 12 times per minute for 5 minutes[21] according to a metronome. Heart Rate Variability (HRV) is a frequency analysis by Fast Fourier Transfer (FFT), Total Power (TP), Low Frequency Band (LF) 0.04 to 0.15 Hz, High Frequency. The power value and CVRR of the band (High Frequency: HF) 0.15 to 0.40 Hz were calculated. All R-waves were calculated using Fast Fourier Transform with computational software (HRV Analysis Software V2.02). Regarding the indicators of autonomic nerve activity, TP is known as the activity of the entire autonomic nerve, LF is known as the the cardiac sympathetic/parasympathetic nerve, HF is the cardiac parasympathetic nerve, LF/HF is the balance between the sympathetic nerve and the parasympathetic nerve, and CVRR is known as the vagus nerve[22].

RESULTS

As for participants who complained of pain by ITT, 13 out of 30 Th1–4 (A1: 13 and B1: 17), 19 out of 30 Th5–9 (A2: 19 and B2: 11), 12 out of 30 Th10–12 (A3: 12 and B3: 18) (Table 1). Comparing the angle of inclination of the sagittal spine with and without pain, the Th1/2 level was 2.4 ± 1.7 ° in the A1 group and 4.5 ± 2.7 ° in the B1 group, which were significantly lower in the A1 group ($p<0.05$). At Th5–Th9 level, Th1/2 group 2.4 ± 1.7 °, B2 group 5.1 ± 2.8 ° ($p<0.05$), Th12/L1 A2 group 1.7 ± 2.3 °, B2 group 3.2 ± 2.2 ° ($p<0.05$) In L2/3, the A2 group had 2.4 ± 1.7 ° and the B2 group had 4.8 ± 3.3 ° ($p<0.05$), and in the A2 group, the inclination angle decreased in the proximal and distal parts of the pain site (Table 2).

As a result of comparing the autonomic nervous function with and without pain, TP was 1,645 (1,175–2,519) ms2 in the A2 group, 3,055 (2,638–6,528) ms2 in the B2 group ($p<0.05$), LF was 1,009 (505.5–1,669) ms2 in the A2 group, and 2,407 (1,737–4,164) ms2 in the B2 group ($p<0.01$), CVRR was 5.19 (4.58–6.51)% in the A2 group and 9.29 (7.89–11.67)% ($p<0.01$) in the B2 group, both of which were lower in the A2 group (Table 3).

DISCUSSION

In this study, we differentiated the presence or absence of somatic dysfunction due to spinal ITT in typical adult males, and compared sitting sagittal spinal alignment and autonomic nervous activity. As a summary of the results, (1) ITT showed pain in 13 patients in Th1–4, Th5–9 in 19 patients, and Th10–12 in 12 patients, and (2) Th1–4 patients with pain in Th1/2. Thoracic spine tilt angle was low, (3) Th5–9 showed pain, and Th1/2, Th12/L1, and L2/3 showed a decrease in thoracic spine tilt angle and a decrease in TP, LF, and CVRR among autonomic nerve activities.

Repetitive loading on joints and surrounding muscle tissue may induce inflammation from microinjury of tissue[23, 24] and transition to repetitive injury[25]. Furthermore, it has been pointed out that the occurrence of repetitive injury is caused by several musculoskeletal disorders including work stress syndrome[26] and cumulative traumatic disorder[27, 28], and that work of 30 hours or more per week may cause repetitive injury[29]. Therefore, ITT-positive patients may have somatic dysfunction in the facet joints due to the accumulation of mechanical stress in the local supraspinous ligament due to poor posture and muscle fatigue in daily life.

Those who showed pain at Th1–4 had a low thoracic spine tilt angle at Th1/2 level. The Th1/2 level is the transition between the cervical spine, which has physiological lordosis and supports the head, and the thoracic spine, which has physiological kyphosis and supports load through the cervical spine and thoracic abdominal organs. This site is the basis for extending and

Table 1. Comparison of spinal sagittal plane tilt angles with and without Th1–4 level pain

Level	A1 (Group with pain, N=13)	B1 (Painless group, N=17)	p-value
Th1/2	2.4 ± 1.7	4.5 ± 2.7	*
Th2/3	5.8 ± 2.3	9.4 ± 5.6	
Th3/4	6.4 ± 2.6	6.7 ± 2.2	
Th4/5	3.8 ± 2.2	3.8 ± 2.1	
Th5/6	2.6 ± 1.2	3.8 ± 2.2	
Th6/7	3.0 ± 2.2	3.5 ± 2.2	
Th7/8	5.1 ± 2.2	5.3 ± 3.0	
Th8/9	5.8 ± 2.8	3.9 ± 1.9	
Th9/10	3.4 ± 2.6	3.1 ± 2.1	
Th10/11	2.9 ± 2.5	2.7 ± 2.2	
Th11/12	2.2 ± 1.9	1.7 ± 1.4	
Th12/L1	1.6 ± 1.2	2.8 ± 2.1	
L1/2	1.5 ± 1.3	2.8 ± 1.9	
L2/3	2.4 ± 1.5	4.0 ± 3.0	
L3/4	2.5 ± 1.4	3.9 ± 1.9	
L4/5	2.9 ± 2.0	2.0 ± 1.9	
L5/S1	1.8 ± 1.1	1.6 ± 1.0	

Mean ± standard deviation, Unit: °, Unpaired t-test, *$p<0.05$.

Table 2. Comparison of spinal sagittal plane tilt angles with and without Th5−9 level pain

Level	A2 (Group with pain, N=19)	B2 (Painless group, N=11)	p-value
Th1/2	2.7 ± 2.0	5.1 ± 2.8	*
Th2/3	6.5 ± 2.6	10.1 ± 6.8	
Th3/4	6.5 ± 2.3	6.8 ± 2.5	
Th4/5	4.1 ± 2.1	3.2 ± 2.2	
Th5/6	3.3 ± 1.6	3.2 ± 2.5	
Th6/7	3.3 ± 2.0	3.1 ± 2.5	
Th7/8	5.5 ± 2.5	4.7 ± 3.0	
Th8/9	5.0 ± 2.6	4.2 ± 2.3	
Th9/10	3.0 ± 2.3	3.6 ± 2.4	
Th10/11	2.5 ± 2.4	3.3 ± 2.2	
Th11/12	2.0 ± 1.8	1.8 ± 1.5	
Th12/L1	1.7 ± 1.3	3.2 ± 2.2	*
L1/2	1.8 ± 1.6	3.0 ± 2.1	
L2/3	2.4 ± 1.7	4.8 ± 3.3	*
L3/4	3.0 ± 1.8	3.8 ± 2.0	
L4/5	2.7 ± 2.2	1.9 ± 1.4	
L5/S1	1.5 ± 1.1	2.0 ± 1.0	

Mean ± standard deviation, Unit: °, Unpaired t-test, *p<0.05.

Table 3. Comparison of autonomic nervous activity with and without pain at Th5–9 level

Measurement item	LF** (ms^2)	HF (ms^2)	TP* (ms^2)	LF/HF	CVRR**
A2 (Group with pain, N=19)	1,009 (505.5–1,669)	138 (57–344.5)	1,645 (1,175–2,519)	7.62 (2.7–12.62)	5.19 (4.58–6.51)
B2 (Painless group, N=1)	2,407 (1,737–4,164)	359 (145–1,362.5)	3,055 (2,638–6,528)	4.64 (3.16–14.04)	9.29 (7.89–11.67)

Central value (quartile range), Mann-Whitney U test, **p<0.01, *p<0.05.
TP: Total power; LF: Low frequency; HF: High frequency; CVRR: Coefficient of variation of RR intervals.

compensating for the cervical spine when the head and neck are in a forward protruding position[30)]. In a previous study of 103 patients with cervical pain[31)], the tilt of the head was correlated with the tilt angle of C0–C2 (r=0.57) and the displacement of the vertebral body in the anterior-posterior direction (r=−0.53). It was reported that the curvature type classified from the anterior-posterior displacement of the cervical spine was correlated with the C0-C2 angle (r=0.38), C2–C7 angle (r=−0.73) and T1 tilt angle (r=−0.40)[31)]. That is, when cervical misalignment occurs, mechanical stress is applied to the supraspinous ligament that supports Th1/2 posterior, which limits the angle at which the thoracic spine tilts forward and causes pain in ITT. It is probable that the thoracic spine tilt angle was reduced.

As for ITT, those who have pain at Th5–9 experience the pain site at the head, Th1/2 at the cervical-thoracic spine transition, and Th12/L1 to L2/3 at the thoracolumbar transition, and the autonomic nerve decreased TP, LF and CVRR, which indicate overall activity. Th5–9 is characterized by being located behind the center of gravity and having the largest thoracic kyphosis[32)], receiving the weight of the head from the cervical spine through the upper thoracic spine as a load from the superstructure. The change in pelvic posture is transmitted through the lumbar spine to change the kyphosis angle in the sagittal plane. In previous studies on spinal alignment in healthy adults, there was a moderate correlation between the thoracic spine and the lumbar spine (r=0.52), and a correlation between the Th1 vertebral body tilt angle and C0–C7 (r=0.63)[33)]. It has been reported that the maximum angles of thoracic kyphosis and lumbar lordosis can be predicted from the Th1 sagittal plane angle[34)]. From these facts, it is possible that head and neck alignment affects the decrease in the inclination angle from the middle thoracic spine to the lumbar spine as mechanical stress on the supraspinous ligament to the middle thoracic spine.

Regarding the evaluation of autonomic nerves, the A2 group, which had pain at Th5–9 levels, had significantly lower TP, LF, and CVRR. It has been reported that patients with chronic pain in the neck and lower back have decreased TP[35)], increased sympathetic nerve activity, and decreased parasympathetic nerve activity[36)]. It has also been reported that sympathetic nerve activity is enhanced in a model of transient muscle dysfunction in which mustard oil is injected into the multifidus muscle[37)]. Some of the effects of abnormal posture alignment on joints and muscles may be connected to muscles, bones, internal organs and blood vessels, and may pass through the deep fascia[38)] where free nerve endings are present. From these facts, it is inferred that the decrease in autonomic nerve activity and the decrease in parasympathetic nerve activity in this study were caused by Th5–9 level pain due to postural abnormalities.

In this study, we compared spinal alignment and autonomic function with and without ITT pain. As a result, those with pain at Th1–4 had a decrease in the thoracic spine tilt angle of Th1/2, and those with pain at Th5–9 had a decrease in the spine tilt angle from the lower thoracic spine to the lumbar spine and autonomic nerve activity. A decrease was observed. As a physiotherapy application, this suggests that if a patient experiences back pain in Th5–9, it is necessary to evaluate and treat it considering not only motor dysfunction but also the effect on autonomic nervous function.

As an application in physical therapy, we believe that the combination of somatic dysfunction such as spinal mobility with autonomic function and pain provocation tests can help interpret the patient's condition.

As a future task of this study, it is necessary to examine the method of detecting spinal mobility by comparing not only the sagittal plane limb position but also different limb positions such as trunk flexion and extension.

The limitations of this study are that the posture of the head and pelvis cannot be evaluated and the muscle function of the erector spinae muscles cannot be evaluated in terms of motor function. Therefore, it is necessary to measure the postural alignment and surface EMG at the same time to investigate the effect of muscle function. In addition, it will be possible to evaluate the autonomic nervous function according to the spinal segment and collect information related to the visceral function that shows its effect by using a questionnaire on digestion and excretion. In this way, we would like to clarify the mechanisms that affect back pain.

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Conflicts of interest

There are no conflicts of interest to be disclosed in this study.

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REFERENCES

1) Japanese Physical Therapy Association: Back Pain Physical Therapy Practice Guidelines, Tokyo, 2009, p 15. http://www.japanpt.or.jp/upload/jspt/obj/files/guideline/07_back_pain.pdf (Accessed Dec. 1, 2019)
2) Ministry of Health, Labor and Welfare. 2016 National Life Basic Survey. III Health status of household members. 1 Status of subjective symptoms. https://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/dl/04.pdf (Accessed Jan. 10, 2020)
3) Imagama S, Ito Z, Wakao N, et al.: Influence of spinal sagittal alignment, body balance, muscle strength, and physical ability on falling of middle-aged and elderly males. Eur Spine J, 2013, 22: 1346–1353. [Medline] [CrossRef]
4) Miyakoshi N, Itoi E, Kobayashi M, et al.: Impact of postural deformities and spinal mobility on quality of life in postmenopausal osteoporosis. Osteoporos Int, 2003, 14: 1007–1012. [Medline] [CrossRef]
5) Greenman PE: Principles of manual medicine, 2nd ed. Baltimore: Williams & Wilkins, 1996, pp 3–11.
6) Magee DJ: Orthopedic physical assessment, 3nd ed. Philadelphia: W. B. Saunders Company, 1997, pp 1–52.
7) Pickar JG. Neurophysiological effects of spinal manipulation. Spine J, 2002, 2: 357–371.
8) Dulcina KR, Genevay S, Dominguez D, et al.: Flexion-relaxation ratio asymmetry and its relation with trunk lateral ROM in individuals with and without chronic nonspecific low back pain. SPINE, 45: E1–E9.
9) Bettany-Saltikov J, Weiss HR, Chockalingam N, et al.: A comparison of patient-reported outcome measures following different treatment approaches for adolescents with severe idiopathic scoliosis: a systematic review. Asian Spine J, 2016, 10: 1170–1194. [Medline] [CrossRef]
10) Iorio JA, Jakoi AM, Singla A: Biomechanics of degenerative spinal disorders. Asian Spine J, 2016, 10: 377–384. [Medline] [CrossRef]
11) Hamaguchi S : Thermography indirectly examines autonomic nervous function. Med Devices (Auckl), 2010, 38: 226–233.
12) Snider KT, Schneider RP, Snider EJ, et al.: Correlation of Somatic dysfunction with gastrointestinal endoscopic findings: an observational study. J Am Osteopath Assoc, 2016, 116: 358–369. [Medline]
13) Poppler LH, Mackinnon SE: The role of the peripheral nerve surgeon in the treatment of pain. Neurotherapeutics, 2019, 16: 9–25. [Medline] [CrossRef]
14) Girasol CE, Dibai-Filho AV, de Oliveira AK, et al.: Correlation between skin temperature over myofascial trigger points in the upper trapezius muscle and range of motion, electromyographic activity, and pain in chronic neck pain patients. J Manipulative Physiol Ther, 2018, 41: 350–357. [Medline] [CrossRef]
15) Yahia L, Newman N: A scanning electron microscopic and immunohistochemical study of spinal ligaments innervation. Ann Anat, 1993, 175: 111–114. [Medline] [CrossRef]
16) Strender LE, Sjöblom A, Sundell K, et al.: Interexaminer reliability in physical examination of patients with low back pain. Spine, 1997, 22: 814–820. [Medline] [CrossRef]
17) Kudo R, Tamura Y, Tamiya S, et al.: Effect of video viewing during exercise on exercise efficiency and autonomic nervous activity. Total Rehabilitation Re-

search, 2018, 6: 73–82.
18) Ogawa A, Maruoka H, Terayama K, et al.: Effect of acute cardiac rehabilitation on cardiac autonomic neuropathy and anxiety-depression after acute myocardial infarction. J Coron Dis, 2015, 21: 93–100.
19) Post RB, Leferink VJ: Spinal mobility: sagittal range of motion measured with the SpinalMouse, a new non-invasive device. Arch Orthop Trauma Surg, 2004, 124: 187–192. [Medline] [CrossRef]
20) Csuhai ÉA, Nagy AC, Váradi Z, et al.: Functional analysis of the spine with the Idiag SpinalMouse System among sedentary workers affected by non-specific low back pain. Arch Orthop Trauma Surg, 2004, 124: 187–192.
21) Iwatsuki H, Ikuta Y: Measurement of R-R interval variations under deep breathing load in healthy persons. Rigakuryoho Kagaku, 2000, 15: 9–12.
22) Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology: Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Eur Heart J, 1996, 17: 354–381. [Medline] [CrossRef]
23) Sbriccoli P, Yousuf K, Kupershtein I, et al.: Static load repetition is a risk factor in the development of lumbar cumulative musculoskeletal disorder. Spine, 2004, 29: 2643–2653. [Medline] [CrossRef]
24) King K, Davidson B, Zhou BH, et al.: High magnitude cyclic load triggers inflammatory response in lumbar ligaments. Clin Biomech (Bristol, Avon), 2009, 24: 792–798. [Medline] [CrossRef]
25) Yassi A: Repetitive strain injuries. Lancet, 1997, 349: 943–947. [Medline] [CrossRef]
26) van Rijn RM, Huisstede BM, Koes BW, et al.: Associations between work-related factors and specific disorders of the shoulder—a systematic review of the literature. Scand J Work Environ Health, 2010, 36: 189–201. [Medline] [CrossRef]
27) Le P, Solomonow M, Zhou BH, et al.: Cyclic load magnitude is a risk factor for a cumulative lower back disorder. J Occup Environ Med, 2007, 49: 375–387. [Medline] [CrossRef]
28) Solomonow M, Baratta RV, Zhou BH, et al.: Muscular dysfunction elicited by creep of lumbar viscoelastic tissue. J Electromyogr Kinesiol, 2003, 13: 381–396. [Medline] [CrossRef]
29) Cole DC, Ibrahim S, Shannon HS: Predictors of work-related repetitive strain injuries in a population cohort. Am J Public Health, 2005, 95: 1233–1237. [Medline] [CrossRef]
30) McLean L: The effect of postural correction on muscle activation amplitudes recorded from the cervicobrachial region. J Electromyogr Kinesiol, 2005, 15: 527–535. [Medline] [CrossRef]
31) Wang K, Deng Z, Li Z, et al.: The influence of natural head position on the cervical sagittal alignment. J Healthc Eng, 2017, 2017: 2941048. [Medline] [CrossRef]
32) Briggs AM, van Dieën JH, Wrigley TV, et al.: Thoracic kyphosis affects spinal loads and trunk muscle force. Phys Ther, 2007, 87: 595–607. [Medline] [CrossRef]
33) Lee SH, Son ES, Seo EM, et al.: Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment. Spine J, 2015, 15: 705–712. [Medline] [CrossRef]
34) Yang M, Yang C, Ni H, et al.: The relationship between T1 sagittal angle and sagittal balance: a retrospective study of 119 healthy volunteers. PLoS One, 2016, 11: e0160957. [Medline] [CrossRef]
35) Gockel M, Lindholm H, Niemistö L, et al.: Perceived disability but not pain is connected with autonomic nervous function among patients with chronic low back pain. J Rehabil Med, 2008, 40: 355–358. [Medline] [CrossRef]
36) Morikawa Y, Takamoto K, Nishimaru H, et al.: Compression at myofascial trigger point on chronic neck pain provides pain relief through the prefrontal cortex and autonomic nervous system: a pilot study. Front Neurosci, 2017, 11: 186. [Medline] [CrossRef]
37) Kang YM, Kenney MJ, Spratt KF, et al.: Somatosympathetic reflexes from the low back in the anesthetized cat. J Neurophysiol, 2003, 90: 2548–2559. [Medline] [CrossRef]
38) Tozzi P: Selected fascial aspects of osteopathic practice. J Bodyw Mov Ther, 2012, 16: 503–519. [Medline] [CrossRef]