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Original Article

Comparison of effects of joint flexibility on the lumbo-pelvic rhythm in healthy university students while bending the trunk forward

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Abstract. [Purpose] To clarify the influence of flexibilities of the hip and lumbar spine joints on bending the trunk forward. [Participants and Methods] We assessed the joint flexibility of 47 healthy university students using the Beighton hypermobility score and assigned them to the group of normal or poor flexibility. We performed electromyography to acquire kinematic data and analyzed the three-dimensional motion while the students bent their trunks forward. Further, we compared the groups based on angular displacements of the hip joint and lumbar spine in each phase of the movement. Offset of the erector spinae and hip extensor muscle activity was calculated as a percentage (%) of the maximum range of motion. [Results] The lumbo-pelvic rhythm differed between participants with and without poor flexibility of the hip joint in the second half of the forward bending task. Participants with poor flexibility of the hip joint showed activation of the erector spinae and biceps femoris for a longer period compared to those with normal flexibility. Notably, flexion–relaxation responses were not found in the biceps femoris of 30% of the participants. [Conclusion] Poor hip joint flexibility may cause low back pain. Measuring the lumbo-pelvic rhythm might help identify individuals at a high risk of low back pain while they are still healthy.
Key words: Flexibility, Low back pain, Lumbo-pelvic rhythm

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INTRODUCTION

Movement proceeds sequentially with minimal resistance in multisegmental systems such as the lumbar spine[1)]. If flexibility differs between neighboring segments, a larger load is placed on the more flexible segments. The lumbar pelvic region is a multisegmental system consisting of five lumbar vertebrae, the sacrum, coccyx, ileum and femur that are connected to muscles, tendons, ligaments and joint capsules. Therefore, the flexibility of these joints depends on the extensibility of these connective tissues. The range of motion (ROM) of joints is in accordance with the laws of physics; a large difference in flexibility between neighboring joints generates pain signals from the loaded joint[1)].

The Global Burden of Disease Study 2010 found in a systematic analysis, that low back pain (LBP) was a leading specific cause of years lived with disability (YLD) between 1990 and 2010[2)]. The most common subjective symptom among Japanese males was LBP, and it was the second most common in females, according to a 2016 survey[3)]. In addition, a comprehensive survey of living conditions in Japan found that LBP is the most common type of complaint[3)]. Low back pain can be specific, caused by intervertebral disc degeneration and spinal canal stenosis, or nonspecific (NSLBP)[1)], and the latter accounts for 85% of all LBP. NSLBP can be associated with musculoskeletal issues involving intervertebral discs, facet and sacroiliac

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joints, as well as organs and social problems, and it can also be multifactorial. Estimates indicate that up to 60% of LBP is a consequence of work-related injuries in the industrial sector[4]. The onset of LBP among university students is associated with lifestyle, posture during classes, stress regarding exams, and smoking habits[5, 6]. The prevention of NSLBP is therefore very important. One concept currently supported by specialists, is that individuals have consistent, and thus recognizable postures and movements that might contribute to NSLBP. For example, excessive end-of-range lumbar movements or postures, excessive or insufficient lumbar contribution to trunk flexion, trunk rigidity, and loss of the flexion–relaxation response (FRR), have been linked to LBP.

Trunk flexion is an interaction between the intervertebral and pelvic joints (lumbo-pelvic rhythm), which is useful to understand spinal kinematics and motion[7, 8]. During optimal trunk flexion, the hip joint contribute 65% to the movement[8–11]. The lumbar spine flexes before the hip joint when bending the trunk forward[7]. Eccentric contraction of the erector spinae (ES) muscles at the start of the bend controls spinal flexion, and eccentric contraction of the hip extensors controls pelvic tilt. At a specific point during trunk flexion, these muscles relax in the FRR[12]. Numerous studies have shown that the FRR is a consistent and predictable response in most healthy individuals without LBP. Poor flexibility of the soft tissues surrounding the lumbar spine, pelvis, and hip joint, and/or weakness of the relevant muscles reportedly result in an abnormal lumbo-pelvic rhythm and loss of the FRR[9, 12]. The soft tissues surrounding these joints need to be moderately flexible and stable to allow movement with minimal load on the joints. The present study aimed to clarify the effects of joint poor flexibility in trunk forward bending task by dividing the movement into some phases.

PARTICIPANTS AND METHODS

This cross-sectional study included 47 healthy university students (male, n=14; female, n=33; mean age ± standard deviation, 19.7 ± 0.6 years) without a history of injuries or physical functional impairment that could result in difficulties with stooped lifting, and an Oswestry Disability Index (Japanese edition) score of 0[13, 14].

All of the students provided written informed consent to participate in this study, which was approved by the Research Ethics Committee at Takasaki University of Health and Welfare (Permission No. 2819).

We evaluated joint laxity in nine joints based on the Beighton hypermobility (BH) score[15], then consecutively divided the participants into groups based on the BH score for bending forward while standing with fully extended knees[16]. Those who could touch the floor with their palms or not were classified into groups with Poor flexibility (PF) and normal flexibility (NF), respectively. Thereafter, we compared age, gender, heights and body weight between the groups.

The main task was bending forward from an upright standing position with the knees extended. Participants stood with their feet at a width of 10% of their total height. Phase definition of trunk flexion while upright was determined by kinematic data obtained as follows. Dynamic motion was captured by having the participants stand upright in a neutral position for 2 s, bend forward with their arms dangling freely for 4 s, then hold the fully flexion for 4 s. During all phases, the movement rhythm was set at 120 beats per minute using a metronome. The fully flexion position was ordered "bending your trunk forward as deep as possible without knee flexion and heel off", and participants performed till their limits. After sufficient practice, participants performed it three times for data collection. The mean values of three trials were analyzed.

Kinematic data were collected using six motion capture cameras with a sampling rate of 100 Hz and recorded during all phases using a VICON three-dimensional motion analysis system (Oxford Metrics Ltd., Oxford, UK). We placed a total of 18 infrared reflective markers at the acromion, C7 spinous projection, jugular notch, L1 spinous process, L4 spinous process, a point 5 cm lateral from the L2 spinous process, anterior superior iliac spine, posterior superior iliac spine, greater trochanter, the outside cleft of the both knees, and the midpoint of the both thighs. Local coordination systems of the upper trunk, lumbar spine, pelvis, and thigh were created from information derived from these markers, and hip and lumbar spine angles were calculated[9]. The start and finish of the bending task were defined in terms of the mean (± 2 standard deviations) angular displacement in degrees (°) from the neutral position and maximum flexion. The task was divided into four flexion phases of 0−25%, 26−50%, 51−75%, and 76−100%[17] by their forward bending angle (Hip flexion angle + lumbar spinal flexion angle), then an angular displacement of the hip or lumbar spine in a phase were divided forward bending angle in the same phase and counted every phases. These angular displacement were divided each joint ROM as the ratio of ROM, and these ratios were compared each phases between the two groups[18].

Surface electromyographic (EMG) activity was recorded using a Delsys Trigno system (Delsys Inc., Boston, MA, USA). The EMG signal from the iliocostalis lumborum muscle was recorded at the first and fourth lumbar vertebrae, with the electrode placed 5 cm to the right of the spinous process (L1 ES, L4 ES). A biceps femoris (BF) long-head electrode was placed at the midpoint between the right ischial tuberosity and the fibular head, after cleaning and lightly abrading the skin with alcohol. The EMG signal was bandpass filtered (cut-off frequencies: 15 Hz high pass, 500 Hz low pass), rectified, and smoothed by calculating their root mean squares, with a time window of 0.02 s. We sampled EMG signals at a frequency of 1,000 Hz. For the FRR, the offset of eccentric flexion activation was defined as the end of the last peak of flexion EMG activity that exceeded the mean (± 2 standard deviations) baseline value while standing upright in a neutral position. EMG Offset positions were calculated as ratios of the maximal ROM (% ROM_{max}) using each ROM during the task.

Statistical analyses were performed using SPSS Statistics (Ver. 24) for windows. Comparisons of ratio of ROM (lumbar spine flexion, hip flexion) each phases between two groups were performed unpaired t-test. Comparisons of degrees and ratio of the maximum ROM at the offset muscle activity between two groups were performed unpaired t-test.

RESULTS

Based on BH scores derived from bend forward from an upright position with extended knees, 21 and 26 participants were respectively assigned to the groups with PF and NF. Table 1 shows that only flexibility significantly differed among the characteristics of the groups. We compared the total range of lumbar spine and hip motion during trunk forward bending between the groups. The ratios (%) of lumbar spine and hip motion while bending forward significantly differed between those with PF and NF (lumbar spine, 49.7 ± 10.4% vs. 41.7 ± 7.1%; hip, 47.9 ± 13.6% vs. 58.1 ± 11.5%; Table 2). The ratio of hip motion during the 76−100% flexion phase of the bending task was significantly higher in the group with NF than PF (87.1 ± 28.9% vs. 60.9 ± 24.7%; Table 2).

Muscle activity offset determined by EMG was evident in all participants in the L1 and L4 ES, but not in the BF in one NF participant and six PF participants, respectively. The offset range of hip flexion significantly differed between the groups, whereas that of lumbar spine did not. The position of offset of L4 ES muscle activity in the hip flexion range was significantly larger for the group with NF than PF (26.5° ± 2.9° vs. 19.8° ± 6.5°; Table 3), and the offset of BF activity was also significantly larger within the hip flexion range of the NF, than the PF group (34.6° ± 5.2° vs. 28.1° ± 15.3°; Table 3). The offset of BF activity was significantly earlier in the group with NF than PF (50.0 ± 7.3 vs 58.9 ± 13.8% ROM_{max}; Table 3).

Table 1. Characteristics of participants with poor flexibility and normal flexibility

	PF (n=21)	NF (n=26)	p-value
Age (years)	19.9 (0.3)	19.5 (0.5)	n.s.
Gender (Males:Females)	9:12	5:12	n.s.
Heights (cm)	160.7 (9.0)	158.1 (7.5)	n.s.
Weights (kg)	51.9 (7.2)	52.3 (8.8)	n.s.
BH scores	4.0 (1.7)	4.6 (2.2)	n.s.

BH: Beighton hypermobility; PF: poor flexibility; NF: normal flexibility.
Paired t-test.

Table 2. Ratios (%) of range of motion, lumbar spine and hip flexion in total forward bending angle with poor flexibility and normal flexibility

Flexion	Lumbar spine flexion		Hip flexion	
	PF	NF	PF	NF
0–25%	71.4 (24.9)	78.7 (29.4)	30.6 (24.8)	25.3 (22.8)
26–50%	61.0 (21.9)	54.5 (17.6)	40.7 (22.5)	47.7 (19.3)
51–75%	44.5 (18.5)	29.0 (19.5)	54.9 (18.2)	64.5 (21.9)
76–100%	24.5 (16.0)	15.9 (29.5)	60.9 (24.7)†	87.1 (28.9)
Total	49.7 (10.4)†	41.7 (7.1)	47.9 (13.6)*	58.1 (11.5)

Data are shown as means (SD). *,† Significant difference between groups in ratios of range of motion (*p<0.01, †p<0.05). PF: poor flexibility; NF: normal flexibility.

Table 3. Degrees and ratios (%) of each joints at offset of each muscle activity

	Offset muscle	Degrees		% ROM_{max}	
		PF	NF	PF	NF
Lumber spine	L1 ES	37.4 (5.1)	40.9 (4.4)	70.6 (6.8)	74.8 (5.4)
	L4 ES	32.1 (7.1)	38.8 (3.3)	61.9 (17.5)	71.6 (9.4)
	BF	46.4 (7.1)	48.6 (4.8)	87.3 (5.1)	88.8 (5.7)
Hip	L1 ES	23.5 (9.3)	27.9 (5.8)	54.2 (13.5)	46.9 (10.3)
	L4 ES	19.8 (6.5)*	26.5 (2.9)	48.3 (19.2)	38.7 (6.3)
	BF	28.1 (15.3)*	34.6 (5.2)	58.9 (13.8)*	50.0 (7.3)

Data are shown as means (SD). *Significant difference between groups (p<0.01). BF: biceps femoris; ES: erector spinae; PF: poor flexibility; L: lumbar; NF: normal flexibility; % ROM_{max}: ratio of maximal range of motion.

DISCUSSION

The contributions of lumbar spine flexion to bending the trunk forward were 50% and 42% in the groups with and without PF, respectively. This contribution in the group with PF was larger than that determined in previous studies of healthy persons without LBP[7, 9]. This difference might be caused by a lower range of hip flexion, because the hip flexion range was significantly smaller in the group with PF, than NF. Forward trunk flexion with straight knees, used in the BH score, is significantly affected by the tightness of the hamstrings[14]. One aim of this study was to identify the physical characteristics of participants without LBP that differ from those determined in previous studies of the FRR and lumbo-pelvic rhythm. Results of FRR in participants with NF followed previous study, the offset of muscle activities were shown 64–90% ROM_{max} of lumbar spinal flexion in ES muscles[18, 19], and 48–56% ROM_{max} of hip flexion in Biceps femoris[20]. The results of participants with PF, the offsets of L4 ES muscle and BF muscle during forward bending task had significantly delay. The study was showed some difference in lumbo-pelvic rhythm in healthy young participants without LBP, and also the discordant of lumbo-pelvic rhythm affected the poor flexibility was found the second half of forward bending task.

The discordant lumbo-pelvic rhythm in the group with PF could have affected the strategy used to maintain the center of pressure within safety margins[21]. The fact that hip movement accounted for >95% of the movement in the lower limbs could be interpreted as a response to bending the trunk. Thus, the trunk could be bent forward without dislocating the center of pressure with minimal control by the muscles[21]. Bending the trunk forward with insufficient hip ROM might require muscle contraction to reduce angular velocity on hip exposed the gravity load. We identified continuous BF muscle contraction in six participants with PF who had a limited ROM of hip motion during the task and lacked the FRR. The others with PF also exhibited longer contraction of BF muscle than those with NF. The combined discriminant validity for the FRR to detect LBP resulted in 93% sensitivity and 75% specificity[22], this study suggested the participants with PF has a risk of LBP.

Non-specific LBP in university students is affected by lifestyle, posture, stress and habits[23]. This means that even healthy young individuals without LBP are at risk for LBP. Poor hamstring flexibility reportedly correlates closely with LBP by restricting pelvic tilt, which results in compensation via increased lordosis of the soft tissues surrounding the lumbar spine[23, 24]. This risk should be higher in the group with PF. Recent findings support the notion that individualized approaches to posture and movement types might reduce LBP. Evaluating the lumbo-pelvic rhythm while bending the trunk forward might identify candidates including apparently healthy university students who are at high risk of LBP, and thus prevent its future development.

Poor flexibility of the BF muscles increases the load on soft tissues surrounding the lumbar spine, so tight BF muscles can be a risk factor for chronic LBP even among healthy university students who are pain-free.

We were unable to clarify enough the effects of poor flexibility while bending the trunk forward. The relationship between joint location and ground reaction forces during this task should be investigated in the future.

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Conflict of interest

None of the authors has any conflicts of interest to declare.

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