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Three-dimensional motion analysis of lumbo-pelvic rhythm during trunk lateral bending

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SUMMARY
The hip and spine coordination known as lumbo-pelvic rhythm (LPR), is only reported in trunk extension movement measured by a lumbar hip ratio (LHR), a ratio of the lumbar movement to the hip movement. This study measured real-time LHR during trunk lateral bending of the young healthy male by the three-dimensional motion analysis system (VICON).
The LHR during trunk lateral bending was 4.4. This is the first study revealing LHR of the trunk lateral bending, showing that lumbar spine laterally bend 4.4° while the hip bend 1° ipsilaterally.

INTRODUCTION
The hip and spine coordination known as LPR is in common with the scapula humeral rhythm during shoulder movement. The concurrent movement of the scapula and humerus is an important component of arm function. Likewise, the coordination of the hip and the lumbar spine contributes to the lower limb movement.
The LPR assessed by LHR, was reported 0.49–1.59 [1] or 0.16–3.04 [2] during trunk flexion. However, no study has reported time variation of the LHR during trunk lateral bending. We clarified time variation of the LHR of the healthy participants during trunk lateral bending.

METHODS
Eight male volunteers (age: 33.5±5.2 years, height: 173.0±6.1cm, weight: 66.9±7.9 kg, BMI: 22.2±1.9 kg/m*m) without any symptoms in trunk motion were enrolled. Verbal and written informed consent was provided from all participants. The protocol of this study was approved by the Institutional Ethics Committee Board at the University of Tokyo (# 3614).
Participants were attached the Plug-In Gait marker set, and seven original markers. The original markers were placed on the both paravertebral muscles at the eleventh thoracic vertebra (T11) level, the posterior superior iliac spines, and the spinous process of the T10, T12, and S3.
The plug-in gait and original marker trajectories were obtained during trunk lateral bending at 100 samples/s using a VICON comprising seven cameras (VICON Motion Systems Ltd. Oxford, UK). The signals from the marker trajectories and ground reaction force were filtered with a fourth-order zero-phase Butterworth low-pass filter with a cut-off frequency of 6 and 16 Hz to eliminate noise from the raw data, respectively.
From the plug-in gait marker, we measured hip range of motion (ROM,) center of gravity (COG), and waist and hip moment. The thoraco-lumbar segment was defined using markers located on T10, T12, and both paravertebral markers at the T11 level. The pelvic segment was defined using markers located on S3 and both posterior superior iliac spines. Lumbar ROM was measured by the movement of the thoraco-lumbar segment against the pelvic segment, which is representative of the sum of lumbar inter-vertebral movements. The angular data were computed using a joint coordinate system convention. We calculated LHR as a ratio of real-time lumbar ROM to hip ROM [1, 2], and normalized COG and joint moment by participants' height and weight, respectively.
Participants were asked to perform lateral bending to right and left four times, respectively. The repeated four data from each right and left lateral bending were averaged. Then, both right and left lower extremity data (ROM, moment) were grouped together. Finally right and left lateral bending data were averaged as a representative motion data for the individual.
We defined start timing when hip ROM was >1° and end timing ≤1°. We separated data in two phases according to hip ROM: descend phase (from the start timing to the timing of mean maximum hip ROM) and ascend phase (from the timing of mean maximum hip ROM to the end timing). After each time phase was change to 100%, we analyzed LHR from each 10% time using one-way repeated measures ANOVA (SPSS ver. 19.0). A Tukey post-hoc test was used to test significant effects. The level of significance was set at P values < 0.05.

RESULTS AND DISCUSSION
The mean maximum ROM of lumbar and hip was 29.5° and 10.3°, respectively (Figure 1).
The LHR significantly decreased from 5.9 to 3.6 (mean 4.5) over time in descend phase [$F(10, 70) = 3.210$, $P = 0.02$], indicating large hip movement compared with lumbar spine movement at the late phase. Contrarily, in ascend phase, the LHR significantly increased from 3.6 to 5.6 (mean 4.2) [$F(10, 70) = 3.871$, $P < 0.001$] (Figure 2).
The mean maximum COG shift was 6.3% ipsilaterally and 3.8% inferiorly (Figure 3).

The mean maximum moment of waist, was 0.7 Nm/kg, and 0.3 Nm/kg, respectively (Figure 4).

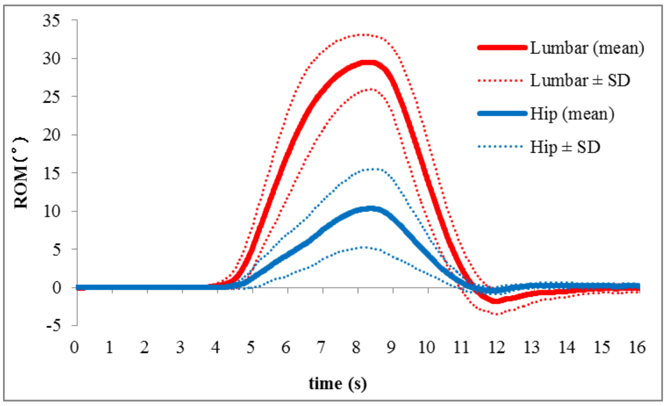

Figure 1: The mean (bold) and SD (thin) of lumbar ROM (red) and hip ROM (blue).

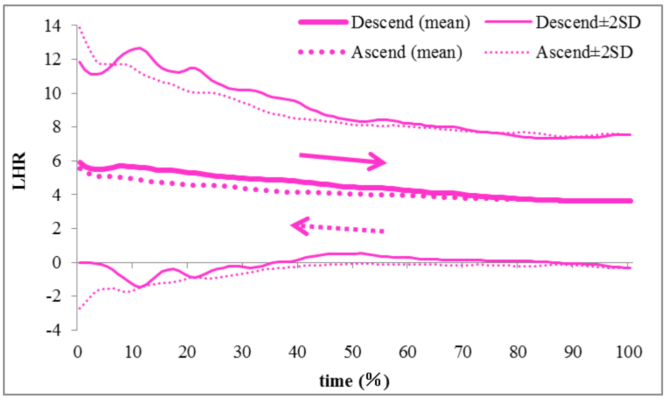

Figure 2: The mean (bold) and 2SD (thin) of lumbar to hip ratio (LHR) for descend phase (solid line) and ascend phase (dotted line).

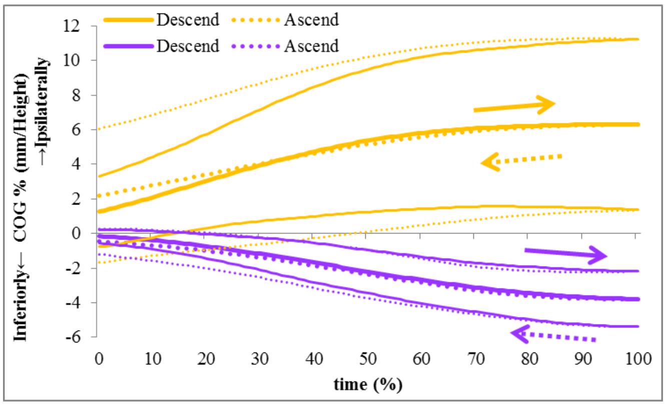

Figure 3: The mean (bold) and 2SD (thin) of Center of gravity (COG) for descend phase (solid line) and ascend phase (dotted line). Positive and negative value denote the shift of COG to ipsilaterally (yellow) and inferiorly (purple), respectively.

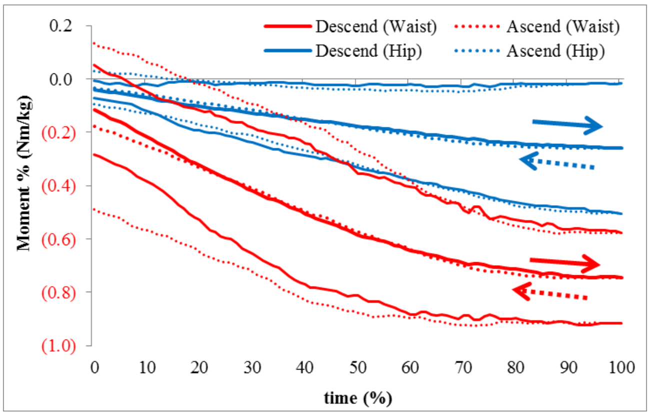

Figure 4: The mean (bold) and 2SD (thin) of contralateral waist moment (red) and hip moment (blue) for descend phase (solid line) and ascend phase (dotted line).

In descend phase, LHR may be decreased as to control the balance as well as to restrict waist moment. As the COG laterally shifts during a lateral bending, the grand reaction force shifts to ipsilateral side, and, at the same time, the hip and waist moment arm extend. From inverse dynamics, extension of the moment arm would produce contralateral abduction and ipsilateral adduction hip moment, and contralateral waist moment. Alternatively, the hip movement may increase to shorten the waist moment arm, which is twice as large as that of the hip. The shortened waist moment arm could restrict the contralateral waist moment. Moreover, with a small pelvis shift to contralateral side, the COG stays under control to maintain well-balanced position. Therefore, the hip movement was larger than that of lumbar spine in descend phase.

In ascend phase, the contra-strategy of descend phase would make LHR increase.

Implication: Our novel method for measuring real-time LHR by VICON will be a useful tool for the analysis of the lumbar movement in patients with spinal/hip disorder such as hip-spine syndrome.

CONCLUSIONS

The LHR decreased from 5.9 to 3.6 (mean 4.5) in descend phase, and increased from 3.6 to 5.6 (mean 4.2) in ascend phase. This strategy could be controlling the balance and restricting contralateral waist moment.

ACKNOWLEDGEMENTS

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