Lumbopelvic Interface and Compensatory Status should be More Predictable of Longitudinal Spinal Alignment than Pelvic Morphology: A Community-Based Cohort Study

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INTRODUCTION:

SRS-Schwab adult spinal deformity (ASD) classification in 2012 heralded the era of prolific ASD research, which based on the cross-sectional data from younger peer of ASD and the statistical correlations between their radiographic parameters and health related quality of life (HRQL) scores. Normal sagittal alignment, such as lumbar lordosis (LL) within 10˚ of pelvic incidence (PI) or lumbopelvic mismatch with PI-LL exceeding 10°, has been deducted and propagated. Historically, the definition of 'normal' sagittal alignment has been 3-tiers; global such as sagittal vertical axis (SVA), proportional such as thoracolumbar curvatures, and pelvis-based equations. Pelvis-based equations could be divided as morphology-based using PI, and interface-based using sacral slope (SS). PI is considered as an anatomical constant, and patients at 40s and at 80s with the same PI share the same LL. SS is the only interface between pelvis and spinal column and has been reported to influence spinal and global alignment. Pelvic tilt (PT) of more than 30° is another element of 'abnormal' pelvic compensation, however PT moves within the range of PI, and the impact of 'PT>30°' differs significantly in a patient with PI value of 40° and 80°. The purpose of this study was to investigate 1) longitudinal relationships between radiographic and clinical parameters, and 2) the influences of reported pelvis-based parameters upon longitudinal changes in sagittal spinal alignment, using community-based adult volunteers.

METHODS:

Community-based female volunteers were recruited from population register and subjected to upright entire spine radiographs and clinical evaluations performed by orthopaedic physicians and physical therapists. Standardized radiographic measurements included thoracic kyphosis (TK), LL, PI, PT, SVA, and SS. Clinical evaluations included isometric muscle strength of trunk flexor (TFL), trunk extensor (TEX), quadriceps femoris (QF), gluteus maximus (GM), and iliopsoas (IP), measured using dynamometer. Muscle strength was calibrated with each participant's body weight (BW). Statistical analyses were performed using analysis of variance (ANOVA) for comparing parametric variables, the paired t test for the differences in longitudinal parameters, and simple linear regression for studying correlations, and a p-value of less than 0.05 was used for significance. This study was a component of our ongoing prospective cohort study, and institutional review board approved current study.

RESULTS:

A final total of 118 female volunteers were included and their longitudinal demographics were as follows; age 65.1±5.4 years to 71.3±5.8 years (mean follow-up period of 6.2±2.9 years), TK30.0±13.0° to 28.9±14.6° (ns; not significant longitudinally), LL40.9±15.1° to 37.8±16.7° (p=.0024), PT24.0±10.4° to 25.5±11.6° (p=.0433), PI54.5±10.8° to 53.7±11.1°(ns), SVA12.0±34.4mm to 33.8±41.0mm (p<.0001), SS30.4±9.6° to 29.0±10.4° (p=.0435). Correlation between longitudinal changes (Δ) in radiographic and clinical parameters showed ΔLL was associated with ΔTEX (r=.213, p=.0363) and ΔQF (r=.284, p=.0047), however, ΔPT and ΔSVA had no significant correlation with muscle strengths, which might indicate physical fitness might not contribute to maintaining pelvic alignment. Correlation between longitudinal changes in radiographic parameters showed ΔLL-ΔSS was solely significant (correlation coefficient r=.47, p<.0001). Reported lumbopelvic parameters, PI-LL, pelvic compensation ratio (PT/PI) and lumbopelvic congruity (LL/SS) were used to predict ΔLL. Baseline PI-LL showed no significance; PT/PI≥0.4 showed significant decrease in ΔLL compared to PT/PI<0.4; and LL/SS≥1.6 showed significant decrease in ΔLL compared to LL/SS=1.0-1.5. Subjects with both PT/PI≥0.4 and LL/SS≥1.6 showed the greatest decrease in ΔLL (-10.1±8.5° vs normal -1.2±11.2°, p=.0005). [Figure]

DISCUSSION AND CONCLUSION:

After a mean 6.2-year longitudinal observation, decrease in LL was associated with decreasing back muscle strength, however, increase in PT or pelvic retroversion seemed to be a natural aging process irrelevant to trunk muscle weakness. Considering the inevitability of pelvic retroversion with aging, spine should be properly aligned not with pelvic morphology but with pelvic alignment at each age. Recent studies indicated that pelvic alignment is hard to control even during corrective surgery, and pelvic non-responders or those who could not acquire ideal pelvic alignment after spinal realignment is associated with continued pelvic decompensation, increased complication rate, and worse HRQL. As has been expected, morphology-based PI or PI-LL could not predict ΔLL, while interface-based SS and LL/SS, and the magnitude of pelvic compensation showed significant relation with ΔLL. Previous studies suggested using PT/PI of 0.25-0.5 instead of PT<20° for evaluating pelvic compensation, and this study substantiated its importance longitudinally, indicating PT/PI≥0.4 should be regarded as impending pelvic decompensation. Introduced LL/SS describes the congruity between lumbar and pelvic alignment, and LL/SS of 1.0-1.5 showed the least ΔLL, and LL/SS≥1.6, which might express overcorrection of LL, showed significant decrease in LL. When aiming for sustainable LL, the overly-expressed LL should be avoided especially in cases with impending pelvic compensation, which led to 8-fold decrease in LL compared to

subjects with ideal lumbopelvic congruity and pelvic compensation (LL/SS=1.0-1.5 and PT/PI<0.4). Limitation of our study included limited number for heterogeneous pathology, and further study should clarify the importance of lumbopelvic congruity and pelvic compensation status for properly targeting sustainable spinopelvic alignment in a long-term perspective.

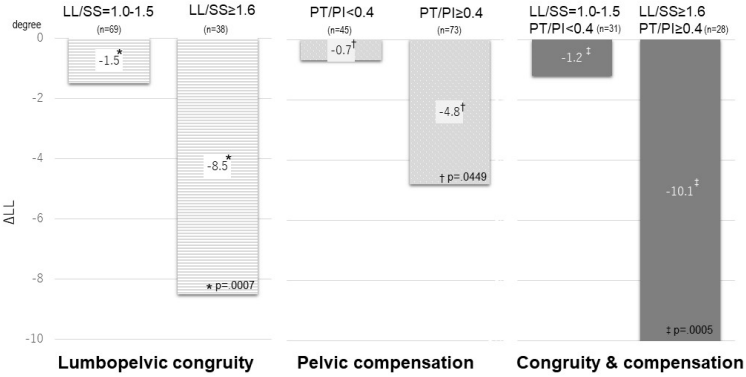

Figure. Longitudinal change in LL - baseline lumbopelvic congruity and pelvic compensation.

Overly-expressed LL, which exceeded 160% of SS, was a risk of greater LL change especially with pelvic compensation ratio exceeding 40%. LL *lumbar lordosis*, SS *sacral slope*, PT *pelvic tilt*, PI *pelvic incidence*, ΔLL *longitudinal change in LL*, LL/SS *denotes lumbopelvic congruity*, PT/PI *denotes pelvic compensation ratio*, p *p-value of ANOVA*.

11 subjects with LL/SS<1.0 were excluded due to non-significant findings.