

Relationships among whole-body sagittal alignment, musculoskeletal parameters, body balance, and health-related quality of life in Hong Kong Chinese adults: abridged secondary publication

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KEY MESSAGES

1. Health-related quality of life was correlated with all sagittal parameters, particularly sagittal vertical axis, T1 pelvic angle, KneeFlex angle, and AnkleFlex angle. Age was correlated with health-related quality of life and the Oswestry Disability Index.
2. Compared with older adults aged ≥ 50 years, younger adults aged ≤ 50 years exhibited less deviation in sagittal alignment, including thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, sagittal vertical axis, and T1 pelvic angle.
3. Women had significantly lower muscle mass, muscle strength, and bone density than men.
4. The three-dimensional odontoid–hip axis angle

varied little between younger and older asymptomatic Chinese adults; standard deviations were 2.3° in the sagittal plane and 1.0° in the coronal plane.

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Introduction

In Hong Kong, 17% of the population is aged ≥ 65 years, and this percentage is projected to increase to 30% by 2050. The provision of preventive and high-quality care for the ageing population is essential to ensure self-reliance and quality of life and to alleviate the associated financial burden.

Skeletal muscles play a crucial role in sagittal alignment changes during ageing. Patients with lumbar degenerative kyphosis exhibit significantly smaller lumbar muscularity and a higher proportion of fat deposits. Alterations in muscle architecture and activity in lower limbs may lead to changes in upright stance. Lower-limb compensations, such as knee flexion, are key mechanisms for maintaining sagittal alignment.¹ Reduced muscularity and increased fatty degeneration increase the risk of proximal junctional kyphosis. Declining muscle mass and functional sarcopenia are closely linked to osteoporosis and fragility fractures in older adults.

In asymptomatic Chinese adults, thoracic kyphosis steadily increases, whereas lumbar lordosis gradually decreases. Pelvic tilt is greater in men than in women across all age groups, with a gradual age-related increase.² Men and women aged 20 to 60 years significantly differ in KneeFlex

and AnkleFlex angles, but these differences are not significant beyond 60 years of age. Ageing affects the compensation mechanism, leading to greater reliance on pelvis and lower limbs in older people.

This study aimed to identify relationships among whole-body sagittal alignment, muscle mass, muscle strength, body balance, and health-related quality of life, as well as bone density, bone quality, and bone strength parameters.

Methods

This was a prospective cross-sectional study. Chinese adults aged 20 to 79 years in Hong Kong were recruited for assessments of sagittal alignment. Whole-body, standing, head-to-toe biplanar low-dose EOS X-ray images (ATEC Spine; Carlsbad [CA], USA) were acquired. The three-dimensional (3D) angle formed by the vertical axis and the line between the odontoid and mid-interacetabular axis (OD-HA angle) was computed and projected onto the sagittal and coronal planes. Bone mineral density, muscle mass, and muscle strength were measured, along with the visual analogue scale score for pain, the Oswestry Disability Index, and the Short Form-36 score.

Results

In total, 467 participants were assessed. Health-related quality of life was correlated with all sagittal parameters, particularly the sagittal vertical axis, T1 pelvic angle, KneeFlex angle, and AnkleFlex angle (Fig). Age was correlated with health-related quality of life and the Oswestry Disability Index. Women

had lower muscle mass, muscle strength—including appendicular skeletal muscle mass (ASMM), ASMM index, and grip strength—and bone mineral density than men. Whole-body sagittal alignment was correlated with health-related quality of life, bone quality, muscle mass, and muscle strength; global spinal parameters exhibited the strongest correlations (Tables 1 and 2). The 3D OD-HA angle

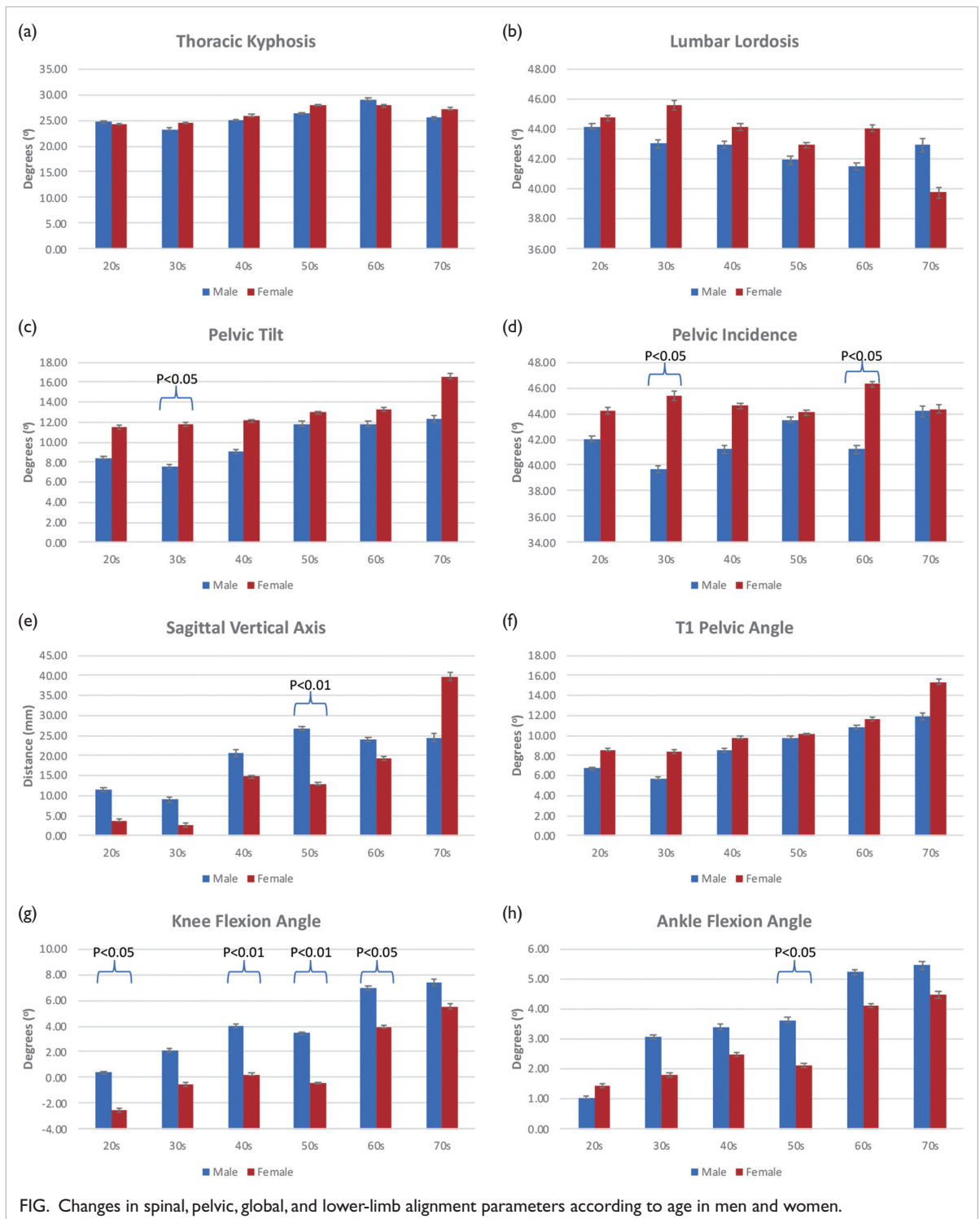


FIG. Changes in spinal, pelvic, global, and lower-limb alignment parameters according to age in men and women.

remained quasi-invariant across age groups, varying little between younger and older asymptomatic Chinese adults; standard deviations were 2.5° in the sagittal plane and 1.1° in the coronal plane. These data provide a reference range for head-pelvis balance, which displayed the strongest correlation with musculoskeletal parameters.

Thoracic kyphosis was negatively correlated with grip strength, whereas pelvic incidence, pelvic tilt, and T1 pelvic angle were positively correlated with ASMM and grip strength. The sagittal vertical axis was positively correlated with ASMM index, whereas the KneeFlex angle was positively correlated with ASMM and ASMM index, and the AnkleFlex angle was positively correlated with ASMM index. The 3D OD-HA angle was positively correlated with ASMM, ASMM index, and grip strength; it exhibited stronger correlations with muscle mass and grip strength. Bone mineral densities in the areal femoral neck, areal lumbar spine, and total hip were significantly lower in women.

Discussion

Bone and muscle health play an essential role in maintaining postural balance. Women exhibited significantly lower muscle mass and muscle strength including ASMM, ASMM index, and grip strength. Women also had significantly higher body fat mass, consistent with findings that women are less muscular than men.³ In the Framingham Osteoporosis Study of 800 older adults, the mean 4-year bone losses at the hip, lumbar spine, and radius ranged from 0.2% to 3.6% in men and from 3.4% to 4.8% in women.⁴

Maintenance of global alignment preserves the alignment of all segments above the pelvis and provides optimal posture with minimal energy expenditure. Failure to maintain the centre of gravity within this ‘conus of economy’ can result in compensatory mechanisms to restore stable global alignment. We have proposed a new 3D index—the OD-HA angle—to quantify 3D head-pelvis alignment, which appears quasi-invariant in both younger and older adults.⁵ The OD-HA angle confirms that the head tends to remain above the pelvis within a small cone of stability. This study provides a reference range for head-pelvis balance across different decades of age and sex. Our findings may facilitate future research concerning spinal deformities, spinopelvic alignment, and global alignment.

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TABLE 1. Correlations between sagittal alignment and muscle parameters.

Parameter	Appendicular skeletal muscle mass	Appendicular skeletal muscle mass index	Grip strength	
			Dominant	Non-dominant
Thoracic kyphosis	-0.078	-0.045	-0.139*	-0.129*
Lumbar lordosis	-0.039	-0.054	-0.044	-0.058
Pelvic tilt	-0.158†	-0.073	-0.190*	-0.177*
Pelvic incidence	-0.110*	-0.055	-0.126*	-0.129*
Sagittal vertical axis	0.085	0.164†	0.012	0.040
T1 pelvic angle	-0.129†	-0.040	-0.158†	-0.141†
KneeFlex angle	0.139†	0.221†	0.074	0.077
AnkleFlex angle	0.004	0.096*	-0.035	-0.032
Odontoid–hip axis angle (sagittal)	0.191†	0.212†	0.157†	0.168†

* P<0.05

† P<0.01

TABLE 2. Correlations between sagittal alignment and bone parameters.

Parameter	Areal femoral neck bone mineral density	Total hip bone mineral density	Areal lumbar spine bone mineral density
Thoracic kyphosis	-0.118*	-0.106	-0.159†
Lumbar lordosis	0.000	-0.027	-0.048
Pelvic tilt	-0.085	-0.073	0.054
Pelvic incidence	-0.049	-0.059	0.010
Sagittal vertical axis	0.011	0.050	0.071
T1 pelvic angle	-0.097	-0.074	0.050
KneeFlex angle	-0.126*	-0.066	0.009
AnkleFlex angle	-0.147*	-0.095	-0.003
Odontoid–hip axis (sagittal)	0.143*	0.212†	0.147†

* P<0.05

† P<0.01

Disclosure

The results of this research have been previously published in:

1. Ho JS, Ko KS, Law SW, Man GC. The effectiveness of robotic-assisted upper limb rehabilitation to improve upper limb function in patients with cervical spinal cord injuries: a systematic literature review. *Front Neurol* 2023;14:1126755.
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