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Roussouly's sagittal spino-pelvic morphotypes as determinants of gait in asymptomatic adult subjects

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ABSTRACT

Sagittal alignment is known to greatly vary between asymptomatic adult subjects; however, there are no studies on the possible effect of these differences on gait. The aim of this study is to investigate whether asymptomatic adults with different Roussouly sagittal alignment morphotypes walk differently. Ninety-one asymptomatic young adults (46 M & 45 W), aged 21.6 ± 2.2 years underwent 3D gait analysis and full body biplanar X-rays with three-dimensional (3D) reconstructions of their spines and pelvises and generation of sagittal alignment parameters. Subjects were divided according to Roussouly's sagittal alignment classification. Sagittal alignment and kinematic parameters were compared between Roussouly types. 17 subjects were classified as type 2, 47 as type 3, 26 as type 4 but only 1 as type 1. Type 2 subjects had significantly more mean pelvic retroversion (less mean pelvic tilt) during gait compared to type 3 and 4 subjects (type 2: 8.2°; type 3:11.2°, type 4: 11.3°) and significantly larger ROM pelvic obliquity compared to type 4 subjects (type 2: 11.0°; type 4: 9.1°). Type 2 subjects also had significantly larger maximal hip extension during stance compared to subjects of types 3 and 4 (type 2: −11.9°; type 3: −8.8°; type 4: −7.9°) and a larger ROM of ankle plantar/dorsiflexion compared to type 4 subjects (type 2: 31.1°; type 4: 27.9°). Subjects with type 2 sagittal alignment were shown to have a gait pattern involving both increased hip extension and pelvic retroversion which could predispose to posterior femoroacetabular impingement and consequently osteoarthritis.

1. Introduction

Spinal deformities are common orthopedic problems in both children [1] and adults [2] which often affect the spine in all 3 planes. While the motive for treatment can be related to aesthetic considerations or pulmonary function deficiency [3], spinal anomalies have also been shown to affect gait and balance [4].

Previous studies based on gait analysis have shown a significant effect of frontal malalignment on the kinematics [5,6], kinetics [7], muscle activation patterns [6] and spatio-temporal characteristics [5,8] of gait. However, there has recently been increased emphasis on the importance of the restoration of physiological sagittal alignment during spine deformity treatment [9].

Normative sagittal alignment requires a harmonious relationship between cervical lordosis, thoracic kyphosis, lumbar lordosis and pelvic parameters. While the absolute values of each of these components can vary in a large range of normality, these parameters are correlated amongst each other in order to maintain proper alignment in healthy subjects [10]. Roussouly et al. suggested that normal sagittal alignment could be divided into 4 types that differ significantly between each other [11]. While previous gait analysis studies have shown a significant effect of sagittal malalignment on gait [7,12–16], there are no studies on the relationship between the variations of normal alignment and gait in asymptomatic healthy subjects.

The aim of this study is to investigate whether asymptomatic healthy adults with different Roussouly sagittal alignment morphotypes walk differently. Our hypothesis was that the kinematics and spatio-temporal characteristics of gait differ between subjects with different sagittal alignment morphotypes.

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2. Materials and methods

2.1. Study design

This is a cross-sectional IRB approved study of the relationship between sagittal alignment and gait in young adult volunteers. The inclusion criteria were age between 18 and 28 years and no history of orthopedic surgery to either the spine, pelvis or lower limbs. Subjects were excluded if they presented any pain, including lower back pain, at the time of the study or if they had any musculoskeletal disease. Most subjects were students recruited at one of the faculties of our university. All subjects signed a written informed consent form.

2.2. Data acquisition

For each subject the following demographic characteristics were noted: age, gender, weight, height and body mass index (BMI).

Each subject underwent three-dimensional gait analysis (3DGA) using a Vicon® (Vicon Motion Systems, Oxford, UK) optoelectronic motion system (7 MX3 infrared cameras, 200 Hz). Marker placement was based on the modified Helen Hayes protocol [17] and was applied as recommended in the Plug in Gait® model. Subjects were asked to walk at a self-selected speed along a 10-m walkway. The consistency of the kinematic curves was verified under Polygon® (Vicon Motion Systems, Oxford, UK) and inconsistent trials were eliminated. One representative trial was then used to calculate three-dimensional joint angles and spatio-temporal parameters. Data was processed using the pipeline in Workstation® (Vicon Motion Systems, Oxford, UK): fill gap routine ±10 frames and Woltring filter with a scale of 10. Kinematic parameters of the pelvis, hip, knee and ankle were then calculated in Matlab® (Mathworks, Natick, USA) for each subject. The following spatio-temporal parameters were calculated by the model: walking speed (m/s), cadence (steps/min), foot off (% of gait cycle), single support (s) and step length (m). Single support was normalized to stride time and was thus expressed as a percentage of the whole gait cycle. All the kinematic and spatio-temporal gait parameters generated in this study have been previously defined [18,19].

All subjects also underwent a full body biplanar X-ray exam (EOS Imaging, Paris, France). Subjects were asked to stand upright in a relaxed manner with their shoulders flexed to about 45° and their hands placed on the zygomatic bones of their face. This consensual free-standing position [10,20] was adopted in order to avoid the superimposition of subjects' arms over their spines on lateral radiographs.

Their spines, pelvises and lower limbs were reconstructed in 3D using SterEOS® (EOS Imaging, Paris, France). Lower limb length (in meters) was measured on the 3D reconstructions of the lower limbs, as the sum of the lengths of the femur (from the center of the femoral head to the middle of the intercondylar region of the distal femur) and tibia (from the middle of the intercondylar region of the proximal tibia to the middle of the horizontal portion of the medial malleolus). Furthermore, the following, previously defined [21,22], sagittal spino-pelvic alignment parameters were generated from these 3D reconstructions: pelvic tilt, sacral slope, pelvic incidence, L1-L5 lordosis, L1-S1 lordosis, T1-T12 kyphosis and T4-T12 kyphosis. Briefly, pelvic tilt is defined as the angle between the vertical and a line drawn from the center of the femoral heads to the midpoint of the sacral plate; sacral slope as the angle between the S1 sacral endplate and the horizontal; pelvic incidence as the angle between the perpendicular to the sacral plate and a line

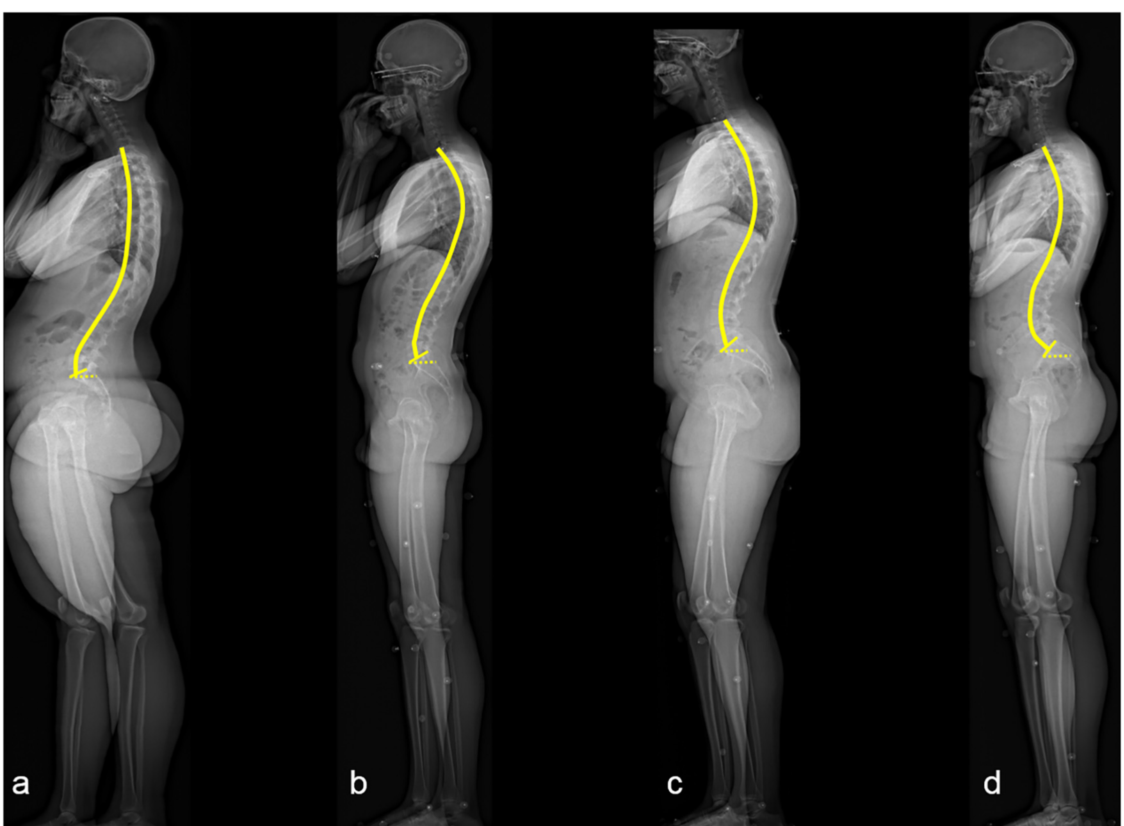

Fig 1. Representative sagittal radiographs of subjects with Roussouly types 1 (a), 2 (b), 3 (c) and 4 (d) sagittal alignment. The sagittal spinal curvatures and sacral slope of each subject are drawn in yellow on the radiographs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)