Biomechanical analysis of posture in patients with spinal kyphosis due to ankylosing spondylitis: a pilot study

S. D. M. Bot, M. Caspers, B. J. Van Royen¹, H. M. Toussaint and I. Kingma

Faculty of Human Movement Sciences, Free University of Amsterdam and
¹Department of Orthopaedic Surgery, Free University Hospital Amsterdam,
The Netherlands

Abstract

Objectives. Patients with ankylosing spondylitis may experience a progressive spinal kyphosis, which induces a forward and downward displacement of the centre of mass (COM) of the trunk. In this pilot study, the possible mechanisms used to compensate for the displacement of the trunk COM were analysed.

Methods. Joint angles of hip, knee and ankle were determined in four patients with ankylosing spondylitis and compared to data of 18 healthy subjects. Each patient stood on a force platform and had to adopt several predefined postures, which were recorded by a video camera.

Results. In three patients, the hips were flexed when standing relaxed, and in all patients hip extension was limited. The knee angles of three patients were smaller and in two patients the angle of the ankles was larger compared to healthy subjects.

Conclusions. The results suggest that the hip joints are at least no longer involved in balance control. This may imply that conservative therapy should focus on the prevention of restriction of the hip joints.

Key words: Posture, Ankylosing spondylitis, Spinal kyphosis, Balance, Hip joints, Biomechanics.

Ankylosing spondylitis leads to total immobility of the spine and a fixed kyphosis may appear [1, 2]. As a consequence of the spinal kyphosis, patients are not able to sit, stand or lie comfortably. Often they are not able to see the horizon, which causes problems in daily activities.

From a biomechanical point of view, the spinal kyphosis causes a forward and downward shift of the centre of mass (COM) of the trunk in the sagittal plane. When the other segments do not change position, it will induce a forward and downward shift of the body COM with respect to the base of support (Fig. 1). To maintain body balance, a patient has to correct for this shift. Owing to the ankylosis of the spine, only the mobile joints of the lower limbs can compensate for the sagittal displacement of the trunk COM. Extension of the hips, flexion of the knees and plantar flexion of the ankles may counterbalance the forward shift of the body COM relative to the base of support. Compensation by the ankles is very efficient, as it demands little plantar flexion of the ankle joints. However, it hardly influences the horizontal view. When the hips are used for compensation, a larger change in joint angle is needed to reach the same result concerning the COM displacement compared to compensation by the ankle joints. Nevertheless,
extension of the hips is beneficial as it induces a posterior rotation of the pelvis and results in a large increase in trunk angle. The more the trunk is rotated posteriorly, the more the field of vision increases and the load on the lumbar spine could possibly decrease. The compensation may become insufficient due to the progress of the disease, which could lead to a permanent displacement of the trunk COM.

Knowledge of the way patients counterbalance the shift of the body COM could be instrumental in designing more optimal conservative and invasive treatment procedures. Up to now, no biomechanical approach has been used to evaluate the posture of patients with ankylosing spondylitis. The purpose of this pilot study was to analyse the possible mechanisms used to compensate for the sagittal displacement of the trunk COM.

Methods

Four male patients (age 28–77 yr) with progressive spinal kyphosis due to ankylosing spondylitis voluntarily participated in this study. All patients were considered to have a lumbar closing wedge posterior vertebral osteotomy [3]. One patient had a total hip replacement (left side) and another patient had severe symmetrical hip involvement. The criterion for participation in this study was a standard radiograph of the entire spine showing a classic bamboo spine with complete calcification of the discs and bridging syndesmophytes.

Procedure

The subjects were standing barefoot on a force platform and were asked to adopt seven different predefined postures for a few seconds, standing as motionlessly and symmetrically as possible. These postures were standing: (1) relaxed, (2) straight, (3) with maximal extension of the hips and straight legs, (4) in between straight standing and maximal hip flexion, (5) in maximal hip flexion, (6) with flexed knees and horizontal view and (7) with maximal extended knees. The postures were recorded by a video camera (JVC SVHS) while the forces at the foot–floor interface were registered by a forceplate (AMTI, OR6-5 Newton, MA, USA). The positions of the markers were recorded at 50 Hz by the video camera, at a distance of 5 m. Video and forceplate recordings were synchronized using a time-code generator. Prior to the posture recordings, the optical field of the video camera was calibrated using a reference frame. The accuracy of the position determination of the markers was within 5 mm [4].

Anthropometry

White markers with contrasting black circles were placed on the skin to indicate the location of several anatomical landmarks (Fig. 2). The co-ordinates of the joint positions defined eight body segments: the feet, lower legs, upper legs, pelvis, upper trunk and head, upper arms, forearms and hands. The trunk segment was determined by the position of the first thoracic vertebra in relation to the position of the lumbosacral joint. Anthropometric data (standing height, total body mass, length of segments) were measured. The mass of each segment as well as the positions of segmental centres of gravity (except for the trunk) and moments of inertia, were calculated according to Plagenhoef [7]. The centre of gravity of the trunk was estimated by an optimization method according to Kingma et al. [6].

Model and kinetics

The co-ordinates of the anatomical landmarks in the sagittal plane were determined by digitizing the video images with the software program Fanslab [4], using a PC (Commodore 486-25c). A two-dimensional linked segment model of the subjects was constructed from these co-ordinates and anthropometric data [5], to calculate the biomechanical parameters. Joint angles were determined by the front angle between the distal and proximal linked segments of a joint. Net sagittal plane reaction torques at the knee joint were calculated [5].

Data analysis

Joint angles of hip, knee and ankle were compared to data of 18 healthy male subjects (age 21–27 yr) standing relaxed. The hip angle in postures 1, 2 and 3 was determined to examine the limitation of compensation of the hip joint. Postures 2, 4 and 5 were used in order to determine the trunk COM [6]. Simple descriptive statistics employed means and standard deviations.

Results

The angles of the patients' hip joints were measured in postures 1, 2 and 3. Asking the subjects to extend the hips maximally with straight legs attained maximal extension of the hip (posture 3). The hip angle changed 1–6°, which means that the hips were almost in maximal
extension in all three postures. There was no difference in knee and ankle angles between these postures.

The angles of the hip joints in three patients were smaller (mean 190 ± 2°) compared to healthy subjects (mean 206 ± 7°) in the posture standing relaxed. The knees of three patients showed a larger flexion (196°, 199° and 209°) compared to healthy subjects (mean 185 ± 6°). When the subjects were asked to adopt a posture that enabled them to see the horizon, knee flexion increased further. The knee torque increased from 10 to 94 Nm in one patient and from 37 to 102 Nm in another patient. One of the patients was able to see the horizon without compensation. The knee torque of the fourth patient was not available. The angle of the ankles of two patients (118° and 111°) was larger compared to the mean ankle angle of healthy subjects (mean 104 ± 4°) in the posture standing relaxed.

Discussion

Patients with ankylosing spondylitis may experience a progressive kyphotic deformity of the spine. This deformity leads to a forward displacement of the trunk COM, which must be compensated in order to maintain balance. The results showed that the patients were hardly able to extend their hips when standing relaxed. Moreover, three patients had flexed hips when standing upright, which enlarges the problem of balance as it induces an anterior rotation of the trunk. Apparently, the expected compensation by the hip joints is not possible.

When hip extension is limited, the knee and ankle remain as components of compensation to ensure equilibrium when standing upright. The knees of the patients were more flexed than the knees of healthy subjects when standing relaxed. Flexion of the knees requires a considerable effort of the quadriceps muscles and will result in earlier fatigue than standing with extended legs. When the patients were asked to adopt a posture which would make it possible to see the horizon, three patients flexed their knees: the knee torque increased 3-fold in one patient and even 9-fold in another patient compared to standing relaxed. Flexion of the ankles is a third way to compensate for the displacement of the trunk COM. The results showed a larger angle of the ankle joints of two patients compared to the ankle angles of healthy subjects. One patient had straight legs when standing relaxed and thus it can be concluded that he only used his ankles to compensate for the forward displacement of the trunk COM. One patient used both his ankle and knee joints to compensate.

The results indicate that patients with spinal kyphosis compensate for the displacement of the trunk COM by flexion of the knees and/or plantar flexion of the ankles. The data suggest that the hip joints are at least no longer involved in balance control. The knees could become overloaded as a consequence of the restricted hip joints in the case of the need for further compensation. If the results prove to be confirmed in further study, the restricted hip extension and the decreased hip angle may contribute to the choice and evaluation of conservative therapy, and advocate surgical treatment of the hips before spinal correction.

References