An Experimental Analysis to Derive Pelvic Tilt from Seating Forces

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Abstract

Background: Among wheelchair dependent patients, a poor sitting posture is often seen which contributes to all kinds of physical problems during long term sitting. Because pelvic tilt is crucial for the adopted sitting posture the possibility to derive pelvic tilt from seating forces was experimentally analysed. Methodology: An adjustable and instrumented wheelchair was developed to analyse seating forces for different sitting postures. Contact forces on the front and back part of the seat were measured independently and mechanical analyses were done to calculate internal joint forces and torques. Based on equivalent 'two-force member' loading, pelvic tilt was estimated from the direction of the equivalent contact force under the tuberosities. Findings: A significant correlation between the equivalent force angle and pelvic tilt was shown. Furthermore, the presence of a lumbar extension torque was found for the total range of pelvic tilt. Interpretations: Previous study (part 1) concluded that minimal lumbar torque was necessary to derive pelvic tilt. Present results however, did not satisfy these criteria. It was suggested that healthy subjects used active trunk muscle control as an important mechanism involving comfort issues such as lumbar spine stabilisation and decubitus prevention. Elaborated experiments among patients with limited trunk muscle function are therefore necessary.

Background

Among wheelchair dependent patients, a poor sitting posture is often seen [1] which contributes to all kinds of physical problems during long term sitting [2-4]. The inability to reposition implies that adequate variation in sitting posture can only be realized by changing the configuration of the chair. Important factors defining sitting posture are the orientation of the trunk, pelvis and thighs. Especially pelvic tilt is crucial for the adopted posture [5-8]. Contrary to pelvic tilt, desired thigh and trunk orientations can easily be invoked by proper adjustment of the seat and back support. For proper pelvic tilt however, information about the pelvic angle is needed. In part 1, a biomechanical analysis to derive pelvic tilt from seating forces resulted in a method to individualize chair configuration. Although the conclusions seemed promising, experimental validation was essential and is therefore the main objective of the present study.

Materials and Method

Experiments were done with an instrumented wheelchair (IBIS Comfort Wheelchair) with build-in force sensors (ATI mini 45, ATI Industrial Automation, NYC, USA) in the front and back part of the seat (figure 1A/B). Different sitting postures could be imposed by changing the configurations of the seat, back support and footrests (figure 1A). Kinematic body and chair data were obtained using a six-camera VICON motion capturing system. Reflective markers were placed on the body and chair to determine the hip joint centre (HJC) [9], lumbar 'joint' centre (LJC), pelvic tilt (α), trunk angle (β), thigh angle (γ), seat angle (φ) and back support angle (ε). The global contact force and centre of pressure on the back part of the seat (F_b and cop_b) and front part of the seat (F_f and cop_f) were calculated and static equations of equilibrium for the pelvis and thigh segments were used to derive the internal lumbar and hip joint forces and torques. In part 1, it was already shown how pelvic tilt could be derived from the equivalent contact force angle (ψ_{eq}) in case of equivalent 'two-force member' loading (figure 1C/D). Various sitting postures, imposed by different configurations of the seat and back support, were analysed in the sagittal plane. Subjects (n=6) were asked to keep their arm folded and adopt a passive sitting posture to prevent redundant active trunk muscle control. Force angle (ψ), equivalent force angle (ψ_{eq}) and lumbar torque (τ_{lum}) were calculated.

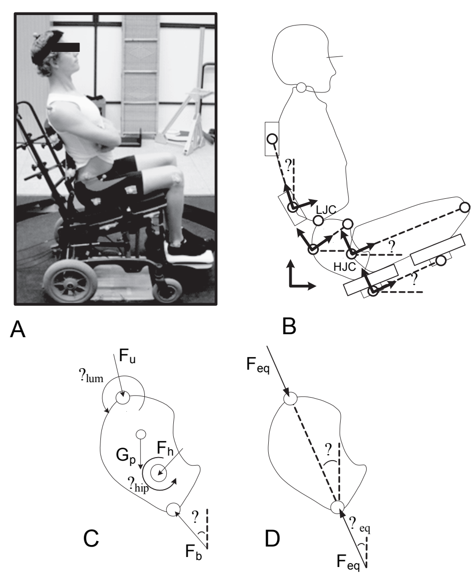

Figure 1. **A**: Experimental setup. **B:** Body and chair angles derived from the reflective markers. **C**: individual pelvic segment including external forces and the contact force angle (ψ). **D**: equivalent two-force member loading in which pelvic angle (α) equals the equivalent force angle ψ_{eq}.

Findings

The force angle (ψ) and the equivalent force angle (ψ_{eq}) are shown in figure 2A. For both variables, a linear fit (resp. r = 0.66 and r = 0.88) reflects the relation with pelvic tilt (α). The solid line refers to the situation when the measured force angle equals α. A relatively small influence of α on ψ is observed meaning that it is not possible to estimate pelvic tilt direct from the contact force under the tuberosities. For ψ_{eq} however, a more significant relation is shown. Figure 2B reflects the presence of lumbar torque for the total range of pelvic tilt. Both α and τ_{lum} are expressed as a percentage of its maximum. Interestingly, for the total range of pelvic tilt an extension torque was observed mainly.

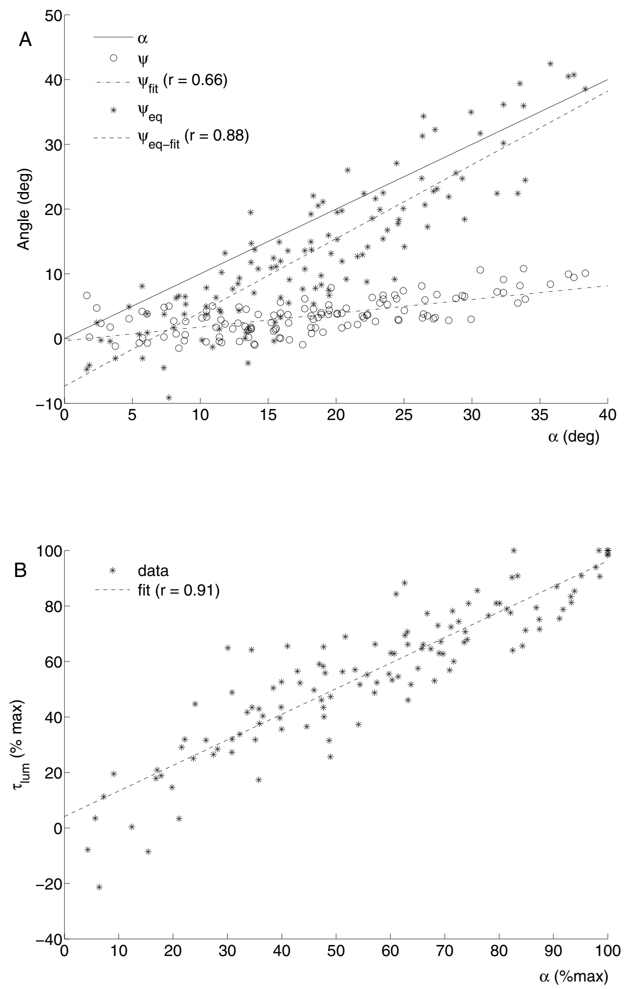

Figure 2. **A**: Positive correlations between pelvic tilt (α) and both the contact force angle (ψ) and the equivalent force angle (ψ_{eq}) are shown (resp. r = 0.66 and r = 0.88). **B:** for the total range of pelvic tilt (α) a positive correlated (r = 0.91) extension torque (τ_{lum}) was observed. Both α and τ_{lum} are expressed as a percentage of its maximum.

Interpretations

In the present study, the possibility to derive pelvic tilt from seating forces was experimentally analysed. Since the presence of lumbar torque greatly influences contact forces on the seat and that knowledge about pelvic angle is needed for estimating lumbar torque, it was assumed that situations of minimal lumbar torque are essential to derive pelvic tilt. A positive correlation is observed between pelvic tilt and the equivalent force angle. However, minimal lumbar torque was only present in situations of maximal pelvic anterior tilt indicating that excessive lumbar lordosis must be performed. Contrary to the implemented passive lumbar spine stiffness in the first study (part 1), these results do not show a range of minimal lumbar torque. Possible explanations could be that healthy subjects use their trunk muscle function involving comfort issues such as lumbar spine stabilisation and decubitus prevention. The mechanism preliminary to the development of pressure ulcers is the response of the body surface to the direction, magnitude and distribution of seating forces. Although, the exact physiological process remains unclear, researchers agree that the problem is directly related to the presence of sustained mechanical loading on skin and underlying tissue with high shear forces in particular [10]. Since lumbar torque greatly influences seating forces, shear forces can be regulated by actively control the amount of lumbar torque. This is supported by the fact that only little variation in ψ is observed indicating minimal shear forces under the tuberosities. Although it seems difficult to derive pelvic tilt for healthy subjects, among patients with limited postural stability however, it might still be possible since no trunk muscle function is present. Elaborated experimental studies among wheelchair dependent patients are therefore necessary to investigate the possibility deriving pelvic tilt from seating forces and for a better understanding in possible mechanisms involving seating comfort.

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