Journal of Biomechanics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Soft tissue displacement over pelvic anatomical landmarks during 3-D hip movements

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ARTICLE INFO

Article history:
Accepted 11 January 2017

Keywords:
Soft tissue artefact
Human movement analysis
Stereophotogrammetry
Pelvis
Multiple anatomical calibration

ABSTRACT

The position, in a pelvis-embedded anatomical coordinate system, of skin points located over the following anatomical landmarks (AL) was determined while the hip assumed different spatial postures: right and left anterior superior and posterior superior iliac spines, and the sacrum. Postures were selected as occurring during walking and during a flexion–extension and circumduction movement, as used to determine the hip joint centre position (star-arc movement). Five volunteers, characterised by a wide range of body mass indices (22–37), were investigated. Subject-specific MRI pelvis digital bone models were obtained. For each posture, the pose of the pelvis-embedded anatomical coordinate system was determined by registering this bone model with points digitised over bony prominences of the pelvis, using a wand carrying a marker-cluster and stereophotogrammetry. The knowledge of how the position of the skin points varies as a function of the hip posture provided information regarding the soft tissue artefact (STA) that would affect skin markers located over those points during stereophotogrammetric movement analysis. The STA was described in terms of amplitude (relative to the position of the AL during an orthostatic posture), diameter (distance between the positions of the AL which were farthest away from each other), and pelvis orientation. The STA amplitude, exhibited, over all postures, a median [inter-quartile] value of 9[6] and 16[11] mm, for normal and overweight volunteers, respectively. STA diameters were larger for the star-arc than for the walking postures, and the direction was predominantly upwards. Consequent errors in pelvic orientation were in the range 1–9 and 4–11 degrees, for the two groups respectively.

1. Introduction

The movement between markers attached to the skin surface, as used in stereophotogrammetry for the analysis of human motion, and the underlying bone (soft tissue artefact: STA) has been investigated in various body segments and during different motor tasks. This was made possible by simultaneously monitoring the movement of the skin markers and of the underlying bone using methods such as intracortical pins (Andersen et al., 2012; Andriacchi et al., 1998; Benoit et al., 2006; Camomilla et al., 2013; Cappozzo et al., 1996; Cereatti et al., 2009; Dal Maso et al., 2016; Fuller et al., 1997; Lafortune et al., 1992; Ramsey et al., 2003; Reinschmidt et al., 1997; Westblad et al., 2002), percutaneous bone tracking devices (Houck et al., 2004; Holden et al., 1997; Manal et al., 2000), fluoroscopy (Akbarshahi et al., 2010; Charbonnier et al., 2014; Kuo et al., 2011; Sati et al., 1996; Stagni et al., 2005; Tsai et al., 2009, 2011), or X-rays (Maslen and Ackland, 1994).

Although a reasonable amount of relevant information concerning the lower and upper limb segments is available in the literature (Leardini et al., 2005; Peters et al., 2010), only two studies provided information on the STA that affects the pelvis. One investigation was performed during gait and sit to stand using markers mounted on pins inserted into the sacrum (Rozumalski et al., 2007). This study showed larger STA for the anterior superior than for the posterior iliac spine areas, and in the craniocaudal direction. A non-invasive assessment of pelvic STA was performed relying on the estimate of the pelvic bone-pose provided by a multiple anatomical calibration (Hara et al., 2014). This technique involves static calibrations performed through manual palpation of relevant anatomical landmarks (ALs) and consequent identification of their position using stereophotogrammetry through the range of motion of the joint of interest (Cappello et al., 1997). In this way, the STA issue is bypassed and a reliable pelvis pose can be assessed in each posture of interest. This method, besides not showing the STA components caused by the wobbling of the soft tissues, suffers from unavoidable intra-operator

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http://dx.doi.org/10.1016/j.jbiomech.2017.01.013
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