VALIDATION OF A METHOD OF LOCATING THE PELVIS AND SPINAL JOINT POSITION IN A SEATED POSITION

Xuguang Wang, Cyrille Grebonval, Philippe Beillas

Univ Eiffel, Univ Lyon 1, LBMC UMR_T 9406, F-69622 Lyon, France

Introduction

To locate the pelvis and spinal joint position accurately in a seated posture is required for biomechanical investigation of seating comfort and safety. However, due to very limited number of the anatomical landmarks (ALs) than one can palpate in a seated position, existing methods based on ALs [1] are not applicable. In the present work, we propose a method consisting of two steps: 1) defining a personalized pelvis and spine kinematic model from a 3D surface body scan in a standing posture, 2) repositioning the kinematic model in a seated position with the ALs that can be easily obtained. The objective of this paper is to validate the proposed method using the MRI scans in four postures (including a standing and a seated one) for three females and six males obtained in [2].

Methods

The pelvis and spine are modeled as a kinematic chain, which is composed of 18 segments and articulated by a spherical joint. To define a personalized model, individual segment lengths are estimated using the PCA based method proposed in [3] from an external trunk shape. To estimate pelvis segment dimension, the statistical regression equations proposed in [4] are used with the anterior and posterior iliac spines (ASIS and PSIS) and pubic symphysis (PS) as inputs. The personalized kinematic model is then repositioned in a desired seated posture, characterized by N joint angles ($q_j, j = 1, N$), by minimizing the distance between M model-based ($\boldsymbol{x}_i,\ i = 1, M$) and target palpable ALs ($\tilde{\boldsymbol{x}}_i$, $i = 1, M$) while keeping close to a reference posture ($\tilde{q}_j, j = 1, N$):

$$f = \sum_{i=1}^{M} w_i(\boldsymbol{x}_i(\boldsymbol{q}) - \tilde{\boldsymbol{x}}_i)^2 + w_g \sum_{j=1}^{N} v_j(q_j - \tilde{q}_j)^2 \quad (1)$$

where w_i, v_j, and w_g are weighting coefficients.

In [2] the 3D external trunk shape and bone surfaces were reconstructed from the MRI scans, allowing the definition of the anatomical landmarks as well as intersegmental joint centers. For each subject, the external trunk shape and skin points closest to the target ALs in the standing posture were used to define the personalized kinematic model, and corresponding local coordinates of the ALs were calculated. The following ALs were defined as targets: left and right ASIS, mid-point between two PS, left and right ischial tuberosities (IT) for the pelvis, as well as jugular notch (IJ), two clavicular notches, and tip of Xiphoid process (XP) for the thorax. To look at the effects of the reference posture for IK repositioning, mean standing and seating posture from the nine subjects were tested as well as the zeros posture for which all segments are aligned. The weighting coefficients were determined by trial and error.

Results and Discussion

The prediction errors were on average 14.3, 17.5, and 14.2 mm respectively for the mean seating, standing and zero postures used as reference for optimization (Table 1). Better prediction was obtained with the seated posture as reference for the pelvis and lumbar joints as illustrated for one subject (Figure 1).

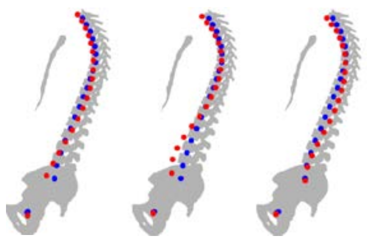

Figure 1: Predicted joint positions (red) using the zero, mean standing and mean seating postures as reference for one subject in comparison with the ground truth positions(bleu)

	Seating		Standing		Zeros	
Joint	mean	std	mean	std	mean	std
RHJC	10.7	5.1	11.2	6.2	11.8	5.7
S1L5	11.2	4.2	28	6.1	22.5	5.7
L4L3	14.6	2.5	29.5	5.5	13.6	3.4
L1T12	15.8	5	16.7	5.7	14	4.4
T7T6	13.4	7.3	13.9	5.1	12.9	5.9
T1C7	19.5	4.3	19.9	4.9	16.4	4.9
ALL	14.3	5.6	17.5	8	14.2	5.4

Table 1: Means and standard deviations of the distances between predicted and MRI joint positions

References

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2. Beillas et al., 2009. Stapp Car Crash Journal, Vol.53, pp. 127-154
3. Nérot et al., 2016. J. of Biomech 49, 3415-3422
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