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Communication

Effects of frontal and sagittal thorax attitudes in gait on trunk and pelvis three-dimensional kinematics

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ABSTRACT

While sagittal trunk inclinations alter upper body biomechanics, little is known about the extent of frontal trunk bending on upper body and pelvis kinematics in adults during gait and its relation to sagittal trunk inclinations. The objective was to determine the effect of the mean lateral trunk attitude on upper body and pelvis three-dimensional kinematics during gait in asymptomatic subjects. Three gait cycles were collected in 30 subjects using a motion analysis system (Vicon 612) and an established protocol. Sub-groups were formed based on the mean thorax lateral bending angle, bending side, and also sagittal tilt. These were compared based on 38 peak angles identified on pelvis, thorax and shoulder kinematics using MANOVAs. A main effect for bending side ($p = 0.038$) was found, especially for thorax peak angles. Statistics revealed also a significant interaction ($p = 0.04993$) between bending side and tilt for the thorax sagittal inclination during body-weight transfer. These results reinforce the existence of different gait patterns, which correlate upper body and pelvis motion measures. The results also suggest that frontal and sagittal trunk attitude should be considered carefully when treating a patient with impaired gait.

1. Introduction[1]

Forward and backward trunk inclinations, i.e. tilt, during gait alter upper body kinematics and kinetics [1,2], partially explained by a top-heavy trunk. Compensations consequential to trunk tilt could also modify the body mediolateral dynamics [3,4]. However, little is known about the extent of frontal trunk bending on upper body and pelvis kinematics in able-bodied adults during gait and its relation to trunk tilt.

Frontal trunk motion during normal gait has attracted little attention because its range is small [5–8]. Individual mean range of trunk tilt was approximately 2° [9]. However, peak values in trunk kinematics can hide postural attitudes, such as forward (positive) or backward tilt, as previously reported, though only on the sagittal plane [1,2]. A 12° range of trunk bending was reported by Chung, Park [10] (mean = −0.1°) while Leardini et al. [11] reported 13.9° range (mean = 0.9°). Whereas mean mediolateral trunk bending is negligible in able-bodied population [6,8], individual differences have not been considered and reported in gait.

Upper body kinematics has been described in terms of pelvic, thoracic, lumbar and shoulder motion during gait [6,11–13]. However, only a few have investigated the coupling motion between pelvis and lumbar spine [14–16] as well as the possible kinematic relationship between thorax and pelvis [1,10]. It was also shown that sagittal trunk inclination alters three-dimensional kinematics of the upper trunk during gait [1]. Though trunk motion is well documented during gait, little is known about their interactions.

Lateral trunk bending is of clinical interest since it adapts with aging [17] to maintain dynamic stability in elderly individuals [18]. In spinal pathologies with mediolateral trunk asymmetries, trunk motion is exacerbated in the frontal and sagittal planes during gait [19]. Furthermore, individuals with Parkinson [20] or cerebral palsy diseases [21] and elderly [22] rely on trunk motion during gait to remain stable. These studies underlined the importance of trunk adaptations but did not account for the individual preferred trunk tilt.

Our objective is to determine the effect of the lateral trunk attitudes on upper body three-dimensional kinematics during gait in asymptomatic subjects. This will be tested for the range and its mean side. Furthermore, the interaction between the mean lateral trunk bending and the accompanying mean forward/backward thorax inclinations is also investigated. We hypothesize that asymptomatic

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[1] Abbreviations used in this manuscript: pelvis frame (Pel); thorax frame (Tho); laboratory frame (Lab); Shoulder line (Sh).

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Table 1
Gender, age, mass, height, body mass index (BMI), mean thorax lateral bending, inclination side, absolute mediolateral trunk bending (ML abs) and mean sagittal inclination (Sag tilt) in forward (Fw) or backward (Bw) direction for the overall population of 30 subjects. All angular values are in degrees.

Gender	Age (years)	Mass (kg)	Height (cm)	BMI (kg/m^2)	ML bend (deg)	Right or left	ML ABS (deg)	Sag tilt (deg)	Fw or Bw
Female	25	62	163	23.3	−4.30	Left	4.30	15.5	Fw
Female	31	49	173	16.4	−4.00	Left	4.00	7.9	Bw
Male	39	78	180	24.1	−3.80	Left	3.80	18.2	Fw
Male	24	69	178	21.8	−2.99	Left	2.99	16.0	Fw
Male	25	80	183	23.9	−2.87	Left	2.87	14.8	Fw
Male	30	69	167	24.7	−2.75	Left	2.75	13.4	Fw
Male	26	73	179	22.8	−2.25	Left	2.25	9.8	Bw
Female	28	52	168	18.4	−2.17	Left	2.17	13.5	Fw
Male	29	99	192	26.9	−1.72	Left	1.72	18.0	Fw
Male	26	85	183	25.4	−1.44	Left	1.44	15.1	Fw
Female	25	55	164	20.4	−0.94	Left	0.94	12.4	Bw
Female	24	50	165	18.4	−0.67	Left	0.67	8.9	Bw
Female	26	48	160	18.8	−0.62	Left	0.62	15.7	Fw
Female	21	46	158	18.4	−0.54	Left	0.54	2.4	Bw
Male	22	75	173	25.1	−0.26	Left	0.26	14.1	Fw
Male	24	75	175	24.5	−0.25	Left	0.25	18.9	Fw
Male	19	78	180	24.1	−0.03	Left	0.03	12.4	Bw
Male	24	55	168	19.5	0.05	Right	0.05	11.1	Bw
Female	28	59	172	19.9	0.26	Right	0.26	21.3	Fw
Male	26	68	178	21.5	0.41	Right	0.41	11.7	Bw
Female	28	54	167	19.4	1.68	Right	1.68	11.7	Bw
Female	26	54	168	19.1	1.94	Right	1.94	7.9	Bw
Female	27	50	170	17.3	2.03	Right	2.03	3.3	Bw
Female	27	54	167	19.4	2.12	Right	2.12	9.5	Bw
Female	28	52	163	19.6	2.20	Right	2.20	13.2	Fw
Male	24	69	178	21.8	2.28	Right	2.28	18.4	Fw
Male	31	106	190	29.4	2.78	Right	2.78	15.5	Fw
Male	28	80	180	24.7	2.96	Right	2.96	11.2	Bw
Female	27	60	181	18.3	3.60	Right	3.60	−0.3	Bw
Female	25	48	156	19.7	5.72	Right	5.72	9.0	Bw
Mean	26.4	65.1	172.6	21.6	−0.1		2.0	12.3	
SD	3.60	15.49	9.08	3.17	2.48		1.43	4.95	

subjects maintain a mean trunk bending that could perturbed pelvic and upper-body kinematics and be related to the mean trunk tilt.

2. Methods

Thirty young asymptomatic subjects without deformities and musculoskeletal disorder history (Table 1) volunteered for the study and signed an informed consent [1]. Three walking trials at self-selected speed were collected using eight cameras at 100 Hz (Vicon 612, Vicon Motion Systems Ltd, UK) and 10 markers (Fig. 1) put on the pelvis (Pel), thorax (Tho) and shoulders (Sh) according to an established protocol [11]. Self-selected speed was preferred because walking speed may affect the upper body kinematics as it does the lower limbs [23]. The right was always the dominant and leading limb. Marker trajectories in the laboratory (Lab) frame were filtered [24] and three-dimensional rotations of the thoracic (Tho/Lab) and pelvic (Pel/Lab) frames with respect to the laboratory frame, and the relative thoracopelvic rotation (Tho/Pel) were calculated [25], to obtain flexion/extension, lateral bending and axial rotation angles (Fig. 1). Shoulder line (Sh) rotations in the frontal and transverse planes of the thorax segment (Sh/Tho) were also calculated. In all, 38 peak angles were identified on these kinematics time histories (Fig. 2) [11].

The overall population was then divided into two groups based on the mean thorax lateral bending angle calculated over the three gait cycles. The overall mean of this motion was $-0.12 \pm 2.48°$ (mean $\pm$SD) with values ranging from $-4.30°$ to $5.72°$ (Table 1). Subjects were arbitrarily divided according to the median as the division point, as in previous studies [1,26,27]. Those with the lower values ($0.86 \pm 0.71°$) were assigned to the small range of trunk bending; the remaining subjects were assigned to the large range ($3.12 \pm 1.01°$). Subjects were also categorized based on the bending side, right or left. The mean right trunk bending for the resulting 13 subjects was

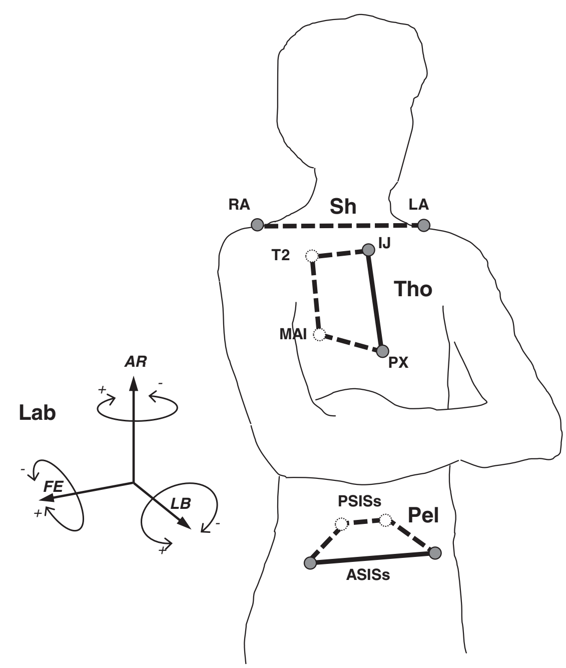

Fig. 1. Diagram of the segments analyzed with relevant 14-mm-diameter spherical skin markers [1,11]: four markers at the pelvis (Pel), four markers at the thorax (Tho) and two markers to form a separate shoulder line segment (Sh). Specifically markers were put on right and left anterior superior (ASIS) and posterior superior (PSIS) iliac spines, the deepest point of incisura jugularis (IJ), *i.e.*, the suprasternal notch, the xiphoid process, *i.e.*, the most caudal point of the sternum (PX), the spinous process of the second thoracic vertebrae (T2), the midpoint between the inferior angles of most caudal points of the two scapulae (MAI), and the right and left acromions (RA, LA).