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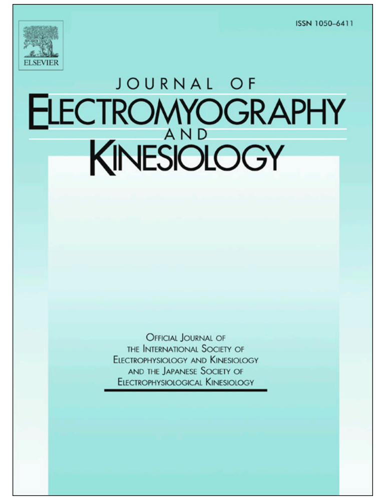

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GAIT ANALYSIS OF YOUNG MALE PATIENTS DIAGNOSED WITH PRIMARY BLADDER NECK OBSTRUCTION

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Key Words: urology; voiding dysfunction; lower urinary tract symptoms; postural control; pelvic imbalances.

ABSTRACT

Primary bladder neck obstruction (PBNO) represents an inappropriate or inadequate relaxation of the bladder neck during micturition. Based on the observation of an increased rate of postural imbalances in male patients with PBNO, we hypothesized a possible role of an unbalanced biomechanics of the pelvis on urethral sphincters activity. Our aim was to identify kinematic imbalances, usually disregarded in PBNO patients, and which could eventually be involved in the etiopathogenesis of the disease.

Seven male adult patients (39.6±7.1 years) were recruited; in all patients, PBNO was suspected at bladder diary and uroflowmetry, and was endoscopically confirmed with urethroscopy. Participants gait was recorded with a motion capture system (BTS Spa, Italy) to obtain three-dimensional joint angles and gait parameters. Multivariate statistics based on a Principal Component model allowed to assess the similarity of patients' gait patterns with respect to control subjects.

The main finding is that patients with PBNO showed significant discordance in the observations at the ankle and pelvis level. Additionally, 6/7 patients demonstrated altered trunk positions compared to normal curves. We suggest that the identified postural imbalances could represent the cause for an anomalous activation of pelvic floor muscles (hypertonia). The consequent urinary sphincters hypercontraction may be responsible for the development of voiding dysfunction in male patients with no significant morphological alterations.

Results reinforced the hypothesis of an etiopathogenetic role of postural imbalances on primary bladder neck obstruction in male patients.

1 INTRODUCTION

Primary bladder neck obstruction (PBNO) represents an inappropriate or inadequate relaxation of the bladder neck during micturition; consequently, this urological condition results in an obstructed urinary flow in the absence of anatomic obstruction (e.g.: benign prostatic enlargement in men or genitourinary prolapse in women). Incidence and prevalence of disease are not completely known; nevertheless, BPNO has been reported in up to 47%-54% of male patients aged 18 to 45 years reporting chronic voiding dysfunction symptoms (Kaplan et al. 1996; Nitti et al. 2002). Moreover, to date the exact pathophysiological pathways leading to disease are still unknown (Nitti 2005). The most reliable scientific theories presented propose a change in bladder neck tissue structure (e.g.: fibrosis or hyperplasia), an altered composition of the detrusor/trigonal musculature (Turner-Warwick et al. 1973), and a possible sympathetic nervous system dysfunction (Awad et al. 1976).

Variations in intra-abdominal pressure and intense physical activity were reported as influencing the contractile activity of pelvic floor muscles in young nulliparous females (Bø 2004), leading to potential structural and/or functional changes that may consequently cause voiding dysfunction.

In our clinical experience we observed an increased rate of postural imbalances in young male patients with PBNO. Thus, in a previous work we hypothesized a possible role of an unbalanced biomechanics of the pelvis on urethral sphincters activity (Camerota et al. 2016). Based on this hypothesis, in the present study we intended to quantitatively analyse gait kinematics in patients with PBNO, supposing to provide further insight into the relationship between this disease and dynamic postural imbalances.

A typical gait analysis evaluation produces a vast amount of data, and despite its objectivity, their interpretation is not straightforward (Cimolin and Galli 2014). Therefore, to assess the presence of common gait patterns in PBNO patients, prior to qualitatively examine the kinematics waveforms, a preliminary synthetic evaluation of the overall gait pattern was necessary.

Several summary measures have been proposed to quantify the degree of gait deviation from normal and evaluate interventions: the Gillette Gait Index (GGI) makes use of multivariate statistics and received a widespread clinical acceptance (Schutte et al. 2000); the Gait Deviation Index (GDI) is based on the extraction of 15 gait features using the singular value decomposition from the gait analysis kinematics of the pelvis and hip in three planes, of the knee and ankle on the sagittal plane and of foot progression (Schwartz et al. 2000); the Gait Profile Score (GPS) summarises the quality of the patient's kinematics, representing a simpler interpretation of the distance measures of the GDI (Baker et al. 2009). GPS can be deconstructed to provide the Gait Variable Score (GVS), an index that measures single gait variable deviation.

However, these indexes were not validated for this particular pathology. Thus, the particular requirements of the considered dataset prompted us to customize our synthetic analysis based on elements coming from the aforementioned indexes. In particular, we relied on a principal component analysis (PCA) approach: PCA is a multivariate statistical technique that allows to find the main features of a large-dimensional dataset. In the context of gait analysis, PCA allows to extract fundamental information from entire gait waveforms, as opposed to arbitrarily-selected parameters and was already adopted to investigate different features of gait in normal and pathological populations (Deluzio et al. 1997; Astephen and Deluzio 2005; Deluzio and Astephen 2007; Sanford et al. 2012).

In sum, the aim of this study was to identify and unveil kinematic imbalances which are usually ignored and uninvestigated in PBNO patients, and which could eventually be involved in the etiopathogenesis of the disease.

2 METHODS

2.1 SUBJECTS

Seven male adult patients (39.6±7.1 years) without history or complaint of neurological disorders, major injury, lower limbs or back surgery were recruited for the study; none of the patients subjectively perceived motor or postural impairments. In all patients PBNO was suspected at bladder diary and uroflowmetry, and was endoscopically confirmed with urethroscopy; urethral strictures and other organic diseases were excluded. Patients underwent neurological clinical evaluation, and no abnormal reflexes were found. All the seven patients were submitted to a full spine X-ray in two projections. None of the patients received treatment for PBNO before or during our study. The severity and the duration of urological symptoms for each patient are summarized in Table 1. Exclusion criteria for controls were: known previous or actual urological, neurological, proctologic or orthopaedic disorders, chronic pelvic pain, and previous surgery.

Mean height and mass of the patients were 177.4±6.4 cm, 76.1±7.5 kg, respectively. The Local Ethics Committee approved the procedures and all participants provided informed written consent.

2.2 Gait analysis

Participants' gait was recorded at 60 Hz with a 9-cameras three-dimensional optoelectronic motion capture system (BTS Spa, Milano, Italy). The protocol consisted of walking ten times through an oval circuit; according to stride length, the two or three central steps on the straight 5-m lane were retained for each trial, thus 20-30 steps were collected for each subject. Participants wore minimal clothing. Thirty-two passive markers were fixed by the same operator on the subjects' skin in the following anatomical landmarks: forehead, C7, sternum, sacrum, tragi, acromia, olecranons, radius styloid processes, greater trochanters, femoral lateral and medial epicondyles, tibial tuberosities, medial and lateral malleoli, first and fifth metatarsal heads, heels. An existent laboratory database including 40 normal-weighted, physically healthy subjects (29.1±4.7 years, walking speed: 1.10±0.07 m/s), recorded in the same conditions, was used as a control group.

2.3 Data reduction

Customized Matlab (The MathWorks Inc., Natick, USA) software was developed for data processing and statistical analysis. Raw marker coordinates were filtered with a 15 Hz, low-pass 2nd order Butterworth filter. Each gait cycle (GC) was time-normalized to a standard 100 samples sequence. Standard gait parameters like step length, width, cadence and stance/swing phase duration were computed.

The skeletal model used in this study was a 3 degree-of-freedom linked rigid segment model consisting of eight segments, including the pelvis, trunk, thighs, shanks, and feet (Lovecchio et al. 2016). Three-dimensional joint angles were computed considering the relative rotation of the pelvis, trunk, thigh and leg anatomical frames, using the ZY'X'' Euler convention (the rotation about each axes correspond respectively to flexion/extension, add/abduction and rotation) (Wu et al. 2002). To graphically compare results, each variable was reported superimposed on the mean±SD bands obtained from control subjects.

2.4 STATISTICAL ANALYSIS

To obtain a global picture of the patients' gait pattern, a PCA was performed on the joints angular kinematics dataset, consisting of 18 variables (right and left hip flexion/extension, abd/adduction and intra/extra rotation, knee flexion/extension, ankle dorsi/plantar flexion and in/eversion; pelvic tilt, obliquity and rotation, trunk flexion, bending and rotation).

In particular, in order to summarise information emerging from kinematic time series, Deluzio et al. (1999) proposed that PC models could be used to interpret the shape and shift of kinematic curves between different cohorts (Deluzio and Astephen 2007; Brandon et al. 2013). The original waveform data of a subject is transformed into a set of PC scores that measure the degree to which the shape of their waveform corresponds to each feature. Following the method explained in (Deluzio et al. 1997, 1999; Sanford et al. 2012), control subjects data were used to develop principal component models for each gait measure. In particular, one PC model was developed for each joint angle.

PC models reduced the waveform data to statistical measures of distance that indicated if a patient had a gait pattern similar to that of the average curve of each normal subject. In this terms, PCA was used as a preliminary step for further analysis to determine differences between the patient and the control groups.

PCA transforms a set of variables into a smaller set of uncorrelated variables, called principal components (PCs), directed along the principal modes of variation. Models reduced the waveform data to statistical measures of distance that indicated if a patient had a gait pattern similar to that of the average curve of each normal subject.

Angular kinematics curves from control subjects were organized in n (the number of controls) × p (variables, the 100 gait cycle samples) matrices. Each PC model represents a projection of data from the original p-dimensional space defined by the original variables to the k-dimensional of the principal components, where k is the number of PCs retained in the model ($k < p$); k was computed such that a k-dimension space contained 90% of the global variance.

Two statistical distance measures were derived to indicate the similarity of each subject's waveform to the average of the normal subjects. The square sum of the residuals, Q, measured the perpendicular distance of each observation from the hyper-plane defined by the model. The T^2 (Mahalanobis distance) is the weighted sum of squares of the PC scores and measured the distance of each observation from the hyper-plane centre. Upper 95% Confidence Interval (CI) limit for the T^2 and Q values were obtained from the normal subjects' data and used as a reference for comparing the patients gait data. In presenting results, a cross (✗) will indicate a significant difference from normal, while a check (✓) will indicate that the waveform pattern is included within the normal limits, as in (Deluzio et al. 1999).

A significant difference from normal was accounted when either the T^2 or Q values were above the normal limit. A simplified 'gait score' can thus be obtained measuring the overall change in the patient's gait pattern and calculated as the number of gait measures within the normal limits. Similarly, a 'variable score' was calculated, to get a measure of how much a joint is affected in the patients' gait (Deluzio et al. 1999).

3 Results

PC models were developed for each joint angle. The number of retained PCs (k) was maximum in ankle knee inversion/eversion (5), while for the other variables, especially those on the sagittal plane, the low (≤ 2) k suggested a simple structure of the waveforms variability (Deluzio and Astephen 2007). Statistical differences in the gait curves of controls and patients are summarized in Table 2: S3 was the patient with the lowest gait score; patients appeared to be more distant from controls at the ankle (variable score of 3-4) and even more at pelvis level (variable score: 0-2). Table 3 reports individual parameters extrapolated from the GC: no macroscopic asymmetries nor discrepancies were detected among patients. Mean patients' walking speed was 1.00±0.07 m/s. In the following, a brief description of the main issues of each patient will be outlined. Representative kinematics plots are reported in Figures 1-2.

P1

The left ankle was extra inverted at heel strike and loading response (0-10% GC), as well as in the pre-swing (50-60% GC, Figure 1). The right ankle was excessively inverted in mid and terminal swing phases (75-95% GC). The right hip was less flexed than in controls in the stance phase (0-60% GC), while the pelvis was backward tilted and clearly leaned on the left side for all the GC. The trunk rotation pattern appeared altered with respect to normalcy (Camerota et al. 2016).

P2

Right and left ankle were excessively dorsiflexed in the mid-stance (10-30% GC, Figure 2), and the left ankle was too much everted in 40-65% of GC. In the swing phase, left hip was more abducted and extra-rotated than normal. Pelvis excessively dropped on the left side in the terminal swing phase.

P3

The left ankle slightly exceeded the control boundaries in the initial phase (0-15%) of GC; the left hip was excessively flexed from mid-stance to terminal swing (30-100% GC). From mid-stance to mid-swing (30-75% GC), the trunk excessively dropped on the right.

P4

The left hip was substantially more abducted than in controls for the whole GC. Pelvis obliquity exceeded normalcy bands from terminal stance to mid-swing, dropping on the left side. Pelvis also resulted overly clockwise rotated during all GC; concurrently, the trunk leaned backwards.

P5

The right hip was overly abducted during all GC; hips, especially the left, were excessively extra-rotated, and the pelvis rotated clockwise and tilted posteriorly from mid-stance to pre-swing (20-55% GC).

P6

The left hip was excessively flexed in the stance phase, and both hips were overly abducted (Figure 1). The right hip was intra-rotated in the initial and mid-swing phase. The pelvis was clockwise rotated for all the GC.

P7

The right ankle was markedly everted in the terminal swing phase (85-100% GC); the left hip was excessively adducted from pre-swing to terminal swing. The pelvis was anteriorly tilted and the trunk clockwise rotated from terminal stance to mid-swing (45-80% GC).

4 DISCUSSION

Despite the fact that PBNO is a frequent disease in young male patients with chronic voiding dysfunction, its etiology is still basically unclear. In accordance with a previously published medical hypothesis (Camerota et al. 2016), the main finding of the present research is that patients with PBNO showed significant discordance in the observations at the ankle and pelvis level in respect to normal subjects at gait analysis.

The statistical technique involving PCA was chosen to provide a first insight on patients' gait pattern through a synthetic score, which was previously adopted to assess knee-arthroplasty patients (Deluzio et al. 1999). The obtained gait and variable scores synthesize a large amount of data into a single logical variable ('in' or 'out' normalcy CIs) and cannot substitute the critical examination of kinematics curves by a clinician. However, the examination of Table 2 enables to readily evaluate a patient's status: the resulting gait score is composed of binary indicators of difference from normal and it was found to be useful as a first level evaluation of the information provided by the PC models (Deluzio et al. 1999). For this reason, we adopted this approach prior to consider each case in detail. While other comprehensive gait indexes have been proposed in literature (Schutte et al. 2000; Baker et al. 2009; Gouelle et al. 2013; McMulkin and MacWilliams 2015); we choose the method introduced by Deluzio et al. (1999) due to its ease of interpretation and adaptability to custom datasets.

Further, we deliberately avoided focusing solely on standard gait parameters (although they were reported for completeness in Table 3), because we aimed at evaluating the entire locomotion pattern. Basing the discussion on discrete parameters from the GC would have reduced the detection of abnormality to finding differences in arbitrarily-selected variables, thus neglecting the larger amount of information included in gait waveforms (Deluzio and Astephen 2007).

Young male patients affected by PBNO presented a variable degree of postural dysfunction. As shown in Table 2, 4/7 patients differed from controls in more than a third of the variables, 2/7 patients had a mild discordance (respectively, in six and seven variables), while only one patient was almost consistent with the normal reference distribution.

Since all the seven patients were completely asymptomatic from a musculoskeletal point of view, none of them subjectively perceived a postural defect. However, in the assessed patients, variable score tended to be lower at the pelvis level. Our preliminary observation seems to be coherent with the findings already published; it has been previously described that an affection in the musculoskeletal system could be involved in the etiopathogenesis of pelvic dysfunction such as chronic pelvic pain in male patients (Segura et al. 1979; Salvati 1987; Hetrick et al. 2003) or anal incontinence in both male and female patients (Altomare et al. 2001). Posture has a direct impact on pelvic functions both during static (Capson et al.

2011; Halski et al. 2014) or dynamic activities (Sapsford and Hodges 2001). At least in a female population, variations may occur in contractility of pelvic floor muscles and in the generation of intra-pelvic pressure. Similar evidences are also associated with a maladjustment of the lumbo-pelvic area (O'Sullivan et al. 2002; Hungerford et al. 2004; Bø and Sherburn 2005). Moreover, as a part of the abdominal cavity's muscular boundaries, pelvic floor muscles are thought to exert a force closure which may contribute to maintain pelvic stability [28–30]. In a recent review Chapple et al. addressed the importance of pelvic floor spasm in the origin of voiding dysfunction in females (Kuo et al. 2015). Moreover, Camerota et al. (2016) hypothesized possible correlations between altered pelvis biomechanics and urethral sphincters activity in young male patients reporting voiding dysfunction in the absence of neurological or orthopedic signs.

In the current study, 6/7 participants with urinary symptoms demonstrated discordant trunk positions at gait analysis when compared to standard curves (rotated trunk in P1, P4, P6, P7; trunk leaning on one side in P1-P3), while none of the controls showed significant alterations. Moreover, in all the seven patients discordant aspects from normality were also found at a full spine X-ray in two projections (e.g slight pelvic upslip, moderate sacral horizontalization, or scoliosis). Unfortunately, only few of these postural characteristics were recurrent in the study cohort, therefore no clear definitive conclusions were possible. Despite the observational nature of our preliminary evaluation, a possible interpretation for the observed results is that the postural imbalances identified at gait analysis may represent the cause for an anomalous activation of pelvic floor muscles (hypertonia). The consequent urinary sphincters hypercontraction may be responsible for the development of voiding dysfunction in young male patients with no significant morphological alterations. Electromyographic studies are required for further investigation of these findings.

4.1 LIMITATIONS

Primary bladder neck obstruction is not a homogeneous entity; for this reason, our subset of patients presents a significant heterogeneity of clinical manifestations including voiding symptoms (e.g.: hesitancy, decreased force of stream, intermittent stream, incomplete emptying), storage symptoms (e.g.: frequency, urgency), or a combination of both. This clinical variability is consonant to the published literature (Kaplan et al. 1994; Nitti et al. 2002; Camerota et al. 2016).

Enrolled patients had no neurological signs at the time of the research, but to date it is not known whether PBNO could represent a first clinical manifestation of a major neurological disease. Therefore, long-term clinical and neurological evaluations are recommended to better understand this clinical entity.

Another limitation of the study was the lack of a gold standard in the clinical evaluation of posture and of pelvic muscle functioning in patients with PBNO. Thus, the present paper represents an initial observation of this clinical entity, and more patients should be examined to obtain statistical power and to draw general conclusions.

Finally, the observational nature of this study precludes definitive conclusions regarding cause and effect relationships.

6 CONCLUSIONS

A better understanding of the nature and etiology of PBNO is required. Our results showed a variable degree of discordance at gait analysis (ankle and pelvis level) in male patients with PBNO, supporting the hypothesis that postural imbalances could be involved in the genesis of the disease. It was not possible to identify a clear correlation between the severity of the urological symptoms and the statistical score elaborated. On the other hand, normal gait analysis patterns were noticed in controls with no urological symptoms.

Further research is required to determine the exact role of pelvic imbalances on pelvic floor muscles activity and on the development of PBNO in male patients. Thus, to draw conclusive considerations randomized clinical trials with an adequate sample size and direct treatment of the postural modifications highlighted at gait analysis should be made.

To our knowledge, the results presented in this paper are the first to quantitatively support the hypothesis of an etiopathogenetic role of postural imbalances on primary bladder neck obstruction in male patients.

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TABLES

Table 1. Patients' urological symptoms collected at anamnesis.

	Participant						
	P1	P2	P3	P4	P5	P6	P7
Age (years)	31	40	29	42	37	38	51
Duration of symptoms (in months)	2	144	12	28	10	1	15
Storage symptoms							
Frequency	X	X	X	X	-	X	X
Urgency	-	X	-	X	-	-	-
Incontinence	-	X	-	-	-	-	-
Painful bladder sensation	X	-	-	-	X	-	-
Nocturia	-	X	-	-	-	-	-
Voiding symptoms							
Intermittent stream	-	X	-	-	X	X	-
Hesitancy	-	X	-	X	-	X	X
Straining	-	X	-	X	-	X	X
Terminal dribble	X	X	X	X	X	X	-
Post-void symptoms							
Feeling of incomplete voiding	-	X	-	X	X	X	X
Post-micturition dribble	X	X	-	X	-	X	-

Table 2. Patients' gait gross pattern. A ✗denotes a significant difference from normal, while ✓indicates that the waveform is similar to the normal pattern. The gait score is the number of gait variables (of a possible 18) that are similar to the normal pattern; it is the sum of ✓'s in the column. The variable score is the sum of ✓'s in the row. R: right; L: left.

Variable	Side	P1	P2	P3	P4	P5	P6	P7	Variable score
Ankle									
Dorsi/plantar flexion	R	✗	✗	✓	✓	✗	✓	✓	4
	L	✓	✗	✓	✗	✗	✓	✓	4
In/eversion	R	✗	✗	✓	✓	✓	✓	✗	4
	L	✓	✓	✓	✗	✗	✓	✓	5
Knee									
Flexion	R	✓	✓	✓	✓	✓	✓	✗	6
	L	✓	✓	✓	✓	✓	✓	✓	7
Hip									
Flexion/extension	R	✓	✗	✓	✓	✓	✓	✓	6
	L	✓	✓	✗	✓	✓	✗	✓	5
Ad/abduction	R	✓	✓	✓	✓	✗	✓	✓	6
	L	✓	✓	✓	✗	✓	✗	✓	5
Internal/external rotation	R	✓	✗	✓	✓	✓	✓	✗	5
	L	✓	✓	✓	✓	✗	✓	✓	6
Pelvis									
Tilt	-	✗	✓	✗	✗	✗	✗	✗	1
Obliquity	-	✗	✗	✓	✗	✗	✗	✗	1
Rotation	-	✓	✓	✓	✗	✗	✗	✗	3
Trunk									
Flexion	-	✗	✗	✓	✓	✓	✓	✓	5
Bending	-	✓	✓	✓	✓	✓	✓	✓	7
Rotation	-	✗	✗	✓	✓	✓	✓	✗	4
Gait score		12	10	16	12	10	13	11	

Table 3. Mean (SD) of extracted gait cycle parameters. R: right; L: left.

Variable	Side	Participant						
		P1	P2	P3	P4	P5	P6	P7
Walking speed (m/s)	-	1.11 (0.03)	1.04 (0.03)	1.10 (0.03)	0.89 (0.02)	1.19 (0.02)	0.98 (0.03)	090 (0.04)
Step length (m)	R	1.29 (0.03)	1.32 (0.04)	1.33 (0.04)	1.09 (0.02)	1.25 (0.03)	1.14 (0.03)	1.07 (0.07)
	L	1.28 (0.03)	1.34 (0.04)	1.34 (0.05)	1.11 (0.04)	1.24 (0.07)	1.15 (0.03)	1.06 (0.06)
Step width (m)	-	0.15 (0.03)	0.17 (0.03)	0.08 (0.01)	0.13 (0.02)	0.10 (0.02)	0.09 (0.02)	0.13 (0.03)
Duration (s)	R	1.17 (0.02)	1.27 (0.04)	1.15 (0.01)	1.22 (0.03)	1.26 (0.06)	1.16 (0.04)	1.22 (0.05)
	L	1.15 (0.03)	1.27 (0.03)	1.15 (0.02)	1.22 (0.02)	1.25 (0.07)	1.17 (0.04)	1.22 (0.05)
Stance phase (%)	R	65.2 (0.8)	61.2 (1.3)	63.0 (1.2)	66.0 (0.9)	62.4 (0.9)	62.3 (1.3)	65.8 (2.0)
	L	65.1 (1.0)	62.8 (1.2)	63. 1 (1.3)	65.7 (0.8)	63.0 (1.3)	62.6 (2.1)	63.8 (1.9)
Swing phase (%)	R	34.8 (0.8)	38.8 (1.3)	37.0 (1.2)	34.0 (0.9)	37.6 (0.9)	37.7 (1.3)	34.2 (2.0)
	L	34.9 (1.0)	37.2 (1.2)	36.9 (1.3)	34.3 (0.8)	37.0 (1.3)	37.4 (2.1)	36.2 (1.9)
Double support (%)	.	21.3 (1.3)	14.3 (3.1)	16.5 (1.1)	23.2 (1.8)	17.0 (1.9)	16.4 (2.2)	20.1 (1.7)

Figures captions

Figure 1: selected kinematics curves of P1 (top) and P6 (bottom). On the bilateral variables, the black and the gray lines relate to the right and left side, respectively. Gray bands: mean±SD obtained from control subjects. ankleE: ankle inversion/eversion; trunkR: trunk rotation; hipA: hip abd/adduction; hipR: hip rotation; pelvisO: pelvic obliquity; pelvisR: pelvic rotation; pelvisT: pelvic tilt.

Figure 2: selected kinematics curves of P2. On the bilateral variables, the black and the gray lines relate to the right and left side, respectively. Gray bands: mean±SD obtained from control subjects. ankleF: ankle dorsi/plantar flexion; ankleE: ankle inversion/eversion; hipA: hip abd/adduction; hipR: hip rotation; pelvisT: pelvic tilt; pelvisO: pelvic obliquity.

GAIT ANALYSIS OF YOUNG MALE PATIENTS DIAGNOSED WITH PRIMARY BLADDER NECK OBSTRUCTION

Authors' biographies

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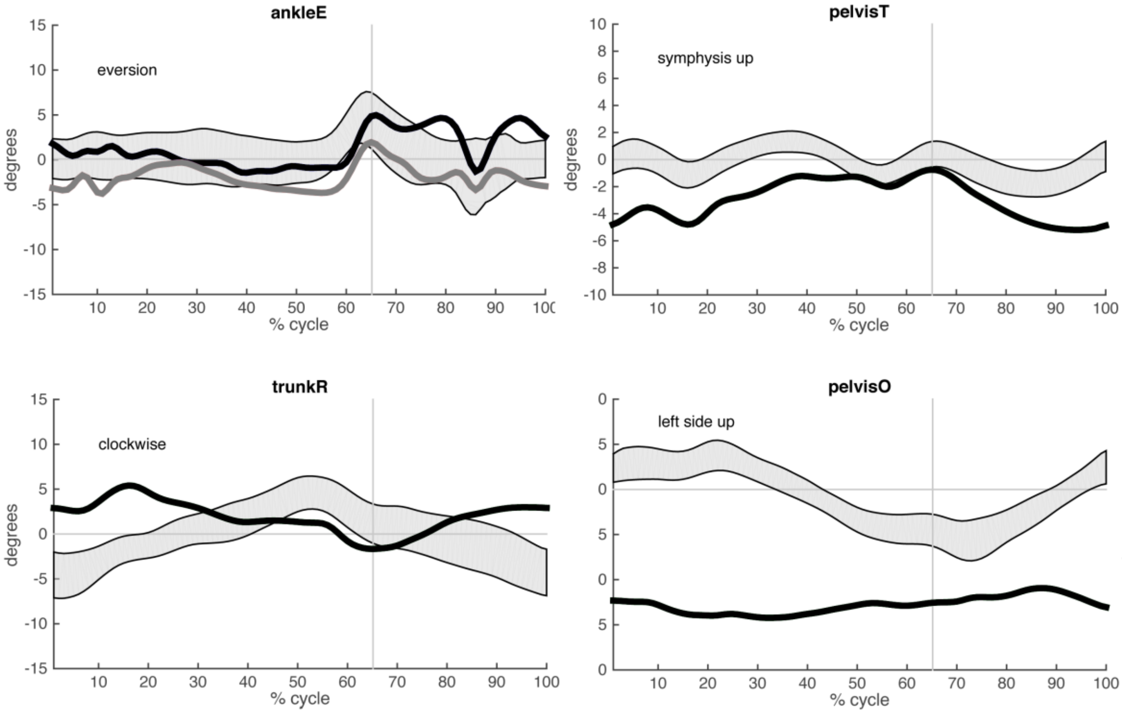
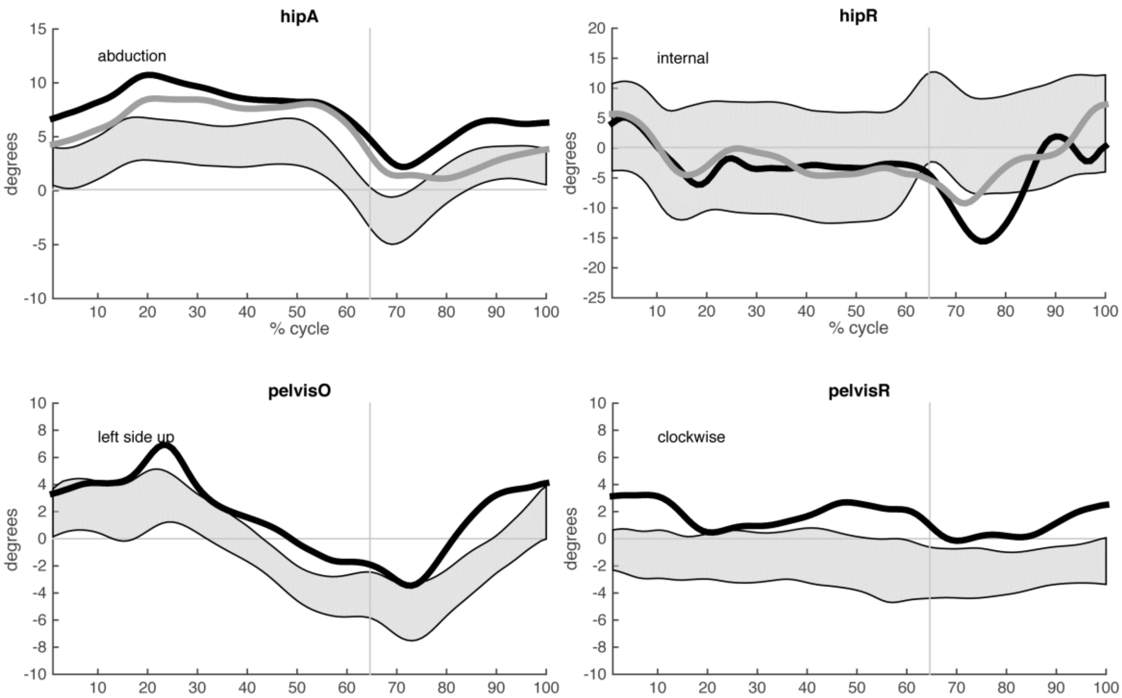
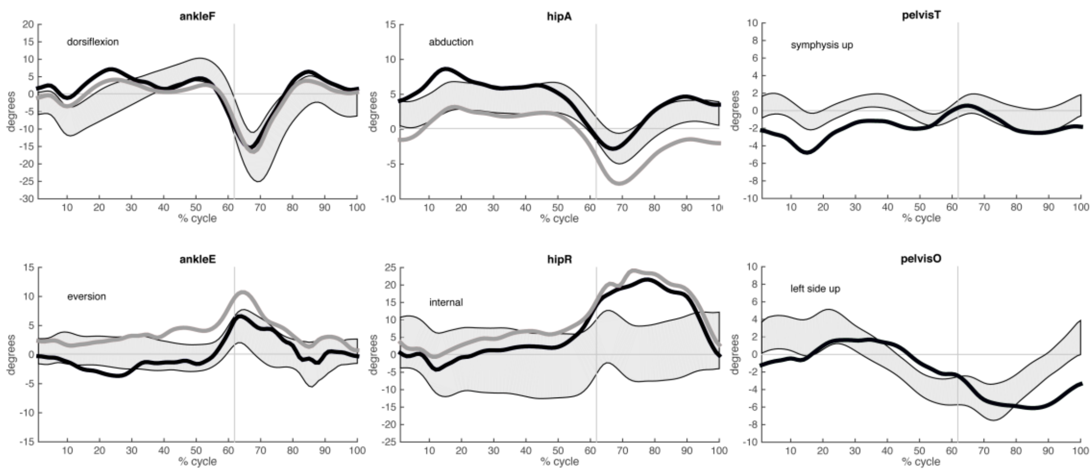
Chiarella Sforza is a full professor of Human Anatomy at the School of Medicine and Dentistry of the Università degli Studi di Milano, and director of the PhD program in Integrative Biomedical Research of the same University. She coordinates the Laboratory of Functional Anatomy of the Locomotor Apparatus, and she is author of more than 310 international research papers on several topic of functional anatomy.

P1


ankleE
eversion
degrees
% cycle
pelvisT
symphysis up
degrees
% cycle
trunkR
clockwise
degrees
% cycle
pelvisO
left side up
% cycle

P6


hipA
abduction
degrees
% cycle
hipR
internal
degrees
% cycle
pelvisO
left side up
degrees
pelvisR
clockwise
degrees


ankleF
dorsiflexion
hipA
abduction
pelvisT
symphysis up
ankleE
eversion
hipR
internal
pelvisO
left side up
degrees
% cycle