Postural balance in hip and knee joint arthroplasty patients

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Abstract— **Static posturography may provide for an objective support to the clinical observation during the evaluation of rehabilitation and functional recovery after total hip arthroplasty (THA) or total knee arthroplasty (TKA). Unfortunately though, many of the studies focused on this topic, have so far given unclear and partially contradictory results. The aim of the present study was to identify those clinically significant Postural Parameters (PPs) likely to enable to discriminate between normal subjects and THA and TKA patients, evaluated immediately before surgery and in the first year of follow-up (f-up).**

Two hundred forty-nine subjects (men and women) were enrolled in the study. They were split into a Reference Group (RG) and an Experimental Group (EG), made of THA and TKA patients evaluated before surgery as well as at a six-month and one-year follow-ups. The test was performed with Open Eyes and Closed eyes. Four Postural Parameters (PPs) were adopted to identify statistically significant differences (SSDs): mean velocity (MV), Sway Area (SA), the root mean square of the resultant distance (RMSD), and the 95% power frequency (PF_95); the last two PPs were considered in the fore-aft (suffixed with fa) and medial-lateral (suffixed with ml) directions. Correlation with Anthropometric Parameters was explored and, when found, PP values were normalized. Gender differences were also considered.

The data obtained are consistent with the clinical situation of the subjects and in good agreement with literature data. All the PPs of the RG did not exhibit SSDs between male and female subjects, but some SSDs with gender were found in the EG. The PPs adopted did not appear to be influenced by false within-subject (i.e. fatigue) and between-subject variability (i.e. anthropometry or positioning) and they allow to identify differences among groups. The results obtained highlight the presence of SSDs between the RG and the EG in terms of both RMSD, indicating an increased sway, and MV, indicating an increased cost for standing, especially in the medial-lateral direction. SA was found to be most robust parameter.

The PPs values registered at follow-up in the EG get closer to those registered in the RG. A worsening in terms of performance seems to occur at the six-month follow-up compared to the pre-operative session and recovery seems to be slower in TKA subjects compared to THA subjects.

In the EG, there is an extremely pronounced increase in RMSDml, both in EO and in CE, compared with the RG. This important feature is considered as the single best predictor of future falling risk in the literature. Finally, PF_95fa values are higher than PF_95ml values in the THA group and even higher in the TKA group, mostly in the Closed Eyes condition. The SSDs observed between the RG and the EG do highlight an increase in both RMSD and MV, i.e. a greater energy cost to maintain posture, especially in the ML direction. The decreased PP values in T2 call for a more in-depth analysis since they seem to contradict the widespread conviction that ascribes performance worsening to fatigue, especially in THA and TKA subjects. Unfortunately it is not possible to make a direct comparison with other studies because the designs of the studies in question differ a lot. The need for a methodological harmonization is therefore once again making itself felt.

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I. Introduction

THE measurement of forces exerted against the ground recorded by a force platform during quiet stance, is common parameter used to quantify postural steadiness, i.e. the dynamics of the postural control system associated with maintaining balance during quiet standing. Body posture during quiet standing depends on the integration of afferent information (visual, vestibular and somatosensory systems) and the generation of motor output (musculo-skeletal actuators).

The adavantage of posturographic analysis is that it requires only a relatively simple experimental set-up which does not noticeably interfere, either physically or psychologically, with patients' comfort. For this reason posturographic analysis is widely used to evaluate fall risks, and to detect i) the postural sway modifications likely to be ascribed to pathologies of one or more components of the postural control system, as well as ii) any age-related changes in the sensorimotor systems [1]-[3].

The Postural Parameters (PPs) commonly reported in the literature describe the statistical properties of the centre of pressure (COP) time series, representing the point location of the ground reaction force vector as it evolves on the horizontal plane. The COP signals reflect the orientations of the body segments, as well as the movements of the body to keep the center-of-gravity over the base-of-support. They are usually analyzed in the time and frequency domains, under the stationary hypothesis [4],[5]. Other methods have relied on different assumptions (wavelet analysis, random-walk models, Langevin equations, and recurrence quantification analysis), but as hopeful as they seem to be, they have not yet been introduced in routine clinical practice [5].

Static posturography may provide for an objective support to the clinical observation during the evaluation of both rehabilitation and functional recovery after hip or knee arthroplasty. Unfortunately though, many of the studies focused on this topic, have so far given unclear and partially contradictory results [6]-[10]. Wykman and Goldie (1989) showed that postural stability improved and sway pattern became normal after hip prosthesis operation [8]. However, Jarnlo and Thorngren (1991) was able to demonstrate that about 2 years after a hip fracture, patients still perceived their balance to be more impaired, and exhibited more postural sway than healthy controls [9]. Tjon *et al.* (2000) reported an 80% decrease in stability among their patients scheduled for total knee arthroplasty having relatively severe lower limb involvement [10].

Several research efforts have focused on posturographic studies of patients affected by knee osteoarthritis, i.e. the main pathology in joint arthroplasty surgery. Such studies have attained different conclusions: either a decrease in postural stability [11]-[15] or no difference observed compared with healthy controls [16].

The aim of the present study was to identify those clinically significant PPs likely to enable to discriminate between normal subjects and THA and TKA patients, evaluated immediately before surgery and in the first year of follow-up.

II. MATERIALS AND METHODS

A. Data acquisition

A Kistler 9286A piezoelectric force plate (Kistler Instrumente AG Winterthur, Switzerland) and a Digivec system and cameras (BTS S.p.A. Milan, Italy) were used.

The force plate Full Scale Output (FSO) was set to: ±0.25 kN for the horizontal components of Ground Reaction Force (GRF); 1 kN for the vertical component of GRF. System calibration was performed in the factory by the manufacturer. The piezoelectric transducer signals were conditioned by a charge amplifier (PCAC-4, BTS S.p.A. Milan, Italy), filtered by means of an analog anti-aliasing filter with a cut-off frequency of 49 Hz and acquired using a 12 bit analog-to-digital acquisition board (National Instruments, Austin, TX, USA), integrated into the Digivec system (BTS S.p.A. Milan, Italy).

Data were collected for 120 s at a sampling rate of 1,000 Hz and processing was carried out by custom scripts in Matlab ® (The Mathworks Inc., Natick, MA, USA).

According to Schmid *et al.* [17], fore-aft and lateral sway were digitally filtered by means of a low-pass FIR filter with a cut-off frequency of 10 Hz.

B. Subjects

Two hundred forty-nine subjects (men and women) were enrolled in the study (Table I). Fifty-nine healthy subjects (Reference Group - RG) were recruited among personnel working for the Faculty of Medicine of Università degli Studi di Bari. The Experimental Group (EG) was made of 82 THA subjects and 108 TKA subjects. EG subjects were evaluated one or two days before surgery and at both a six-month and one-year follow-up (f-up). All the THA and TKA operations were performed by the surgery team of the "Sezione di Ortopedia" of the University of Bari. All the EG members were given physiotherapy training. Based on a self-report, none of the subjects of the RG were affected by an orthopedic or neurologic disease. None of the subjects of all groups had consumed alcohol, or used medications expected to compromise tests of postural performance. All subjects were required to sign informed consent before undergoing study tests.

The total amount of tests performed was 858.

C. Procedures

Anthropometric measures of height, weight and foot length (shoe size) were collected prior each test from each subject. To evaluate the postural control system in a natural state, participants were allowed to stand barefoot onto an A3 paper sheet placed on the force platform, in a comfortable self-chosen stance, with arms at the side, facing toward the positive fore-aft direction of the force platform. They were instructed, using written instructions, to stand as still as possible during all balance tests and to breathe normally. Room illumination and noise were kept under control.

The first trial was executed with eyes open (EO) and the second one with eyes closed (EC). The ratio of the EC measure to the EO measure was referred to as the Romberg ratio (R) [18]. For the EO trial, each subject was asked to look straight ahead at a visual reference (a 3-cm-diameter red circle) placed at 2 m in front of the eyes. After the EO trial, the subject rest in a chair for approximately two minutes before the procedure was repeated with EC. The tests were performed in the laboratory of Sezione di Ingegneria Biomedica between May 2002 and September 2007.

The RG and EG differences were analysed in T1 time period, ranging from 10 s to 60 s, as indicated in the literature [19], while data from 61 s to 120 s (T2) were matched with T1 for fatigue detection [17],[19].

D. Postural parameters

In literature a huge variety of measures, both in time and frequency domain, have been computed and used to

TABLE I.
AGE, BODY MASS AND HEIGHT FOR THE PARTICIPANTS

Variab.	Groups	Female				Male			
		Mean	s.d.	Min	Max	Mean	s.d.	Min	Max
Age (yrs)	RG	**57**	5	50	67	**58**	7	48	76
	TKA	**62**	12	17	81	**65**	13	39	80
	THA	**70**	8	32	86	**68**	8	54	80
Body mass (kg)	RG	**61**	9	46	82	**78**	9	64	100
	TKA	**72**	13	28	104	**81**	12	56	112
	THA	**74**	11	37	103	**87**	10	67	105
Height (cm)	RG	**153**	8	142	171	**168**	7	152	184
	TKA	**155**	6	143	167	**165**	8	150	185
	THA	**152**	6	133	164	**163**	5	151	178

(s.d – standard deviation)

compare postural steadiness among healthy young and elderly adults, as well as to compare healthy reference groups with subjects affected by different pathologies. The present study was however not intended either to describe and evaluate all previously used COP-based measures, or to investigate theories on the way stable upright stance is achieved and maintained. But, the aim of the present research was to elucidate the reason why some of those parameters have were adopted in this study. The PPs adopted have been selected considering only those parameters with a clear clinical significance in the literature and taking into account that more than one measure is required to adequately characterize multiple aspects of postural steadiness. As a matter of fact, the following parameters were adopted to verify if they can help discriminate among the different groups under study:

1. The mean velocity (MV) is the average velocity of the COP. MV is the ratio between the total excursions and the analysis interval. The total excursions are computed as the sum of the distances between consecutive points on the COP path.
2. The root mean square of the resultant distance (RMSD), defined as the distance between the barycenter of COP points and each COP point.
3. The sway area (SA) estimates the area enclosed by the COP path per unit of time. This measure is approximated by summing the area of the triangles formed by two consecutive points on the COP path and the mean COP.
4. The 95% power frequency (PF_95), i.e. the frequency below which 95% of the total power is found which is readily interpretable as an estimate of the extent of the frequency content of the time series.

The clinical significance of these PPs, as reported in the literature, is as follows:

1. MV was related to the amount of regulatory activity associated with a level of stability [4], [18], [20].
2. RMSD was related to the effectiveness of the stability achieved by the postural control system. Large sway (quantified by RMSD) may reflect delayed somatosensory feedback [4] and a reduced ability to activate appropriate postural muscles quickly. [21].
3. SA was quantifying the relationship between the activity of the postural control system and the level of stability achieved [4].
4. PF_95 was related to the periodicity exhibited by a physiological system which may be an important marker of its functional ability [22].

The composite measures, based on both the FA and ML directional components, are not sensitive to the orientation of the base-of-support with respect to the axes of the force plate; on the contrary, the directional measures (RMSD and FP_95) could be affected by this error. Therefore, the foot position of 85 random-selected subjects, belonging to the RG and EG, have been examined to verify the misalignment error between the subject's sagittal plane and the platform longitudinal axes. The misalignment was 3° ± 2° and so it was considered as negligible (it imply an error of 0.013 mm per millimeter of postural displacement, i.e. less than the platform spatial resolution). The components along the fore-aft (fa) and the medial-lateral (ml) directions have been considered for RMSD (named: RMSDfa and RMSDml) e PF_95 (named: PF_95fa and PF_95ml).

E. Normalization

The correlation between anthropometric parameters (APs) and PPs was evaluated by means of Pearson correlation coefficients (PCCs). The PP which presented the PCC > 0.1 (with $p \leq 0.001$) was normalized by means of quadratic detrending [23]. The method adopted gives normalized data with the same units and a range overlapping that of experimental data, thus allowing for a simpler physical interpretation of the results.

The base-of-support was taken into account considering that the subject's feet were placed onto a A3 paper sheet. In fact, the measure of the distances between the lateral extremities of the footprints was 25.2 ± 1.8 cm. Foot length is related to height [24], therefore it was implicitly considered normalizing the data by the subject's height.

F. Statistical Analysis

Statistical procedures were conducted with Minitab 14 (Minitab Inc., State College, PA, USA), performing at first the Kolmogorov-Smirnov (K-S) normality tests for PPs and R. All the examined PPs reported non-normal distribution (verified by one-sample K-S test), hence non-parametric statistical analysis (Kruskall-Wallis test and Friedman test) was adopted.

Only comparisons with $p \leq 0.01$ were considered indicative of a Statistically Significant Difference (SSD) between the groups or eye conditions.

III. RESULTS

The PCCs between APs and PPs are reported in Table II. MV was normalized by both body weight and height because the two APs were not strongly correlated (PCC = 0.131). Subsequent analyses were conducted adopting the normalized data. The gender influence in the PPs was tested and when a SSD ($p \leq 0.05$) was found, the PPs values were differentiated by gender (Table III).

Excluding RMSD and PF_95ml, all the PPs values of the EG (Table IV) were higher than RG matched values (Table V).

Considering the f-up, almost all the PPs exhibited a SSD in the pre-operative session. In the 6-month and the 1-year sessions, there was a progressive decrease in the SSDs, mainly for the THA group.

The parameters examined were not able to detect any difference across different trial sessions, neither in the THA nor the TKA group.

Both in the EG and the RG, the R values were higher than unity for all the PPs, with the exception of RMSDml. Almost always higher in EG than in RG, the R value was higher in RG only for PF_95fa; there were no differences between the EG and RG in the R values for PF_95ml.

The median values of the PPs calculated in the T2 interval did not show any SSD compared to T1 interval matched values.

TABLE II.
CORRELATION (PCC) AMONG PPS AND APS

PP	Body mass (kg)	Height (cm)
MV	0.117	-0.135
RMSDfa	0.138	0.069
RMSDml	0.185	-0.036
PF_95fa	0.093	-0.210
PF_95ml	-0.062	0.022
SA	0.133	-0.065

TABLE III.
SSD P-VALUES BETWEEN GROUPS (K-W), REFERRED TO THE PRE-OPERATIVE SESSION (PRE), THE 6-MONTH F-UP SESSION AND 1-YEAR FOLLOW-UP SESSION, IN BOTH EO AND EC CONDITIONS.

Groups	PPs	pre-op		6months		1year	
		EO	EC	EO	EC	EO	EC
RG vs THA	MV	§§	§§	§§	§§	+	§
	RMSD	§§	§§		++		
	SA	§§	§§	§§	§§	+	++
	PF_ 95fa (males)	++	+	++	++	+	
	PF_ 95fa (females)	++	+	++		+	+
	PF_ 95ml						
RG vs TKA	MV (males)	§§	§§		+	+	+
	MV (females)	++	§	++	++	++	++
	RMSD		++		+		+
	SA	§§	§§	§	§§	§§	§§
	PF_ 95fa (males)	§§	++	+		+	
	PF_ 95fa (females)	§	++	+		++	++
	PF_ 95ml						

Symbols: §§: $p \leq 0.0005$; §: $0.0005 < p \leq 0.001$;
++: $0.001 < p \leq 0.01$; +: $0.01 < p \leq 0.05$.

IV. DISCUSSION

All the PPs of the RG did not show SSDs between male and female subjects, but some SSDs with gender were found in the EG. The PPs adopted did not appear to be influenced by false within-subject (i.e. fatigue) and between-subject variability (i.e. anthropometry or positioning) and they allow to identify differences among groups.

Osteoarthritis (OA), which accounts for the main etiologic factor of THA and TKA [25],[26], is a degenerative joint disease characterized by an enzymatic and mechanical breakdown of the extracellular matrix, leading to degeneration of articular cartilage. OA can provoke the so called pain-related arthrogenous inhibition of muscle functions which is thought to contribute to muscle weakness in knee and hip [26]. Nevertheless, the fact that standing balance is not always associated with pain suggests that standing balance in hip OA may also result from factors other than pain [25]. However, several investigators believe that postural control and proprioception are worse in OA patients than in controls [11], [25]. In addition, decreased muscle strength and impaired balance are considered to be important risk factors in causing falls in the elderly [25]. In line with these considerations, the experimental data show that the PPs values for all the patients examined are higher than in the RG subjects immediately before surgery, and one year after surgery they still exhibited more postural sway than healthy controls.

Increased values of PPs indicate a greater effort in maintaining balance, as substantiated by the SA values (nearly 100% higher in CE than in OE), ascribable to higher MV [18] and RMSDml values. Moreover, PF_95 increase indicates a more frequent involvement of the postural control system. This could ultimately be a sign of postural instability.

Of the adopted PPs, SA seems the most robust parameter that exhibits the highest percentage variation between the RG and the EG.

In the RG, the RMSDfa values are higher than RMSDml values; in both directions, the eyes condition does not account for a significant difference. This means that the COP position varied more along the fore-aft axis than along the medial-lateral axis. This result is in a good agreement with Popovic [27] who suggests that during quiet standing the subjects exhibit a higher body stiffness in the medial-lateral direction compared to the anterior/posterior direction. In the EG, there is an extremely pronounced increase in RMSDml, both in OE and in CE, and there is a less remarkable increase in RMSDfa only in CE. This is an important feature, because Maki [28] asserted that the lateral spontaneous-sway COP amplitude is the single best predictor of future falling risk, and McClenaghan [22] reported that a hip fracture was more likely to occur when an individual falls in the medial-lateral direction. Even though RMSDfa is substantially greater than or equal to RMSDml in the EG, the sizeable increase of RMSDml in the RG could be in line with Tjon A Hen *et al.* assertion [6] that postural stability in the RG patients should be affected by the very displacement of the body mass in the medial-lateral direction by pain-induced weight transfer from one leg to the other. Considering the spectral analysis, PF_95fa values are lower than PF_95ml values in the RG. Quite the contrary, the PF_95fa values are higher than the PF_95ml values in the THA group and even higher in the TKA group, mostly in the CE condition. This result is consistent with Carpenter [29] findings. PF_95fa is not correlated to PF_95ml in all the groups under study.

TABLE IV. PPS VALUES FOR THE RG

Variable	Eyes condition					
	OE			CE		
	Q1	**Median**	Q3	Q1	**Median**	Q3
MV (mm/s)	7.56	**9.09**	10.11	8.99	**11.19**	13.02
RMSDfa (mm)	2.86	**3.99**	5.43	3.17	**4.12**	4.88
RMSDml (mm)	1.89	**2.39**	3.19	1.74	**2.47**	3.33
SA (mm^2/s)	9.18	**11.36**	14.91	9.67	**12.53**	17.80
PF_ 95fa (Hz) (males)	0.47	**0.61**	0.79	0.76	**0.94**	1.14
PF_ 95fa (Hz) (females)	0.36	**0.58**	0.72	0.67	**0.83**	0.88
PF_ 95ml (Hz)	0.59	**0.79**	0.98	0.64	**0.91**	1.14

(Q1 – First quartile; Q3 –Third quartile)

TABLE V. PPS VALUES FOR THE EG (DIFFERENTIATED IN THA AND TKA)

Variable	Test Session	THA						TKA					
		OE			CE			OE			CE		
		Q1	**Median**	Q3	Q1	**Median**	Q3	Q1	**Median**	Q3	Q1	**Median**	Q3
MV (mm/s) (males)	pre-op	9.28	**13.13**	15.27	12.95	**20.53**	26.62	10.27	**12.38**	15.22	15.26	**19.62**	25.81
	6 months	8.44	**11.89**	16.93	12.48	**15.93**	24.90	8.24	**11.13**	14.46	12.68	**14.20**	16.60
	1 year	7.36	**10.82**	19.75	10.14	**14.54**	24.72	10.69	**12.09**	13.98	13.81	**15.80**	21.71
MV (mm/s) (females)	pre-op	8.74	**11.85**	16.19	13.32	**14.90**	19.54	8.65	**10.87**	14.21	11.31	**13.89**	18.89
	6 months	9.32	**13.15**	17.69	12.78	**15.38**	17.59	9.37	**10.88**	16.33	12.82	**15.01**	17.08
	1 year	8.40	**12.74**	15.91	14.43	**16.56**	19.44	9.25	**10.58**	16.77	10.41	**14.66**	21.68
RMSDfa (mm)	pre-op	3.27	**3.97**	5.52	3.96	**4.94**	6.39	3.03	**3.53**	4.32	3.42	**4.25**	5.22
	6 months	3.11	**3.97**	4.84	3.88	**4.37**	5.88	3.42	**3.82**	5.51	3.65	**4.79**	5.52
	1 year	2.72	**3.39**	5.44	3.05	**4.05**	6.00	3.17	**4.16**	5.27	3.38	**4.84**	5.65
RMSDml (mm)	pre-op	2.75	**3.29**	4.65	3.00	**3.85**	5.48	2.53	**3.34**	4.14	2.68	**3.76**	4.62
	6 months	3.12	**3.99**	4.89	3.27	**3.96**	4.46	2.70	**4.07**	5.10	2.77	**3.55**	4.57
	1 year	2.34	**3.74**	4.85	2.76	**3.33**	4.91	2.71	**3.54**	4.20	3.00	**3.48**	4.05
SA (mm^2/s)	pre-op	12.54	**17.66**	28.36	17.98	**29.26**	53.73	11.06	**16.63**	22.88	16.94	**23.56**	36.92
	6 months	12.25	**19.48**	34.17	19.50	**25.57**	35.32	12.31	**21.25**	27.00	17.38	**24.30**	32.58
	1 year	9.55	**14.82**	32.85	15.68	**22.41**	36.11	12.42	**19.45**	24.31	17.39	**21.44**	39.88
PF_ 95fa (Hz) (males)	pre-op	0.66	**0.89**	1.09	0.95	**1.09**	1.34	0.81	**0.94**	1.17	0.92	**1.18**	1.64
	6 months	0.72	**1.08**	1.25	1.09	**1.33**	1.50	0.73	**0.84**	1.08	0.85	**1.16**	1.23
	1 year	0.81	**0.96**	1.06	0.91	**1.08**	1.24	0.82	**0.91**	1.10	0.91	**1.07**	1.28
PF_ 95fa (Hz) (females)	pre-op	0.61	**0.86**	1.08	0.74	**1.01**	1.25	0.62	**0.83**	1.13	0.82	**1.03**	1.36
	6 months	0.68	**0.97**	1.02	0.49	**0.92**	1.33	0.56	**0.73**	0.93	0.72	**0.89**	1.12
	1 year	0.68	**0.89**	1.01	0.87	**1.22**	1.29	0.61	**0.84**	0.94	0.87	**1.07**	1.35
PF_ 95ml (Hz)	pre-op	0.59	**0.81**	1.02	0.76	**0.99**	1.25	0.51	**0.73**	0.94	0.65	**0.88**	1.12
	6 months	0.56	**0.72**	0.79	0.75	**0.88**	1.07	0.44	**0.72**	0.90	0.62	**0.78**	0.96
	1 year	0.64	**0.84**	1.07	0.81	**0.94**	1.11	0.49	**0.58**	0.85	0.57	**0.76**	1.00

(Q1 – First quartile; Q3 –Third quartile)

Accepting the hypothesis of hip and knee compensatory strategies, it could be asserted that the postural control actions in the medial-lateral direction are more frequent in the EG patients also because pain is expected to provoke more frequent weight transfers from one leg to the other. What is more, the decrease in PPs values in the T2 interval indicates the absence of fatigue effects and the acquisition of an increased capability of postural control. In addition, the absence of SSDs compared to the T1 interval suggests that a 60-s test duration is adequate.

V. CONCLUSION

The present work was aimed to identify a set of clinically significant PPs and verify if they are able to discriminate between postural control in normal subjects and in THA and TKA patients evaluated immediately before surgery and in the first year of follow-up. It can be asserted that the research goal was attained, because SSDs were found to be present between the RG and the EG in terms of RMSD, indicating an increased sway, as well as in terms of MV, indicating an increased cost for standing, especially in the medial-lateral direction.

These findings are in line with both the clinical picture of the conditions in question, and with the literature data under which postural control and proprioception are worse in the OA patients than in controls. SA is the most robust parameter, which is expected to allow to identify a correlation between posturographic and clinical data.

During the f-up, the EG PPs values get closer to the RG values. No SSDs was found, neither in the different test sessions nor between THA and TKA patients in the same test session. A worsening in the performance seems to occur six months after surgery while functional recovery appears to be slower in TKA than in THA patients, as already observed in a previous study [30]. Unfortunately no direct analysis can be made with other studies in view of the different designs of the studies in question. Therefore the need for a methodological harmonization is making itself felt once again.

The lack of numerical references and the variability of indications associated to the stability/instability notion suggest to report the presence of SSDs in some of the parameters examined compared to the PPs values of the RG, instead of reporting a substantial postural instability [6] in patients who were scheduled for THA and TKA. The fall risk may be evaluated only considering the data of each subject in correlation with his/her personal history.

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