POSTURAL ASYMMETRY IN HUMAN STANCE : THE MEAN CENTER OF PRESSURE POSITION

A. Mouzat, LAPSCO UPRESA CNRS 6024, Université Blaise Pascal, Clermont-Ferrand, France
M. Dabonneville, LIMOS FRE CNRS 2239, Université Blaise Pascal, Clermont-Ferrand, France
P. Bertrand, LAPSCO UPRESA CNRS 6024, Université Blaise Pascal, Clermont-Ferrand, France
P. Vaslin, LIMOS FRE CNRS 2239, Université Blaise Pascal, Clermont-Ferrand, France

Abstract- **The aim of this study is to point out the influence of the feet position on the mean center of pressure (COP) position on a population of 25 healthy young right-handed men. Results have been compared to those of the literature. Most of them have been confirmed : mean COP position is on the subject's right side, that points out the asymmetry of the orthostatic posture. Moreover, the findings showed the feet position effects : when the clearance and/or the angle between the feet increase the mean COP moves backward and to the right.**
Keywords - **Upright posture, center of pressure, asymmetry**

I. Introduction

The human upright stance can be studied with stabilometric measurements. The successives positions of the body COP are caculated with force-plate recorded data. Then, many parameters can be computed, e.g. the displacement length, the average speed, the sway area, the confident ellipse [1], the mean COP position. The mean COP position can be expressed in the force-plate or in an anatomical referencial. Some studies found similar results about the mean COP position.

M.P. Murray, A.A. Seireg and S.B. Sepic [2] tested 24 healthy men (19 right-handed) selected in three age categories: the third, the fifth and seventh decades. The subjects stood upright for one minute with feet apart in confortable stance. The parameters were calculated on the central 30 seconds of each trial. The authors sampled the data at 5 Hertz. They expressed the mean COP position from the heels ligne in the fore-aft direction and from the fore-aft mid-line of the base of support (the area beneath and between the feet) in the medio-lateral direction. For the total population, the results shown that the fore-aft mean position were 11.5 centimeters forward from the heels line and the medio-lateral mean position were 0.6 centimeter on the rigth side of the base of support mid-line. There was no difference within the age group.

R.L. Kirby, N.A. Price and D.A. MacLeod [3] tested five men and five women on several feet positions. Nine subjects were rigth-handed. They had to look at a fixed point in a quiet room. Data were recorded during 20 seconds with a rate frequency of 100 Hertz. In the fore-aft direction, the distance between the heel line and mean COP position is expressed as a percentage of the base of support length (AP). In the medio-lateral direction, the distance between the external side of the right foot and the mean COP was expressed as a percentage of the base of support width (ML). For the total population, the authors found, in average, an AP value close to 40 % in the classic feet positions used in stabilometry. ML was in average always less than 50 %. It means that the mean COP position was always on the right side.

J. Tarantola, A. Nardone, E. Tacchini and M. Schieppati [4] tested six men and six women with feet together and with feet parallel, spaced 10 centimeters apart. The subjects had to look at a target placed at about 50 centimeters. Data were sampled at 10 Hertz during 51 seconds. Among the studied parameters, the authors used the mean COP position in percentage of foot length. Without giving numerical results the authors observed that the mean COP position was more forward when the feet were spaced with 10 centimeters than when they were together.

The population's characteristics (age, gender…), the subject's environment, the visual target, the record duration and rate frequency, the studied parameters have an importance on the results of the stabilometric studies. Thus, it is difficult to know exactly the influence of the subject's posture on the mean COP position.

The first purpose of our study is to highlight the feet positions effects on upright stance in a population of young right-handed men on the mean COP position in open eyes condition. Second is to compare our results with those of the literature, when it is possible.

II. Methodology

TABLE I
CHARACTERISTICS OF THE POPULATION
(B.M.I. : BODY MASS INDEX.)

n = 25	Age (years)	Height (cm)	Mass (kg)	B.M.I. ($kg.m^{-2}$)
Mean	23.8	175.8	71.0	23.0
(Std)	(3.6)	(5.9)	(6.4)	(2.2)

25 healthy right-handed men whose characteristics are presented in TABLE I were tested. They did not present any recent pathology of the lower limbs nor of hearing or visual disorders.

The force-plate was an AMTI model OR6-5. The signals were amplified through an AMTI model SGA6-4 amplifier. The numerical-analog converter card was a Data Translation model DT2801 (12 bits). Recorded data were the three forces and the three moments on the surface of the force-plate. The rate frequency was 100 Hertz for one duration of 60 seconds.

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Abstract

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From the forces and moments, we calculated the subjects' COP coordinates (X,Y). X axis of the platform corresponds to the fore-aft direction and Y axis corresponds to the medio-lateral direction, whereas Z axis corresponds to the vertical axis (positive downwards). The parameters used for the comparison between the various feet positions feet are calculated starting from the COP co-ordinates (X and Y) :

- the mean COP postion (X_H and Y_B) expressed from the heels ligne in the fore-aft direction and from the fore-aft mid-line of the base of support in the medio-lateral direction;
- AP and ML : the parameters calculated by R. L. Kirky [3] as described in the introduction.

To compare our results to those of the literature, we computed the parameters used by the various authors starting from our own data. We used the same methods of calculation as those of the papers that we listed. When the rate frequencies were lower than ours, data were resampled.

All these parameters have been calculated with Matlab 5.2 (Math Works Inc.).

The subjects were placed on the force-plate in a cabin conformed to the standards [5] of the Association Française de Posturologie (AFP). They had to stand upright during one minute. The resting time between trials was one minute too. They had to fix a plumb line placed at about 90 centimeters in front of them. The subjects' feet positions were controlled by a special frame fixed on the force-plate which allowed to impose four clearances (0, 2, 10 and 20 centimeters) and four angles (0, 15, 30 and 45 degrees) (Fig. 1). Theses angles are defined by the medial sides of the feet. For each subject, the testing order of the 16 feet positions was randomized. In order to calculate the fore-aft and medio-lateral base of support dimensions, for each subjects the heels, the first and fifth toes X and Y positions were measured.

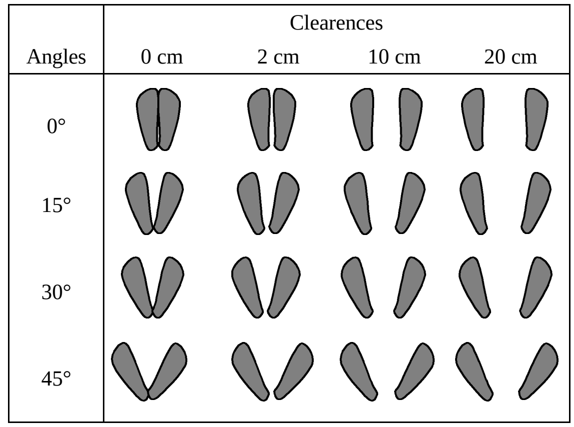

Fig. 1. The sixteen feet positions.

For each group, fitting to the Gaussian law and variances homogeneity have been verified. Statistical analysis has been made with a two-factors ANOVA with interaction and a Scheffe post-test.

The comparisons between literature results and ours were made with a Student t-test in the same feet positons. Statistical tests were made with SPSS 8.0 (SPSS Inc.).

III. Results

A. Feet position effects

Means and standard deviations are presented in Table II. The ANOVA results are presented in Table III. The Scheffe post-test results are presented in Table II, for each parameter and for each factor (clearance or angle), the symbols (§, ¤, ✝ and ⊗) point out the groups.

TABLE II

MEANS AND STANDARD DEVIATIONS FOR EACH FACTOR AND EACH PARAMETER

			X_H (cm)	Y_B (cm)	AP (%)	ML (%)
Clearance (cm)	0	Mean	9.18 §	0.24 §	35.97 §	48.43
		(Std)	(1.22)	(0.50)	(4.57)	(3.17)
	2	Mean	9.13 §	0.17 §	35.76 §	49.01
		(Std)	(1.31)	(0.46)	(4.77)	(2.63)
	10	Mean	8.85 ¤	0.47 ¤	34.65 ¤	48.18
		(Std)	(1.22)	(0.58)	(4.35)	(2.28)
	20	Mean	8.83 ¤	0.59 ¤	34.53 ¤	48.34
		(Std)	(1.26)	(0.71)	(4.36)	(1.97)
Angle	0°	Mean	9.33 ✝	0.24 ✝	35.47	49.13 ✝
		(Std)	(1.18)	(0.53)	(4.19)	(2.05)
	15°	Mean	9.17 ✝	0.36 ✝	35.13	48.56 ✝
		(Std)	(1.31)	(0.58)	(4.76)	(2.49)
	30°	Mean	8.86 ⊗	0.37 ⊗	34.85	48.46 ⊗
		(Std)	(1.25)	(0.58)	(4.62)	(2.45)
	45°	Mean	8.63 ⊗	0.49 ⊗	35.47	47.82 ⊗
		(Std)	(1.20)	(0.65)	(4.62)	(3.03)

TABLE III
ANOVA RESULTS
(n.s. : NONSIGNIFICANT ; * : P < 0.05 ; ** : P < 0.01 ; *** : P < 0.001)

		X_H	Y_B	AP	ML
Factors	Clearance	*	***	*	n.s.
	Angulation	***	***	n.s.	**
Interaction	Clearance × Angulation	n.s.	n.s.	n.s.	n.s.

The clearance and angle factors (Fig. 2) have a significant influence on the values of X_H. For the clearance factor, the 0 and 2 centimeters group is 0.31 centimeter more forward than the 10 and 20 centimeters group ($P < 0.05$). For the angle factor, it is the 0 and 15 degrees group that is 0.51 centimeter more forward than the 30 and 45 degrees group ($P < 0.001$).

The clearance and angle factors (Fig. 3) have a significant influence on the values of Y_B ($P < 0.001$). For the clearance factor, the group with 20 and 10 centimeters is 0.33 centimeter more on the rigth than the one with 0 and 2 centimeters. For the angle factor, the group with 45 and 30 degrees is 0.13 centimeters more on the right than the one made with 15 and 0 degrees.

The clearance factor (Fig. 4) has a significant ($P < 0.05$) influence on the values of AP. We can observe two groups : 0 centimeter associated with 2 centimeters and 10 centimeters associated with 20 centimeters. When the feet clearance increases, AP decreases.

The angle factor (Fig. 5) has a significant ($P < 0.01$) influence the values of ML. Two groups appear : 45 degrees associated with 30 degrees and 15 degrees associated with 0 degree. When the feet angle increases, ML decreases.

In all case there is no significant interaction between clearance and angle factors.

B. Comparison with literature results

The comparison of our results with those of the litterature are presented in the TABLE IV. With the Murray's study [2], we found the same result on Y_B. In the two studies, the mean position was on the right side. However, we found a significant difference ($P < 0.001$) on X_H. In the Murray's study, the mean position is 2.43 centimeters more forward than in our study. We had only one feet position common with Kirky's study [3]. We found no significant difference for AP between his study and ours. We found a significant ($P < 0.001$) for ML, but in the two studies ML indicates that the medio-lateral mean COP position is on the right side.

IV. DISCUSSION

The feet position shift involves a displacement of the mean COP position. On the one hand, X_H significantly moves backward when the clearance ($P < 0.05$) and the angle ($P < 0.001$) increases. The angle effect is easily explainable by the geometry shift of the base of support. Indeed, more this angle increases more fore-aft base of support dimension decreases. Thus, the subject's heels being always at the same position on the force-plate, the base support center moves backward. This explanation is consolidated by the fact that the angle has no significant effect on AP. When the clearance increases X_H backward move can not have the same explanation. Indeed, in this case, feet clearance has also a significant effect ($P < 0.05$) on AP. In other words, when feet clearance decreases, the subject tends to bend forward. No authors whos tested several clearances [3][4] found such an effect for the same feet position, but in both case, the tested population were smaller than ours (ten men for Kirby [3] and six men and six women for Tarantola [4]). Murray [2] tested only one feet position with the two feet on the force-plate. The confortable stance adopted by his subjects corresponds to 10 centimeters of clearance and 15 degrees of angle. Our values of X_B are significantly more backward than Murray's [2]. The two populations have the same anthropometrics characteristics. The Murray's [2] population was older, but he did not observe any age effect on this parameter. The Murray's [2] subjects had no visual target and ours had one placed at about 90 centimeters of the eyes. This fact can explain the difference found between the two studies.

In our study, Y_B is always positive, which indicates that the subjects stand more on the right side. The fact that the totality of our subjects is a right-handed can explain it. Murray [2] found the same result and his population was made up with 80 % of right-handed subjects. For a population made up with 90 % of right-handed men, Kirby [3] found a similar result too on ML which was always less than 50 %. Also, we find an effect of the various feet position : when clearance and angle increase Y_B moves to the right side. Kirby [3] found no such an effect of clearance and angle on ML on comparables feet positions. Moreover, we find no effect of clearance on ML.

TABLE IV
COMPARISONS WITH LITERATURE RESULTS
(n.s. : NONSIGNIFICANT ; * : P < 0.05 ; ** : P < 0.01 ; *** : P < 0.001)

		Murray's results		Our results	Kirby's results		Our results
Feet position		10 cm – 15°			0 cm – 0°		
Fore-aft direction	Mean	11.50	***	9.07	38.70	n.s.	36.14
	(Std)	(2.00)		(1.34)	(6.40)		(3.71)
Medio-lateral direction	Mean	0.60	n.s.	0.41	45.00	***	49.36
	(Std)	(0.90)		(0.61)	(4.80)		(2.22)

Only angle has a significant effect on ML. This difference in the angle effect with Kirby's [3] study can be explain with his population which is smaller than ours.

V. Conclusion

The wole results of this study proves that, in most case, the expression of the mean COP position in a fixed referencial as X_H and Y_B is more sensitive to posture effects than express it as a percentage of the base of support dimensions.

P.M. Gagey, B. Asselain, N. Ushio and J.B. Baron [6] found that the asymmetry of orthostatic posture was not randomly distributed. Our results confirm this asymmetry of the orthostatic posture. To explain it, we have three hypotheses : the masses distribution in the human body is not symmetric and there is more masses on the right side; during orthostatic posture regulation, subjects shift their mass center on the preferential side; the masses distribution is related to the preferential side (e.g. muscles can be more developed on the preferential side). So, complementary studies on a left-handed population are necessary in order to test these hypotheses.

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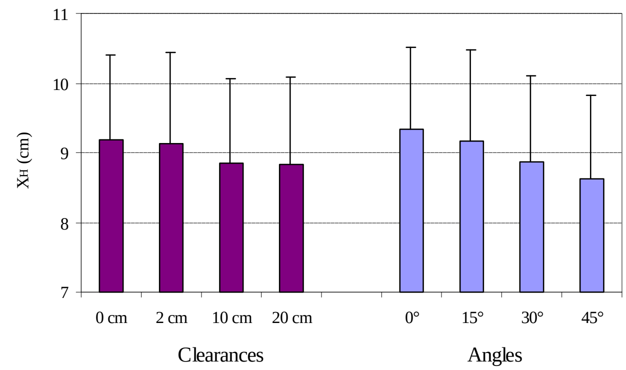

Fig. 2. Results for each factor on X_H.

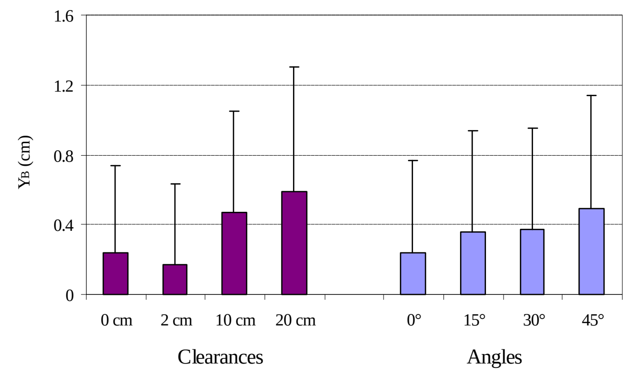

Fig. 3. Results for each factor on Y_B.

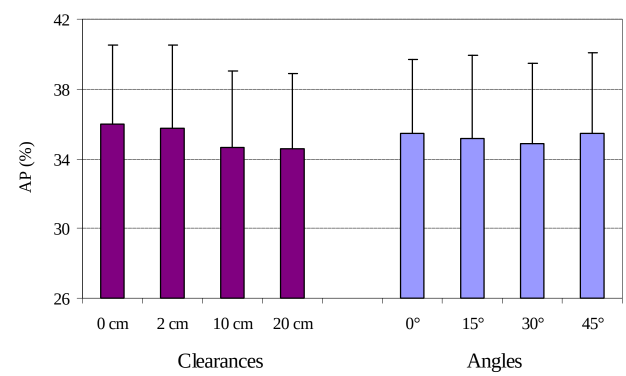

Fig. 4. Results for each factor on AP.

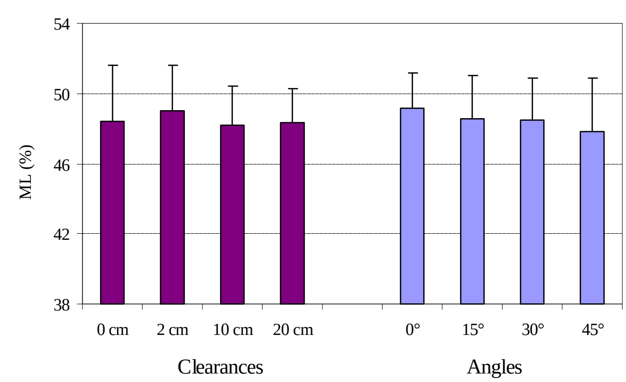

Fig. 5. Results for each factor on ML.