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Computerised static posturography in neurology

Research Article

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Abstract: Posturography is a general term for techniques used to measure postural stability on static or dynamic measuring platforms. The principle of static computerised posturography (SCPG) is the detection of the centre of foot pressure (CFP) in upright stance on a posturography platform. Our communication deals with the importance of SCPG in differential topodiagnosis of vestibular syndromes in neurology. The set of examinations and evaluations carried out was divided among a control group of healthy subjects (77), a group of subjects with peripheral vestibular disorder (159), and a group of subjects with a non-peripheral balance disorder (82). Results obtained through the measurements were evaluated using descriptive statistics procedures and basic numerical and graphic statistical characteristics of the given groups. Our observations demonstrate that posturography is a valuable auxiliary test for balance disorders, especially given the lack of more suitable tests. According to our results, SCPG can be used for a rough differential topodiagnosis of balance disorders in neurology.

Keywords: *Static and dynamic computerised posturography • Differential diagnosis • Central and peripheral vestibular dysfunction*

1. Introduction

Posturography, also known as a test of balance, is a general term for methods used to measure postural stability on static or dynamic measuring platforms. The principle of measurement is detection of the centre of foot pressure (CFP) during examination on a posturography platform. The CFP projects the center of gravity of the body to the ground. It must be maintained within the area defined by the feet. Balancing requires information from the vestibular, somatosensory and visual system. Failure of any of these systems causes specific balance disturbances. Even between the lesions of the central and peripheral vestibular systems are observable clinical differences which may be reflected in the body sway measurement. Posturography is an objective technique, so it is not burdened by subjective interpretation, and the results can be documented both graphically and numerically. This enables a detailed assessment of postural balance, a comparison of results, and an ability to archive [1]. Dynamic posturography (DPG) is presented as a method for the detection of stance and dynamic movement, with the capacity to quantify the information inputs, central integration, and mechanisms for creating effective postural movements [1,2]. Static posturography is based on the principle of measuring the shifts in CFP on a stationary platform [3-5]. Opinions on the importance of posturography and its position among

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other machine-based techniques in vestibulology are divided. Prevailing opinion is that both posturography techniques (SCPG and DCPG) are beneficial especially for the quantitative assessment of postural balance [2,6,7]. Posturography is deemed a suitable complement to standard vestibular examinations, especially in patients with CNS pathology and is useful for evaluating susceptibility to falling [8-10].

One of the main issues in neuro-otologic assessment of patients with dizziness is determining the topography of the vestibular lesion. The purpose of this study is to examine the effectiveness of static posturography in distinction between non-peripheral balance disorders and peripheral vestibular system disturbances.

2. Study population and methods

The measurements presented in this work were obtained on an STP-03 computerised posturograph under the standard conditions of an audio-vestibular lab. The posturograph measures CFP distance To quantify an activity necessary to maintain stability, the posturograph measures CFP trajectory per a fixed period Way, W; [cm/s]) upon visual fixation (open eyes; Wf) and suppression (closed eyes; Ws), the area obtained by CFP trajectory (Area: Af, As; [cm^2/s]), deviation of CFP in the anteroposterior X and lateral Y axes and their ratios upon visual fixation (ALf) and suppression (ALs) and visual balance control expressed in terms of Way (RW = Wf/Ws) and Area (RA = Af/As). These parameters were also studied in the presented communication.

The determination of standards is essential for the assessment of pathology. However, the COMES Trading posturograph used here contains neither normative values nor instructions for how to interpret the measurements. Therefore, the criteria established by Dolejš were adopted and the following values were considered physiological: Wf < 1.5 cm/s, Ws < 3 cm/s, Af < 0.5 cm/s, As < 1 cm/s, RW = 0.8 to 1, RA = 0.8 to 1.11 In addition, no standards have been set for the parameters X and Y. Thus, from 2001 to 2004, a set of measurements was performed on patients with physiological postural balance to establish standard values for use in identifying pathological conditions. The control group was comprised of 77 volunteers not limited by age, gender, or mental or somatic illnesses. The exclusion criteria for the control group were a history of a vestibular disorder (a medical diagnosis of dizziness or of a balance disorder), current dizziness or an obvious balance disorder at the time of examination, inability or unwillingness to undergo the examinations.

Based on clinical findings (otological and neurologic examination, audiometry and conventional complementary examination), a group of patients with a confirmed vestibular diagnosis was selected from the outpatient neurootology office of the University Hospital in Hradec Králové. Patients with multifactorial and unclear balance disorders were excluded. This group was further divided into subgroups with peripheral vestibular lesions (59 patients) and non-peripheral postural balance disorder (82 patients).

In presenting and discussing the data, the following abbreviations were used: *min*, minimum value of a sample; *max*, maximum value of a sample; *med*, median of a sample; q_α, α-quartile of sample, where $0 < \alpha \leq 1$ (*i.e.*, $q_{0.25}$ refers to the first quartile and $q_{0.75}$ to the third quartile); *avg*, sample mean; *SD*, standard deviation; *Norm*, patients with no history of a vestibular disorder; *Per*, patients with peripheral vestibular deficits; *Nonper*, patients with central nervous system vestibular dysfunction. Basic clinical characteristics of the patient groups were in Table 1.

Table 1. Basic clinical characteristics of the patient groups.

Group	count	mean (age)	SD (age)	range (age)
Norm	77	36.2	18.9	4 to 86
Per	159	50.5	13.5	19 to 79
Nonper	82	50.6	15.4	11 to 93

SD*: standard deviation,* Norm*: patients with no history of a vestibular disorder,* Per*: patients with peripheral vestibular deficits,* Nonper*: patients with central nervous system vestibular dysfunction.*

Graphs were created and statistical tests were performed using R version 2.10.1 (R Foundation for Statistical Computing). After descriptive statistical analysis was performed for each group (*Norm, Nonper, Per*) and measured parameter (Wf, Ws, Af, As, ALf, ALs, Xf, Xs, Yf, Ys, RW, RA); outlier values were excluded and normality of distribution was tested. As shown below, non-normal distribution precluded ANOVA tests for equality between mean parameter values within single groups. Normality of sample distribution was assessed using three different tests: the Shapiro-Wilk test, the Lilliefors (Kolmogorov-Smirnov) test, and the Pearson test. A sample was considered non-normally distributed if two or more of the normality tests failed. The Mann-Whitney U-test for non-normally distributed samples was performed to test equality between pairs of expected values for given parameters. For all statistical tests, a p-value < 0.05 was considered significant.

Approval by an ethical committee was not required because all of the analysed variables were collected as part of the standard diagnostic process, and the study itself did not influence patients' other examinations or further care by any means. All study participants have signed the written informed consent.

3. Results

For ANOVA testing of a given parameter, the samples in each group must have a normal distribution and homoscedasticity. Normality was observed only for RW parameter. However, the Bartlett test for homogeneity of variance failed (p-value = 7.685e-07). For all the parameters (including RW), equality among groups was evaluated by the Kruskal-Wallis rank sum test, which is an alternative to ANOVA for non-normally distributed heteroscedastic samples. For each parameter, the p-value of the Kruskal-Wallis test for the hypothesis $H_0 : \mu_{Norm} = \mu_{Nonper} = \mu_{Per}$ as less than 0.01, which means that the null hypothesis was rejected for each parameter. The goal was to decide about the kinds of inequalities among groups. The data distributions of observed parameters within the three groups of patients are shown in Tables 2, 3, 4. Some judgments can be made based on Table 5, which summarises the sample means and standard deviations calculated after excluding outliers and box plots (Figure 1, 2, 3) of such samples. To confirm or reject relationships that seemed to appear in the Table 5, a Welch Two Sample t-test was used for pairs of normally distributed samples (RW) and a Mann-Whitney U-test was used for pairs of non-normally distributed samples.

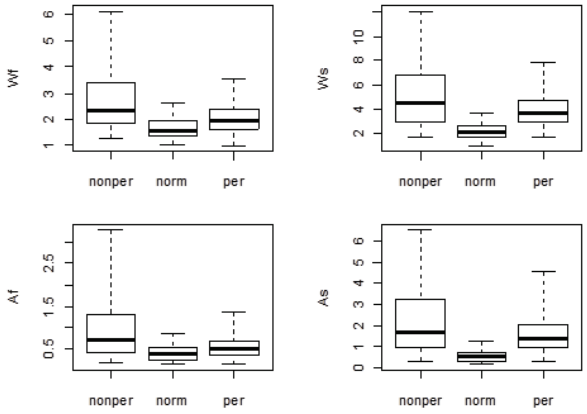

Figure 1. The graphical depiction after excluding outliers of parameters (Wf, Ws, Af, As) of the patient groups.

Table 2. Data distribution of observed parameters in patients with no history of vestibular disorder.

Norm	Wf	Ws	Af	As	ALf	ALs	Xf	Xs	Yf	Ys	RW	RA
Min	1.008	1.033	0.147	0.145	0.812	0.816	8.008	8.859	7.842	8.875	0.544	0.257
$q_{0,05}$	1.102	1.273	0.187	0.197	0.832	0.840	9.210	9.990	9.227	9.093	0.550	0.304
$q_{0,25}$	1.344	1.771	0.261	0.319	0.911	0.930	12.223	13.333	12.619	12.136	0.672	0.621
Med	1.586	2.116	0.369	0.547	0.974	1.016	16.602	18.111	14.861	17.093	0.775	0.772
$q_{0,75}$	1.945	2.624	0.540	0.768	1.055	1.071	19.939	22.870	19.986	22.505	0.860	0.910
$q_{0,95}$	2.465	3.170	0.741	1.068	1.158	1.148	24.731	31.318	26.996	32.682	1.023	1.165
Max	2.580	3.746	0.872	1.268	1.188	1.200	28.902	34.471	29.892	35.712	1.073	1.322
Avg	1.663	2.155	0.405	0.573	0.975	0.986	16.286	18.639	16.085	18.059	0.760	0.741
SD	0.414	0.598	0.186	0.291	0.107	0.098	4.976	6.864	5.368	7.549	0.133	0.254

Min*: minimum value of a sample,* max*: maximum value of a sample,* med*: median of a sample, q_α, α-quartile of sample, where $0 < \alpha \leq 1$ (*i.e., $q_{0.25}$ *refers to the first quartile and $q_{0.75}$ to the third quartile), avg: sample mean, SD: standard deviation, Norm: patients with no history of a vestibular disorder, Wf, Ws: the centre of foot pressure (CFP) trajectory per a fixed period [cm/s] upon visual fixation (open eyes; Wf) and suppression (closed eyes; Ws), Af, As: the area obtained by CFP trajectory [cm²/s], Xf, Xs, Yf, Ys: deviation of CFP in the anteroposterior X and lateral Y axes and their ratios upon visual fixation (ALf) and suppression (ALs), RW, RA: visual balance control expressed in terms of Way (RW = Wf/Ws) and Area (RA = Af/As).*

Table 3. Data distribution of observed parameters in patients with peripheral vestibular deficits.

Per	Wf	Ws	Af	As	ALf	ALs	Xf	Xs	Yf	Ys	RW	RA
Min	0.981	1.713	0.136	0.309	0.440	0.453	6.404	12.820	7.376	10.695	0.030	0.003
$Q_{0,05}$	1.217	2.229	0.221	0.562	0.557	0.538	10.238	16.299	9.865	14.602	0.270	0.089
$Q_{0,25}$	1.640	3.149	0.369	1.023	0.673	0.660	13.691	22.179	13.979	19.934	0.422	0.211
Med	1.998	3.807	0.524	1.469	0.819	0.822	18.606	26.798	17.140	28.225	0.516	0.346
$Q_{0,75}$	2.538	5.042	0.778	2.495	1.001	1.088	25.172	35.067	23.870	35.375	0.633	0.508
$Q_{0,95}$	4.174	8.939	1.639	7.597	1.370	1.549	37.253	61.908	40.962	67.772	0.880	0.968
Max	20.508	47.190	41.562	78.218	1.833	2.251	144.710	161.691	165.360	228.206	3.931	13.612
Avg	2.432	4.917	1.158	3.200	0.871	0.904	22.883	32.861	21.966	34.345	0.581	0.652
SD	2.172	4.631	3.852	8.214	0.269	0.316	19.863	21.669	18.458	28.381	0.434	1.727

Table 4. Data distribution of observed parameters in patients with central nervous system vestibular dysfunction.

Nonper	Wf	Ws	Af	As	ALf	ALs	Xf	Xs	Yf	Ys	RW	RA
Min	1.267	1.741	0.189	0.315	0.449	0.428	8.000	10.932	6.666	10.460	0.111	0.009
$q_{0.05}$	1.423	2.225	0.228	0.493	0.572	0.600	11.211	14.883	10.565	12.586	0.334	0.152
$q_{0.25}$	1.830	2.938	0.425	1.090	0.734	0.778	15.347	24.175	14.154	21.309	0.443	0.265
Med	2.425	4.597	0.761	1.903	0.874	0.935	20.499	31.843	18.422	26.706	0.629	0.435
$q_{0.75}$	3.676	6.913	1.663	3.506	1.175	1.226	28.648	46.101	33.448	38.026	0.787	0.685
$q_{0.95}$	6.144	11.345	3.891	9.683	1.848	2.014	50.951	65.939	63.541	90.506	1.088	1.277
Max	10.289	13.258	22.267	27.572	3.938	2.925	128.529	143.893	123.485	178.955	2.241	14.391
Avg	3.075	5.117	1.489	3.223	1.033	1.067	25.092	38.111	26.894	36.567	0.649	0.704
SD	1.826	2.675	2.681	4.207	0.532	0.456	16.273	24.082	20.734	30.170	0.292	1.579

Table 5. Data distribution of observed parameters in patients with central nervous system vestibular dysfunction.

group		Wf	Ws	Af	As	ALf	ALs	Xf	Xs	Yf	Ys	RW	RA
Norm	***avg***	1.6633	2.1549	0.4050	0.5729	0.9748	0.9863	16.2859	18.6391	16.0849	18.0585	0.7604	0.7412
	SD	0.4138	0.5978	0.1861	0.2908	0.1069	0.0979	4.9759	6.8639	5.3677	7.5488	0.1330	0.2538
Per	***avg***	2.0232	4.0526	0.5548	1.6795	0.8421	0.8904	19.4324	27.4577	18.3391	27.2432	0.5289	0.3587
	SD	0.5510	1.3981	0.2792	1.0073	0.2180	0.2908	7.4791	8.1061	6.5148	10.0423	0.1582	0.1988
Nonper	***avg***	2.7967	5.0162	0.9875	2.2457	0.9289	0.9618	22.1456	34.3906	22.3988	28.2568	0.6295	0.4829
	SD	1.3309	2.5312	0.7432	1.6046	0.2937	0.2928	9.0450	14.7415	12.1465	11.7734	0.2326	0.2875

Norm*: patients with no history of a vestibular disorder,* Per*: patients with peripheral vestibular deficits,* Nonper*: patients with central nervous system vestibular dysfunction,* avg*: sample mean,* SD*: standard deviation, Wf, Ws: the centre of foot pressure (CFP) trajectory per a fixed period [cm/s] upon visual fixation (open eyes; Wf) and suppression (closed eyes; Ws), Af, As: the area obtained by CFP trajectory [cm²/s], Xf, Xs, Yf, Ys: deviation of CFP in the anteroposterior X and lateral Y axes and their ratios upon visual fixation (ALf) and suppression (ALs), RW, RA: visual balance control expressed in terms of Way (RW = Wf/Ws) and Area (RA = Af/As).*

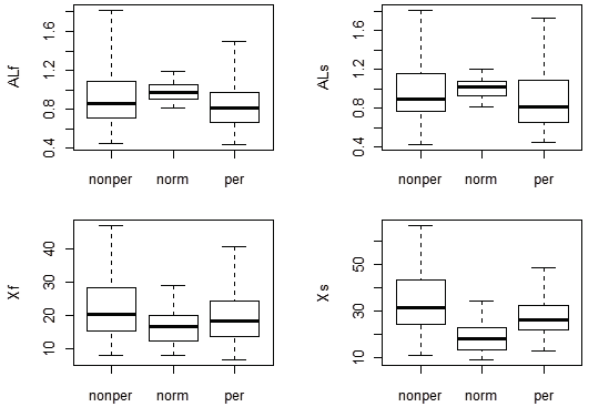

Figure 2. The graphical depiction after excluding outliers of parameters (Alf, ALs, Xf, Xs) of the patient groups.

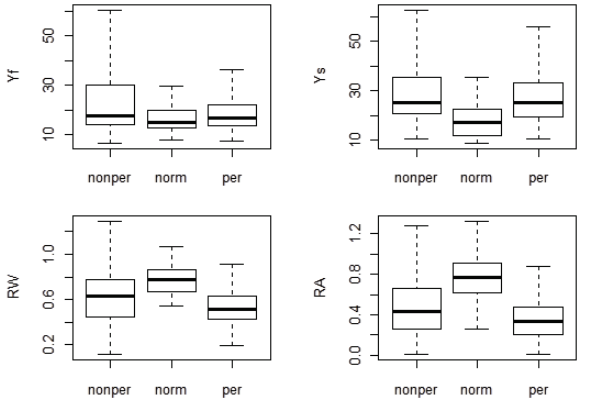

Figure 3. The graphical depiction after excluding outliers of parameters (Yf, Ys, RW, RA) of the patient groups.

4. Discussion

Both the graphical depiction and numerical values clearly indicate that both groups of patients (*Per* and *Nonper*) had higher values than the control group (*Norm*). This applies to the parameters of distance (Wf, Ws) and area (Af, As) obtained by CFP trajectory, and during the examination, the difference is larger upon visual suppression (Ws, As) than upon visual fixation (Wf, Af). The measured values Wf, Ws, Af, and As in both groups of patients (*Per* and *Nonper*) on average exceeded the physiological range (Figure 1). A similar but less considerable difference was observed for the parameters Xf and Yf, and the difference was larger in the parameters Xs and Ys (Figure 1). For the parameters RW and RA, the values were within physiological limits for the *Norm* group. However, RW and RA were lower in both patient groups (*Per* and *Nonper*). In the

Per group, low values were observed in accordance with published data, reflecting the importance of visual fixation in compensating for a peripheral vestibular lesion [11]. Surprisingly, however, lower values were also measured in the *Nonper* group as compared with the control group (*Norm*), which indicates that visual fixation is an important compensatory mechanism in the *Nonper* group (*i.e.*, patients with central vestibular dysfunction) (Figure 1). A difference in the findings between patients with peripheral and central disorders has also been reported by Baloh [2].

A large variation of results is typical for the entire group of examinations and constitutes one of the main factors reducing the topodiagnostic value of the method. In this respect, it is interesting that only a few authors in the available literature make their conclusions regarding SCPG from a larger number of subjects [12].

Additional confounds to interpreting individual SCPG results are a high dispersion of results of individual measurements and the ability to intentionally influence the course of the testing. The device records CFP deviations of any origin, including disturbances during the measurement, mental stress, and so on. Posturography measurements are also influenced by medication, anthropometric characteristics and age [13,14]. An approach to this problem is analogous to the issues related to Romberg's test and its modifications [8]. Potential aggravation (simulation) of balance disorders can be excluded based on observations of patients during the clinical examination and on the measurement of SCPG. Similar conclusions were reached by Gianoli and Krempl during the use of dynamic posturography [15,16].

SCPG provides no specific findings for differentiating the diseases related to a postural balance disorder [17,18].

5. Conclusion

Static posturography is a rapid, objective examination of postural balance. The principle of the method is the objective measurement of CFP shifts in upright stance and the modifications thereof.

We observed statistically significant differences in the results of measurements between the patients with normal balance, peripheral vestibular lesions, and non-peripheral balance disorder. These results confirm that SCPG represents a valuable method for examining balance disorders and can be used for the differential topodiagnosis of central and peripheral vestibular lesions. However, the method is hindered by high variability and sensitivity to biological artefacts. These factors can be reduced by performing repeated examinations at different times.

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