METHODS

Comparative Analysis of Methods for Evaluation of Stabilometry Parameters

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Cluster analysis of stabilometry results in 251 subjects (129 men and 122 women, age 20-60 years) was carried out. Four methods were used in the study: European stabilometry variant, Romberg test (European variant), Romberg's test (American variant), and Romberg's test (American Universal variant). Cluster analysis has shown virtually the same diagnostic informative value of all 4 methods. The absolute and relative stabilometry parameters are the most objective, this validating their clinical usefulness. The frequency and amplitude parameters possess no diagnostic significance. The European stabilometry variant is the best fit for practical use and provides information about the function of the ocular, maxillofacial, and other components of the postural system.

Key Words: stabilometry; cluster analysis; stabilometry methods

The disorders in the postural (statokinetic) system in various diseases have attracted special attention of neurologists, manual therapists, and dentists in recent years. The polysensory theory of the balance function is universally acknowledged [9]. Under normal functioning conditions of the postural balance system the information from each of the sensory systems is modulated by other systems, due to which the posture is regulated [9]. The maxillodental system is one of the afferent entries of the postural system, and its function cannot be neglected. A precondition of ideal functioning of the postural system "mandibular pickup" is harmonious orthognathic occlusion [6]. Because of the polysystematic regulation of the postural balance, its diagnosis is an intricate and, no doubt, important problem in comprehensive examinations of patients

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with disorders of the postural balance [1-3]. Computer stabilometry is a diagnostic method detecting the disorders in the postural balance and evaluating the efficiency of therapeutic measures [5-7].

Many stabilometry platforms are used at present. The majority of them record the absolute, frequency, and relative parameters of the patient's postural stability in accordance with the NORMES, 1985 [10]. In addition, some authors of the stabilometry platforms make it possible to evaluate additional parameters of an individual's postural stability by means of computer analysis of the results of stabilometric diagnosis. The following stabilometry methods are universally acknowledged: Romberg's test, European variant (RTEV), stabilometry European variant (EV), Romberg's test, American universal variant (RTAU), and Romberg's test, American variant (RTAV). In addition to these tests, there are numerous accessory methods for stabilometric studies, for example, the MBN stabilometric complex, recording 16 quantitative parameters.

By the present time there is no scientifically based method for stabilometric studies for evaluating the impact of the maxillodental function for the postural balance.

We compared various stabilometry parameters and methods and their efficiency for the diagnosis of postural disorders by cluster analysis.

MATERIALS AND METHODS

Comprehensive studies were carried out in 251 subjects (122 women, 129 men) aged 20-60 years.

The following conditions served as the criteria for exclusion from the study group: complete absence of teeth, acute somatic diseases, exacerbations of chronic diseases, myocardial infarction during the first 6 months of the disease, mental disorders, alcohol and narcotic dependence, locomotor disorders (groups I and II disability).

Stabilometry was carried out in accordance with basic requirements of the International Posturological Society [9] on a Stabilometer MBN biological feedback computer stabiloanalyzer (stabiloanalyzer – stabilometric platform) and Stabilometry software (MBN), using the European (heels together, toes apart) and American (feet parallel, separated at the shoulders' width) variants of the subject's posture on the platform. The following tests were carried out: with the eyes open, mandible relaxed; eyes open, teeth clenched; eyes closed, mandible relaxed; eyes closed, teeth clenched. Due to this it was possible to evaluate the impact of occlusion disorders for the postural balance and mutual effects of the maxillodental system and oculomotor function on each other.

Standardized matrix of stabilometric values was processed by cluster analysis by the medium clusters method, forming groups of parameters with similar weight coefficients [4]. The informative value of a parameter was evaluated using dispersion analysis options in the cluster analysis method. The parameters with dispersion under p=0.05 were considered informative. The matrix was subjected to cluster analysis twice, after which parameters with dispersion higher than p=0.05 were excluded from analysis.

The following clusterization parameters were chosen at stage 1: 3 clusters, 10 iterations; at stage 2: 4 clusters, 10 iterations.

RESULTS

Analysis of dispersions after the data matrix clusterization detected the least informative stabilometry parameters: the relative and frequency characteristics. These parameters were excluded from further analysis.

Analysis of the composition of clusters obtained

by tests used in the protocol of this study showed that the results of stabilometric studies carried out by different methods (EV, RTEV, RTAU, RTAV) were similarly informative. Hence, these methods provided comparable information about the postural stability of a subject.

The most objective and informative characteristics of the postural stability are the parameters of frequency characteristics of the pressure center fluctuations, pressure center deviations (PCD), statokinesiogram area, stability index, pressure center translocation velocity, and the amplitude characteristics of pressure center fluctuations. Cluster 1 parameters were the most objective for the test with the eyes open, mandible relaxed (EV stabilometry), while cluster 2 parameters were the least informative in this test (Table 1). Cluster 3 was formed by the least informative parameters. It included mainly the relative and frequency characteristics of the patient's postural stability evaluated by all the 4 stabilometry variants. It is noteworthy that cluster 3 parameters were the most distant from its center and their clinical significance was the least vs. the parameters of the two other clusters.

The results of stabilometry clusterization parameters during the test with the eyes open and mandible relaxed can be used as the basal values with which the results of other tests should be compared (Table 2).

Cluster 1 was formed by mainly the absolute characteristics of postural stability evaluated by RTEV stabilometry. In contrast to the test with the eyes open, mandible relaxed, cluster 1 included several RTAU and RTAV values. Cluster 2 was mainly formed by the absolute RTAU and RTAV stabilometry values, with a trend to greater distance between these characteristics and the cluster center in comparison with cluster 1 parameters. Cluster 3 was formed from stabilometry frequency parameters.

The results of cluster analysis were similar to clusterization data for the test with the eyes open and mandible relaxed: the factor was formed mainly by the relative and frequency parameters of postural stability according to all 4 methods. The greatest number of the parameters was from the American stabilometry variants. Importantly, these parameters were the most distant from cluster 3 center in comparison with clusters 1 and 2.

The main components of cluster 1 in testing with the eyes open and teeth clenched are the absolute parameters of postural stability of patients according to the European stabilometry methods (Table 3). These parameters remain close to the cluster center and hence, their informative value remains high in testing with the teeth clenched.

Cluster 2 in testing with the eyes open and teeth clenched is formed by the frequency and relative char-

TABLE 1. Cluster Analysis of Stabilometry Results (Test with the Eyes Open, Mandible Relaxed)

	Parameter	Unit	Method	Distance from cluster center
Cluster 1	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.842
	PCD velocity	V (mm/sec)	RTEV	0.579
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTEV	0.746
	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.633
	Square deviation of PCD in the frontal plane	x (mm)	EV	0.574
	Square deviation of PCD in the sagittal plane	y (mm)	EV	0.597
	PCD velocity	V (mm/sec)	EV	0.634
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	EV	0.597
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	EV	0.602
	Area of statokinesiogram 90	S90 (mm²)	EV	0.516
Cluster 2	Square deviation of PCD in the sagittal plane	y (mm)	RTEV	0.731
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTEV	0.777
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTEV	0.779
	Square deviation of PCD in the frontal plane	x (mm)	RTAU	0.717
	Square deviation of PCD in the sagittal plane	y (mm)	RTAU	0.790
	PCD velocity	V (mm/sec)	RTAU	0.667
	Square deviation of PCD in the frontal plane	x (mm)	RTAU	0.717
	Square deviation of PCD in the sagittal plane	y (mm)	RTAU	0.529
	Area of statokinesiogram 95	s95 (mm²)	RTAU	0.529
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTAU	0.747
	Square deviation of PCD in the frontal plane	x (mm)	RTAV	0.652
	Square deviation of PCD in the sagittal plane	y (mm)	RTAV	0.598
	PCD velocity	V (mm/sec)	RTAV	0.764
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAV	0.731
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAV	0.546
	Area of statokinesiogram 90	S90 (mm²)	RTAV	0.501
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTAV	0.990
Cluster 3	Vertical constituent 60% spectrum power	xf60% (Hz)	RTEV	0.956
	Statokinesiogram length/area	LFS90 (1/mm)	RTEV	0.801
	Vertical constituent 60% spectrum power	xfZ% (Hz)	RTEV	0.796
	Stability index	Stab (%)	RTEV	0.728
	Statokinesiogram length/area	LFS90 (1/mm)	EV	0.838
	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	EV	0.909
	Stability index	Stab (%)	EV	0.854
	Frontal constituent spectrum peak 1 frequency	XfI (Hz)	RTAU	0.904
	Statokinesiogram length/area	LFS95 (1/mm)	RTAU	0.736
	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	RTAU	0.873
	Vertical constituent 60% spectrum power	xfZ% (Hz)	RTAU	0.793
	Stability index	Stab (%)	RTAU	0.678
	Frontal plane spectrum 60% power	xf60% (Hz)	RTAV	1.043
	Statokinesiogram length/area	LFS95 (1/mm)	RTAV	0.694
	Vertical constituent spectrum 60% power	xfZ% (Hz)	RTAV	0.752
	Stability index	Stab (%)	RTAV	0.735

TABLE 2. Cluster Analysis of Stabilometry Results (Test with the Eyes Closed, Mandible Relaxed)

	Parameter	Unit	Method	Distance fro
Cluster 1	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.752
	Square deviation of PCD in the sagittal plane	y (mm)	RTEV	0.585
	PCD velocity	V (mm/sec)	RTEV	0.713
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTEV	0.729
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTEV	0.642
	Statokinesiogram 90 area	S90 (mm²)	RTEV	0.492
	Square deviation of PCD in the frontal plane	x (mm)	EV	0.614
	Square deviation of PCD in the sagittal plane	y (mm)	EV	0.702
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	EV	0.735
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	EV	0.559
	Statokinesiogram 90 area	S90 (mm²)	EV	0.563
	Square deviation of PCD in the sagittal plane	y (mm)	RTAU	0.703
	PCD velocity	V (mm/sec)	RTAU	0.682
	Statokinesiogram 95 area	s95 (mm²)	RTAU	0.663
	PCD velocity	V (mm/sec)	RTAV	0.727
Cluster 2	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTEV	0.732
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	EV	0.803
	Square deviation of PCD in the frontal plane	x (mm)	RTAU	0.487
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAU	0.668
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAU	0.696
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTAU	0.748
	Square deviation of PCD in the frontal plane	x (mm)	RTAV	0.648
	Square deviation of PCD in the sagittal plane	y (mm)	RTAV	0.650
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAV	0.683
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAV	0.654
	Statokinesiogram 95 area	s95 (mm²)	RTAV	0.563
	Amplitude of vertical constituent spectrum peak 1	XaZ1 (kg)	RTAV	0.777
Cluster 3	Statokinesiogram length/area	LFS90 (1/mm)	RTEV	0.776
	Vertical constituent spectrum 60% power	xfZ% (Hz)	RTEV	0.761
	Stability index	Stab (%)	RTEV	0.816
	Statokinesiogram length/area	LFS90 (1/mm)	EV	0.770
	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	EV	0.833
	Vertical constituent spectrum 60% power	xfZ% (Hz)	EV	0.785
	Stability index	Stab (%)	EV	0.853
	Frontal constituent spectrum peak 1 frequency	Xfl (Hz)	RTAU	0.990
	Frontal plane spectrum 60% power	xf60% (Hz)	RTAU	0.970
	Statokinesiogram length/area	LFS95 (1/mm)	RTAU	0.681
	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	RTAU	0.770
	Vertical constituent spectrum 60% power	xfZ% (Hz)	RTAU	0.836
	Stability index	Stab (%)	RTAU	0.802
	Mean PCD position in sagittal plane in the new American SK	Ya1 (mm)	RTAU	1.059
	Frontal constituent spectrum peak 1 frequency	XfI (Hz)	RTAV	0.919
	Frontal plane spectrum 60% power	xf60% (Hz)	RTAV	0.975
	Statokinesiogram length/area	LFS95 (1/mm)	RTAV	0.712
	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	RTAV	0.726
	Vertical constituent spectrum 60% power	xfZ% (Hz)	RTAV	0.680
	Stability index	Stab (%)	RTAV	0.779

 TABLE 3. Cluster Analysis of Stabilometry Results (Test with the Eyes Open, Teeth Clenched)

	Parameter	Unit	Method	Distance fron cluster cente
Cluster 1	PCD velocity	V (mm/sec)	RTEV	0.610
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTEV	0.560
	Square deviation of PCD in the frontal plane	x (mm)	EV	0.592
	Square deviation of PCD in the sagittal plane	y (mm)	EV	0.557
	PCD velocity	V (mm/sec)	EV	0.575
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	EV	0.616
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	EV	0.701
	Statokinesiogram 90 area	S90 (mm²)	EV	0.381
Cluster 2	Statokinesiogram length/area	LFS90 (1/mm)	RTEV	0.567
	Stability index	Stab (%)	RTEV	0.647
	Mean PCD position in frontal plane, European SK	Xe (mm)	RTEV	0.766
	Statokinesiogram length/area	LFS90 (1/mm)	EV	0.828
	Stability index	Stab (%)	EV	0.828
	Mean PCD position in frontal plane, European SK	Xe (mm)	EV	0.699
	Frontal constituent spectrum peak 1 frequency	Xfl (Hz)	RTAU	0.870
	Statokinesiogram length/area	LFS95 (1/mm)	RTAU	0.765
	Stability index	Stab (%)	RTAU	0.695
	Mean PCD position in frontal plane, new American SK	Xa1 (mm)	RTAU	0.810
	Frontal constituent spectrum peak 1 frequency	Xfl (Hz)	RTAV	0.849
	Statokinesiogram length/area	LFS95 (1/мм)	RTAV	0.708
	Stability index	Stab (%)	RTAV	0.547
	Mean PCD position in frontal plane, American SK	Xa (mm)	RTAV	0.787
Cluster 3	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.780
	Square deviation of PCD in the sagittal plane	y (mm)	RTEV	0.617
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTEV	0.530
	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.499
	Square deviation of PCD in the frontal plane	x (mm)	RTAU	0.662
	Square deviation of PCD in the sagittal plane	y (mm)	RTAU	0.593
	PCD velocity	V (mm/sec)	RTAU	0.593
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAU	0.656
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAU	0.600
	Statokinesiogram 95 area	s95 (mm²)	RTAU	0.537
	Square deviation of PCD in the frontal plane	x (mm)	RTAV	0.798
	Square deviation of PCD in the sagittal plane	y (mm)	RTAV	0.413
	PCD velocity	V (mm/sec)	RTAV	0.578
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAV	0.802
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAV	0.445
	Statokinesiogram 95 area	s95 (mm²)	RTAV	0.546
	Mean PCD position in frontal plane, American SK	Ya (mm)	RTAV	0.996

 TABLE 4. Cluster Analysis of Stabilometry Results (Test with the Eyes Closed, Teeth Clenched)

	Parameter	Unit	Method	Distance from cluster center
Cluster 1	Square deviation of PCD in the frontal plane	x (mm)	RTEV	0.697
	Square deviation of PCD in the sagittal plane	y (mm)	RTEV	0.747
	PCD velocity	V (mm/sec)	RTEV	0.614
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTEV	0.701
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTEV	0.565
	Statokinesiogram 90 area	S90 (mm²)	RTEV	0.522
	Square deviation of PCD in the frontal plane	x (mm)	EV	0.705
	Square deviation of PCD in the sagittal plane	y (mm)	EV	0.615
	PCD velocity	V (mm/sec)	EV	0.659
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	EV	0.745
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	EV	0.638
	Statokinesiogram 90 area	S90 (mm²)	EV	0.518
	PCD velocity	V (mm/sec)	RTAU	0.678
	PCD velocity	V (mm/sec)	RTAV	0.667
Cluster 2	Vertical constituent spectrum peak 1 frequency	XfZ1 (Hz)	RTEV	0.903
	Square deviation of PCD in the frontal plane	x (mm)	RTAU	0.505
	Square deviation of PCD in the sagittal plane	y (mm)	RTAU	0.439
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAU	0.485
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAU	0.524
	Statokinesiogram 95 area	s95 (mm²)	RTAU	0.369
	Square deviation of PCD in the frontal plane	x (mm)	RTAV	0.526
	Square deviation of PCD in the sagittal plane	y (mm)	RTAV	0.543
	Amplitude of frontal constituent spectrum peak 1	Xa1 (mm)	RTAV	0.577
	Amplitude of sagittal constituent spectrum peak 1	Ya1 (mm)	RTAV	0.502
	Statokinesiogram 95 area	s95 (mm²)	RTAV	0.448
Cluster 3	Statokinesiogram length/area	LFS90 (1/mm)	RTEV	0.624
	Stability index	Stab (%)	RTEV	0.744
	Frontal plane mean PCD position, European SK	Xe (mm)	RTEV	0.863
	Frontal constituent spectrum peak 1 frequency	Xfl (Hz)	EV	0.830
	Statokinesiogram length/area	LFS90 (1/mm)	EV	0.735
	Stability index	Stab (%)	EV	0.828
	Frontal plane mean PCD position, European SK	Xe (mm)	EV	0.884
	Frontal constituent spectrum peak 1 frequency	XfI (Hz)	RTAU	0.813
	Frontal plane spectrum 60% power	xf60% (Hz)	RTAU	0.948
	Statokinesiogram length/area	LFS95 (1/mm)	RTAU	0.685
	Stability index	Stab (%)	RTAU	0.578
	Frontal constituent spectrum peak 1 frequency	Xfl (Hz)	RTAV	0.858
	Statokinesiogram length/area	LFS95 (1/mm)	RTAV	0.713
	Stability index	Stab (%)	RTAV	0.540

acteristics obtained by RTAU and RTAV stabilometry, the distance of these parameters from cluster 2 center being longer than for cluster 1.

Cluster 3 is presented by RTEV, RTAU, and RTAV stabilometry values – their absolute parameters.

Results of stabilometry parameters clusterization during testing with the eye closed and teeth clenched are presented in Table 4.

Cluster 1 components were mainly absolute parameters of European stabilometry methods. In addition, it included the velocity of transposition of the pressure relative center evaluated by RTAU and RTAV stabilometry. Cluster 2 was formed by the absolute parameters of postural stability evaluated for the patient in the American posture. Cluster 3 consisted mainly of the relative and frequency characteristics of stabilometry. Similarly as in the two former tests, this cluster was formed by the relative and frequency parameters of the postural balance of patients examined by 4 stabilometry methods. The distance of the values for the components of all 3 clusters from its center was greater in testing with the eyes closed and teeth clenched vs. testing with the eyes open, teeth clenched.

Hence, in the protocol we suggest cluster 1 is formed by mainly absolute parameters of EV and RTEV stabilometry, and they are recommended for use in studies of the postural balance. The results of cluster analysis indicate the highest clinical informative value of the absolute stabilometry parameters evaluated by all stabilometry methods used in our study. The relative and frequency characteristics of the postural balance proved to be less informative.

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