Head position influence on stabilographic variables

Elżbieta Szczygieł[1]*, Karol Piotrowski[2], Joanna Golec[1], Dorota Czechowska[1],
Agata Masłoń[1], Aneta Bac[1], Edward Golec[1]

[1] Department of Rehabilitation in Orthopedics, Faculty of Motor Rehabilitation,
Bronisław Czech University School of Physical Education, Cracow, Poland.
[2] Department of Physiotherapy, Institute of Physiotherapy, Faculty of Health Sciences,
Jagiellonian University Medical College, Cracow, Poland.

Purpose: Head constitutes 6% of our body weight and significantly influences human body motor system mechanics. From physiological point of view, it should be located at extension of body middle line. Its location being modified results in many consequences in motor system. Our research was aimed at assessing the influence of head position on human body balance stabilographic variables. *Methods:* The research was made on a group of 62 patients: 45 women and 17 men, aged from 40 to 60 yrs, 46 yrs on average. Head position in sagittal and frontal plane was assessed with photogrammetric method. Chosen stability parameters were estimated with dynamometric platform PEL 38 and computer software TWIN 99. *Results:* The results confirmed correlations between existing stabilographic values and head position in frontal plane only. Head position, when changed in this plane, increased the amplitude ($p = 0.001$) and average speed of body gravity center trembilng ($p = 0.002$). There were no significant relations found in sagittal plane ($p > 0.05$). *Conclusions:* Our results show that the head position influences stabilographic variables. Its change in frontal plane decreases body posture stability to the largest extent.

Key words: *postural stability, head, posturography*

1. Introduction

The most significant feature of human posture is its straight vertical axis in relation to relatively small supporting surface. Such body orientation in a gravity field makes us easily vulnerable to loss of balance. Balance, defined as a postural state with vertical body orientation, both in static and dynamic conditions. The stability of regaining lost balance after being affected by destabilizing factors is defined as stability [5], [21]. Common posture stability indicator is a trajectory of general center of gravity (COG). Smaller COG amplitude and movement speed are the signs of more stable posture [5]. A grown up person's gravity center of erected body is located at the level of the second lumbar vertebra, and its sway in standing position is 4–5 cm forward from the line between the lateral parts of ankles [9]. These postural sways may be observed

as a translocation of the center of pressure (COP), which is considered as the indicators of a posture in general view. For a stable vertical position many coupled neurological system structures are responsible. These are the following: proper functioning labyrinth, cerebellum, eyes, inner ear semicircular canals, proprioceptive receptors of soft tissues and skin touch sensors, especially for blind people (e.g., between the sole and the ground). Descriptions of stability disturbances concern mainly neurological diseases: brain stroke [4], Parkinson's disease [15] or multiple sclerosis [17]. Available literature describes also the influence and meaning of individual body segments in stability preservation. They usually refer to some pathological changes, e.g., ankle fractures [6], idiopathic scoliosis [16], degenerative hip joint disease [22].

Head constitutes 6% of our body weight. Its position conditioned by neck reflexes operates the tension

of abdominal and lower limbs postural muscles. Because of its special role in the motor system biomechanics, we set ourselves an aim to assess the influence of head position on human body balance stabilographic variables modification.

2. Material and methods

Participants

The research included 62 persons: 45 women and 17 men, aged 40–60 yrs, 46 yrs on average (SD +/– 6.12 yrs). The persons were healthy, recruited from the general population, with excluded diseases or disturbances influencing balance. Subjects were excluded if they had a history of neuromuscular disorder, scoliosis, pain, vestibular disease, dizziness, history of falls over the past one year.

The research report has been approved by the Bioethics Committee (No. 36/KBL/OIL/2011). Tests were carried out with the written consent of each study participant.

Measurements

Head position

Head position was assessed with photogrammetrical body positioning using the Opto-electronic Body Explorer (OBE). OBE is a system positioning selected human body points, which allows one to determine spatial coordinates of these body points. The measurement was entirely remote. Reflective markers were taped on the points that describe the position of the head in two dimensions (Table 1) and their positions were captured with an opto-electronic system. Sections created by connection of the indicated points, including the *Y*, *X* created angles used for further analysis. The *Y* axis was represented by the vertical alignment line running across the spinous process of the seventh cervical vertebrae [24]. In the PBE system, points determined by the photogrammetric measurement represent the transfer of skeleton elements to the body surface and they are signalled by the polystyrene balls of 4–5 mm in diameter. The precision of determining the spatial coordinates of the signalled body points is high and amounts to ±2–4 mm. In order to limit the measurement errors, the balls were fixed by one person. The additional factor favourable for these studies was the fact that they were performed in a static position, thus, the risk of relocation of the balls was minimised. Moreover, for the assessment of head alignment in the frontal plane, pupils

were used, and one of the points for the assessment of head alignment in the sagittal plane was the middle point of the upper lip – these points did not require our intervention. The task of the subjects was to keep a casual, habitual standing position with their weight evenly distributed on both feet and looking straight ahead. To evaluate the head posture, the following standards were applied: sagittal plane: 60 +/–1° (values over 60° indicated head in the protraction, while values below 60° – to the retraction), frontal plane: 90 +/– 1° (values over 90° indicated head bend to the right, while values below 90° – to the left) [14]. Additionally, the research considered body posture, also in sagittal and frontal planes (Table 1). To evaluate the body posture, the following standards were applied: sagittal and frontal plane: 180 +/–1° (values over 180° indicated body leaning to the right, while values below 180° – to the left and forward).

Table 1. Chosen photogrammetric points
(in sagittal and frontal plane)

Chosen photogrammetric points in sagittal plane	
Head posture (L_O)	L – midle point of upper lip, O – occipital protuberance; angle between middle point of upper lip, occipital protuberance and *Y* axis
Body posture (O_CT)	O – occipital protuberance, CT – the center of the line connecting the calcanean tubers: left and right and *Y* axis
Chosen photogrametric points in frontal plane	
Head posture (EL_ER)	EL – left eye, ER – right eye; angle between right and left eye and *Y* axis
Body posture (O_CT)	O – occipital protuberance, CT – the center of the line connecting the calcanean tubers: left and right and *Y* axis

Stabilographic variables

In order to gain the COP sways image a system consisting of pedobarographic platform PEL 38 and computer software TWIN 99 was used. The research was made in free standing posture, on both feet, barefoot, with eyes open. Observation period lasted 30 seconds. Each patient came through a single trial. According to the research precision rules, the tensometric platform measurements were made in an isolated compartment, in order to keep each patient focused on the test.

Results of studies conducted by postural method were obtained in the form of a stabilogram. Charts show the displacement of the center of foot pressure (COP-center of foot pressure) on a support plane, and

separately show the frontal axis (medio-lateral) and sagittal (a-p), as well as the speed at which these data change. Values obtained in both a-p and lateral planes were the results of the posture study, which has previously been carried out [1]:

1. width – the range of oscillation in millimeters,
2. average deviation in millimeters,
3. average speed in millimeters/second.

In addition, the posture instability graph was described by the following variables:

1. path length – the length of the pressure center trajectory in millimeters,
2. path area – the surface area of the figure created by joining the extreme points of statokinesiogram in square millimeters,
3. avg.Q.speed – average square speed of pressure center in a-p and medio-lateral planes in millimeters/second.

Statistical analysis

The statistical analysis used Statistica 10.1 and Microsoft Excell 2010 softwares. We used descriptive statistics to characterize the study sample: we used means with SDs for continuous variables. For large discrepancies between the results and lack of conformity with a normal distribution, the analysis involved Spearman's method with consideration of *R* (rho) coefficient and correlation coefficients significance test, which was also used to compare the results with the assumed significance coefficient $p = 0.05$.

3. Results

Statistics of head and body posture in sagittal and frontal planes

The obtained results of the studies describing the head and body alignment in the frontal plane showed distribution compliant with the standard distribution.

For that reason they were subject to further statistical analysis by means of *t* Student test for a single sample, in which the results obtained were compared to the generally applicable standard ($90° \pm 1$ for the head and $180° \pm 1$ for the body), *t* Student test for two independent variables, where, due to the compliance of the results obtained with the standard distribution, variances of the averages were compared, describing the head and body leaning. Due to the fact that the results obtained indicated no differences between the right and the left-hand side ($p > \alpha$, where $\alpha = 0.05$), no division into the right and left-hand side was taken into account in further analysis.

The descriptive statistics of head and body posture in sagittal and frontal planes are shown in Table 2.

Influence of head position in sagittal plane over stabilographic variables changes

Despite noticeable negative correlation, the results did not prove significant impact of head position on stabilographic variables. Considering head position, including the body posture, in sagittal plane a wider body inclination angle was noticed, which caused increase of lateral sways, which considerably decreased stability.

The descriptive correlation between the angle, describing head position and body posture in sagittal plane and variables obtained in posturographic research are shown in Table 3.

Influence of head position in frontal plane over stabilographic variables changes

The results obtained proved that head position in frontal plane significantly influences the stabilographic variables. Larger head frontal sway determines extension of the way the gravity center needs to move ($p = 0.003$). The negative correlation between head position and center of pressure dislocation speed ($p = 0.004$), lateral sways speed ($p = 0.005$), feet pressure surface ($p = 0.006$) and average frontal plane center of pressure sways speed ($p = 0.007$) is noticeable.

Table 2. Descriptive statistics of head and body posture (in sagittal and frontal plane), $N = 62$

Descriptive statistics of head and body posture in sagittal plane					
	Norm	Mean	SD	Min	Max
Head posture (L_O)	60 +/– 1°	70.38	7.22	46.72	89.07
Body posture (O_CT)	180 +/– 1°	178.34	1.34	171.56	180.63
Descriptive statistics of head and body posture in frontal plane					
Head posture (EL_ER)	90 +/– 1°	91.08	2.55	83.26	97.56
Body posture (O_CT)	180 +/– 1°	181.18	1.08	178.86	183.43

Table 3. Coefficients Spearman's *R* (rho) and *p* (probability)
between the angle describing head position and body posture in sagittal plane
and variables obtained in posturographic research

Assessed variables	Head position in sagittal plane (L_O)		Body posture in sagittal plane (O_CT)	
	R	*p*	*R*	*p*
Postural Instability-Path area	−0.082	0.525	−0.162	0.208
Postural Instability-Path Length	−0.060	0.643	−0.156	0.227
Postural Instability-L/A	0.056	0.666	−0.137	0.289
Postural Instability-Avg.Q.Speed	−0.088	0.495	−0.181	0.159
AP-Width	−0.026	0.843	−0.119	0.356
AP-Average Deviation	0.024	0.850	−0.092	0.476
AP-Average speed	−0.116	0.369	−0.193	0.133
Lateral-Average Deviation	−0.113	0.381	−0.189	0.141
Lateral_Width	−0.097	0.455	−0.186	0.148
Lateral Average speed	−0.027	0.836	0.127	0.327

Table 4. Coefficients: Spearman's *R* (rho) and *p* (probability)
between angle describing head position and body posture
in frontal plane and variables obtained in posturographic research.
Data in bold are significant

Assessed variables	Head position in frontal plane (EL_ER)		Body posture in frontal plane (O_CT)	
	R	*p*	*R*	*p*
Postural Instability-Path area	**−0.325**	**0.010**	**0.274**	**0.031**
Postural Instability-Path Length	**−0.323**	**0.010**	**0.261**	**0.041**
Postural Instability-L/A	**0.286**	**0.024**	−0.146	0.257
Postural Instability-Avg.Q.Speed	**−0.337**	**0.007**	**0.275**	**0.030**
AP–Width	**−0.269**	**0.034**	0.023	0.858
AP-Average Deviation	−0.189	0.140	0.012	0.924
AP-Average speed	**−0.365**	**0.004**	**0.347**	**0.006**
Lateral-Average Deviation	**−0.353**	**0.005**	**0.344**	**0.006**
Lateral_Width	**−0.342**	**0.006**	**0.341**	**0.007**
Lateral Average speed	**−0.280**	**0.027**	0.137	0.288

The descriptive correlation between the angle describing head position and body posture in frontal plane and variables obtained in posturographic research are shown in Table 4.

Considering frontal plane body posture assessment, it was proved that the increase of inclination angle causes an increase of gravity center sways in frontal plane as well as an increase in postural instability.

4. Discussion

Head constitutes an important link in body motor biokinematic chain. In physiological conditions it should extend body central line. Such head position conditions low energy consumption, which is neces-sary to maintain proper musculo-skeletal balance. Its change results in various consequences described in the literature. Malihi proved that each head sway from its natural position increased eye internal pressure. The highest pressure was noticed in full head leaning forward, which, as he describes, increased glaucoma risk [13]. Another interesting reports describe relations between head position and jaw opening, or closing movements. It was proved that leaning head forward increases jaw opening extent, while its closing is more stable when head is retracted [10], [25]. Fernandez-de-las-Penas proved positive correlation between leaning head forward and neck mobility. He compared patients suffering from chronic headaches with the ones free from such illnesses and noticed that patients from the first group have their heads leaned forward more visibly than the ones from the second group. He additionally noticed that head bending an-

gle increase in frontal plane decreases spine cervical mobility [7]. A number of reports confirms a relation between head position and cervical spine aches [11], [20], [23]. Literature often includes papers confirming the influence of head position on the structures located below it. Quek et al. described the influence of head leaned forward and thoracic kyphosis on cervical lordosis. Such head position determines cervical spine mobility decrease by limiting rotation and leaning range [18]. Griegel-Morris proved that protracted head, except the neck, influences also thoracic spine and blade bone, creating a misbalance in musculo-skeletal system [8].

Considering the above-mentioned relations, we strived at finding the answer to the question whether head position does influence body stability. The available literature includes interesting research of Kang [12]. He tested a group of 20 office workers, using a computer on their posts (more than 6 hours a day) and proved their stronger tendency to lean their heads forward, which considerably decreased their stability. Our research of head position in frontal plane proved no significant influence on stability. However, when head and abdomen posture was considered, then body inclination angle increased also lateral sways. Comparing to Kang's research, we should notice differences in selectivity and number of participants. We used 62 random persons, while Kang used office workers, using computers. Moreover, Kang measured head dislocation in frontal plane through analyzing photos by conventional photogrammetry, which may be considered a less sensitive method compared to photogrammetry based on opto-electronic approach. The differences considered also the patient's posture – we asked our participants to stand with their arms down, while Kang's participants stood with their arms on their chests. Our results and lack of relation between head leaned forward and body stability are confirmed by the research of Buckley [3] and Silva [19]. Buckley, working with a group of 12 elder persons proved that protracted head in free standing does not influence gravity center location. Similar conclusion was due to Silva, after testing 25 young persons. Head position was assessed by measuring an angle between seventh cervical vertebra feather bone and ear conch. His results confirmed lack of relation between head position and body stability variables.

Among others, our research is special for its using both planes: sagittal and frontal in head position survey. Frontal plane head position changes proved to be the most determining for gravity center dislocations in all possible directions. Our research may be completed with Bonnet's reports. He proved that leaning one's head in any direction (left–right), increases sways of body posture. What is relevant is that unlike in our research, Bonett verified forced head positions, asking his patients to follow dots moving on a wall with their eyes [2]. The distance between two extreme points measured was 150 degrees.

5. Conclusions

Head position influences stabilographic variables. Its frontal plane position change has the greatest impact on postural stability. We hope that our data would stimulate further study.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

References

[1] BARATTO L., MORASSO P.G., RE C SPADA G., *A new look at posturographic analysis in the clinical context: sway-density versus other parametrization techniques*, Motor Control, 2002, 6, 246–270.

[2] BONNET C.T., DESPRETZ P., *Large lateral head movements and postural control*, Hum. Mov. Sci. J., 2012, 31, 1541–1551.

[3] BUCKLEY G.J., ANAND V., SCALLY A., ELLIOT B.D., *Does head extension and flexion increase postural instability in elderly when visual information is kept constans?*, Gait Posture, 2005, 21(1), 59–64.

[4] CARVER T., NADEAU S., LEROUX A., *Relation between physical exertion and postural stability in hemiparetic participants secondary to stroke*, Gait Posture, 2011, 33, 615–619.

[5] DANIS C.G., KREBS D.E., GILL-BODY K.M., SAHRMANN S., Relationship between standing posture and stability, Phys. Ther., 1998, 78(5), 502–517.

[6] DUDEK K., DRUŻBICKI M., PRZYSADA G., ŚPIEWAK D., *Assessment of standing balance in patients after ankle fractures*, Acta Bioeng. Biomech., 2014, 16(4), 59–65.

[7] FERNANDEZ-DE-LAS-PENAS C., ALONSO-BLANCO C., CUADRADO M.L., PAREJA J.A., *Forward head posture and neck mobility in chronic tension-type headache: a blinded, controlled study*, Cephalalgia, 2006, 26(3), 314–319.

[8] GRIEGEL-MORRIS P., LARSON K., MUELLER-KLAUS K., OATIS C.A., *Incidence of common postural abnormalities in the cervical, shoulder and thoracic regions and their association with pain in two age groups of healthy subjects*, Phys. Ther., 1992, 72, 425–431.

[9] HELD-ZIÓŁKOWSKA M., *Static and dynamic body balance*, Mag. Otolaryngol., 2006, 2(18), 1–4.

[10] HIGBIE E.J., SEIDEL-COBB D., TAYLOR L., CUMMINGS G.S., *Effect of head position on vertical mandibular opening*, J. Orthop. Sports Phys. Ther., 1999, 29(2), 127–130.

[11] Ho Ting Yip Ch., Tai Wing Chiu T., Tung Kuen Poon A., *The relationship between head posture and severity and disability of patients with neck pain*, Man. Ther., 2008, 13(2), 148–54.

[12] Kang J.H., Park R.Y., Lee S.J., Kim J.Y., Yoon S.R., Jung K.I., *The effect of the forward head posture on postural balance in long time computer based worker*, An. Rehab. Med., 2012, 36, 98–104.

[13] Malihi M., Sit AJ., *Effect of head and body position on intraocular pressure*, Ophthalmol., 2012, 119, 987–991.

[14] Mikrut S., Tokarczyk R., *Close Range Photogrammetry System for Medicine and Railways*, International Archives of the Photogrammetry Remote Sensing, Vol. B-5, Amsterdam; 2000.

[15] Nantel J., Bronte-Stewar J., *The effect of medication and the role of postural instability in different components of freezing of gait (FOG)*, Parkins. Rel. Disord., 2014, 20(4), 447–451.

[16] Paolucci T., Morone G., Di Cesare A., Grasso M.R., Fusco A., Paulocci S., Saraceni V.M., Iosa M., *Effect of Cheneau brace on postural balance in adolescent idiopathic scoliosis: a pilot stud*, Europ. J. Phys. Rehab. Med., 2013, 49(5), 649–657.

[17] Popova N.F., Shagaev A.S., Demina T.L., Boiko A.N., *Dynamic stabilometry as a monitoring of movment and coordination disorders in the rehabilitation of patients with multiple sclerosis*, Zh Nevrol Psikhiar im SS Korsakova, 2009, 109(1), 35–39.

[18] Quek J., Pua Y.H., Clark R.D., Bryant A., *Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults*, Man. Ther., 2013, 18(1), 65–71.

[19] Silva A.G., Johnson M.T., *Does forward head posture affect postural control in human healthy volunteers?*, Gait Posture, 2013, 38, 352–353.

[20] Silva A.G., Punt T.D., Sharples P., Vilas-Boas J.P., Johnson M.I., *Head posture and neck pain of chronic nontraumatic origin: a comparison between patients and pain-free persons*, Arch. Phys. Med. Rehab., 2009, 90(4), 669–674.

[21] Szczepek E., Czerwosz L., *Posturographic research and computer walk analysis in Computer Dyno Graphy as a noninvasive assessment of advanced normal pressure hydrocephalus*, Pol. J. Neurol. Neurosurg., 2008, 42(2), 139–152.

[22] Szczygieł E., Satko-Skawińska N., Mazur T., Golec J., Golec E., *Evaluation of stabilographic variables in patiens with degenerative hip joint disease*, Kwart. Ortop., 2010, 3, 452–465.

[23] Szeto G.P., Straker L., Raine S., *A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers*, Applied Ergonomics, 2002, 33(1), 75–84.

[24] Tokarczyk R., Mazur T., *Photogrammetry-principles of operation and application on rehabilitation*, Med. Rehab., 2006, 10(4), 31–38.

[25] Yamada R., Ogawa T., Koyano K., *The effect of head posture on direction and stability of mandibular closing movement*, J. Oral Rehab., 1999, 26, 511–520.