Study Regarding the Importance of Patients Assessment with Static and Dynamic Balance Disorders Depending on the Topography of the Lesion

Maria Ștefana SOLOMON-PÂRȚAC[a*], Adrian COJOCARIU[a], Sebastian COZMA[b]

[a]*Alexandru Ioan Cuza din Iași, Facultatea de Educație Fizică și Sport, Strada Toma Cozma, Iasi, 700554, ROMANIA*
[b]*Universitatea de Medicină și Farmacie Grigore T. Popa din Iași, Strada Univeristății, nr. 16, Iasi, 700115, ROMANIA*

Abstract

The purpose of this study is represented by the way in which the therapeutic approach of patients with vestibular syndrome can be improved as a result of the identification of some parameters related to the visual, somesthetic, vestibular, global and preferential scores, parameters reffers to static and dynamic balance.

We included in this reasearch a number of 37 subjects (11 male and 26 female), aged between 36 and 75, diagnosed with a form of of vestibular syndrome. They were divided into two groups; the first group consists in 20 subjects with peripheral vestibular syndrome (14 female and 6 male), while the second group was represented by 17 subjects with mixed vestibular syndrome (12 female and 5 male).

In order to realise functionally assessment, we used Synapsys posturograph, through which we collected data on somesthetic, visual, vestibular, preferential and global parameters, both in the anterior-posterior and in the mid-lateral axis and the results were subjected to statistical analysis, using the SPSS 20 program.

The results highlight the fact that the use of the Synapsys posturography equipment for patients with vestibular syndrome proves to be a valuable therapeutic measure, by accurately describing the balance parameters and, above all, by analyzing the patients' ability to use somatosensory, visual and vestibular informations in order to maintain balance in the anterior-posterior and mid-lateral axis.

* Corresponding author.
E-mail address: stefanasolomon@yahoo.com

Keywords: *vertigo; vestibular assessment; balance platform; center of gravity.*

1. Introduction

The topicality of the theme results from the fact that body balance is an important component of health and the way of carrying out socio-professional activities and an adequate postural control is necessary to safely manage the way of doing daily activities. Balance deficits have been identified as important factors that increase the risk of falls and injuries in both children and adolescents and especially in the adult population (Kiss, Schedler & Muehlbauer, 2018). Patients diagnosed with vestibular syndrome may present an impairment of static and/or dynamic balance and their therapeutic behavior is extremely complex. Balance disorders due to dizziness or vestibular syndrome are a risk factor for falls and can have a significant impact on quality of life as they are common in the adult population (Murdin & Schidler, 2015).

At the same time, about 30% of people will suffer from rotational or postural vertigo at some point in their lives; the prevalence of this condition increases with age and is approximately two to three times more common in women than in men (Strupp, Dieterich & Brandt, 2013; Neuhauser, 2016). Vestibular syndrome represents a condition with a diverse etiology, which requires a thorough anamnesis and a complex evaluation, so that the collected data can lead to the initiation of a treatment adapted to the patient's needs and with increased efficiency.

In Romania, the studies that focused on patients diagnosed with vestibular syndrome are limited, especially from the point of view of describing a therapeutic intervention plan aimed at functional rehabilitation and allowing the improvement of static and dynamic balance parameters. In a 2014 study conducted in our country were included a number of 245 romanian patients diagnosed with recurrent peripheral vestibular syndrome, treated with betahistine 48 mg/day for 3 months; sustained and statistically significant improvements in multiple observational study indices were found in patients with this condition and the safety and

tolerability of the treatment was good in this group, with only one patient reporting adverse reactions (Bajenaru et al., 2014). In another report from Romania regarding the management of unilateral peripheral vestibular disorders, it was demonstrated that early treatment with corticosteroids associated with electrolytes, antiemetic and vasodilator drugs led to recovery of vestibular function without differences between types of peripheral vestibular dysfunction and it was obtained a complete recovery of vestibular and acoustic dysfunction in cases treated with intratympanic injection (Petri, Chirila, Bolboaca & Cosgarea, 2015).

We can state according to these two reference studies carried out in Romania that patients diagnosed with vertigo follow, in particular, a drug treatment, which proves effective in terms of symptom relief, but still the data related to the functional rehabilitation programs to be performed under the guidance of a physiotherapist are limited; we believe that it is essential that this patients must follow such a rehabilitation program, which is focused on achieving the objective of socio-professional reintegration and on improving the vestibular deficit as much as possible.

In this study, we aim to identify effective assessment methods for patients diagnosed with vestibular syndrome who present static and dynamic balance disorders and to differentiate them according to the topography of the lesion. This approach will conduct our research in order to describe a vestibular rehabilitation protocol, which will materialize in a best practice guide for clinicians.

2. Purpose, objectives, hypotheses

The **purpose** of this research is represented by the way in which the therapeutic approach of patients with vestibular syndrome can be improved as a result of the identification of some parameters related to the visual, somesthetic, vestibular, global and preferential scores, parameters aimed at static and dynamic balance.

Among the **objectives** of the study are the identification of innovative technological equipment used in vestibular rehabilitation, the selection of

research subjects or the collection, analysis and interpretation the results, including statistical analysis.

Two **hypotheses** were formulated; the first hypothesis referred to the fact that the assessment of patients with vestibular syndrome will allow the identification of distinct elements related to balance parameters, depending on the location of the lesion and the second hypothesis assumed the identification of an association between the results obtained by patients with vestibular syndrome in terms of someesthetic, visual, vestibular, preferential and global scores.

3. Methods

The period of this study was one year, it started in September 2021 and was completed in August 2022. The research site was represented by the Rehabilitation Hospital of Iasi, the Audiology and Vestibulology Compartment.

We included in this study a number of thirty-seven subjects (male=11 and female=26), aged between 36 and 75 years.

The subjects were diagnosed with a form of vestibular syndrome and were divided into two groups: in group 1 were included a number of twenty subjects with peripheral vestibular syndrome (fourteen female and six male) and in group 2 were included seventeen subjects with mixed vestibular syndrome (twelve female and five male).

Subjects' inclusion criteria were their diagnosis, treatment approach to the condition, consent to evaluation with the Synapsys posturographic device and consent to participate in the study.

Exclusion criteria were the existence of any other pathology, which could have been responsible for influencing the results (neurological conditions, ophthalmological conditions or orthopedic conditions).

In order to functionally evaluate the subjects it was used the Synapsys posturograph, through which data were collected on somesthestic, visual, vestibular, preferential and global parameters, both in the antero-posterior and in the mid-lateral axis. The evaluation involved the subjects being positioned on the platform in orthostatic position, with arms held by the

body, under six conditions (which were related to the static or unstable platform as well as changes in the visual stimulus), while sensors calibrated to the software recorded data of the oscillations of the center of gravity on the anterior-posterior and mid-lateral axis.

The software of Synapsys allows to obtain numerical scores related to reference values, which are expressed as follows:

- the somesthetic score - obtaining the score for the somesthetic assessment required reporting the results of condition 2 with the results of condition 1, a report that makes it possible to eliminate visual information and not stimulate the vestibular one, as well as the subject's ability to use somatosensory information;
- the visual score- involves the comparison of condition 4 with condition 1 and highlights the subject's ability to use the visual analyzer, as somesthetic information is eliminated due to the unstable platform and the visual analyzer is responsible for maintaining balance, while the vestibular information is non-existent;
- the vestibular score- is quantified following the reporting of condition 5 to condition 1, so the somesthetic information is eliminated by moving from a stable base to an unstable one, and the visual one is eliminated due to the evaluation position with closed eyes;
- the preferential score- involves reporting conditions 3 and 6 to conditions 2 and 5 and refers to the subject's ability to ignore erroneous visual information (specific to conditions 3 and 6) in order to maintain balance;
- the global score - sums up the results from all six assessment conditions and represents a general assessment that allows highlighting the subject's ability to use all the information necessary to maintain balance.

4. Results

The analysis of the results is illustrated by means of the graphic method, with a series of graphic representations that allow conclusively the

presentation of the data collected. At the same time, the statistical analysis program SPSS 20.0 was used, for highlight some statistically relevant results.

In order to highlight the role of balance compensation mechanisms in the case of subjects with peripheral and mixed vestibular syndrome, we performed graphic representations, through which we presented the results of subjects compared to the reference values (expressed by Figures 1 and 2), but and the Independent t test, through which we highlighted whether the average values of the two groups show statistically significant differences, expressed in Table 1, thus also testing the first hypothesis.

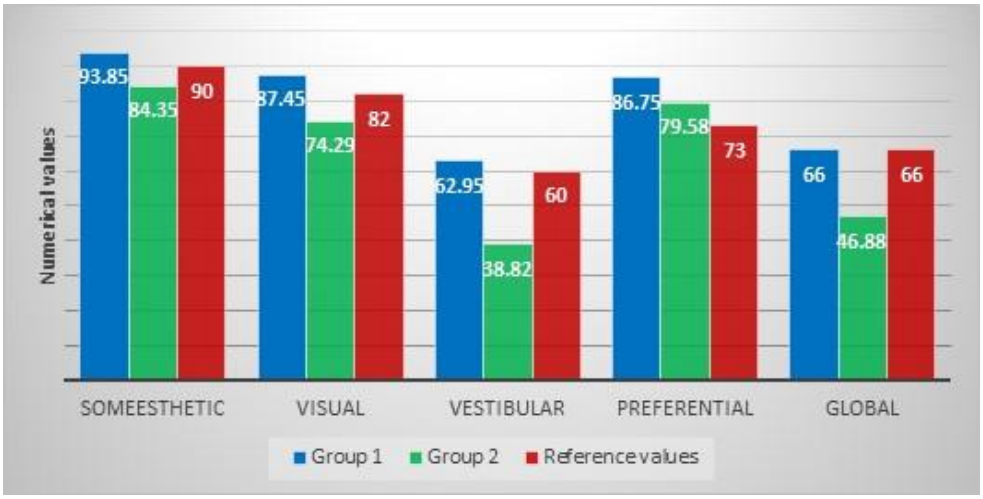

Figure 1. Average results of the two groups in the assessment of balance on the anterior-posterior axis

In Figure 1 we can see the average results of the two groups regarding the assessment of balance in the antero-posterior plane and superior results are found for subjects with peripheral vestibular syndrome, results that are close to the reference values, while subjects with mixed vestibular syndrome shows results below the reference values for most parameters, except for the preferential one.

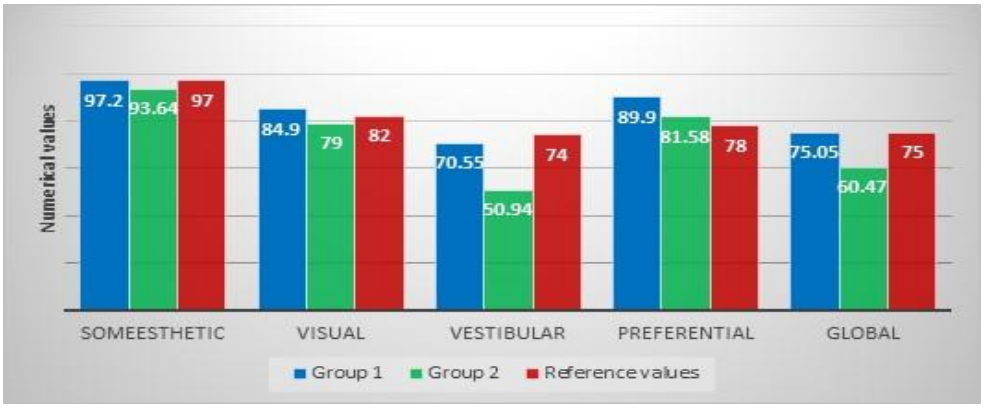

Figure 2. Average results of the two groups in the assessment of balance on the medio-lateral axis

According to Figure 2, we can see the results of the two groups regarding the evaluation of the balance in the mid-lateral plane and superior results are found for subjects with peripheral vestibular syndrome, results that are close to the reference values, with only one situation in which the value is lower than the value of reference (vestibular parameter), while subjects with mixed vestibular syndrome show results below the reference values for most parameters, except for the preferential one.

Table 1. Independent t-test to evaluate the balance between the two groups, according to the location of the lesion

PARAMETERS	AP AXIS	ML AXIS
SOMEESTHETIC	p=.005	p=.014
VISUAL	p=.009	p=.302
VESTIBULAR	p=.003	p=.027
PREFERENTIAL	p=.184	p=.048
GLOBAL	p=.000	p=.002

Legend: AP axis=anterior-posterior axis; ML axis=mid-lateral axis.

The analysis of Table 1 and Figures 1 and 2 shows that the average values of the two groups show statistically significant differences in the case of most balance parameters ($p<0.05$), except for the preferential one ($p=0.184$), which means that we found a superior efficiency of compensation

mechanisms of balance in the anterior-posterior axis for subjects with peripheral syndrome; the average values of the groups show statistically significant differences in most balance parameters ($p<0.05$), except for the visual one ($p=0.302$), which means that we found a better efficiency of balance compensation mechanisms in the mid-lateral axis are for subjects with peripheral syndrome; the fact that in the antero-posterior axis the average values do not show statistically significant differences of the preferential parameter ($p=0.184$) would suggest that both subjects (with peripheral and mixed vestibular syndrome) have a good ability to ignore of the erroneous visual stimulus; the fact that in the mid-lateral axis the mean values do not present statistically significant differences in the visual parameter ($p=0.302$) would suggest that both groups have a good ability to use the visual analyzer.

In order to test the second hypothesis, we performed the Pearson correlation, through which we highlighted if exist an interdependence relationship between the balance parameters (somesthetic, visual, vestibular, preferential and global) for each of the two groups, as well as whether it is established a relationship of interdependence between the balance parameters on the two axes (anterior-posterior and mid-lateral).

Table 2. Pearson's correlation for assessment of balance on the anterior-posterior axis

Correlations	Group 1	Group 2
Someesthetic-Visual	p=.01, r=.667	p=.675, r=110
Someesthetic -Vestibular	p=.018, r=.525	p=.001, r=.710
Someesthetic -Preferential	p=.932, r=-.020	p=.975, r=.008
Someesthetic -Global	p=.011, r=.553	p=.010, r=.607
Visual-Vestibular	p=.000, r=.878	p=.583, r=.143
Visual-Preferential	p=.043, r=.457	p=.137, r=.376
Visual-Global	p=.000, r=.915	p=.028, r=.532
Vestibular-Preferential	p=.121, r=359	p=.895, r=.-035
Vestibular-Global	p=.000, r=.924	p=.003, r=.681
Preferential=Global	p=.000, r=.614	p=.168, r=351

Table 2 shows the results of the Pearson correlation for the average values obtained by the two groups the assessment of balance on the anterior-

posterior axis and we can describe the following aspects: group 1 recorded statistically significant (positive) correlations in most situations, with the exception of someesthetic-preferential, respectively vestibular-preferential parameters, which may suggest that in the case of subjects with peripheral vestibular syndrome we identify an interdependence relationship between balance parameters in the anterior-posterior axis, and somaesthetic, visual and vestibular information show similar changes after the onset of the condition; group 2 registered statistically significant (positive) correlations in isolated situations, predominating the correlations that are not statistically significant, which may suggest that in the case of subjects with mixed vestibular syndrome, the interdependence ratio between the balance parameters in the anterior-posterior axis is less significant and someesthetic, visual and vestibular information do not necessarily show linear changes after the onset of the condition; the fact that subjects with peripheral vestibular syndrome recorded statistically significant correlations in most situations and subjects with mixed vestibular syndrome predominantly recorded correlations that are not statistically significant could suggest that the efficiency of compensatory mechanisms (in order to maintain balance in the anterior-posterior axis) after the onset of the syndrome is different, depending on the topography of the lesion and it can be suggested that patients with mixed vestibular syndrome present a less efficient compensation process of the vestibular function, which could lead to a greater accentuation of balance disorders and functional deficits in the anterior-posterior axis.

Table 3. Pearson's correlation for the assessment of balance on the mid-lateral axis

Correlations	Group 1	Group 2
Someesthetic-Visual	p=.001, r=.686	p=.643, r=-.121
Someesthetic -Vestibular	p=.000, r=.772	p=.198, r=.328
Someesthetic -Preferential	p=.291, r=.248	p=.527, r=-.165
Someesthetic -Global	p=.000, r=.781	p=.512, r=.171
Visual-Vestibular	p=.000, r=.911	p=.807, r=.064
Visual-Preferential	p=.016, r=.530	p=.049, r=.484
Visual-Global	p=.000, r=.947	p=.102, r=.410
Vestibular-Preferential	p=.043, r=.457	p=.304, r=-.265
Vestibular-Global	p=.000, r=.979	p=.000, r=.790
Preferential=Global	p=.018, r=.523	p=.559, r=.152

Analyzing Table 3 allows the identification of the results of the Pearson correlation for the average values obtained by the two groups regarding the assessment of balance on the mid-lateral axis, namely: group 1 recorded statistically significant (positive) correlations in most situations, with the exception of the someesthetic –preferentially correlation, which may suggest that in the case of subjects with peripheral vestibular syndrome we identify an interdependence relationship between the balance parameters in the mid-lateral axis and somesthetic, visual and vestibular information show similar changes after the onset of the condition; group 2 recorded correlations that are not statistically significant in most situations, except for the vestibular-global and visual-preferential correlations, which may suggest that in the case of subjects with mixed vestibular syndrome, the interdependence ratio between the balance parameters in the mid-lateral axis is restricted and someesthetic, visual and vestibular information do not necessarily show linear changes after the onset of the condition; the fact that subjects with peripheral vestibular syndrome recorded statistically significant correlations in most situations and subjects with mixed vestibular syndrome predominantly recorded correlations that are not statistically significant could suggest that the efficiency of compensatory mechanisms (in order to maintain balance in the mid-lateral axis) after the onset of the syndrome is different, depending on the topography of the lesion and it can be suggested that patients with mixed vestibular syndrome present a less efficient compensation process of the vestibular function, which could lead to a greater accentuation of balance disorders and functional deficits in the mid-lateral axis.

Table 4 is suggestive for the description of the correlations between the average results obtained by the two groups in terms of the balance parameters in the antero-posterior and mid-lateral axis and thus highlights the following aspects: in the case of group 1 the correlations are statistically significant (positive) for the visual, vestibular and global parameters, while for somesthetic and preferential parameters the correlations are not statistically significant, which would suggest that subjects with peripheral vestibular syndrome show similar changes in visual, vestibular information, but also in the ability to use all the necessary stimuli globally maintaining

balance in the two axis; in the case of group 2, the correlations are statistically significant (positive) in the case of all parameters, which may suggest that the reporting of subjects with mixed vestibular syndrome to someesthetic, visual and vestibular information undergoes similar changes in the two axis.

Table 4. Pearson's correlation for balance assessment on the two axes

Corelații	Group 1	Group 2
Someesthetic x axis- Someesthetic y axis	p=.076, r=.405	p=.003, r=.674
Visual x axis- Visual y axis	p=.000, r=.978	p=.000, r=.791
Vestibular x axis- Vestibular y axis	p=.000, r=.945	p=.002, r=.689
Preferential x axis- Preferential y axis	p=.282, r=.253	p=.000, r=.760
Global x axis - Global y axis	p=.000, r=.935	p=.006, r=.636

5. Discussions

The results were collected through the Synapsys device and in this way we recorded data regarding the oscillations of the center of gravity in the anterior-posterior axis, but also in the mid-lateral axis. The same parameter was also targeted in the research of Nair et al. (2017), who used the static platform to record changes in the center of gravity as a statokinesiogram, each test condition being performed for a period of twenty seconds and being scored on the visual score, the vestibular score and the someesthetic score on the antero- posterior and mid-lateral axis. In another research it was used the MediPost mobile posturographic, a newly developed device that has a high sensitivity and specificity in differentiating healthy people from those with vestibular deficit by performing a specific protocol (Rosiak et al., 2022).

According to the results of our preliminary study, it can be stated that subjects diagnosed with a form of peripheral or mixed vestibular syndrome show a different efficiency of compensation mechanisms in order to maintain

balance. Taking all this into account, we can direct a future vestibular rehabilitation protocol according to the data collected using the Synapsys platform. The same is supported by the research done by Rosiak et al. (2022), which demonstrated that mobile posturography may be a promising solution to the growing problem of a society suffering from balance disorders. According to these authors, the advantage of posturography, equipped with a multitude of sensors, compared to systems with force plates, is represented by the possibility of following the movements performed and thus identifying including gait disorders.

A basic idea that emerges from the analysis of the preliminary results refers to the fact that subjects with mixed vestibular syndrome show inferior results compared to subjects diagnosed with peripheral vestibular syndrome, which can also be attributed to compensatory mechanisms. This aspect is also supported by Michel, Laurent & Alain (2020), who stated that peripheral vestibular disorders are the most common and can be treated both pharmacologically and by vestibular rehabilitation, but when the treatment is not effective, a mechanism compensatory may develop in the central nervous system and improve the patient's ability to maintain static and dynamic balance. Conversely, in patients with central vestibular syndromes, even if they are less common than peripheral conditions, they should be considered, given their impact on both prognosis and rehabilitation. At the same time, some drugs applied in the treatment of vertigo can have a negative impact on the development of the compensatory phenomenon (Casani, Gufoni & Capobianco, 2021).

There is a lot of research that shows that age is an important factor in the ability of patients diagnosed with a form of vestibular syndrome to maintain their balance. Neuhauser (2016) highlights that each year 5% of the general population experience symptoms of vertigo and the prevalence, frequency and severity of vertigo generally increase with age. At the same time, it is estimated that 25% of the population aged 70 years or older have symptoms of dizziness, most of them remain with these symptoms for more than one year (Vaz et al., 2013) and older people reported more falls due to vertigo than the younger population (Prell, Finn & Axer, 2022). This may also be explained by the fact that older adults with vertigo often suffer from

multisensory deficits such as central bilateral vestibulopathy and benign paroxysmal positional vertigo (Lindell et al., 2021).

Lifetime prevalence data for vertigo show a 30% to 50% increase in the elderly (Penger, Strobl & Grill, 2017). Silva et al. (2016) note that some changes due to aging are directly related to the vestibular system, which can cause several otoneurologically related symptoms, such as vertigo and other types of dizziness, hearing loss, tinnitus, changes in body balance, gait disturbances and occasional falls. Similar aspects are also described by Casani (2021), according to which benign vertigo affects approximately 20% of all cases of vestibular syndromes and, even if it can appear at any time of life, it manifests itself more frequently in adults and older patients, with a maximum incidence between the fifth and seventh decades of life.

Regarding the incidence of vertigo according to gender, it was described that, although the number of female patients was higher than that of males, no significant difference in the incidence rate between the two categories was identified (Yin et al., 2009) and the study by Della Torre et al. (2021) highlighted that there were no statistically significant differences in baseline characteristics of subjects with vestibular syndrome by gender. Taking into account all these aspects it is distinguished that the prevalence of vertigo is higher for women (3.2%) than for men (1.6%), but this gender difference disappears in the very old (Silva, 2016; Maarsingh et al. al., 2010); it is also highlighted that 65% of patients are women (Skuladottir et al., 2021; Hulse et al., 2019), and the significant association of female gender with vertigo was mainly explained by the types of orthostatic vertigo and,, rocked" (Filippopulos et al., 2017).

Given the fact that vestibular syndrome, regardless of the etiological factor that led to its installation, produces changes in the ability to maintain balance, we consider it important to study how balance parameters are modified. Such aspects have also been the subject of other studies, through which it has been demonstrated that the sudden alteration of sensory information arising from peripheral vestibular sensory and/or neural elements evokes typical vestibular symptoms characterized by a cascade of functional disturbances that include postural imbalance at rest and during movement, and patients diagnosed with peripheral or mixed vestibular

syndrome show an impairment of visual, vestibular and proprioceptive functions (Tighilet et al., 2017).

In this study, we highlighted the importance of somatosensory, visual and vestibular information in order to maintain balance and this aspect is supported by current research, in which it was mentioned that the integration, processing and correct coordination of the stimuli responsible for maintaining balance allow maintaining the projection of the center of body weight inside the support surface, and posturographic assessment proves to be an objective, accurate and complex method of balance assessment (Krawczyk-Suszek, Martowska & Sapula, 2022).

All this information can be valuable due to the possibility of describing a future vestibular rehabilitation protocol, which will be customized according to the topography of the lesion and, above all, depending on how the balance parameters are affected (somesthetic, visual, vestibular). Vestibular rehabilitation is aimed at improving the vestibular compensation process, but its effect on functional recovery is not fully known (Lacour, Tardivet & Thiry, 2021). Some authors state that vestibular rehabilitation is of major importance, both for central and peripheral vestibular disorders (Dunlap, Holmberg & Whitney, 2019) and individual vestibular rehabilitation training decreases the sensation of vertigo, adapts the vestibulo-ocular reflex and, most importantly, it improves stability and can reduce the risk of falling (Carender, Grzesiak & Telian, 2021). However, more than 80% of patients experiencing vertigo in the Netherlands, the United Kingdom and the United States are mainly treated by their general practitioner or primary care physician and are never referred to a specialist (Van Vugt et al., 2019, Stam et al., 2016). Despite the scientific evidence for vestibular rehabilitation, less than 10% of general practitioners in the Netherlands and the UK reported using this therapy (McDonnell & Hillier, 2015; Bhattachayya et al., 2017).

6. Conclusions

The results obtained in this research support the first hypothesis because, following the assessment of subjects with vestibular syndrome by

means of the Synapsys posturography equipment, we identified distinct elements of the balance parameters, depending on the location of the lesion, and thus we can state that both subjects with peripheral vestibular syndrome and subjects with mixed vestibular syndrome, show balance changes in the antero-posterior and mid-lateral axis, specifying that these changes are more significant in the case of subjects with mixed vertigo.

Regarding the second hypothesis we can say that it is partially supported by the collected results because we identified reports of interdependence between balance parameters for subjects with peripheral vestibular syndrome, while in the case of subjects with mixed vestibular syndrome they were limited. However, we highlighted similar changes in balance parameters on the two axes, especially for subjects with mixed vestibular syndrome.

The use of the Synapsys posturograph for patients with vestibular syndrome proves to be a valuable therapeutic measure, by accurately describing balance parameters and, above all, by analyzing the patients' ability to use somatosensory, visual and vestibular information in order to maintain balance in the antero-posterior and in the mid-lateral axis.

References

Băjenaru, O., Roceanu, A. M., Albu, S., Zainea, V., Pascu, A., Georgescu, M. G., Cozma, S., Mărceanu, L., & Mureşanu, D. F. (2014). Effects and tolerability of betahistine in patients with vestibular vertigo: results from the Romanian contingent of the OSVaLD study. *International journal of general medicine*, *7*, 531–538. https://doi.org/10.2147/IJGM.S71015

Bhattacharyya, N., Gubbels, S. P., Schwartz, S. R., Edlow, J. A., El-Kashlan, H., Fife, T., Holmberg, J. M., Mahoney, K., Hollingsworth, D. B., Roberts, R., Seidman, M. D., Steiner, R. W., Do, B. T., Voelker, C. C., Waguespack, R. W., & Corrigan, M. D. (2017). Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngology--head and neck surgery: official journal of American Academy of Otolaryngology-Head and Neck Surgery*, *156*(3_suppl), S1–S47. https://doi.org/10.1177/0194599816689667

Casani, A. P., Gufoni, M., & Capobianco, S. (2021). Current Insights into Treating Vertigo in Older Adults. *Drugs & aging*, *38*(8), 655–670. https://doi.org/10.1007/s40266-021-00877-z

Carender, W. J., Grzesiak, M., & Telian, S. A. (2021). Vestibular Physical Therapy and Fall Risk Assessment. *Otolaryngologic clinics of North America*, *54*(5), 1015–1036. https://doi.org/10.1016/j.otc.2021.05.018

De la Torre, J., Marin, J., Polo, M., Gómez-Trullén, E. M., & Marin, J. J. (2021). MCQ-Balance: a method to monitor patients with balance disorders and improve clinical interpretation of posturography. *PeerJ*, *9*, e10916. https://doi.org/10.7717/peerj.10916

Dunlap, P. M., Holmberg, J. M., & Whitney, S. L. (2019). Vestibular rehabilitation: advances in peripheral and central vestibular disorders. *Current opinion in neurology*, *32*(1), 137–144. https://doi.org/10.1097/WCO.0000000000000632

Filippopulos, F. M., Albers, L., Straube, A., Gerstl, L., Blum, B., Langhagen, T., Jahn, K., Heinen, F., von Kries, R., & Landgraf, M. N. (2017). Vertigo and dizziness in adolescents: Risk factors and their population attributable risk. *PloS one*, *12*(11), e0187819. https://doi.org/10.1371/journal.pone.0187819

Kiss, R., Schedler, S., & Muehlbauer, T. (2018). Associations Between Types of Balance Performance in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. *Frontiers in physiology*, *9*, 1366. https://doi.org/10.3389/fphys.2018.01366

Krawczyk-Suszek, M., Martowska, B., & Sapuła, R. (2022). Analysis of the Stability of the Body in a Standing Position When Shooting at a Stationary Target-A Randomized Controlled Trial. *Sensors (Basel, Switzerland)*, *22*(1), 368. https://doi.org/10.3390/s22010368

Lacour, M., Tardivet, L., & Thiry, A. (2021). Posture Deficits and Recovery After Unilateral Vestibular Loss: Early Rehabilitation and Degree of Hypofunction Matter. *Frontiers in human neuroscience*, *15*, 776970. https://doi.org/10.3389/fnhum.2021.776970

Lindell, E., Karlsson, T., Kollén, L., Johansson, M., & Finizia, C. (2021). Benign paroxysmal positional vertigo and vestibular impairment among older adults with dizziness. *Laryngoscope investigative otolaryngology*, *6*(3), 488–495. https://doi.org/10.1002/lio2.566

Maarsingh, O. R., Dros, J., Schellevis, F. G., van Weert, H. C., Bindels, P. J., & Horst, H. E. (2010). Dizziness reported by elderly patients in family practice: prevalence, incidence, and clinical characteristics. *BMC family practice*, *11*, 2. https://doi.org/10.1186/1471-2296-11-2

McDonnell, M. N., & Hillier, S. L. (2015). Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. *The Cochrane database of systematic reviews*, *1*, CD005397. https://doi.org/10.1002/14651858.CD005397.pub4

Michel, L., Laurent, T., & Alain, T. (2020). Rehabilitation of dynamic visual acuity in patients with unilateral vestibular hypofunction: earlier is better. *European archives of oto-rhino-laryngology: official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS): affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery*, *277*(1), 103–113. https://doi.org/10.1007/s00405-019-05690-4

Murdin, L., & Schilder, A. G. (2015). Epidemiology of balance symptoms and disorders in the community: a systematic review. *Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *36*(3), 387–392. https://doi.org/10.1097/MAO.0000000000000691

Nair, S., Gupta, A., Nilakantan, A., Mittal, R., Dahiya, R., Saini, S., Prasad, R., & Vajpayee, D. (2017). Impaired Vestibular Function After Cochlear Implantation in Children: Role of Static Posturography. *Indian J Otolaryngol Head Neck Surg*. 69(2):252-258. doi: 10.1007/s12070-017-1124-3

Neuhauser H. K. (2016). The epidemiology of dizziness and vertigo. *Handbook of clinical neurology*, *137*, 67–82. https://doi.org/10.1016/B978-0-444-63437-5.00005-4

Penger, M., Strobl, R., & Grill, E. (2017). Country-specific and individual determinants of dizziness in Europe: results from the Survey of Health Ageing and Retirement in Europe (SHARE). *Public health*, *149*, 1–10. https://doi.org/10.1016/j.puhe.2017.04.002

Petri, M., Chirila, M., Bolboaca, S., & Cosgarea, M. (2015). Unilateral peripheral vestibular disorders in the emergency room of the ENT Department of Cluj-Napoca, Romania. *Clujul medical (1957)*, *88*(2), 181–187. https://doi.org/10.15386/cjmed-412

Prell, T., Finn, S., & Axer, H. (2022). How Healthcare Utilization Due to Dizziness and Vertigo Differs Between Older and Younger Adults. *Frontiers in medicine*, *9*, 852187. https://doi.org/10.3389/fmed.2022.852187

Rosiak, O., Gawronska, A., Janc, M., Marciniak, P., Kotas, R., Zamyslowska-Szmytke, E., & Jozefowicz-Korczynska, M. (2022). Utility of the Novel MediPost Mobile Posturography Device in the Assessment of Patients with a Unilateral Vestibular Disorder. *Sensors (Basel, Switzerland)*, *22*(6), 2208. https://doi.org/10.3390/s22062208

Silva, C. N., Ribeiro, K. M., Freitas, R. V., Ferreira, L. M., & Guerra, R. O. (2016). Vertiginous Symptoms and Objective Measures of Postural Balance in Elderly People with Benign Paroxysmal Positional Vertigo Submitted to the Epley Maneuver. *International archives of otorhinolaryngology*, *20*(1), 61–68. https://doi.org/10.1055/s-0035-1565915

Skuladottir, A. T., Bjornsdottir, G., Nawaz, M. S., Petersen, H., Rognvaldsson, S., Moore, K., Olafsson, P. I., Magnusson, S. H., Bjornsdottir, A., Sveinsson, O. A., Sigurdardottir, G. R., Saevarsdottir, S., Ivarsdottir, E. V., Stefansdottir, L., Gunnarsson, B., Muhlestein, J. B., Knowlton, K. U., Jones, D. A., Nadauld, L. D., Hartmann, A. M., … Stefansson, K. (2021). A genome-wide meta-analysis uncovers six sequence variants conferring risk of vertigo. *Communications biology*, *4*(1), 1148. https://doi.org/10.1038/s42003-021-02673-2

Stam, H., Harting, T., Sluijs, M. v., van Marum, R., Horst, H. v., Wouden, J. C., & Maarsingh, O. R. (2016). Usual care and management of fall risk increasing drugs in older dizzy patients in Dutch general practice. *Scandinavian journal of primary health care*, *34*(2), 165–171. https://doi.org/10.3109/02813432.2016.1160634

Strupp, M., Walther, L. E., Eckhardt-Henn, A. & Zitz, P. F. (2013). Diagnosis of vertigo: keep an eye on central eye movement disorders. *Ophthalmologe*. 110(1):31-8

Tighilet, B., Péricat, D., Frelat, A., Cazals, Y., Rastoldo, G., Boyer, F., Dumas, O., & Chabbert, C. (2017). Adjustment of the dynamic weight distribution as a sensitive parameter for diagnosis of postural alteration in a rodent model of vestibular deficit. *PloS one*, *12*(11), e0187472. https://doi.org/10.1371/journal.pone.0187472

Van Vugt, V. A., van der Wouden, J. C., Essery, R., Yardley, L., Twisk, J., van der Horst, H. E., & Maarsingh, O. R. (2019). Internet based vestibular rehabilitation with and without physiotherapy support for adults aged 50 and older with a chronic vestibular syndrome in general practice: three armed randomised controlled trial. *BMJ (Clinical research ed.)*, *367*, l5922. https://doi.org/10.1136/bmj.l5922

Vaz, D. P., Gazzola, J. M., Lança, S. M., Dorigueto, R. S., & Kasse, C. A. (2013). Clinical and functional aspects of body balance in elderly subjects with benign paroxysmal positional vertigo. *Brazilian journal of otorhinolaryngology*, *79*(2), 150–157. https://doi.org/10.5935/1808-8694.20130027

Yin, M., Ishikawa, K., Wong, W. H., & Shibata, Y. (2009). A clinical epidemiological study in 2169 patients with vertigo. *Auris, nasus, larynx*, *36*(1), 30–35. https://doi.org/10.1016/j.anl.2008.03.006