Is My Balance Disorder Patient improving with this Rehabilitation Treatment? Rapid Stabilometric platform test

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Abstract:

The aim of the present study is to compare the results of a rapid stabilometric platform test with traditional clinical scales to assess the clinical evolution of heterogeneous patients with balance disorders during rehabilitation treatment. The 67 participating vertigo patients underwent two assessment sessions, one before starting rehabilitation treatment and one after starting treatment. In each session, six static balance assessment tests with the stabilometric platform were accomplished. The centre of pressure (COP) measured by the device, was processed using the MCQ-Balance method, that transforms the signal into clinical interpretable results. To compare the results, three medical diagnostic tests were conducted and a methodical flag system to classify their results was proposed. The agreement rises until 85.71% with a contingency coefficient of 0.751 and a Kappa of 0.775. The platform showed a sensitivity of 100% with a specificity of 72.99%. Furthermore, it was not found false negatives in the platform. The stabilometric platform provided valuable assistance in the diagnosis of the evolution of balance pathology.

1. Introduction

An imbalance occurs when one of the three systems that control balance –visual, vestibular and somatosensory- is disturbed [1,2]. The etiologies that can cause vertigo are: vestibular, neurological, cervical, and persistent postural-perceptual dizziness (PPPD).[3,4,5,6,7]

The aim of vestibular rehabilitation is to eliminate vertiginous clinical symptoms, reduce instability and the risk of falls, and return the patient to normal activities as soon as possible. It consists of carrying out a programme of exercises aimed at promoting the greatest possible compensation of the vestibular system, or selecting substitution strategies according to the need of each patient. [8] Vestibular rehabilitation and the prescription of its exercises has shown clinical improvement in neurological vertigo, acting, as in vestibular vertigigo, on the somatosthetic balance system [9]. [10]. [11].

In rehabilitation, it is essential to assess the progression of a patient´s balance between two separate consultations in order to objectify the response to treatment [12]. This helps to determine whether there have been relevant changes in the patient, influencing treatment decision-making.[13,14] There are clinically applicable functional tests that assess balance and vertiginous intensity [1,15,16,17].

Stabilometric Platform studies the control of posture through the movements of the centre of pressure (COP) on a mobile or fixed forces platform. [5] Stabilometric Platform are able to determine which balance control system (vestibular, somatosensory or visual) is affected. [18]

The MCQ-balance method [19,20,21,22], that transforms the COP signal into clinical interpretable results, was recently developed. Thus, based on functional tests performed on the platform, an intelligent and automatic scoring system is used that provides a comparative result between two measurement sessions to find out whether the patient has improved their balance between sessions, identifying whether the improvement has been visual, vestibular, somatosensory or a combination of these.

This method still needs to be checked against clinical criteria and scales. In other words, it must be known whether the result of the stabilometric platform combined with the MCQ-balance method[19,20,21,22], which is, objective, intuitive and requires little training, can be compared with a clinical assessment accomplished by doctors using traditional clinical examination. If both assessments converge, it would indicate that the platform and the MBQ method can facilitate the work of clinicians in making treatment decisions.

Thus, the aim of this study is to compare the assessment of clinical evolution in patients with different balance pathologies, before and after rehabilitation treatment, using traditional clinical criteria and scales, versus the results obtained from a stabilometric platform combined with the MCQ-balance method.

2. Materials and Methods

2.1. Participants

The sample consisted of 67 patients with vertigo referred to the Rehabilitation Service of the Hospital de Alcañiz (Teruel, Spain).

The inclusion criteria for the sample were as follows:

1- To be over 20 and under 70 years of age
2- To have experienced a vertigo episode with a demonstrable vestibular, neurological or cervical cause in the year prior to the first visit to the rehabilitation physician.

The exclusion criteria for the sample were as follows:

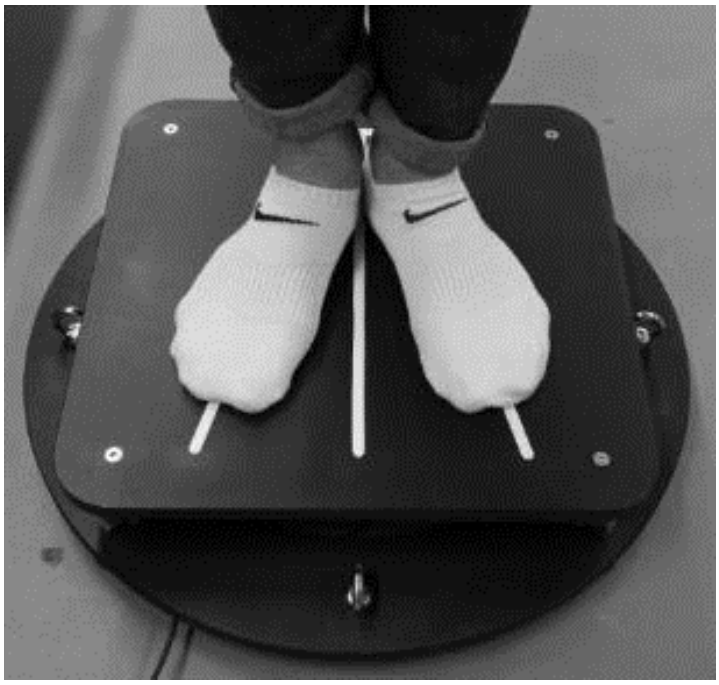
1- To present vertigo with an obvious phobic etiology
2- To present acute musculoskeletal pathology in the lower limbs or lumbar spine, this could alter the result of the stabilometric platform
3- To have any amputation of lower limbs
4- Presenting unresolved visual problems
5- Oncological pathology in active treatment.

2.2 Stabilometric platform

In this study, a static stabilometric platform was used for posturography designed and manufactured by the IDERGO research group (Engineering Research Institute of Aragon, I3A, of the University of Zaragoza), which was validated in previous studies [19,20,21,22].

It is a research device made up of four load cells and a light aluminium structure, whose dimensions and characteristics are detailed in the study by De la Torre et al.[22] The acquisition and processing of the platform data, as well as the format and export method, were carried out according to the procedure used by this author in 2017[22]

Fig.1. Patient position: feet well aligned in the centre of the platform and at 30



2.3. Experimental protocol

All tests and assessments were carried out at the aforementioned Rehabilitation Service. The team consisted of two doctors, a nurse and a biomedical engineer. The study was approved by the Research Ethics Committee of the Community of Aragon (C.P. – C.I. PI18/377). All selected participants signed a consent form for their participation in the study.

Participants accomplished the clinical tests and the stabilometric platform test at the beginning of the study and three months after the rehabilitation treatment. The first consultation in which the first captures with the stabilometric platform were performed was one month before the start of treatment. The second consultation in which the second captures with the stabilometric platform were performed was one month after the fifth week of active treatment.

The sample was divided into three groups according to aetiology, and the vestibular rehabilitation exercises to be performed daily for three months were given and explained at the consultation. [23].

In each test session, regardless of the etiology causing their vertiginous condition, data derived from the anamnesis, examination (Get Up and Go Test, Unterberger Test, Unipodal support time)[1], and stabilometric platform were recorded.

On the stabilometric platform, the Romberg Test is carried out in its four variants, which analyse balance in a static situation: Romberg on rigid surface with eyes open (RSEO), Romberg on rigid surface with eyes closed (RSEC), Romberg on soft surface with eyes open (SSEO), Romberg on soft surface with eyes open (SSEC). A foam cushion[24,25] was used to alter the proprioceptive system.

In the LOS (Limits of Stability) test the patient had to try to reach a ball moving in the screen thought eight radial directions. This allows to measure the area through which a person can move their COP. These limits are directly related to the risk of falling.[26]

2.4. Proposed Flag System

In order to compare the data provided by the platform to the anamnesis and functional test accomplished, a vertigo flag system was developed. This system allows to systematically classify the evolution of the anamnesis and functional test between two sessions, concluding if the patient had positive change, no change, or negative change.

To use the system, the clinician has to compare the patient´s vertigo detected in each sign or symptom of the anamnesis and functional tests, between two measurements. With the results of both sessions, the clinician has to check (activate) all those boxes of Table 1 that apply to the patient. After that, the clinician must sum the scores of the marked (activated) boxes, considering that some can add (improvements) and others can subtract (worsening).

Table 1 is divided into three columns, one for each type of flag. The flags are associated with the importance of the change in symptoms or signs, whether it is an improvement or a worsening.

The difference in importance with Flags is essential since not all signs or symptoms have the same clinical value to assess a change. Therefore, it is proposed that the red flag implied one point (positive if there was improvement in change and negative if there was worsening), the orange flag implied half a point and the yellow flag a quarter of a point (with the same positive and negative characteristics as the red flag).

The final score could range from -6.5 (absolute worsening) to +6.5 (absolute improvement). Nevertheless, to clinically interpret this result, it is proposed to qualitatively classify the final score as a positive change when it is greater or equal than 1 and as a negative change when it is less or equal than -1. All between 1 and -1, indicates no change in the patient. This classification is related to the nature of the flag system, where a red change of one point (whether positive or negative) has importance enough to justify an overall evolutionary change on its own.

Table 1 Vertigo flag system to classify the evolution of the patient´s vertigo considering anamnesis and functional test.

	RED FLAGS Change of high importance ±1		**ORANGE FLAGS Change of medium importance ±0.5**		**YELLOW FLAGS Change of low importance ±0.25**	
ANAMNESIS						
Episodes	Presence of 2 episodes or more	-1	Longer duration being important for the patient	-1		
	Reduction in 2 episodes or more	+1	Shorter duration being important for the patient	+0.5		
Pain					Instability and pain had worsened	-0.25
					Instability and pain had improved	+0.25
Instability	One or more falls more than in the previous month	-1	Presence of instability with positional change	-1		
	One or more falls less than in the previous month	+1	Absence of instability with positional change	+0.5		
Drugs					Need for the use of specific drugs	-0.25
					No Need for the use of specific drugs	+0.25
Visual perception			Presence of turning objects	-1		
			Absence of turning objects	+0.5		
Vegetative break			Presence of vegetative break	-1		
			Absence of vegetative break	+0.5		
EXPLORATION						
Dynamic tests	Worsening Unterberger Test	-1	Worsening 2 seconds Get Up and Go Test:	-1		
	Improving Unterberger Test	+1	Improving 2 seconds Get Up and Go Test	+0.5		
Static tests			Worsening 2 seconds Unipodal Support Test	-1		
			Improving 2 seconds Unipodal Support Test	+0.5		

* **How to use:** Check all those boxes that apply to the patient, and sum the scores.
* **Qualitative classification:** Final score >=1: Positive change, <1 Final Score >1: No change, Final <=-1 Negative change

Once the anamnesis and examination scores were obtained, the final clinical score was obtained. If both were +1, 0 or -1, the final clinical score was the same. In those patients where the anamnesis and examination scores did not agree, priority was given to the score with the most red flags, and

in the event of a tie, to the score with the most orange flags, and in the event of a tie, if there were yellow flags in the anamnesis, giving that value. In the event that there were no yellow flags in the anamnesis, the value of the exploration was given precedence.

2.5. MCQ-Balance Method

The method developed to assess balance progression using a clinically validated score is detailed in depth in the articles by De la Torre et al. [19,20,21,22].

The MCQ-Balance assessment consists of three stages in which the progression of a patient's balance is Measured (M), Classified (C), and Qualified (Q)[30]. The method inputs are the balance test variables at two temporal points, i.e., the values of the variables at pre-session and post-session. The outputs of the method are conclusions in natural language, providing information about the Balance Sensory Systems (BSS) involved in the progression of a patient's balance, facilitating the clinician to adapt medical treatment, focusing on the balance disorder of the patient.

Subsequently and according to the study by De la Torre et al. [19,20,21,22] the following variables were selected as being the most significant for diagnostic purposes in balance assessment studies: the range of displacement in the anteroposterior and mediolateral directions in mm, area in cm^2 (surface area covered by the COP trajectory,), average COP velocity in mm/s and RMS position in mm. Additionally, in the limits of stability (LOS) test, two more variables were evaluated: the COP limits in mm (maximum displacement achieved along each axis of the octagon radii), and the "success" variable in percentage (quantification of COP handling and coordination along each axis of the octagon radii), both defined in previous studies [19,20,21,22].

The stages of the method and its most relevant aspects are described below:.

Stage 1: Measure

The first stage of the method involves measuring the progression of the balance variables previously selected by detecting relevant changes between two measures of each variable recorded at different temporal points . For this purpose, the method used in this stage is the Magnitude Based Decision (MBD) statistical method.

Stage 2: Classify

The second stage of the method consists of classifying the progression of each patient using a discrete scoring. Negative scoring (-2 y -1: clinical worsening), null scoring (0: no progression) and positive scoring (+1 y +2: clinical improvement) are the possible values selected to classify balance progression.

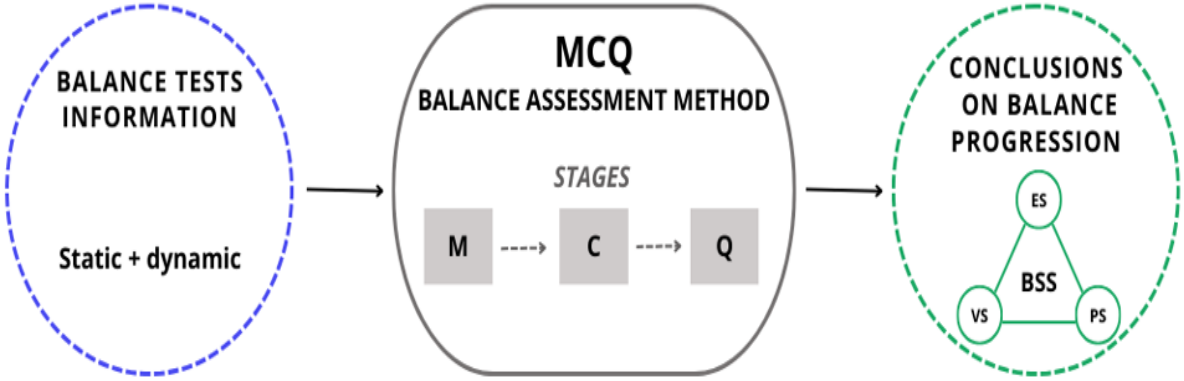
To facilitate the interpretations for the clinician, given the greater specificity of the platform than the clinical exploration tests, in order to determine the changes that have occurred, it was decided to homogenize the negative and positive markers. In any case, the -2 and -1 worsening of the platform, for this study, were catalogued as -1 and the same with the improvements, in which +1 and +2 were catalogued as +1.

Stage 3: Qualify

The third and final stage qualify the balance progression and the influence of the BSS involved based on the scores resulting from stage two. The results from this stage are conclusions written in natural language for clinicians, providing information about the BSS involved in the progression of a patient's balance.

Simplified description of the MCQ method, inputs and outputs. M: Measure; C: Classify, Q: Qualify;

BSS: Balance Sensory Systems; ES: Eye-Sight System; PS: Propioceptive System; VS: Vestibular System.



Once we had obtained the final clinical assessment and the final platform assessment, we compared them. If the value of both (negative, neutral or positive) coincided, we spoke of concordance. We accepted concordance if the direction of evolution coincided between the two assessments, regardless of the numerical value, since the platform measured the change that had occurred in greater depth than the clinical assessment.

When a discrepancy between the clinic and the platform was noted, the patient´s medical records were reviewed to try to find an explanation for the discordance. If an explanation was found, the patient was treated as an explainable discordance. If we did not find one, we referred to the discrepancy as an unexplained discordance. Once the concordances and discrepancies were obtained, we proceeded to calculate the percentage of clinical-platform concordance, the contingency coefficient and the Kappa value.

2.6. Statistical comparative analysis

The Flag system allows to make a comparative statistic with the objective data extracted from the platform. In this manner, each patient has two numberings: one for each sign and symptom from the anamnesis assessments (flag system) and one resulting from the balance test. The codings should be summarised in a single score for each assessment: "Anamnesis and examination" and in turn in a single "Final clinical assessment" for each patient.

We used the statistical software IBM SPSS statistics Version 25for the statistical analysis of the data. To make the comparison between the MCQ-Balance (Measured (M), Classified (C), and Qualified (Q) Balance) assessment results and the assessment of clinician 3, the Cohen's Kappa statistical coefficient (κ) was chosen, [27]. Likewise, the confusion matrix was calculated to obtain the accuracy and percentage of false negatives.

3. Results

We recommend reviewing the supplementary material to the article with the Clinical Situation and Platform Situation, including Discordances, of the 67 participants.

With respect to the total sample, there are 31 patients in whom there is a discordance between the clinical findings and the result of the stabilometric platform. Of these 31, there are 25 in which some type of reason or motive can be recognised that may explain this discordance.

Table 2 show the situation of the clinical-platform concordance. In 6 patients there is a clinical-platform discordance for which we have not found an answer.

Table 2: Concordances

Sample of 67 patients	
Clinical-platform concordance	53,73%
Contingency coefficient	0,537
Kappa Value	0,331
Sample of 42 patients (25 explainable discrepancies discounted)	
Clinical-platform concordance	85,71%
Contingency coefficient	0,751
Kappa Value	0,775

4. Discussion

In line with the aim of this study, the clinical evolution of these patients with different balance pathologies who underwent vestibular rehabilitation treatment was compared with the results obtained from a stabilometric platform in combination with the MCQ-balance method.

From this comparison, each of the study participants could present clinical-platform concordance, explainable discordance or non-explainable discordances. Regarding concordances, as can be seen in the results, if explainable discordances were eliminated from our sample, both the contingency coefficient and the Kappa index improved substantially. The total number of explainable discordances was 25 out of 67 cases. Explainable discordances lead us to calculate concordance data without these patients, as we know that there was a cause that can be said to invalidate or falsify the test result.

The reasons for the discordances could be explained as follows:

Six patients in the sample were classified as having a vestibular, neurological or cervical etiology, while having another etiology. For example, if the patient was classified as vestibular and at the same time had another undetected cervical pathology origin. If we have treated exclusively the vestibular pathology, the platform may detect that the cervical pathology is causing problems, even though the patient is feeling better. The reverse is even clearer. If have treated the patient as having a cervical etiology, even if the patient is feeling better, the more complicated the platform tests are, the more the vestibular deficit is detected, as the vestibular deficit produces a more "pure" vertigo.

In four patients we must recognise the presence of phobic vertigo as a double etiology associated with one of the other three origins. If the psychological situation of the patient is not adequate, the platform can recognise the discordance between what the patient says and the objective evidence. Therefore, these patients would not be included in the study if it were to be repeated and would force us to be even more selective with the inclusion and exclusion criteria.

Two patients with benign paroxysmal positional vertigo (vestibular etiology) who meet seasonally, given the behaviour of this pathology in the form of crises. The patient may refer to feeling very bad because of a recent crisis, but if the crisis is resolved, the platform will give the tests as non-pathological.

There were three patients who did not report balance problems on the second time they performed the platform test, but nevertheless, the test did not go well because they were suffering from flu, pneumonia or a recent bee sting. In any case, this had a negative influence on the process of performing the test itself, even without active vertiginous pathology. We must recognise that these circumstances should have been taken into account and the test postponed.

In another case, during the second round of platform tests, a patient was not concentrating because he was more concerned about a family member who was out of the office than about the test. This explains why the test did not go well, as the platform requires concentration.

Four patients, during the second performance of the tests, worsened their recordings and it was necessary to stop the test several times. The explanation is that the test itself may have caused a vertiginous crisis. It should also be recognised that the possibility that the fact of knowing the test for the second time, compared to the first, can produce a suggestion that incites the crisis (in the form of phobic vertigo).

Five patients reported feeling well, yet the platform reported the opposite. Within less than three days, they had to go to the emergency room or to their primary care physician because of a vertiginous crisis. In other words, the platform can be considered to have "predicted" the vertiginous crisis. The platform pointed out false negatives in the anamnesis and examination.

We did not obtain an explanation for the discordance in six other patients.

Better concordance was observed for cervical and neurological etiology than for vestibular etiology. Patients with vestibular pathology present a clinical picture that usually behaves in episodes, the examination between episodes is normal, while the other two etiologies present a greater persistence of their clinical picture over time and it is easier for the clinician to measure pre- and post-treatment changes. However, the platform used in the study was able to detect the instability of the vestibular clinic, even between vertiginous episodes, which was impossible for the clinician to detect in the examination.

According to a meta-analysis, the sensitivity and specificity of stabilometric platforms is around 50% [29]. The platform used in this study showed no falses negatives, it had 100% sensitivity. All patients, in whom the platform showed a clinical worsening or stabilisation of their severe vertiginous condition, coincided with the clinician´s anamnesis and examination.

The usefulness of a balance platform in real clinical practice, which had already been tested in previous studies on healthy volunteers, has been demonstrated[20]. A smaller platform than the traditional stabilometric platforms, with the advantage of ease of use and transport that this entails for its use in clinical practice.

As limitations of the study, we consider it important to mention that the sample was small. Another limitation of the study is that we left it up to the patients to perform the vestibular rehabilitation exercise protocol on an outpatient basis.

The clinical situation of the majority of the 67 patients in the sample improved with the proposed treatment, but more studies are needed with a larger sample to obtain the reasons for the non-improvements found, although we believe that this may be related to the low adherence to rehabilitation treatment [30,31].

It is important, given the evolution of technology, that devices capable of measuring the clinical evolution of different pathologies are available in the clinical world. Even that patients could be able to see their evolution at home, with clear and simple information. This could be an interesting tool both for future telerehabilitation systems and for the system to gather information from many patients in order to apply automatic learning techniques, even applying the possibility of artificial intelligence.

5. Conclusions.

Using a stabilometric platform, whose diagnostic algorithms have already been approved in previous studies, the concordance of the results of its tests with the traditional study of vertigo was verified. The results of the platform and the traditional examination, eliminating explainable discordances, coincide in acceptable percentages (85.71% of cases). It is important to highlight the absence of false negatives in the platform, given the importance of the non-existence of these in a complementary test. The platform has shown a sensitivity of 100% with a specificity of 72.99%. Consequently, the platform seems to be a good complementary tool to clinical tests.

Conflicts of Interest: The authors declare that they have not conflicts of interest.

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