MCQ-Balance: A method to monitor patients with balance disorders and improve clinical interpretation of posturography

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Globally, approximately 20 to 30% of the world population has suffered a vertiginous episode, and of this group, 20% do not receive a clear diagnosis. Improved methods, indicators and metrics are necessary to assess the balance sensory systems, especially during treatments; patients with balance disorders should be monitored for changes at the individual level to gather objective information. For this purpose, we propose the MCQ-Balance assessment for examining a patient's balance progression using tests to measure static balance control and dynamic postural balance with a stabilometric platform. The method comprises three stages: i) measuring the progression of each variable between two separate and consecutive days (called sessions) using the Magnitude Based Decision analysis to detect changes; ii) classifying the progression of the patient's balance with a score; and iii) qualifying progression from the resulting scores using a set of rules. This method was applied to 42 patients with balance disorders characterised by vertigo, of peripheral or central origin, as the cardinal symptom. Balance progression was measured between two sessions spaced three months apart, and to discuss the potentialities and limitations of the proposed method, the results of the patients were compared with the assessment of a clinical expert. Results were presented for each patient and test as a gradual scale of positive, null or negative progression, also assessing the balance sensory systems. The results of the comparison between the MCQ-Balance assessment and the assessment of a clinical expert showed an accuracy of 83.4% and a Cohen’s Kappa coefficient of 0.752. We concluded that the proposed method facilitates the monitoring of patient balance and provides objective information that would allow adjusting of treatment at an individual level, thus improving medical decision making.

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Abstract

Globally, approximately 20 to 30% of the world population has suffered a vertiginous episode, and of this group, 20% do not receive a clear diagnosis. Improved methods, indicators and metrics are necessary to assess the balance sensory systems, especially during treatments; patients with balance disorders should be monitored for changes at the individual level to gather objective information. For this purpose, we propose the MCQ-Balance assessment for examining a patient's balance progression using tests to measure static balance control and dynamic postural balance with a stabilometric platform. The method comprises three stages: i) measuring the progression of each variable between two separate and consecutive days (called sessions) using the Magnitude Based Decision analysis to detect changes; ii) classifying the progression of the patient's balance with a score; and iii) qualifying progression from the resulting scores using a set of rules.

This method was applied to 42 patients with balance disorders characterised by vertigo, of peripheral or central origin, as the cardinal symptom. Balance progression was measured between two sessions spaced three months apart, and to discuss the potentialities and limitations of the proposed method, the results of the patients were compared with the assessment of a clinical expert. Results were presented for each patient and test as a gradual scale of positive, null or negative progression, also assessing the balance sensory systems. The results of the comparison between the MCQ-Balance assessment and the assessment of a clinical expert showed an accuracy of 83.4% and a Cohen’s Kappa coefficient of 0.752.

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Introduction

Vertigo is an illusion of movement, either of the external world revolving around the individual or of the individual revolving in space (Medical Subject Headings (MeSH), 2020). It is the cardinal symptom of balance disorders and usually associated with the symptoms of vasovagal syncope, which leads to a significant reduction in the quality of life and an increase in disability, anxiety and depression (Neuhauser, 2016). There is a high prevalence of balance disorders among elderly people in developed countries (Penger, Strobl, & Grill, 2017; Rubenstein, powers, & maclean, 2002). In combination with a gradual increase in the ageing index of the population (Gavrilov & Heuveline, 2003; Muir, Kiel, Hannan, Magaziner, & Rubin, 2013; Vaupel & Loichinger, 2006), it has resulted in an increase in the risk of falls of elderly people (Aftab, Robert, & Wieber, 2016; Khalaj, Osman, Mokhtar, Mehdikhani, & Abas, Wan Abu Bakar Wan, 2014). Globally, approximately 20 to 30% of the population has a vertiginous episode of various origins and severity over a lifetime (da Costa Barbosa & Vieira, 2017; Lin, Seol, Nussbaum, & Madigan, 2008; Tinetti, 2003; Wolf et al., 1996). Moreover, 20% of them do not receive a clear diagnosis (Swanenburg, de Bruin, Favero, Uebelhart, & Mulder, 2008).

Vertigo is most often caused by dysfunction resulting from a peripheral or central lesion (Stanton M, 2020 Apr 28); therefore, depending on the origin, it can be classified as vertigo of peripheral or central origin (Baumgartner B, 2019 Jun 3; Strupp, Dieterich, & Brandt, 2013). Vertigo of peripheral origin is characterised by sudden crises of short duration, sometimes with associated auditory symptomatology and more prominent vasovagal symptoms in comparison to central vertigo, which is mainly represented by vertigo with a vestibular origin (Wipperman, 2014). Likewise, vertigo with a cervical origin could also be included in this group, with a demonstrated relationship between cervicalgia and vertigo (Dieterich & Eckhardt-Henn, 2004; Reiley, Vickory, Funderburg, Cesario, & Clendaniel, 2017). In contrast, vertigo of central origin is usually continuous and prolonged over time. Generally, its appearance is progressive with associated instability, vasovagal symptoms and a slow recovery. It is also described as vertigo with a neurological origin (Solomon, 2000).

To analyse the causes of vertigo, the degree of alteration must be measured in isolation or in combination of each balance sensory system (BSS), including the vestibular (VS), visual (ES; eye-sight), and proprioceptive (PS) systems. A vertiginous episode or trauma can affect these systems to a greater or lesser extent, and consequently, the patient's balance (Hanes & McCollum, 2006; Shumway-Cook, A., Woollacott, Shumway-Cook, & Woollacott, 2001). It is therefore necessary to have methods or indicators to determine how the BSS progresses, especially during a balance disorder treatment (Patrícia Paludette, Fabrício Santana da, & Carlos Bolli, 2015).

When it is challenging to establish a clear pathology related to any of the BSSs, or when multiple origins of the condition are found, the clinical diagnosis becomes complicated (Derebery, 2000; Swanenburg et al., 2008), and additional measures and tests are required to provide important information to the clinician. In this regard, certain functional balance assessments are frequently used, including the Unterberger test (Hickey, Ford, Buckley, & O'connor, 1990), the Up and Go test (Martínez Carrasco, 2016; Shumway-Cook, Brauer, & Woollacott, 2000) and the unipodal support test (Vellas et al., 1997), although their reliability and scope are improvable (Martínez Carrasco, 2016).

As an alternative or complement to the functional tests, using a stabilometric platform, posturography allows movements of the centre of pressure (COP) in the standing position to be measured. It constitutes a functional assessment with medical-legal validity that provides objective information regarding balance disorders in clinical practice (de la Torre, Marin, Marin, Auria, & Sanchez-Valverde, 2017; Dounskaia, Peterson, & Bruhns, 2018; Lin et al., 2008). Although posturography is a validated assessment, difficulties are encountered with regard to discerning the origin caused by the imbalance pattern. This is because, although sensory analyses suggest a proprioceptive-visual-vestibular pattern, this is not always accurate (El-Kashlan, Shepard, Asher, Smith-Wheelock, & Telian, 1998; Stewart et al., 1999; Timothy C. Hain, May 5, 2019). Related to the above, although the clinical results from traditional posturography are useful, they are insufficient in certain cases, requiring smarter devices (Allum, Zamani, Adkin, & Ernst, 2002; Di Fabio, 1996).

Posturography devices can provide useful information in clinical decision-making at the individual level of each patient; however, they would be required to be practical and manageable. For this, they should not require additional experts or clinicians for their use because this would entail high costs, and the test would lose practicality for clinical use (Visser, Carpenter, van der Kooij, & Bloem, 2008). Regarding this, the clinical information obtained from posturography reports should be clear, concise, and easily interpretable by clinicians and be sufficiently supported to achieve an adequate functional assessment value. However, currently, posturography reports do not offer enough depth to reach the importance that other tests currently have (e.g. imaging tests) (Climent Barbera JM, 2003; Visser et al., 2008). Likewise, most studies are focused on evaluation at the group level, requiring more studies at the individual level (Visser et al., 2008).

Other authors have also delved into this idea and considered that the posturography report should provide concise information about the patient's balance status and, if possible, the BSS that has the greatest influence on the patient's imbalance (Derebery, 2000). Likewise, the report should be provided with enough automation so that it does not require long periods of processing for analysis and interpretation. It should be supported in an understandable language without the technicalities that usually accompany certain medical equipment (Visser et al., 2008; Von Lubitz & Wickramasinghe, 2006). Likewise, both validation and standardization of the protocols for reproducibility and a possible comparison with similar studies are required (Visser et al., 2008).

Although several balance assessment tests have been applied through a stabilometric platform (Karlsson & Frykberg, 2000), their resulting scores are sometimes complex and difficult to interpret (Peterson, Ferrara, Mrazik, Piland, & Elliott, 2003). Moreover, difficulties exist in using subjective scoring due to the lack of standardization and interpretation, which makes it difficult to diagnose balance disorders and identify the BSS that originate this imbalance pattern (Jacobs, Horak, Tran, & Nutt, 2006; Saxena & Prabhakar, 2013; Visser et al., 2008).

In rehabilitation, it is critical to measure the progression between two separate sessions and to objectively characterise the response to treatments to improve medical decision-making (Hamburg & Collins, 2010). With this objective, to monitor the patient, it is especially vital to determine whether relevant changes have occurred in a patient at the individual level between two measures obtained at different temporal points (Hopkins, Will G., 2017; Visser et al., 2008). Regarding this, we can highlight the proposal of (Hopkins, 2017) to assess the change between two measurements in an individual through the magnitude-based decision (MBD) method (Hopkins, Will G., 2017), which is used in this work.

In this paper, we propose an assessment called the MCQ-Balance to detect relevant changes between two consecutive balance tests (monitor) with a stabilometric platform in patients with balance disorders and provide objective information. This method comprises three stages: (i) measuring the progression of each variable of a set of balance tests between two separate and consecutive days (called sessions) using the MBD analysis method to detect changes in the patient; (ii) classifying the progression of the patient's balance with structured and interpretable scoring; and (iii) qualifying the progression from the resulting scores, thereby allowing clinicians

to discern the altered BSS and assess its progression. This method was applied to 42 patients with balance disorders with vertigo, of peripheral or central origin, as the cardinal symptom. The progression between two separate sessions spaced three months apart was measured. In addition, to discuss the potentialities and limitations of the method, as well as to show whether it achieves its intended purpose, we compared the patient results provided by the method with the assessment of a clinical expert.

Materials & Methods

Participants and ethics statement

In the present work, a sample of 42 patients with balance disorders characterised by vertigo, of peripheral or central origin, as the cardinal symptom was monitored via balance tests with a stabilometric platform.

The patients were referred by the Primary Care, Otorhinolaryngology and Neurology Services of the Alcañiz Hospital (Teruel, Spain) after being diagnosed with a balance disorder. The methods for determining the deficit, whether peripheral or central, varied according to the service where the diagnosis was made: i) in Primary Care, medical history was considered; ii) in Otorhinolaryngology, in addition to the medical history, magnetic resonance imaging, videonystagmography, and tests such as the Dix-Hallpike manoeuvre were used; and iii) in Neurology, in addition to medical history, magnetic resonance imaging, computerised axial tomography and neurophysiology tests, such as auditory evoked potentials, were used. Table 1 presents the main diagnoses of the patients with respect to peripheral or central deficits. The data of general and anthropometric patients are presented in Table 2, illustrating no difference between gender because no statistically significant differences occurred in the results (Yin, Ishikawa, Wong, & Shibata, 2009).

Table 1 about here

Table 2 about here

From these diagnostic services, patients were referred to the Rehabilitation Service (Physical Medicine and Rehabilitation Service (PM&R) of the Alcañiz Hospital), having been identified with vertigo as the cardinal symptom. A doctor (clinician 1) of the PM&R service then evaluated the patients, considering i) their medical history and physical examination, ii) previous diagnosis and iii) results of the functional balance assessments, such as the Unterberger test (Bartual & Pérez, 1998; Hickey et al., 1990), up and go test (Martínez Carrasco, 2016; Shumway-Cook et al., 2000), and unipodal support test (Vellas et al., 1997). The selected patients met the following inclusion criteria: (i) between 35 and 70 years old and (ii) having suffered a vertiginous episode of peripheral or central origin in the last year. The following were the exclusion criteria: (i) presented acute osteomuscular pathology in the lower limbs or lumbar spine, which may alter the

outcome of the stabilometric platform, (ii) presented any amputation in the lower limbs, or (iii) presented oncological pathology or was in active treatment with chemotherapy, radiotherapy, or hormonal therapy.

Patients were evaluated by clinician 1 on two different days (sessions) spaced three months apart (first session: pre-session; second session: post-session). After the pre-session, clinician 1 prescribed the rehabilitation treatment according to the specific balance disorder of each patient. Patients with vertigo of peripheral or central origin performed vestibular rehabilitation exercises (Boomsaad, Telian, & Patil, 2017). For patients with a specific diagnosis of benign paroxysmal peripheral vértigo (BPPV), the Epley manoeuvre was performed in addition to vestibular rehabilitation exercises (Hansson, Persson, & Malmström, 2013; Orejas, Varea, Rodrigo, & Navas, 2020).

After the evaluation by clinician 1, in each session (pre and post), the patients conducted the set of balance evaluation tests with a stabilometric platform (three months apart between the pre- and post-session). The tests were performed by the PM&R of the Alcañiz Hospital between February and July in 2019. The fieldwork was performed by a team of a clinician (clinician 2), a nurse, and a technician in the same hospital.

The present study was approved by the Research Ethics Committee of the Community of Aragon (CEICA) (January 16, 2019). Prior to the start of the tests, the participants signed a consent form sheet that involved accepting the tests and understanding the purpose of them. The participants in this study has given written informed consent to publish these case details.

Instrumentation, protocol, and variables

The device used was the stabilometric platform MoveHuman-Dyna UZ, which was designed and manufactured by the IDERGO (Research and Development in Ergonomics, University of Zaragoza, Spain) research group (see Figure 1). It is a static posturography device designed for research and is currently not commercially applicable. It comprises four load cells and a lightweight aluminium structure, whose dimensions and characteristics are detailed in the study of Delatorre et al. (2017). The acquisition and processing of the platform data, as well as the format and method of exporting them, have been carried out according to the procedure used by (de la Torre et al., 2017). Processing the force data in function of the cells' position means we can calculate the real-time position of the trajectory that describes the position of the CoP by applying the appropriate formula (López & Calidonio, 2009; Ma, Wong, Lam, Wan, & Lee, 2016).

Likewise, in accordance with the aforementioned study, the stabilometric platform 'meets the standards established by the International Society for Posture and Gait Research (ISPGR) for its clinical application' (Scoppa, Capra, Gallamini, & Shiffer, 2013) in relation to various parameters, such as accuracy, precision, linearity, dimensions, resolution, sampling, and so on. The precision parameters (accuracy, precision, linearity, dimensions and resolution) were obtained through an experiment in which the metrological characteristics of the platform were tested with a gold standard force platform, as well as the error of measurement (de la Torre et al.,

2017). Likewise, the stabilometric platform has been used in different studies and research projects with patients in different hospitals: "Clinical Test based on Smart Health Technology to Assess Personalized Rehabilitation Treatments with Botulinum Toxin in Patients with Spasticity" in the public hospital Miguel Servet (Zaragoza, Spain); "Biomechanical behaviour of the talus-calcaneus joint during gait to design a prosthetic prototype for joint replacement of the talus" in the public university hospital Lozano Blesa (Zaragoza, Spain); "Mobile units for functional assessment of the musculoskeletal system" in hospital MAZ (Zaragoza, Spain). These studies were approved by the CEICA Committee (the respective references of the studies/research projects are: CEICA, June 20, 2018; CEICA, January 31, 2018; OTRI-2019/0108). In addition, the characteristics of the platform and its portability make it suitable for clinical use where, for example, the medical office space is limited (de la Torre et al., 2017; Scoppa et al., 2013). The conditions of the consultative environment where the tests were conducted (e.g. noise, space, etc.) were defined according to (Scoppa et al., 2013) and (Kapteyn et al., 1983); the position of the body and feet, additional instrumentation (e.g. foam rubber for soft surface tests) were defined according to (de la Torre et al., 2017) (see Figure 1).

Figure 1 about here

The static and dynamic balance were both assessed with a set of tests previously applied in other studies (de la Torre et al., 2017). The static balance control was assessed with a test based on the Romberg test and the Modified Clinical Test of Sensory Interaction in Balance (CTSIB-M), with consideration given to four different situations: (1) rigid surface with eyes open (RSEO), (2) rigid surface with eyes closed (RSEC), (3) soft surface with eyes open (SSEO), and (4) soft surface with eyes closed (SSEC). On the other hand, the dynamic postural balance was assessed measuring the limits of stability (LOS) that a patient is able to reach and with it, the management capacity of COP (Ku, Osman, & Abas, 2016). The dynamic LOS test was based on protocols found in the literature (Peydro de Moya, Baydal Bertomeu, & Vivas Broseta, 2005).
The variables selected for the present study were those determined by (de la Torre et al., 2017) to be more significant in balance assessment studies, which details, and method of obtaining are also explained in the same study. The variables selected for the assessment of the static and dynamic balance were the range of displacement in the anteroposterior and mediolateral directions, area (surface area covered by the trajectory of the COP), average speed of the COP, and RMS position. Additionally, in the LOS test, two more variables were assessed: the COP limits (maximum displacement reached along each axis of the octagon radii), and the "success" variable (quantification of the management and coordination of the COP along each axis of the octagon radii), both defined in a previous study (de la Torre et al., 2017).

MCQ-Balance assessment method

Figure 2 presents the application outline of the MCQ-Balance assessment, which consists of three stages in which the progression of a patient's balance is Measured (M), Classified (C), and

Qualified (Q). The method input is the variables provided by the set of balance tests in two temporal points, that is, the values of the variables in the pre-session and post-session. The variables are analysed individually until stage two, where they are grouped at the test level until the end of the assessment. The application outline shows the inputs and outputs of each stage, as well as the processes (P1-P5) applied to them. It also includes the type of information that is handled and the interpretative changes during the process.

Figure 2 about here

Stage 1: Measure

The first stage of the method involves measuring the progression of each variable of the balance tests set by detecting relevant changes between two measures of each variable recorded at different temporal points (e.g., a measure of 26.4 for one session and 27.2 for another session). For this purpose, the process (P1) used in this stage is the statistical method MBD, as described in the Spreadsheet for Monitoring an Individual's Changes (Hopkins, 2017) (formerly known as magnitude-based inferences) (Hopkins, William G., 2019). According to the MBD method, some inputs are required for each analysed variable:

- Xdif: difference between the measures taken in two temporal points: pre-value (pre-session) and post-value (post-session) (Equation 1).

$$Xdif = X_{post} - X_{pre} \quad (1)$$

- MBD threshold: for this method, a threshold (numerical value) must be defined from which a change is considered relevant. In our case, we selected the minimal detectable change (MDC) (Equation 2). The implications of this election are explained in the discussion section.

$$MDC = 1.96\ \sqrt{2}\ SEM;\ SEM = SDpool\sqrt{1 - ICC} \quad (2)$$

  Where the standard deviation (SDpool) is the pooled average between the standard deviation of the test and retest, ICC is the intraclass correlation coefficient (specifically, the calculated coefficient was ICC3, k (similar to ICC2.1) (Ruhe, Fejer, & Walker, 2010); the statistical software used for the ICC calculations was the IBM SPSS statistics (IBM Corp, 2017)) and SEM is the standard error of measurement. Following the exposed calculation procedure, ICC, SEM and MDC values were obtained in a previous test-retest study.
- Short-term typical error (STTE): this represents the error/deviation in the subject's repeated measurements in a short period for a sample of measurements instead of just one measurement per session, without any substantial change between them (as an intervention, for a long time between measurements, etc.) As proposed by (Hopkins, Will G., 2000; Hopkins, Will G., 2017), this input was obtained with a previous short-term reliability study of the balance test set; similar study to the calculation of variables for the MDC.

To detect whether the change is relevant between two recorded measures, clinical MBD is followed (Hopkins, Will G. & Batterham, 2016). This allows us to determine whether the detected progression is positive (beneficial), negative (harmful) or inconclusive.
First, with the value and sign (positive or negative) of Xdif, we determine the tendency of the change towards a positive or negative progression. In the MCQ-Balance assessment method, we follow the following criteria: for the static balance group, a positive progression is considered if Xdif has a negative sign, and for the dynamic balance group, a positive progression is considered if Xdif has a positive sign.
Subsequently, following the calculation method set forth by (Hopkins, Will G., 2017), the probability of change (PoC in %) is obtained, which can be defined as the probability that the difference between the two values is relevant. This probability corresponds to the percentage of the confidence interval of the difference (calculated using the Xdif and STTE) that is outside of the range (+MDC, -MDC).
Once the PoC is calculated in the method, criteria must be established to consider a positive, negative, or null (unclear) progression of each variable. In a case study following the clinical MBD, a positive PoC that is greater than or equal to 25% corresponds to a relevant positive change, whereas a negative PoC that is greater than or equal to 5% corresponds to a relevant negative change in the patient. In contrast, if the positive PoC is less than 25% or the negative PoC is less than 5%, the change is considered 'unclear'. The asymmetry between the two intervals is because, in 'Clinical MBD the effects have an unacceptable risk of harm' (Hopkins, Will G. & Batterham, 2016).

Stage 2: Classify

The second stage of the method consists of classifying the progression of each patient using a scoring. First, a specific score for each variable is calculated individually. Subsequently, from the scores of each variable, a score is obtained for each test. Finally, the test score is simplified, and a homogenised score (a discrete variable with the values -2, -1, 0, +1 and +2) is calculated for each of them, making it possible to compare the tests with different numbers of variables.
To determine the specific score for each variable ($Score_{v_m}$ or the score of the variable m), Equation 3 (P2) was used:

$$Score_{v_m} = PoC + CQ \qquad (3)$$

- PoC: Probability of change for one unit (calculated in 2.4).
- CQ: Quantification of the change that represents the dimensionless difference between the pre- and post-sessions (for one unit) calculated using Equation 4, in which Xdif is divided by the maximum value of the pre- or post-session. If Xdif is very large (tending to infinity), CQ approaches 1:
  - $$CQ = \frac{Xdif}{Max\,(X\,post; X\,pre)} \qquad (4)$$

Considering Equations 2 and 3, the range of $Score_{v_m}$ is 0 to +2 (positive progression) or -2 to 0 (negative progression). The score per variable is a continuous quantitative variable.

As mentioned above, the present study included five tests (four variants of the Romberg test and the LOS test); therefore, through a calculation based on the variable scores (P3), we obtained five values referred to as $\text{Score}_{\text{Test}_n}$. In the static balance tests, four situations were considered in which five variables were obtained in each one. In the LOS test, 20 variables were obtained. Equation 5 shows how to calculate the value for $\text{Score}_{\text{Test}_n}$.

$$Score_{Test_n} = \sum_{m}^{N_{test}} Score_{v_m} \quad (5)$$

where N_{test} is the number of variables per test. Likewise, in Equations 6 and 7, the maximum and minimum scores that the $\text{Score}_{\text{Test}_n}$ can reach are shown.

$$MaxScore_{Test_n} = N_{test} \cdot 2 \quad (6)$$

$$MinScore_{Test_n} = N_{test} \cdot (-2) \quad (7)$$

For the static balance tests, the maximum and minimum scores were +10 and -10, respectively. For the LOS test, the maximum and minimum scores were +40 and -40, respectively.

Due to the different ranges of scores for each test, it is necessary to perform a classification that homogenises and simplifies the scores independently of the number of variables selected in the previous phases. For this, a process (P4) is conducted in which the global scores are transformed into a discrete quantitative variable through categorisation (González, Villegas, Atucha, & Fajardo, 2014), establishing a classification of five scores between -2 and +2. The proposed intervals are shown in brackets, which were defined based on statistical criteria, the processing and analysis of the data and the view of the clinician 2 involved in the present study:

- -2: high negative progression from Test_n (30% $MinScore_{Test_n} > Score_{Test_n}$).
- -1: negative progression from Test_n (30% $MinScore_{Test_n} \leq Score_{Test_n} <$ 10% $Min\ Score_{Test_n}$).
- 0: no progression from Test_n (10%$MinScore_{Test_n} \leq Score_{Test_n} \leq$ 10%$Max\ Score_{Test_n}$).
- +1: positive progression from Test_n (10%$MaxScore_{Test_n} < Score_{Test_n} \leq$ 30%$Max\ Score_{Test_n}$).
- +2: high positive progression from Test_n (30% $MaxScore_{Test_n} < Score_{Test_n}$).

Stage 3: Qualify

The third and final stage involves using established criteria to qualify the progression based on the resulting scores from stage two. For this purpose, rules based on a decision tree model (see Figure 3) are proposed to qualify the progression of the balance in a patient and the influence of the involved BSS.

As mentioned above, balance is supported by the visual, proprioceptive and vestibular systems. Consequently, in the set of tests presented in Section 2.2, the patient was deprived successively of one or more BSS:

- RSEO: no BSS altered.
- RSEC: ES altered. The balance depends on the VS and PS.
- SSEO: PS altered. The balance depends on the VS and ES.
- SSEC: ES and PS altered. The balance depends only on the VS.
- LOS: no BSS altered. Unique dynamic postural balance test.

Thus, five rules are proposed that lead to their corresponding conclusions (see 'Conclusions for each situation assessed' in Figure 3). The clinicians of the present study developed these conclusions. In addition, the rules are divided into two groups: those directly obtained (1, 2, and 3) and those obtained in combination (4 and 5).

Rules 1 and 2 allow to obtain a global assessment of the progression of the static balance control and the dynamic postural balance of a patient from the RSEO and LOS tests, respectively. Rule 3 allows to obtain an assessment of the influence of the VS on the progression of a patient's balance, analysing the SSEC test. Rules 4 and 5 assess the influence of the ES and PS, respectively, on the progression of a patient's balance. These rules result from the combination of SSEC with SSEO (Rule 4) and with RSEC (Rule 5), first analysing the SSEC test and then the corresponding one according to the rule.

Figure 3 about here

Comparison between the MCQ-Balance assessment and clinician judgment

To analyse the application of the MCQ-Balance assessment, the patient results provided by this method have been compared with the assessment of a clinical expert (clinician 3).

The pre- and post-session data collected by clinician 1 (history and physical examination, diagnosis and functional assessment tests) were assessed by clinician 3 at the end of the field work, which allowed an assessment of the balance progression of each of the 42 patients. To avoid the results being influenced or contaminated by the interaction between the clinicians, there was no contact between them during the research.

The assessment of clinician 3 established three possible categories to evaluate patient progression: positive, null or negative progression (represented by "+", "=" and "-", respectively). Regarding the MCQ-Balance assessment, the RSEO variant of the static balance test and LOS test was chosen to make the comparison. This decision was motivated by the fact that, in the RSEO test, the subject has all the BSSs necessary to maintain stability, which corresponds to the standard situation where all BSSs are intact; it is a more favourable test and more consistent with the performance of daily living activities. In addition, in the LOS test (where the capacity or stability limits of patients are measured), the patient is also not deprived of any BSS; therefore, both tests are performed under the same conditions, which we consider in favour of the assessment used in this study (between the results of the pre-treatment and post-treatment session).

Likewise, and since clinician 3 could only establish a classification in three categories, the MCQ-Balance assessment scores have been simplified to a positive (+2 and +1 simplified to '+'), null

(0 simplified to '=') and negative (-2 and -1 simplified to '–') progression in order to properly conduct the comparison.
Regarding the results of the comparison, it would be reasonable to obtain a Cohen's Kappa coefficient of a moderate or higher category (index above 0.4), as well as an accuracy of more than 70% to minimise the number of false negatives.

Statistical analysis
We used the statistical software IBM SPSS statistics Version 25 for the statistical analysis of the data. To make the comparison between the MCQ-Balance assessment results and the assessment of clinician 3, the Cohen's Kappa statistical coefficient (κ) was chosen, which is used to measure inter-rater reliability for qualitative (categorical) items. Likewise, the confusion matrix was calculated to obtain the accuracy and percentage of false negatives.

Results
Results are presented for each patient and organised according to the stages that comprise the MCQ-Balance assessment. The results of the statistical analysis of the comparison between the MCQ-Balance assessment and the evaluation of clinician 3 are also presented.

Stage 1
Regarding phase 1, the average PoC is presented for each patient's tests (see Table 3). The motivation for the choice of PoC is the main output of phase 1 and, therefore, the most representative variable. Due to the volume of information handled, it was not possible to include the information at the variable level as explained in the method; however, the information of each variable from the pre- and post-sessions (pre-value, post-value, difference, MDC, STTE, PoC, CQ and the scores of each variable) of the patients' tests has been calculated and compiled as supplementary material.

Table 3 about here

Stage 2
The results related to stage 2 correspond to the homogenised scores of the five tests of the 42 patients, as presented in Table 4. This score is a discrete value between -2 and +2; negative values (-2 and -1) indicate negative progression, null values (0) indicate no progression and positive values (1 and 2) indicate positive progression.

Stage 3
Qualification of the scores of each patient, a process conducted in stage 3, is presented in Table 4 with the same identifying code detailed in Figure 3, where the conclusions are presented based on the scores obtained.
Table 4. Stage 2 and 3 results: homogenised scores and conclusions.

Table 4 about here

Comparison between the MCQ-Balance assessment and clinician judgment

The results of the comparison between the MCQ-Balance assessment and the assessment of clinician 3 for the RSEO and LOS tests are presented in Tables 5 and 6, respectively. They include the confusion matrix, Cohen's Kappa coefficient with its significance (p-value) and the number of false negatives.

Table 5 about here

As shown in Table 5, for the RSEO test, Cohen's Kappa coefficient is 0.752 (between 0.61 - 0.80 as substantial (McHugh, 2012)), the accuracy is 83.4% between the two assessments and there are no false negatives.

Table 6 about here

As shown in Table 6, for the LOS test, Cohen's Kappa coefficient is 0.581 (between 0.41 - 0.60 as moderate (McHugh, 2012)), the accuracy is 72.9% between the two assessments and there are four false negatives, including three cases where the method did not detect changes and the clinical expert estimated worsening as well as one case where the method detected positive progression and the clinical expert estimated worsening.

Discussion

In the present study, to detect relevant changes between two sessions in patients with balance disorders, the MCQ-Balance assessment was proposed and compared to the interpretation of the assessment by an expert clinician. The method comprises three stages in which the progression of a patient's balance is measured (M), classified (C) and qualified (Q). The results of this work can be reproducible due to the availability of resources used.

Few studies have focused on the clinical utility of posturography at the individual patient level (Visser et al., 2008). Likewise, although posturography is considered the gold standard, limitations exist regarding its use as a functional assessment (Climent Barbera JM, 2003). Thus, MCQ-Balance assessment method proposed, focuses on the individualised monitoring of patients, try to respond to this problem. Indeed, the transformation of information from continuous quantitative variables to conclusions in medical language facilitates the clinical interpretation of the results, providing greater intelligence to posturography devices (which is a limitation detected in posturography reports) (Climent Barbera JM, 2003). This situation favours the development of applications based on posturography that could be used in clinical practice. Stages two and three of the method are adapted to clinical needs because they are the result of multidisciplinary work involving clinicians and technicians. This highlights the relevance of the

conclusions that the MCQ-Balance method can generate from the results of the balance tests, which have been defined and written by the clinicians involved in the present study. Likewise, the definitions of the intervals of the homogenised scores have been adjusted according to the patients that have been assessed by the clinician 2.

The proposed method has advantages over traditional posturography; however, it is necessary to discuss certain issues and decisions related to the application process, which are explained below.

The first consideration refers to the chosen MBD threshold, a numerical value from which a change is considered relevant. Regarding this, the MDC has been selected as the reference value in the present study because it represents the random balance variability in addition to the measurement errors of the device and the experiment (Furlan & Sterr, 2018; Steffen & Seney, 2008). It would be of interest, however, to inquire about the concept of minimal important difference (MID) (de Vet & Terwee, 2010) applied in this field. The MID study involves a complex qualitative interpretation process, although its complexity should not detract from its development because the MID index should complement MDC values in the future. In this sense, one study (de Vet & Terwee, 2010) argued that both values are related, and if it is possible to define a MID value for a specific test, the experiment related to that test must have sufficient accuracy, which is defined by the value of the MDC. Thus, the MID value should preferably be applied, unless the value is lower than that of the MDC, which limits the accuracy of the method.

The scoring proposed in the present work makes it possible to simplify the interpretation of the results of balance monitoring at the patient level. For this, the scoring allows the results to be standardised to enable a comparison between tests of the same patient and even between studies of different patients.

In the present work, and according to (de la Torre et al., 2017), the considered variables have the same importance and are assigned the same weight. However, future studies might advise assigning a different weight to each variable depending on its importance in improving the sensitivity of the MCQ-Balance method for diagnostic purposes. In this case, the maximum and minimum achievable score for each test would be based on the weights assigned to each variable.

The choice of the five intervals to establish the homogenised scores was medically motivated. Clinically, it makes sense to make a five-level classification because the progression of the patient is towards improvement, maintenance, or deterioration of the patient's clinical picture (Porta, 2014), assessing the existing graduation in improvement or deterioration. The multidisciplinary agreement reached in the present work combined with the experience of fieldwork and data processing has been concluded at the presented intervals.

Although the homogenised score proposed allows to obtain a classification of the progression of a patient, discriminating between a positive or negative progression (+ 1/-1) and a very positive or very negative progression (+ 2/-2), in the group of rules obtained by combination, this method is not able to issue a logical conclusion when two tests have the same progression trend but different scores (e.g. SSEC = +1 and SSEO = +2). Therefore, a future study is proposed to improve the accuracy of the method using machine learning techniques, such as neural networks

(Krafczyk, Tietze, Swoboda, Valkovič, & Brandt, 2006), so that the method can more accurately define the degree of improvement or deterioration of a patient.

Regarding the conclusions in medical language resulting from the method, the ability to portray the influence of the three BSS involved in balance is highlighted in the progression of a patient's balance. In this way, the method facilitates the clinician to adapt medical treatment, focusing on the balance disorder of the patient.

Regarding the comparison between the MCQ-Balance assessment and the assessment of clinician 3, both for the comparison with the RSEO test and for the LOS test comparison, 70% accuracy was exceeded, and its Cohen's Kappa coefficient was greater than 0.4. However, the differences between the two comparisons should be highlighted. While there were no false negatives in the comparison with the RSEO test, with the LOS test, there were four (10.8% of the sample). This is explained by the possible learning factor associated with this test (Wrisley, 2007), although 4 of the 37 patients who completed this test is not a representative sample; similar to the comparison with RSEO, there are more cases in which the method determined a negative progression (worsening) where clinician 3 did not. This may be due to the increased sensitivity of the method when detecting worsening that is not visible to the clinician with traditional assessment tools. Finally, we would like to establish that the decision to choose these two tests has been motivated because all BSSs are intact, a situation more in line with the performance of daily living activities. In our opinion is the best adaptation to the assessment of the clinician 3.

Conversely, no differences have been detected between the results obtained for patients with vertigo of a peripheral or central origin; however, it should be noted that, due to the severity of the diagnoses of patients with vertigo of central origin, some of them were unable to complete all the tests (especially the SSEC and LOS tests due to the difficulty involved), as shown in Tables 3 and 4. Likewise, the influence of participant characteristics has not been analysed because there is no significant difference (gender) and it is not within the scope of the research; however, it was observed that older patients showed less positive progression relative to younger patients. The analysis of the possible influences of the anthropometric variables will be addressed in a future study.

Regarding the progression of the patients, it can be observed that there is no trend in improvement (positive progression) of the sample since the number of positive and negative scores across all the tests is similar, which generates certain questions that should be highlighted. The main reason lies in the nature of the prescribed treatments. To achieve effectiveness in rehabilitative treatment, patients need to be constant in performing the prescribed treatment, which is a great handicap of rehabilitation (regardless of subspecialty). A minority of patients perform the prescribed exercises at home, whereas a majority do not because the maintenance of the exercises decreases when they are not performed as guided by a professional (68,69). Likewise, some cases of fear in the patients were detected in the post-session due to a negative experience in the pre-session. This explains certain cases that present a negative progression provided by the method, which does not coincide with the clinical expert assessment. This

problem is frequent in studies of balance disorders (Timothy C. Hain, May 5, 2019; Visser et al., 2008). However, we tried to minimise the problem with additional safety measures, such as the presence of the clinician 2 and a nurse around the patient during the tests.
We acknowledge the major limitation inherent to the applied treatments, although the purpose of the study was not to assess the efficacy of treatments for balance disorders. Likewise, in the assessment of those patients diagnosed with BPPV to whom the Epley manoeuvre was applied, no greater positive progression was detected than the rest of the sample due to the use of a specific treatment. The effectiveness of the treatments will be addressed in a subsequent study with a sample similar to that of the present study.
Regarding the implications and possibilities of the assessment method MCQ-Balance, note that it is extrapolated to other cases of balance assessment with different tests, variables, and perspectives (e.g. balance during gait or by combining the test with cognitive tasks). Therefore, the conclusions transcend the present study.

Conclusions

A method of assessing the progression of a patient's balance has been proposed to detect relevant changes in patients with balance disorders at the individual level, providing clinically interpretable, objective information. The comparison between the results of the MCQ-Balance assessment method with the assessment of a clinical expert shows remarkable similarity, with an accuracy of 83.4% and a Cohen's Kappa coefficient of 0.752, which provides evidence that the new method achieves its intended purpose. This allows us to conclude that the proposed method provides objective information, which facilitates the monitoring of patients with balance disorders and measuring of the alteration of the BSS. Although this method allows adapting and adjusting of treatments at the individual level, improving medical decision-making, it is necessary to continue deepening the comparison between the results provided by the method and clinical judgment.

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Figure 1

Stabilometric platform and test work environment.

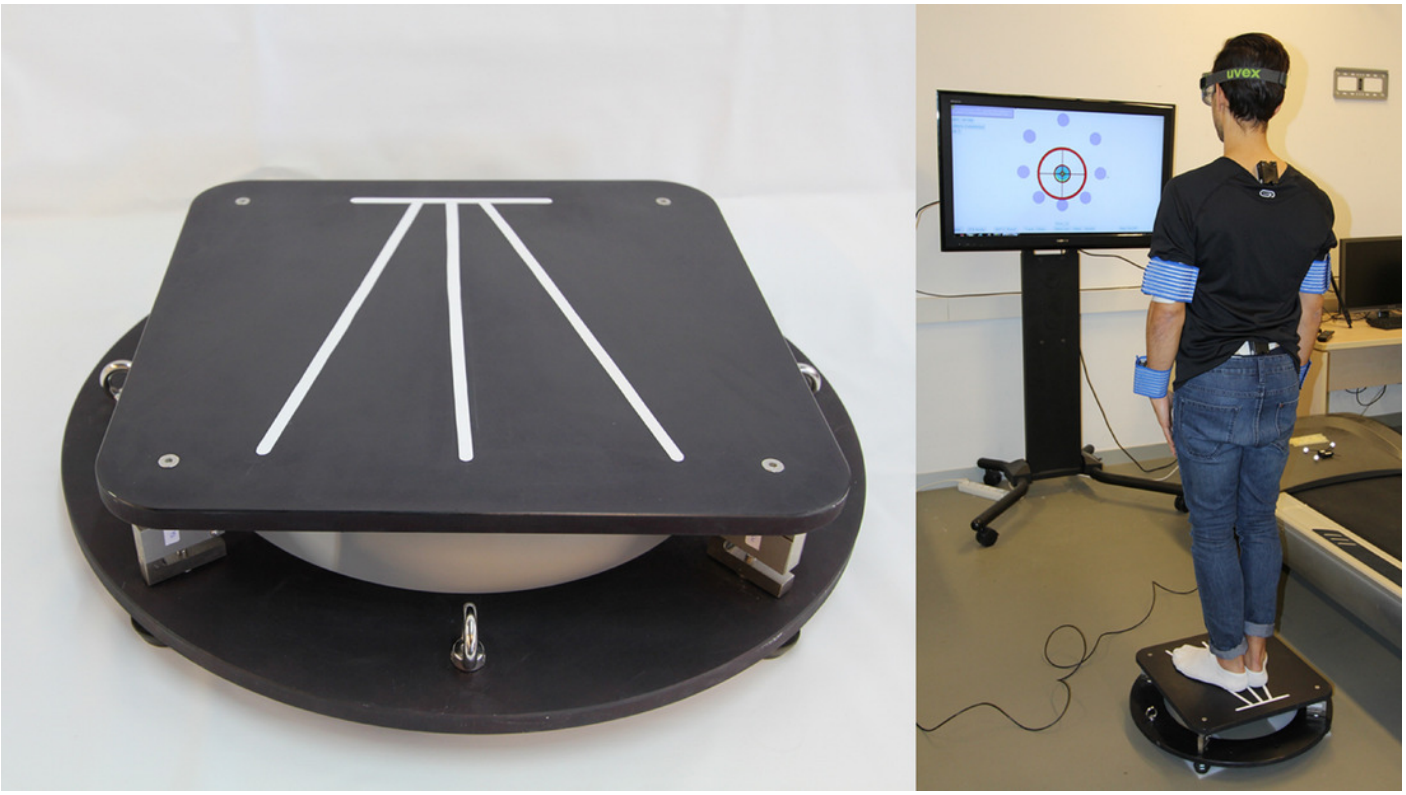

Figure 2

MCQ-Balance assessment method.

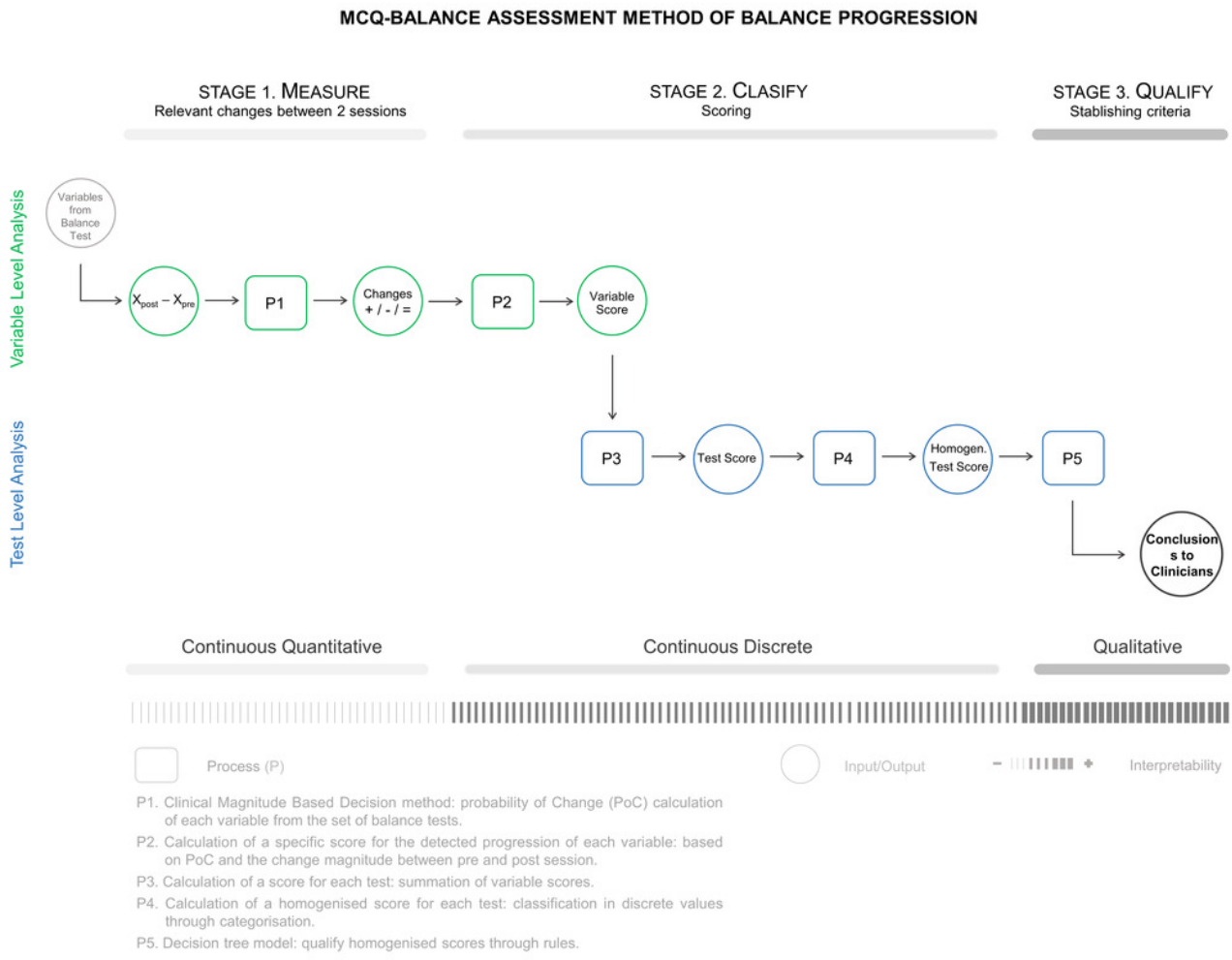

Figure 3

Stage3: Qualify.

RSEO: Rigid Surface, Eyes Open; RSEC: Rigid Surface, Eyes Closed; SSEO: Soft Surface, Eyes Open; SSEC: Rigid Surface, Eyes Closed. VS: vestibular system; ES: visual system; PS: proprioceptive system. E1,..., E3: conclusions for the progression of static balance; D1,..., D3: conclusions for the progression of dynamic postural balance; V1,..., V3: conclusions for the progression of balance due to VS; S1,..., S9: conclusions for the progression of balance due to ES; P1,..., P9: conclusions for the progression of balance due to PS.

RULES TO QUALIFY THE BALANCE PROGRESSION OF A PATIENT AND THE INFLUENCE OF THE SENSORY SYSTEMS

Rules of direct obtaining

Rule 1. Overall progression of Static balance

RSEO = 0	S1
RSEO = +1/+2	S2
RSEO = -1/-2	S3

Rule 2. Overall progression of Dynamic balance

LOS = 0	D1
LOS = +1/+2	D2
LOS = -1/-2	D3

Rule 3. Progression of balance due to Vestibular system

SSEC = 0	V1
SSEC = +1/+2	V2
SSEC = -1/-2	V3

Rules of obtaining by combination

Rule 4. Progression of balance due to Eyesight system

SSEC = 0	SSEO = 0	E1
	SSEO = +1/+2	E2
	SSEO = -1/-2	E3
SSEC = +1/+2	SSEO = 0	E4
	SSEO = +1/+2	E5
	SSEO = -1/-2	E6
SSEC = -1/-2	SSEO = 0	E7
	SSEO = +1/+2	E8
	SSEO = -1/-2	E9

Rule 5. Progression of balance due to Proprioceptive system

SSEC = 0	RSEC = 0	P1
	RSEC = +1/+2	P2
	RSEC = -1/-2	P3
SSEC = +1/+2	RSEC = 0	P4
	RSEC = +1/+2	P5
	RSEC = -1/-2	P6
SSEC = -1/-2	RSEC = 0	P7
	RSEC = +1/+2	P8
	RSEC = -1/-2	P9

Conclusions for each situation assessed

Rule 1

S1: No progression in the overall static balance.
S2: Positive progression in the overall static balance.
S3: Negative progression in the overall static balance.

Rule 2

D1: No progression in the dynamic postural balance.
D2: Positive progression in the dynamic postural balance.
D3: Negative progression in the dynamic postural balance.

Rule 3

V1: No progression in the balance due to the VS.
V2: Positive balance progression due to the VS.
V3: Negative balance progression due to the VS.

Rule 4

E1: With the PS altered, without demonstrable changes in the VS: no balance progression due to the ES are demonstrated.
E2: With the PS altered, without demonstrable changes in the VS: positive balance progression is due to the ES.
E3: With the PS altered, without demonstrable changes in the VS: negative balance progression is due to the ES.
E4: With the PS altered, the improvement of the VS is compensated for by the deficit of the ES: negative balance progression due to the ES.
E5: With the PS altered, considering the improvement of the VS: no balance progression are demonstrated due to the ES.
E6: With the PS altered, the improvement of the VS is compensated for by the significant deficit of the ES: very negative balance progression is due to the ES.
E7: With the PS altered, the deterioration of the VS is compensated for by the improvement of the ES: positive balance progression due to the ES.
E8: With the PS altered, the deterioration of the VS is compensated for by the significant improvement of the ES: very positive balance progression is due to the ES.
E9: With the PS altered, considering the deterioration of the VS: no balance progression are demonstrated due to the ES

Rule 5

P1: With the ES altered, without demonstrable changes in the VS: no balance progression due to the PS are demonstrated.
P2: With the ES altered, without demonstrable changes in the VS: positive balance progression is due to the PS.
P3: With the ES altered, without demonstrable changes in the vestibular system: negative balance progression is due to the PS.
P4: With the ES altered, the improvement of the VS is compensated for by the deficit of the PS: negative balance progression is due to the PS.
P5: With the ES altered, considering the improvement of the VS: no balance progression are demonstrated due to the PS.
P6: With the ES altered, the improvement of the VS is compensated for by the significant deficit of the PS: very negative balance progression is due to the PS.
P7: With the ES altered, the deterioration of the VS is compensated for by the improvement of the PS: positive balance progression is due to the PS.
P8: With the ES altered, the deterioration of the VS is compensated for by the significant improvement of the PS: very positive balance progression is due to the PS
P9: With the ES altered, considering the deterioration of the VS: no balance progression are demonstrated due to the PS.

Table 1(on next page)

Patients diagnosis

BPPV: benign paroxysmal peripheral vertigo

Peripherical deficit (n=32)	Central deficit (n=10)
BPPB (n=15)	Ictus (n=6)
Ménière syndrome (n=8)	Neoplasia (n=2)
Vestibular hypofunction (n=6)	Demyelinating disease (n=2)
Otoesclerosis (n=3)	

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Table 2 (on next page)

Participant anthropometric characteristics: mean (SD).

[a] *Foot length measurements were taken between the proximal and distal points on the foot outline (Pawar & Dadhich, 2012).*

Characteristics	Peripherical. deficit (n=32)	Central deficit (n=10)
Gender (men/women)	11/21	4/6
Age (yr)	54.7 (8.99)	57.4 (7.92)
Height (cm)	162.9 (7.28)	162.5 (9.98)
Weight (kg)	75.5 (16.25)	79.6 (14.73)
BMI	28.4 (5.90)	29.5 (4.60)
Foot length (cm)[a]	25.3 (1.09)	25.4 (1.11)
Abdominal perimeter (cm)	95.8 (15.57)	101.2 (12.61)

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Table 3(on next page)

Stage 1 results: PoC.

ID	Def	RSEO	RSEC	SSEO	SSEC	LOS	ID	Def	RSEO	RSEC	SSEO	SSEC	LOS
01	P	0.12	0.79	0.16	0.40	0.11	**22**	P	0.22	0.29	0.26	0.70	0.72
02	P	-0.06	-0.12	-0.17	-0.38	-0.08	**23**	P	0.58	0.02	0.06	0.35	0.16
03	P	0.19	-0.03	0.15	-0.05	0.09	**24**	C	0.09	0.77	0.69	-0.74	0.01
04	P	-0.21	-0.80	-1.00	-0.52	-0.23	**25**	P	-0.30	-0.40	-0.60	-0.37	0.05
05	P	-0.49	-0.49	-0.30	0.06	-0.10	**26**	C	0.21	-0.06	-0.06	0.22	0.19
06	P	-0.14	-0.26	0.02	-0.62	-0.14	**27**	P	-0.15	-0.39	0.48	-0.31	-0.15
07	P	0.39	-0.02	0.46	0.18	0.34	**28**	P	0.00	-0.19	-0.03	0.35	-0.07
08	P	0.13	-0.31	0.21	-0.22	0.15	**29**	P	0.18	1.00	0.58	0.23	-0.07
09	P	-0.66	-0.02	0.15	-0.46	0.13	**30**	C	0.62	0.40	0.76	0.26	-0.21
10	P	-0.57	-0.02	0.15	-0.93	0.15	**31**	P	0.05	-0.15	-0.34	-0.13	0.06
11	P	-0.05	-0.05	-0.03	0.04	-0.07	**32**	P	-0.78	0.09	-0.23	-0.94	-0.32
12	P	-1.00	n/a	n/a	n/a	n/a	**33**	P	-0.04	-0.73	0.19	-0.06	0.00
13	P	0.25	-0.06	-0.39	-0.52	0.16	**34**	C	-0.80	-0.69	0.28	n/a	n/a
14	C	-1.00	-0.98	n/a	n/a	n/a	**35**	P	0.23	-0.19	0.26	0.18	0.17
15	P	-0.14	-0.64	-0.90	0.98	-0.05	**36**	P	0.10	-0.43	0.22	-0.14	-0.16
16	P	0.19	0.94	0.59	0.99	0.16	**37**	P	0.13	1.00	-0.03	0.29	0.16
17	C	0.17	0.00	-0.07	0.75	0.43	**38**	C	-0.86	-0.32	0.07	-0.71	0.00
18	P	-0.07	-0.30	0.84	-0.26	0.13	**39**	P	0.15	0.55	-0.06	-0.08	0.17
19	P	-0.40	-0.25	0.50	0.04	-0.26	**40**	C	-1.00	n/a	n/a	n/a	n/a
20	C	-0.20	-0.22	-0.64	-0.43	0.58	**41**	C	-0.68	-0.63	-0.84	n/a	n/a
21	P	0.07	0.05	-0.38	-0.08	0.11	**42**	P	-0.19	-0.11	-0.11	-0.03	0.01

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Table 4(on next page)

Stage 2 and 3 results: homogenised scores and conclusions.

ID: patient identifier; VO: vertigo origin; P: peripherical deficit; C: central deficit; n/a: tests not performed; RSEO: Rigid Surface Eyes Open; RSEC: Rigid Surface Eyes Closed; SSEO: Soft Surface Eyes Open; SSEC: Soft Surface Eyes Closed; LOS: Limits of Stability ; R1…R5: Rules from stage 3, consult figure 3; S, D, V, P, E: consult conclusions from figure 3.

			STAGE 2: CLASIFY					STAGE 3: QUALIFY				
ID	**VO**	**CA**	**RSEO**	**RSEC**	**SSEO**	**SSEC**	**LOS**	**R1**	**R2**	**R3**	**R4**	**R5**
01	P	=	0	2	0	1	0	S1	D1	V2	E4	P5
02	P	=	0	0	-1	-1	0	S1	D1	V3	E9	P7
03	P	+	1	0	0	0	1	S2	D2	V1	E1	P1
04	P	-	-1	-2	-2	-2	-1	S3	D3	V3	E9	P9
05	P	-	-2	-2	-1	0	-1	S3	D3	V1	E3	P3
06	P	=	-1	-1	0	-2	0	S3	D1	V3	E7	P9
07	P	+	2	0	2	1	1	S2	D2	V2	E5	P4
08	P	=	0	-2	1	-1	0	S1	D1	V3	E8	P9
09	P	+	-2	0	1	-1	1	S3	D2	V3	E8	P7
10	P	-	-2	0	1	-2	0	S3	D1	V3	E8	P7
11	P	+	0	0	0	0	0	S1	D1	V1	E1	P1
12	P	-	-2	n/a	n/a	n/a	n/a	S3	n/a	n/a	n/a	n/a
13	P	+	1	0	-1	-2	1	S2	D2	V3	E9	P7
14	C	-	-2	-2	n/a	n/a	n/a	S3	n/a	n/a	n/a	n/a
15	P	+	-1	-2	-2	2	0	S3	D1	V2	E6	P6
16	P	+	1	2	2	2	1	S2	D2	V2	E5	P5
17	C	+	1	0	0	2	1	S2	D2	V2	E4	P4
18	P	=	0	-1	2	-1	0	S1	D1	V3	E8	P9
19	P	=	-2	-1	2	0	-1	S3	D3	V1	E2	P3
20	C	-	-1	-1	-2	-1	2	S3	D2	V3	E9	P9
21	P	=	0	0	-1	0	0	S1	D1	V1	E3	P1
22	P	+	1	1	1	2	2	S2	D2	V2	E5	P5
23	P	+	2	0	0	1	1	S2	D2	V2	E4	P4
24	C	=	0	2	2	-2	0	S1	D1	V3	E8	P8
25	P	-	-1	-2	-2	-1	0	S3	D1	V3	E9	P9
26	C	+	1	0	0	1	1	S2	D2	V2	E4	P4
27	P	-	-1	-1	2	-1	-1	S3	D3	V3	E8	P9
28	P	=	0	-1	0	1	0	S1	D1	V2	E4	P6
29	P	+	1	2	2	1	0	S2	D1	V2	E5	P5
30	C	+	2	1	2	1	-1	S2	D3	V2	E5	P5
31	P	=	0	0	-1	0	0	S1	D1	V1	E3	P1
32	P	-	-2	0	-1	-2	-1	S3	D3	V3	E9	P7
33	P	=	0	-2	1	0	0	S1	D1	V1	E2	P3
34	C	-	-2	-2	1	n/a	n/a	S3	n/a	n/a	n/a	n/a
35	P	+	1	-1	1	1	1	S2	D2	V2	E5	P6
36	P	=	0	-2	1	-1	-1	S1	D3	V3	E8	P9
37	P	+	1	2	0	1	1	S2	D2	V2	E4	P5
38	C	-	-2	-1	0	-2	0	S3	D1	V3	E7	P9
39	P	+	1	2	0	0	0	S2	D1	V1	E1	P2
40	C	-	-2	n/a	n/a	n/a	n/a	S3	n/a	n/a	n/a	n/a
41	C	=	-2	-2	-2	n/a	n/a	S3	n/a	n/a	n/a	n/a
42	P	+	-1	0	0	0	0	S3	D1	V1	E1	P1

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Table 5(on next page)

MCQ-Balance assessment and clinician judgment comparative: RSEO.

N: count of each case; %: percentage of total.

			MCQ-Balance Assessment			Total
			-	=	+	
Clinical Expert Assessment	-	N	**12**	0	0	12
		%	**28.6%**	0%	0%	28.6%
	=	N	3	**10**	0	13
		%	7.1%	**23.8%**	0%	31%
	+	N	3	1	**13**	17
		%	7.1%	2.4%	**31%**	40.5%
Total		N	18	11	13	**42**
		%	42.9%	26.2%	31%	**100%**
Symmetric Measure	**Kappa**	**0.752**	P-Value	0.000	**False Negatives**	**0 0%**

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Table 6(on next page)

MCQ-Balance assessment and clinician judgment comparative: LOS.

N: count of each case; %: percentage of total.

			MCQ-Balance Assessment			Total
			-	=	+	
Clinical Expert Assessment	-	N	**4**	3	1	8
		%	**10.8%**	8.1%	2.7%	21.6%
	=	N	2	**10**	0	13
		%	5.4%	**27%**	0%	32.4%
	+	N	1	3	**13**	17
		%	2.7%	8.1%	**35.1%**	45.9%
Total		**N**	7	16	14	**37**
		%	18.9%	43.2%	37.8%	**100%**
Symmetric Measure	**Kappa**	**0.581**	P-Value	0.000	**False Negatives**	**4 10.8%**

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