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Balance study in asymptomatic subjects: Determination of significant variables and reference patterns to improve clinical application

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ABSTRACT

Postural control is essential when carrying out everyday activities and its possible disorders have a very significant impact on personal autonomy. To provide the means to accurately measure postural control in the clinical environment, this study checks and discusses the suitability of procedures for a new balance assessment system with a stabilometric platform (MoveHuman-Dyna © UZ-IDERGO), which meets the criteria of clinical stabilometric standardisation established by the International Society for Posture and Gait Research (ISPGR) at the Bologna meeting (2009). The study was applied to a sample of 30 healthy volunteers (12 women, 18 men) aged between 18 and 30 years. A total of six balance tests were performed: four variations of the Romberg test, one test for a study of the limits of stability (LoS) and one test for rhythmic weight shift (RWS). Analysis of the results confirms that the variables assessed yielded similar values to other studies, the consistency of values between tests was checked, and preliminary reference values were obtained for asymptomatic subjects. We propose the following variables as the most significant for balance diagnosis: *CoP mean speed, RMS, Range of CoP displacement and area.* As a result of the study, the system is considered of interest in the medical/legal and forensic settings to assess the balance control and degree of collaboration during the tests.

1. Introduction

Postural control is essential when carrying out everyday activities and its possible disorders will have a very significant effect on personal autonomy, being indicative of possible incipient physical or neuronal pathologies (García et al., 2012). These disorders are common dysfunctions encountered by both general practitioners and specialists alike (Baydal-Bertomeu et al., 2004). Included among these conditions are vertigo and dizziness which, together with gait disorders, represent the second leading cause of falls after accidents (Rubenstein and Josephson, 2002). Falls and fall-related injuries correspond to major, global, public health problems. Around 30% of people aged over 65 years and more than 50% of individuals in health centres or care homes will suffer one or more falls per year (Tinetti, 2003). Ageing, sensory changes, musculoskeletal or neurological disorders, cardiovascular diseases, infections or metabolic disorders (Ma et al., 2016), are closely related to balance disorders.

A balance assessment involves measuring centre of pressure (CoP) displacement and quantifies postural control during standing, sitting and walking. Different non-invasive evaluation tests can be used that allow objectifying the degree of control of static and dynamic balance (Duarte and Freitas, 2010). In static balance control methods (Romberg test), subjects must maintain their CoP within the support base throughout the assessment period. Assessments of dynamic postural balance, which is vital for motor control, involve measuring the limits of stability (LoS), corresponding to the maximum voluntary angle or distance in which an individual can regulate their CoP in a given direction without losing balance (Ku et al., 2016). These are tests that can diagnose, measure the evolution of a treatment, or even serve as a means of postural re-education therapy (García et al., 2012). Additionally, the combination of tests was conducted because it allows consistency to be assessed and, consequently, the patient's degree of collaboration when completing the tests, which is relevant in medical/legal and forensic settings (Ramírez et al., 2014).

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Research into mechanisms involved in balance and postural control has sparked the interest of professionals from several fields, including physical therapy, sport, engineering, physics, biomechanics, medicine, psychology (Duarte and Freitas, 2010) and entertainment and leisure (Weaver et al., 2016). However, these professionals also use a range of measurement and assessment techniques that often generate different results, with divergent opinions regarding questions such as: the duration of the test, position of the feet, which variables are included or surrounding conditions (Kapteyn et al., 1983; Scoppa et al., 2013; Pinsault and Vuillerme, 2009; Solovykh et al., 2011; Cvecka et al., 2014).

The International Society for Posture and Gait Research (ISPGR) at the Bologna meeting (2009) (Scoppa et al., 2013), has achieved some unification of criteria. The ISPGR addressed the problem of clinical stabilometric standardisation, establishing certain criteria to obtain appropriate accuracy and sensitivity in the measure of the CoP.

There have been subsequent meetings of the ISPGR (Vancouver in 2014 and Seville in 2015) as well as different proposals and recommendations, such as the Japanese standardisation of the evaluation of clinical stabilometry. However, there are still issues without agreement, such as the posture to be adopted by the patient or the most significant clinical parameters.

Given the interest in providing the means to supply objective information about the real balance ability of an individual as well as the need to create useful and simple user assessment systems for health professionals, this study evaluates the balance of a sample of healthy people through a new instrumentation, applying tests based on the literature. The objective is to generate knowledge about the protocol of use, to provide preliminary reference values in healthy people, and to select the most useful information to evaluate the postural control, thus improving the clinical applicability in health care, and forensic environments.

With this objective, the steps carried out in the present study were (1) to verify that the applied instrumentation complies with established standards (Scoppa et al., 2013) (ISPGR) on stabilometric platforms in relation to metrological and anthropometric characteristics, environmental test conditions, and data acquisition, (2) to perform an analysis and assessment of the results of the balance tests on a sample of asymptomatic subjects to obtain preliminary reference data and check the suitability of the procedures and protocols for its clinical application, and (3) to propose the most useful and significant variables for stabilometric diagnosis.

2. Methods

2.1. Ethics and participants

The series of balance assessment tests object of this study were applied to a sample of 30 volunteers (12 women, 18 men) aged over 18 years (mean age = 23.9 years (4.14); mean body weight: 67.52 kg (11.8); mean height: 172.13 cm (6.92)) (Table 1). Of all the volunteer participants, for the purposes of this study, the group whose ages ranged from 18 to 30 years was selected.

Table 1
Participant anthropometric characteristics, mean (SD).

Characteristics	Men (n = 18)	Women (n = 12)
Age (yr)	23.16 (4.02)	25.1 (4.23)
Weight (kg)	73.22 (9.17)	59.4 (10.52)
Height (cm)	174.84 (5.78)	167.83 (6.56)
Body fat index (%)	13.62 (5)	22.69 (7.33)
Foot length (cm)[a]	26.14 (1.05)	23.73 (0.93)

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

The following inclusion criteria were established for study participation: (i) aged between 18 and 30 years, (ii) no prior history of neurological, visual, vestibular or balance alterations, (iii) no record of musculoskeletal or neurological disorders in the last 12 months, (iv) no prior history of surgery on the lower limbs or which could affect balance, (v) ability to walk normally, (the subject's lifestyle does not represent an obstacle). The study was previously approved by the Government of Aragon's Human Research Ethics Committee. Before starting the tests, the volunteers signed a form that meant they consented to undergo the tests and understood the aim of the study.

Subjects completed a practice run of each test so that the tester could verify they understood how it worked, assumed the correct posture and executed the tests correctly. This also gave the subjects the chance to get used to the platform and environment, which are considered relevant factors in some balance studies (Taylor et al., 2015).

After finishing the tests, subjects were asked to complete an evaluation questionnaire regarding their performance: muscle aches (and their location), possible feelings of instability, dizziness or vertigo, degree of difficulty of the test, and a functional evaluation of the tests and the resources used, both software and hardware. The questionnaire was designed to detect any deficiencies while carrying out the tests and any points for improvement.

2.2. Description of the instrumentation

The tests made use of the force platform (*Move*Human-Dyna ©UZ) designed and manufactured by the IDERGO research group (the Aragon Institute for Engineering Research, *I3A*, at the University of Zaragoza). The platform consists of two aluminium plates (Al-6062). The upper plate is square-shaped, measuring 415×415 mm; the lower plate is a circular ring with an outer diameter of 555 mm; both plates are 15 mm thick. There are four 100 kg, S-type load cells located between the two plates; they are positioned in the corners, separated by 332 mm and connected to a *PhidgetBridge 4-Input* (Phidgets, 2017). The result is a monoaxial force platform (Postolache and Postolache, 2017) that can measure vertical forces (Fig. 1b and c).

The *PhidgetBridge* interface board was connected directly to a PC featuring the software that controls the device and gathers data from the load cells. The information transmitted by these cells is converted from volts to kg-force in accordance with each load cell's calibration parameters at a frequency of 60 Hz. 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 (Ma et al., 2016; López and Calidonio, 2009). A foam rubber "balance pad", with characteristics in line with those employed in the literature (Baydal-Bertomeu et al., 2004), was used in the tests that had to be conducted with a soft surface on top of the force platform (Fig. 1e).

2.3. Verification of instrumentation according to standards

It proved that the stabilometric platform (SP) meets the standards established by the ISPGR for clinical application (Scoppa et al., 2013). Regarding the metrological characteristics, the parameters were calculated according to the calibration data of each load cell supplied by the manufacturer (Phidgets, 2017), using the error propagation law. Based on the CoP calculation (López and Calidonio, 2009), the following values have been obtained:

- Accuracy: 0.0619 mm (better than 0.1 mm) (Scoppa et al., 2013). An error due to non-linearity and hysteresis in the most unfavourable situation has been considered in each cell.