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CLINICAL GROUP

International Journal of Spine Research

DOI: https://dx.doi.org/10.17352/ijsr

Mini Review

Technological methods used in evaluating the balance

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Received: 17 September, 2020
Accepted: 28 September, 2020
Published: 29 September, 2020

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Keywords: Balance; Assessment; Technology; Rehabilitation

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Abstract

Balance is evaluated within the concept of coordination and is defined as the ability to maintain the body's center of gravity on the support surface. Technological methods used in the assessment of balance are robotic systems, virtual reality applications, tele-rehabilitation, web-based applications and sensor applications. In this review, we aimed to explain today's technological assessment methods and their relationship with technological rehabilitation in balance assessment. The technological method to be used in balance assessment suitability of the patient, ease of use, time saving, active participation, depending on the person's financial situation and the severity of the disease although the advantages vary, It seems that it may differ. More studies are needed for a more objective assessment of balance, designing products and using these technologies in different patient groups.

Introduction

Balance is evaluated within the concept of coordination and is simply defined as the ability to maintain the body's center of gravity on the support surface [1]. Coordination is the ability to perform smooth, controlled movements that are fit for purpose. Motor coordination is required in the use of fine motor skills, performing professional activities, performing activities in daily life such as walking, running, jumping. Coordinated movements require the correct sequence and timing of synergistic and reciprocal muscle activities, together with good balance and posture. Highly complex neuro-muscular mechanisms are required to maintain upright posture and maintain balance during activities [1,2]. This mechanism obtains information from various sensory sources (proprioceptive, visual, vestibular) about the position, orientation and movements of the body in space and it consists of a nerve-muscle interaction that uses this information to generate an appropriate motor response to keep the center of mass at the support center. These sensory data are integrated in the central nervous system and modulated by impulses from the reticular formation, extra-pyramidal system, cerebellum and cortex [2,3].

Balance is examined in two subsections as static and dynamic balance. Static balance is defined as the ability to control postural swing during standing still. In order to maintain static balance, the center of gravity of the body must pass through the level of the second sacral vertebra and remain on the support surface. Dynamic balance is defined as predicting the postural changes that occur during movement and providing appropriate responses to balance changes [2,4]. For this reason, among the clinical and laboratory evaluation methods of balance, today there are technological evaluation methods.

Balance assessment methods are currently used in all diseases in which pediatric, neurological, orthopedic, vestibular and musculoskeletal systems are impaired. The use of technological balance assessment methods is increasing today in many patient groups, including especially stroke, head trauma, spinal cord injuries, parkinson, multiple sclerosis, cerebral palsy and congenital balance disorders [3,5].

In the past 15 years, advances in healthcare technology have allowed physiological measures of motor and non-motor behavior to be analyzed objectively. There are many technologies for evaluating balance, but there is no technology yet that meets the requirements of balance in all cases. Research is currently focused on developing mobile apps to enable seniors, caregivers and clinicians to also monitor balance and fall risk. Studies reveal that mobile apps show only 38% validity and 23% reliability in balance assessment [6]. Balance assessment systems can be inexpensive and widely available, will be of great benefit to those at high risk of falling

Citation: Soyuer F (2020) Technological methods used in evaluating the balance. Int J Spine Res 2(1): 060-063. DOI: https://dx.doi.org/10.17352/ijsr.000016

due to impaired balance and can be useful in identifying what is happening [7,8].

These systems also allow the therapists to better personalize the intervention of the individual's lack of balance, allowing the balance to be evaluated in all planes.

Technological balance assessment methods are robotic systems, virtual reality applications, tele-rehabilitation, web-based applications and sensor applications.

In this review, we aimed to explain today's technological balance assessment methods and to investigate the relationship between physical therapy practices and technological rehabilitation.

Robotic systems: It provides effective evaluation of the proprioceptive, visual and vestibular system in the patient. Rehabilitation robots can simplify assessment procedures and increase their clinical value. The innovation and main benefits of using robots for assessment are the ability to evaluate patients "severely affected" by providing assistance when needed, and the ability to make consistent changes in standing and walking, based on the patient's reactions [8,9].

For balance assessment, robotic devices can be classified in three ways, regarding their potential applications;

a. How the device interacts with the body,

b. In what sense the device is mobile and

c. The surface on which the person is standing or walking while using the device.

Studies explain that robotic devices are promising and can become useful tools for the assessment of balance, especially in patients with neurological disorders, in both research and clinical use. Robotic balance assessment will allow for individual adaptation of rehabilitation training and will provide a chance to provide an increasingly detailed assessment that can eventually increase the effectiveness of the training [9,10].

Sensor systems: Sensors used in the assessment of balance are of two types, wearable sensors and ambient sensors. These are systems that measure the patient's environment data, foot sole load pressures, active and passive normal joint motion values. Wearable sensors are virtually revolutionizing the assessment of static balance. In recent years, wearable sensors based on miniaturized Inertial Measurement Units (IMUs) or Magneto Inertial Measurement Units (MIMUs) are increasingly used in balance assessment, as a number of studies focusing on this issue have shown [11,12].

In the last 15 years, significant advances in technology have provided wearable solutions for balance assessment and management of postural instability, especially in patients with neurological disorders. Recent developments in micro-electronics have led to the production of small flexible sensors integrated into clothing, thus making the wearable devices suitable for leisure applications. These sensors can be easily attached to a variety of body segments by means of elastic straps or Velcro® bands. The number and location of the sensors can be adjusted according to the application-evaluation often considered. To date, the main wearable technologies available for balance assessment include mechanical devices such as inertia and pressure sensors, and physiological devices such as surface electromyograph sensors (sEMG) [12,13].

A wearable inertial sensing unit typically includes accelerometers, gyroscopes, and magnetometers. The triaxial accelerometer measures the linear acceleration of movements in a three-dimensional (3D) frame fixed with a sensor; the measured data includes both motion and gravitational components. A three-axis gyroscope measures the appropriate angular velocity in a 3D space, and the components of the rotation velocity are evaluated in a three-dimensional frame fixed with the sensor. A magnetometer measures both the amplitude and the direction of the local magnetic field in a 3D space; the magnetic field components are specified in a triaxial frame fixed with the sensor. Usually accelerometer, gyroscope and magnetometer measurements refer to a common triaxial frame fixed to the sensing IMU [14,15].

Besides inertial devices, wearable sEMG sensors evaluate specific muscle activation during static and dynamic postural disturbances. Therefore, sEMG allows a better understanding of the physiological mechanisms responsible for balance control [16].

Wearable pressure sensors also include instrumented insoles that are inserted or integrated into the shoe to measure pressure changes between the foot and the floor. However, wearable sensors have not yet become a standard due to the uncertainty of the accuracy of IMU-based evaluations for balance assessment compared to the gold standard force platform. If their accuracy is proven, it is clear that the use of wearable sensors for balance measurements would be ideal in terms of low cost and easy usability in different environments. These systems enable wearable and non-wearable technology together in walking labs, and also provide a game environment. The flexibility provided in the selection of wearable, non-wearable systems meets most clinical and research requirements in balance assessments today [15,17].

Force plates provided the gold standard technology for measuring centers of pressure as the cornerstone of balance evaluation. Although the force plate is considered the gold standard for reliable balance measurements, it is not practical to use in clinical settings and sports centers because it is expensive and heavy [17].

Virtual reality applications: These are systems that are used in the evaluation of balance with their three-dimensional technology feature, give the participants a real feeling, and are created by computers in order to develop and evaluate the balance. The purpose of using Virtual Reality (VR) in rehabilitation is to induce and / or train the brain and behavioral responses in a controlled laboratory or clinical environment, similar to those that occur in the real world. A key feature of VR is immersion, that is, the exact extent to which the user is integrated into the virtual environment. VR also creates

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opportunities to create visual changes at different levels during (VR) balance tests. Compared to the commonly used eyes-open or closed-eyes conditions, VR applications can more finely differentiate the visual and vestibular systems, by providing a wide range of visual distortions. These systems also allow the balance to be evaluated in all planes, it allows therapists to better record the assessments of the individual's balance problem [8,18].

Web-based applications, Tele-rehabilitation system: It includes systems that record and send instant data such as the tele-rehabilitation system, to what extent the balance is disturbed in patients with balance problems. It covers personalized applications. These are systems that evaluate all body parameters of the patient remotely through sensors, record instant data and send it to healthcare professionals in the presence of physiotherapists and physicians. For preventive and treatment strategies, allowing for long-term monitoring, wireless sensors will encourage tele-rehabilitation and reduce some of the burden of healthcare services. There has been little work to date regarding the role of tele-rehabilitation in balance assessment through wireless sensors. However, tele-rehabilitation should be considered from the following points of view; a. Access to care-treatment is quite difficult in patients with balance disorders due to transportation difficulties and dependence on caregivers. Wireless sensors appear to be a sensitive and objective tool for measuring balance control in the home environment. Current evidence also shows that tele-rehabilitation promotes a reduction in patient and caregiver burden. b. Assessments made in a hospital setting often do not always reflect real-life situations. Therefore, long-term monitoring of postural ability during daily activities can provide reliable data on patient balance control in free living conditions [10,19,20].

The main purpose of rehabilitation is to develop individual postural skills by supporting patient independence in ecological environments. For this purpose, by using information and communication technologies, it will provide tele-rehabilitation and rehabilitation services directly at home, with an efficiency similar to traditional therapy.

Nowadays, the increasing use of mobile phones and other technological devices in many areas of daily life encourages widespread technological education among the general population, including the elderly. Accordingly, in the coming years, wearable devices will be increasingly used to increase adherence to tele-rehabilitation strategies. Tele-rehabilitation will also reduce the number of periodic hospitalizations, thanks to remote and continuous evaluation by physicians and physical therapists [21,22].

These technological methods are applications that increase treatment efficiency and patient motivation by providing visual and auditory input to the patient. These are methods that have been put forward to serve patients and clinicians by saving time and money. These methods, which are completely under the control of the physiotherapist using the application, the frequency and number of repetitions can be adjusted optionally. By increasing the motor learning method, it helps to eliminate disturbances in balance thanks to sensory, auditory and visual stimulation. The tasks or movements performed by the physiotherapist are similar to the tasks and movements in practice. Motor learning is provided with task-oriented motor activities that cover movements in daily life. It maximizes the functional movements of the patient. Therefore, it includes patient-specific assessment methods [21-23].

Conclusion

Today, there are many technologies such as sensor systems, virtual reality applications, tele-rehabilitation system, web-based applications, robotic systems in evaluating balance. The choice of this technology depends on the patient. The method chosen varies according to the suitability for the patient, ease of use, time saving, active participation, financial situation of the person and the severity of the disease.

Clinically useful and efficient evaluation of balance during standing and walking is difficult, especially in patients with neurological disorders. According to the studies, considering that balance disorders are generally of neurological origin and considering the explained factors, we think that sensor-based virtual reality applications increase patient motivation, apply well in balance and movement evaluation, and increase balance and mobility.

Fusion systems offer possibilities to combine wearable and non-wearable technology as well as play games in walking labs. Convenience in selecting wearable, non-wearable and fusion systems can meet most clinical and research needs.

We think that more research is needed for the outcome criteria of this promising technology about the verification, validation and usability of wearable systems against the traditional balance assessment approaches with the ability to provide measurements in different environments with mobile balance assessment applications.

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