Differences in Kinematic Variables in Single-Leg Stance between Patients with Stroke and Healthy Elderly People Measured with Inertial Sensors: A Cross-Sectional Study

David Perez-Cruzado, PhD,* Manuel Gonzalez-Sanchez, PhD,* and Antonio Ignacio Cuesta-Vargas, PhD*,†

Objective: The study aimed to analyze the differences between kinematic parameters in the single-leg stance (SLS) in patients with stroke and in healthy elderly people measured with 2 inertial sensors—1 in the trunk and 1 in the lumbar region. *Methods:* Two groups of participants were measured: the first group consisted of 5 healthy elderly people over 65 years of age; the second group consisted of 5 patients with stroke over 65 years of age, recovering for more than 6 months after suffering a stroke, and who had been undergoing rehabilitation treatment for at least 6 months. Two inertial sensors were located in the participants: in the trunk region (T7-T8) and in the lumbar region (L5-S1). The SLS test was performed in 4 conditions: right-dominant leg, open eyes; right-dominant leg, closed eyes; left-nondominant leg, open eyes; and left-nondominant leg, closed eyes. *Results:* Significant differences in displacement in the lumbar and trunk sensors are highlighted in 6 of 36 variables. In the velocity variables, significant differences were only found in 1 variable. Differences during SLS between the affected and the nonaffected legs in patients with stroke were found in 5 of the 36 analyzed variables and in 1 variable in velocity. The intraclass correlation coefficients were higher than .866 (95% confidence interval: .828-.857) for all variables. *Conclusions:* Only significant differences were found in 7 of the 128 kinematic variables analyzed in both groups, so that it could be confirmed that there are no significant differences in the static balance between healthy elderly people and people with stroke who undergo the rehabilitative treatment. **Key Words:** Stroke—elderly people—rehabilitation—body balance—static balance—kinematic.

Introduction

Loss of balance is one of the main problems that prevent people with diseases from carrying out their daily activities.[1,2] It is one of the main side effects of stroke and causes an increased risk of falling in patients with stroke.[3]

The single-leg stance (SLS) is an appropriate test to measure the maintenance of static balance in healthy people[4-6] and in patients with stroke.[7-9] This test is widely used in research and clinical practice due to its ease of use.[7]

Rehabilitation is very important for people who suffer a stroke, especially in the first stage.[8] Rehabilitation

From the *Departmento de Fisioterapia, Instituto de Investigación Biomédica de Málaga (IBIMA), Málaga, Spain; and †School of Clinical Sciences of the Faculty of Health, Queensland University of Technology, Brisbane, Queensland, Australia.

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Address correspondence to Manuel Gonzalez-Sanchez, PhD, Departmento de Fisioterapia, Instituto de Investigación Biomédica de Málaga (IBIMA), Arquitecto Francisco Peñalosa s/n. (ampliación Campus Teatinos), 29071 Málaga, Spain. E-mail: mgsa23@uma.es.

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treatment can help the patient with stroke regain lost strength and mobility or balance functions.[9] Recovery of balance in patients with stroke is very important because this gives them greater independence in carrying out their daily activities and reduces the risk of falling.[10]

Inertial sensors are tools that help us to measure the kinematic parameters of a gesture,[11,12] and these instruments have been used in balance tests on healthy people[13,14] and in patients with stroke [15,16] with a range validity of .66-.99[17] and a reliability of .84-.97,[18] which has led to their wider use in research and in clinical practice.

Despite inertial sensors having been used in patients with stroke and in healthy people to measure balance, there are no studies that analyze the differences between the kinematic parameters in these groups of people with SLS.

The main objective of the present study was to analyze the differences between kinematic parameters in the SLS in patients with stroke and in healthy elderly people measured with 2 inertial sensors—1 in the trunk and 1 in the lumbar region. Our hypothesis is that there will be no significant differences between the 2 groups in the SLS due to the rehabilitation treatment that the patients with stroke are undergoing.

Methods

Design and Participants

A cross-sectional study was conducted. Two groups of participants were measured: the first group consisted of 5 healthy elderly people over 65 years of age who were not suffering from any illness that affected their motor skills or balance and who were required be right-handed; the second group consisted of 5 patients with stroke over 65 years of age, recovering for more than 6 months after suffering a stroke, able to walk at least 15 meters without help and to stand for more than 30 seconds without any help, whose affected leg was the left leg, and who had been undergoing rehabilitation treatment for at least 6 months, including deep-water running and exercises of stretching and strengthening of the affected leg 3 sessions weekly, with a total duration of 12 weeks. In the group of patients with stroke, the exclusion criteria were severe heminegligence, another neurological or musculoskeletal pathology, or sharp pain.

Ethical approval for the study was granted by the Ethics Committee of the Faculty of Health Sciences, University of Málaga. The study complied with the principles established in the Declaration of Helsinki.

Before carrying out the SLS, each participant obtained information about the procedure and was asked to sign a declaration of informed consent for study participation. All participants declared that participation was voluntary and that they could withdraw at any time. We also made sure that their data were treated according to the Organic Law on Data Protection (Law 15/1999).

Inertial Sensors

The inertial sensors used were InertialCube3 (Intersense Inc., Bedford, MA), with a sampling frequency of 180 Hz. The InertiaCube3 is a sensor based on microelectromechanical systems technology and does not incorporate castors, which might generate noise and inertial forces and increase the risk of mechanical failure. The InertiaCube3 measures 3 physical properties simultaneously, namely, angular rates, linear accelerations, and magnetic field components along the 3 axes (yaw, pitch, and roll). Miniature vibrating elements were used to measure all angular velocities and linear accelerations.

Inertial sensors were located in the trunk region (T7-T8) and in the lumbar region (L5-S1) to obtain kinematic data. Sensors were placed with tape and reinforced with elastic surrounding the entire participant to ensure that the sensor did not move from this position. Movement was recorded 3 seconds before the participant carried out the test and the recording was finished 3 seconds after the participant had finished; this allowed the SLS to identify in the kinematic data when the participant started and finished the test.

The origin of the coordinate sensor was positioned in the left posterior inferior corner.

Procedure: Single-Leg Stance

The SLS is performed as follows: participants had to stand on 1 leg and with their arms on their hips; when the participant was in this position, the time that the participant could stand in this position until their foot touched the ground or until their arms were separated from the hip was recorded.[19]

Soft modifications of the test were made to carry out the SLS on all the participants. All participants were asked to perform the test for 20 seconds, regardless of whether their arms left the hip or the leg was not sustained at 90° of knee flexion (Fig 1). Two researchers were around the participant to provide more security in case of loss of balance or falling. The patients were also surrounded by mats to minimize the effects if a fall occurred. All participants had a rest of 60 seconds between each test run to minimize the effects of fatigue.

The SLS test was performed in 4 conditions: right-dominant leg, open eyes; right-dominant leg, closed eyes; left-nondominant leg, open eyes; and left-nondominant leg, closed eyes.

Before the test was performed and the data recorded, the test was explained to the participants and they were given the opportunity to practice for as much time as they felt was necessary to perform the test properly when the sensor measurement was started.

Variables

Displacement: rotation (left or right side): maximum positive displacement (right) and negative displacement