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Changes in the standing posture of stroke patients during rehabilitation

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Abstract

The aim of this study was to analyze the changes in the standing center of pressure (COP) in a hemiplegic adult population at the beginning and the end of in-patient rehabilitation. The trajectory of the COP was recorded on a force platform and was analyzed in terms of the frequency spectra of the center of gravity (COG), and the frequency spectra of the COP minus COG, a derived measure of neuromuscular stiffness.

The study population consisted of eight hemiplegic subjects, median age of 53.5 years (range 27–79 years). The median interval between stroke and the first series of measures was 31 days (range 4–127) and the median interval between the two measures was 47.5 days (range 12–92). All the subjects were treated in an inpatient setting in a Neurorehabilitation Center.

Our results showed that following rehabilitation, there was a reduction in the amplitude of the medio-lateral frequency spectra of the COP from a median of 5.651 mm (range 3.13–14.05) at the first measurement to 4.408 mm (range 2.40–8.58) at the second measurement. These changes were significant ($p < 0.05$). Significant changes were also observed in the measure of COP minus COG, from 1.324 mm (range 0.92–2.63) on the first measure to 0.917 mm (range 0.46–1.53) on the second measure.

In conclusion, the medio-lateral COP trajectory of hemiplegic subjects significantly improved during rehabilitation. We hypothesized that a major component of this improvement was the decrease in neuromuscular stiffness of the adductor and abductor muscles of the hips.

Keywords: Hemiplegia; Equilibrium; Rehabilitation; Standing posture; Force platform

1. Introduction

Postural unsteadiness represents a very common impairment in hemiplegic stroke patients and is the major source of falls and limitation in functional independence [1,2]. Recovery of a stable standing position is a crucial step in the rehabilitation process of the hemiplegic subject [3].

As the notion of standing balance is more qualitative than quantitative, we prefer the term standing posture. The majority of publications on the subject use variation of the center of pressure (COP) to describe the characteristic of the standing posture. This measure refers to the point of application of the component reaction forces of the ground. Characteristically, the COP of a hemiplegic subject is displaced laterally towards the side of hemispheric damage [4–8]. Hemiplegic patients also have a larger total COP area, as well as a larger medio-lateral movement of the COP in comparison to healthy subjects [6].

Most of these analyses assume that in the standing position, the human body can be treated as a rigid system articulated around the axis of the ankles. Consequently, in the standing position, the vertical projections of the center of gravity (COG), or center of gravity of the mass centers of the body segments, will on average be the same as the COP.

It is however necessary to refine this theory if we want to analyze the components of standing posture using COP measurements [9–12]. Recent publications have proposed the breakdown of the displacement of the COP into two elementary trajectories, namely that of the COG and of the COG subtracted from the COP. Such an approach allows dissection of this complex system to better reflect the role of neuromuscular control. The trajectory of the COG gives information on the control of the movements of the body

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necessary to maintain a standing posture [9,10], while the trajectory of COP − COG (difference of the center of pressure from the center of gravity) probably expresses the neuromuscular stiffness of the biomechanical system controlling the center of gravity [11,12].

To our knowledge, there is no publication describing the changes in COP in hemiplegic subjects during rehabilitation. In a previous study, we compared a population of hemiplegic subjects to healthy adults using this new analysis model [13]. We demonstrated that during standing, the characteristics of the trajectory of the COP − COG were different between the two populations. The aim of the present study was to compare, using a similar approach, the evolution of the standing posture in hemiplegic adults during rehabilitation. We hypothesized that the characteristics of the trajectory of the COP − COG (probably expressing neuromuscular stiffness) during standing will tend to normalize during rehabilitation. A better understanding of the mechanisms required to maintain balance may allow the development of treatment strategies and rehabilitation plans for the hemiplegic patient.

2. Subjects and methods

2.1. Subjects

We evaluated all hemiplegic subjects hospitalized from October 2001 to June 2002 in our Neurorehabilitation Center due to hemorrhagic or ischemic stroke during the preceding 3 months. Patients had to be able to give informed consent, to be able to remain standing without help or support for at least 60 s and to understand simple orders. Subjects were excluded if they had had multiple strokes involving both cerebral hemispheres; if they had sensory deficiencies of another origin than stroke (e.g. polyneuropathy, peripheral vestibular lesion, etc.) or if they had an epileptic seizure during the rehabilitation period. Strokes of the brainstem were included. The study protocol was reviewed and accepted by the local ethics committee.

2.2. Equipment

All subjects were tested on a force platform made of a rigid plastic board (60 cm × 60 cm) sufficiently thick to retain its shape, mounted on three vertical dynamometric mono-axial sensors (sensitiveness resolution: 900 points/kg; non-linearity: 0.2%; hysteresis: 0.2%) [14]. The analogue signal from the sensors was digitalized after amplification by a 16-bit acquisition card and recorded on a personal computer. For this purpose, an original program (Winposture 2000, version 2.24[a]) was used to record sequences of 2048 points with a sampling frequency of 40 Hz during 51.2 s for the three sensors [14]. The number of points were chosen as a compromise with the frequency, the time to extract all the informations. The spatio-temporal coordinates of the COP were calculated from the recorded data [14], by applying a low pass 10 Hz filter to the recorded values.

2.3. Study protocol

For each measure, the subject stood barefoot on the force platform. The feet formed an open angle of 30° and the heels were separated by 8 cm. Instructions were given to the subject to oscillate as little as possible, while keeping the arms along the body if possible. The subjects were instructed to stare at a point on the opposite wall at eye level and to maintain the position for about 60 s. After 5 s of stabilization, data were recorded for 51.2 s. The experimenter remained near the subject for security purposes, but did not touch the patient or provide additional instructions. After a rest period of 30 s, the measurement was repeated for a total of five times. If the subject moved his foot during data recording, the trial was abandoned and a new measurement performed.

The first measurements were made at the start of rehabilitation, as soon as the subject met the eligibility criteria and had signed the informed consent. They were repeated at the end of rehabilitation.

The Rivermead motor assessment [15] was performed to assess motor function at the time of the first and the second series of measurements.

This protocol is similar to the majority of the other tests of postural control [4,11,13,16,17]. Its reliability has been largely presented in previous papers.

2.4. Data analyses

The COP's trajectory allows measurement of the average medio-lateral and antero-posterior position of the COP as well as the COP area. Temporal changes of the COP can also be analyzed in the two planes (Fig. 1). The temporal data were transformed to frequencies using fast Fourier transformations (FFT), thus giving the frequency spectrum of the COP [16] (Fig. 2). Trajectories of the COG and of the COP − COG were also analyzed [14,16]. By multiplying each COP frequency spectrum by the filter COG/COP (Fig. 3) [16], the frequency spectrum of COG was derived. The COP − COG frequency spectrum was obtained by subtracting the frequency spectrum of the COG from the frequency spectrum of the COP [16] (Fig. 4). The medio-lateral and antero-posterior COG and COP − COG frequency spectra were analyzed by calculating the root mean square (R.M.S.) and the median frequency (MF) of the amplitude of the movements (Matlab®, version 6 for Windows) [18]. In the R.M.S. formula, N represents the number of values, $x1(n)$ each value and $\overline{x1}$ the mean of each value. In the MF formula, i represents each class of frequency, n the superior limit of the frequency band chosen,