Acta of Bioengineering and Biomechanics
Vol. 18, No. 3, 2016

Original paper
DOI: 10.5277/ABB-00481-2015-02

Impact of multi-task on symptomatic patient affected by chronical vestibular disorders

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Purpose: After a vestibular deficit some patients may be affected by chronical postural instability. The aim of this study was to identify the emotional and cognitive factors of these symptomatic patients. In particular, the double cognitive task and the anxiety disorder were identified by our patients. Through a retrospective study, 14 patients (65.4 ±18 years) participated in the experiment. *Method*: The experimentation consists in the study of the standing position of our patients through the aggregate of the trajectories of the center of pressure (COP) using a force plate device. With the aim of isolating the emotional and cognitive influence, this experimentation was defined in two conditions. In the first one, the patients were asked to maintain their balance without additional tasks. In the second one, the patients were submitted to an additional cognitive arithmetic task. The stabilogram surface, length (the forward and backward displacement distance during deviations in COP), lateral and the antero-posterior deviations were assessed. *Results*: Our results showed an increase of postural instability of patients affected by chronical vestibular disorders when submitted to the double task. The patients submitted to the cognitive task present a larger surface of activity in comparison with the free-task one (Wilcoxon test *p*-value equals $p = 0.0453$). In addition, their displacements inside this area are more important ($p = 0.0338$). The COP of all our patients deviated forward in the presence of the double task. *Conclusion*: The increase in instability during the double cognitive task could be explained by an additional stress caused by the desire to make a success of the cognitive task.

Key words: *rehabilitation, posturography, ability, cognitive skills, vestibular disorders, anxiety posture balance*

1. Introduction

Control of static and dynamic posture is facilitated by multiple sources of information permitting compensation of internal and external perturbations. However, when information is defective, balance may be disturbed affecting daily activities. The patients affected by a unilateral acute vestibular deficit present during a first period – vertigo–nystagmus (horizontal-rotatory beating to the healthy side) and a head and postural deviation to the side of the lesion [5]. Later, the static vestibular disturbances (ocular nystagmus, postural asymmetry) are corrected spontaneously more or less completely [10], [11] and [15]. Patients with dynamic vestibular disorders will often compensate by adaptation, substitution or habituation, vestibular rehabilitation being a determining factor to optimize this compensation [11]. But, in the chronic phase, postural instability persists in approximately 20% of patients with a unilateral lesion [10]. In the case of a bilateral vestibular lesion, postural stability remains more or less constant [14]. The disorder may appear only in certain contexts, such as during sensory stimulation, head movements or walking on unstable ground. Posturography under various sensory or cognitive conditions provides a means by which to elucidate the pathophysiological mechanisms, Visser et al.

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Received: October 7th, 2015
Accepted for publication: November 4th, 2015

[24], allowing the effects of rehabilitation to be quantified with the aim of optimizing rehabilitation. The measurements of oscillations of the upright body position according to the imposed constraints can use characteristics described by the COP over a given time, like their his surface, displacement and velocity [24].

Some patients describe postural instabilities (PI) or vertiginous feelings in their daily life. The impact of PI can be much more important than the results of the clinical examination and/or quantitative measurements. The degree of compensation can vary according to various psychological constraints [12]. Redfern et al. [21] evokes the importance of conscious attention necessary for a good compensation. During a vestibular attack, attention must be directed to the proprioceptive, visual and vestibular sensory integration [20]. The influence of the attentional factors on balance, particularly in the elderly, have attracted much research emphasizing the dependence of balance maintenance on attentional resources [18]. Concentrating on cognitive task may result in deterioration of balance [25]. Nevertheless, few studies have been performed on the impact of cognitive tasks on the postural stability of subjects with vestibular deficit.

This retrospective study aimed at measuring the impact of these different factors (cognitive and emotional) on the balance of symptomatic patients affected by chronic vestibular deficits. Through a posturographic study we emphasize a perturbation of the patients' balance when they are submitted to a cognitive task. Models of explanation are discussed in the present study.

2. Materials and methods

2.1. Patients

14 patients (65.4 ± 18 years), 10 females and 4 males participated in the study. All subjects had a chronic vestibular peripheral pathology. Patients were asked about the effect of postural instability in their daily life. All those included in this study were identified from situations of double cognitive tasks like for instance "stop talking when walking" or "postural instability when talking".

The fourteen subjects were divided into a group with a unilateral right vestibular deficit (5), left vestibular deficit (4) and another group with bilateral deficit (5). All subjects had at least 16 months' history of vestibular symptoms. We noted that the patients had the first evaluation at the end of this period. During the examination, several variables characterizing postural control were studied. All those subjects affected by increasing instability during cognitive tasks followed the protocol described below. All underwent a neurological examination: 3 subjects had proprioceptive disorders from diabetic neuropathy. One subject had Mild Cognitive Impairment (MCI). All brain MRIs were normal. No orthopedic disorder or visual impairment (which may affect balance) was found in any of the subjects.

2.2. Methodology

The Satel force plate was used for quantification of the trajectory of the COP. The force plate of 12 kg in weight comprises an upper stable support (480 mm × 480 mm) fixed on three strain-gauge force transducers which record the displacement of the COP in each direction (medio-lateral and antero-posterior) at sampling frequency of 40 Hz. Each sensor had a certified sensitivity of 0.0017% for a wide measurement range from 0 to 100 kg. Before each trial, a calibration and an automatic calibration of the three sensors were made to assure accuracy of the platform. The data recorded corresponded to the global displacement of the COP. With eyes open, the subject was asked to fixate on visual target in the upright position, without shoes in a normalized foot position for 30 s. The force plates used in our experimentation have been used in several other studies [29].

In this study, the subjects were asked to perform a cognitive task, consisting of a reverse serial 7 s countdown (i.e., 100, 93, 86...). The investigator encouraged the subject to answer as fast as possible. In a standing position and under the conditions "open eyes" and "open eyes with a cognitive task", the postural strategies were studied from the trajectory of the COP. We focused on the following usual postural variables:

- the surface area of the stabilogram calculate the 95% confidence interval sway area to reduce the otherwise commonly large effects of recording outliers. This indicator measures the area of patients activities,
- the length of the stabilogram (the forward and backward displacement distance during deviations in COP) which gives indication about the amplitude of movement inside the activity area,
- the lengths of the stabilogram in the medio-lateral and antero-posterior directions,

– the average medio-lateral and antero-posterior deviations for all the subjects.

2.3. Statistical analysis

We emphasized significant behavior differences between the patient's balance according to whether they were submitted to the cognitive task or not. We followed the present steps of analysis: first, we investigated the impact of the cognitive task on the activity area. Then, we focused on the amplitude of movement inside the activity area. Finally, we investigated the impact of the cognitive task on the incidence (medio-lateral and antero-posterior).

We performed a descriptive analysis and pairwise comparison tests. The significance level for these tests has been fixed to 5%. Normality of the difference between the two conditions of observations was firstly tested for each variable. Then we performed a pairwise Student or Wilcoxon test, depending on whether the normality was confirmed or not.

3. Results

The results are summarized in Table 1 and Figs. 1 and 2 and detailed in the following paragraphs.

Table 1 presents some position and dispersion indicators for each variable, for both experimental conditions (without and with cognitive task).

Figure 1 presents, for each of the fourteen patients, relative evolution of the stabilogram surface, lengths and deviations from the original behaviour (without cognitive task) to the experimentation with cognitive task. Precisely, we have represented the percentage of increase or decrease (for surface and lengths) and the modification of the COP positions.

Figure 2 presents a comparison of the mean values of stabilogram surface, lengths (medio-lateral, antero-posterior and total) between the two experimental conditions.

3.1. Stabilogram surface and lengths

Both stabilogram surface and total length increase for 10 subjects and decrease for the other four (subjects 5, 9, 12 and 13).

The mean stabilogram surface with cognitive task significantly increased with respect to the one without cognitive task (Wilcoxon test *p*-value equals 0.0453), yielding a significant augmentation of the activity area of patients when submitted to a cognitive task.

The mean stabilogram total length with cognitive task significantly increased with respect to the one without cognitive task (Wilcoxon test *p*-value equals 0.0338). This augmentation was essentially due to a significant increase in the length in the antero-posterior direction (Wilcoxon test *p*-value equal to 0.0158).

3.2. COP deviations

All patients presented backward – or posterior – incidence deviations when not submitted to cognitive task, as reported in Table 2. All of them moved forward when submitted to the cognitive task. This incidence evolution appeared significant (Student test *p*-value less than 10^{-4}).

No general result was observed on medio-lateral (ML) deviations: some patients (5, 6, 11 and 14) corrected their ML deviations, some others (patients 2, 3 and 10) over-corrected and the remaining ones (1, 4, 7, 12, 13) increased their ML deviations.

Table 1. Position and dispersion indicators of postural indices, according to whether the patients were submitted to a cognitive task or not

	Without cognitive task						With cognitive task					
	Surf. (mm^2)	Length (mm)	LX (mm)	LY (mm)	Xm (mm)	Ym (mm)	Surf. (mm^2)	Length (mm)	LX (mm)	LY (mm)	Xm (mm)	Ym (mm)
Mean	638	539	265.7	406.7	3.236	–49.17	1114.2	719.1	334.7	555.2	1.17	–38.08
Min	149.7	312.4	163.4	191.9	–10.93	–90.92	186.2	319.4	164.1	239.1	–19.03	–84.66
Max	1893.3	983.4	416	871.2	14.16	–30.57	4026	2116.2	779.9	1747.4	19.26	–23.55
St. dev	469.53	226.89	67.58	223.89	8.21	16.49	1149.8	472.14	158.52	415.78	9.79	15.49

LX, LY, Xm and Ym denote respectively medio-lateral and antero-posterior lengths and incidence deviations from the origin.

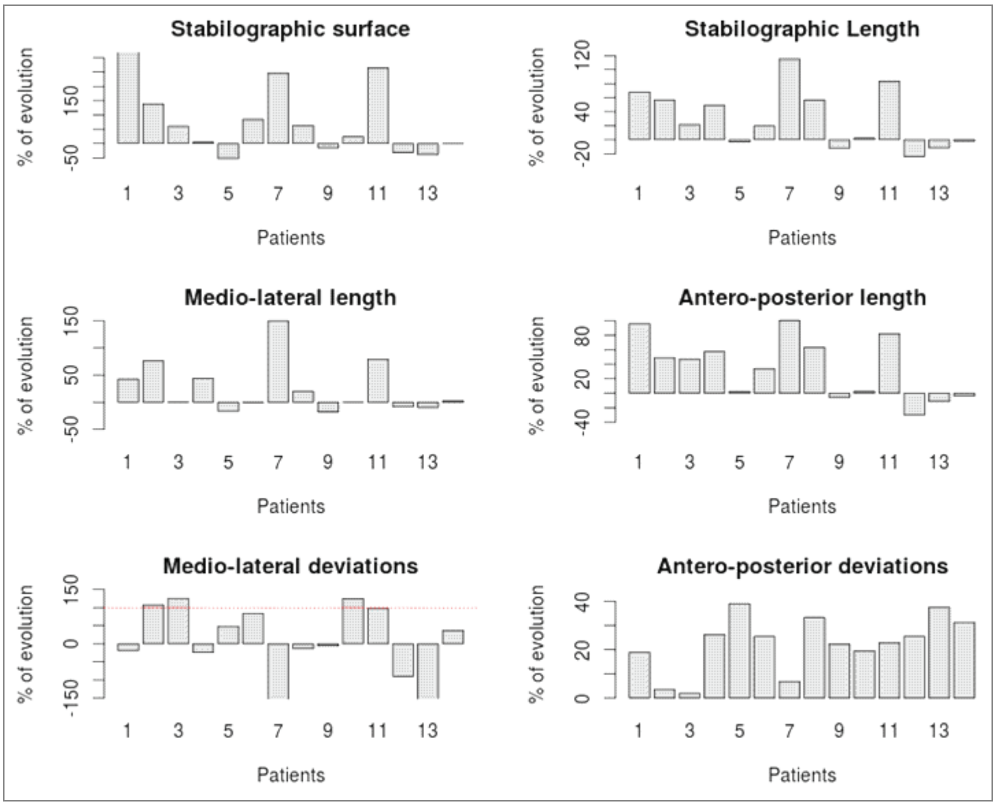

Fig. 1. Relative evolution of stabilogram surface, length (total, medio-lateral and antero-posterior) and deviations of patients when submitted to cognitive task with respect to their original behaviour (without cognitive task), in percentage of increase or decrease.
The dotted red line for medio-lateral deviations indicates the limit above which subjects over-corrected their deviations

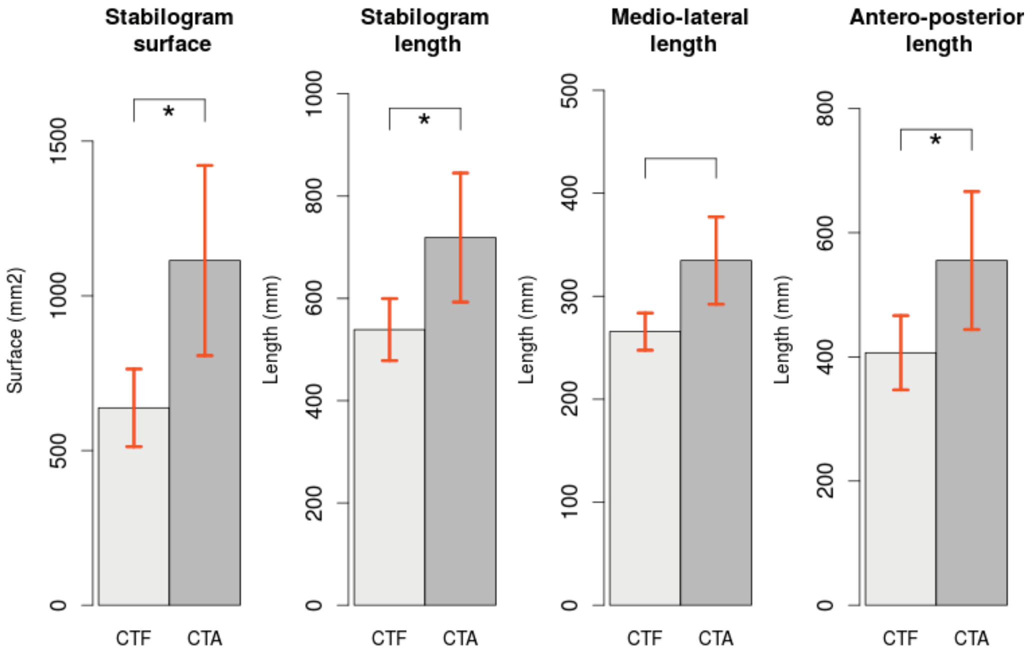

Fig. 2. Comparison of the mean stabilogram surfaces and lengths (total, medio-lateral and antero-posterior) according to the cognitive activity (abbreviations CTF and CTA are used respectively for "Cognitive-task free" and "Cognitive task actived"). Red segments represent the standard errors. Significant differences exist between the two experimental conditions, highlighted by an asterisk

Table 2. Medio-lateral and antero-posterior deviations (in mm) of COP with respect to its original position for both experimental conditions

Patient ID	1	2	3	4	5	6	7
ML deviations (CTF)	–10.93	–6.96	8.06	–4.6	14.16	1	1.8
ML deviations (CTA)	–12.99	0.55	–2.08	–5.71	7.3	0.16	10.96
AP deviations (CTF)	–60.98	–34.77	–35.16	–40.46	–44.99	–38.89	–90.92
AP deviations (CTA)	–49.44	–33.52	–34.45	–29.78	–27.38	–28.96	–84.66
Patient ID	8	9	10	11	12	13	14
ML deviations (CTF)	2.27	9.99	4.66	14.09	10.13	–7.35	8.98
ML deviations (CTA)	2.58	10.58	–1.18	0.29	19.26	–19.03	5.67
AP deviations (CTF)	–60.66	–44.57	–35.28	–30.57	–67.75	–51.08	–52.09
AP deviations (CTA)	–40.39	–34.7	–28.36	–23.55	–50.44	–31.83	–35.72

4. Discussion

This study confirms the increase of postural instability of patients affected by vestibular deficit when they stand in static conditions (with open eyes) and when submitted to the cognitive task. The increase in amplitude and the oscillation speed is well known in bilateral vestibular disability [1]. However, the normal posturography is typically reported in patients affected by unilateral disability [7]. Our patients showed a significant increase in the postural instability with a concomitant arithmetic task. Some results found in the literature are different from ours, in patients affected by chronic vestibular deficits in the dual task condition and different condition of stance. Yardley et al. [27] found a decrement performance in the cognitive task, when the stance remains relatively stable. This cognitive performance decreases depending on the complexity of the cognitive and balancing tasks. Redfern et al. [21] reported that asymptomatic patients having undergone a unilateral vestibular neurotomy, compensated well under the influence of a double task with reaction times, on four different postural conditions. All the patients performed less well in the cognitive task than controls. Still, the postural oscillations increased in healthy subjects as well as in patients, when the postural constraints became more complex. These authors concluded that in the case of a vestibular attack, the postural task is a priority over the cognitive task. The impact thus depends on the sensory context in which postural balance is carried out [22]. The cognitive chronometric performances of our patients were not noted in this study. They were encouraged to complete the cognitive task successfully. In other words, we have imposed a strategy based especially on the success of the cognitive task. This alternative experimentation can partly explain these differences between our results and earlier studies. In addition, the participants in this study were mainly elderly, which may explain the increase in instability independent of the vestibular disability. In the healthy subjects, particularly in the elderly people even if the task is easier [18], [23], simultaneous cognitive and postural tasks cause a reduction in the muscular effort dedicated to this postural task [19]. In other pathologies, for example, in patients with multiple sclerosis, the reaction times are slowed down [13]. The postural oscillations increase in a double cognitive task (generating word lists) whatever the EDSS score (Expanded Disability Status Scale) [3]. Various double tasks have been used in the evaluation of postural disorders regardless of the pathology studied: visuo-spatial memory – Maylor et al. [18], reaction time – Redfern et al. and Yardley et al. [20], [27], the mental calculation – Brown et al. [4], and the digit span (the request of the visuo-spatial working memory given more instability) [18]. Two models of explanation for the impact of the double cognitive task on postural stability have been advanced by Woollacott et al. [25]: in model 1, two tasks use the same pathway (“bottleneck” effect); in model 2, a limited capacity of cognitive resources which limit the completion of the tasks to be achieved (“capability” effect). The type of the cognitive task chosen, in simple terms saturates the working memory. Nevertheless, Yardley et al. [26] highlights that the cognitive task such as was applied here, requires simultaneously both attention and vocal articulation. The same task performed without speech does not result in instability. Speech is thus more destabilizing than a pure arithmetic task. Moreover, the posturographic tests are carried out with eyes opened; requesting more attentional resources for the sensory integration [18], [27]. Finally, the patients in this study were confronted with the multi-task rather than the double task: postural, sensory, arithmetic and vocal working memory. These situations closely mimic their difficulties in daily life.

Nevertheless, an emotional stress may also be a factor during this test affecting the balance strategy [30]. The associated fear of falling increases the oscillations in elderly people [16]. Anxiety disorders are frequently associated with vestibular pathology without correlations to the degree of vestibular deficit [2]. Psychological factors can play a part in persistent symptoms: 3% of the patients after vestibular neuritis have an insufficiently compensated deficit, but 29% remain symptomatic [8]. Anxiety and preexistent preoccupations or the conviction that the disease represents disability are also causal factors [2], [28]. An anxiety found on the Dizziness Handicap Inventory (DHI), associated or not with vestibular symptoms increases instability in the anteroposterior axis [9], [30]. No evaluation of anxiety was possible in this study, but anxiety may well be a factor affecting postural compensation.

In general, whatever the type of vestibular disorder and independently of the presence of a neuropathy of the lower extremities, patients manifest a posterior orientation of the COP, a position which is centered during the double cognitive task. Maki et al. [17] showed this orientation of the COP which moves forwards in healthy subjects with arousal, during the arithmetic double cognitive task and following the activation of the anterior tibialis muscle. Finally, the multi-cognitive task increases instability, the anxiety especially in anteroposterior axis. But the orientation of the COP becomes centered in anteroposterior axis. Probably, the patients experience the cognitive multitask similarly to how they would experience a high stress situation. The increase in instability during the double cognitive task could be explained by an additional stress caused by the desire to make a success of the cognitive task.

Our retrospective study suffers from some reservations: limited number of subjects, quantification of the level of anxiety during the cognitive task. The posturographic measurement of the vestibular disorders is subjected to controversies. The variables retained for the signal analysis, the conditions of disparate measurements are in the literature. Inter and intra individual variability has been emphasized [6], [1]. These data would deserve to be confirmed by an exploratory study. The comprehension of the origin and methods of expression of the persistent symptoms among patients with vestibular deficits may make it possible to better direct the vestibular rehabilitation, by specifying the nature of exercises that can be carried out.

5. Conclusion

In this paper, an experimental analysis of patients affected by vestibular disorders was performed. Through two cognitive conditions the discriminate parameters of the patients' behavior were obtained. Our study showed an increase of postural instability in static conditions with open eyes. With reference to the COP, the patients showed a posterior orientation, a position which is centered during the double cognitive task. In this context, the emotional and cognitive factors together may affect the stability behavior of patient. Indeed, in the daily life of patients both variables are very important and cannot be separated. In terms of rehabilitation, the results obtained could help optimize the symptomatic diagnosis of various patients and to suggest the type of exercises that could be prescribed. Taking into account the principal results, the next step of our study will focus on the modeling of the patient's behavior. The utilization of a mathematical model should allow the number of experiments to be reduced by including only the adjustable parameters characterizing postural control with the aim of optimizing rehabilitation.

Acknowledgement

We would like to express our gratitude to Ms. Denisse Espino, Mr Ellie Abdi for giving us helpful comments.

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