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The Phasic Influence of Vestibular Neural Inputs During Sit-to-Stand: A Case Report

Ali A Bani-Ahmad*

Department of Physical Therapy, University of Tabuk (UT), Tabuk, Kingdom of Saudi Arabia (KSA)

***Corresponding author:** Ali A Bani-Ahmad, PT, CPT, CKTP, PhD, Assistant Professor and consultant of Physical Therapy, Department of Physical Therapy, Faculty of Applied medical Sciences, University of Tabuk, 71491 Tabuk, KSA, Tel: (00966) 533933971; E-mail: ali.baniahmed@gmail.com

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Abstract

Introduction: Deeper understanding of the contribution of the vestibular system while performing sit-to-stand task is needed to determine the root cause of functional limitations to develop more effective assessment and interventions. We introduced Galvanic Vestibular Stimulation (GVS) to interrupt vestibular neural signals and examine the phasic influence of vestibular neural input during two phases of sit-to-stand.

Method: A 25 yrs old healthy male with No previous history of motion sickness, No neurological, musculo-skeletal or vestibular problems. The medio-lateral Center of Mass (COM) was used as the main outcome measure: Peak-to-peak (Med-Lat P_P) and Root mean Square (Med-Lat RMS). The stimulus intensity threshold (x) was reported. Then the COM displacement was measured in three conditions: No stimulation (NO), 2x threshold stimulation and 4x threshold stimulation during sit-to-stand task.

Results: As stimulation increased, Med-Lat P_P and RMS increased. Specifically, (1) there were 42% & 69% overall increase in overall P_P in 2x and 4x compared to NO, respectively (2) there were 56% & 76% overall increase in overall RMS in 2x and 4x compared to NO, respectively. Phase II showed 21% and 36% increase in P_P compared to Phase I in 2x and 4X respectively. Phase II also showed 18% and 54% increase in RMS compared to Phase I in 2x and 4X, respectively.

Conclusion: We report a phase dependent maneuver of the vestibular inputs during sit-to-stand. We hope that these novel data will shed some light on the influence of vestibular inputs on functional tasks like sit-to-stand. Clinicians could benefit from an in-depth understanding and feasible analysis of the role of vestibular inputs during sit-to-stand and what they expect from their patients as elderly or patients with balance disorders. Such understanding could also make tests like timed up-and-go and 30-second sit-to-stand test more potentially useful in clinical decision making.

Introduction

The vestibular system serves as the main navigation system that provides stability and equilibrioception inputs to maintain balance during performing any dynamic task in which detection of angular or linear acceleration is *crucially important [1].*

Translocation from a sitting position to a standing is one of the common activities of daily living which - if impaired - would result in significant functional limitations. many studies have shown that patients with peripheral vestibular disorders showed different movement patterns and limitations while performing standing from a chair task and other dynamic tasks [2]. Similar findings have been found in older adults with bilateral vestibular loss [3]. Additionally, rising from a sitting position at an abnormal- slow speed has been shown to be correlated with institutionalization and a higher risk of falling in elderly population.

Understanding the phase-dependent influence of the vestibular information is needed to have deeper understanding of the contribution of the vestibular system while performing sit-to-stand task and to determine the root cause of functional limitations to develop more effective interventions. Subsequently, Galvanic Vestibular stimulation (GVS) [4] has been used as a valid model as a multi-purpose tool that assess the vestibular system contribution while performing different dynamic task such as walking [5].

Sit-to-stand movement can be observed to be occurred in 3 phases: acceleration, transition and deceleration [6]. During initiation, an individual has to generate enough propulsive impulse force in order to bring the body forward. This propulsive force was found to be related to a posterior movement of the Center of Mass (COM). This was shown in several studies by employing the force platform. Once the subject is off the chair, the transition phase takes place in which the COM moves from the initial Base of support created by the chair to a smaller one created by the foot placement on the ground. Finally, phase III which represent the termination of sit-to-stand.

Based on our knowledge no study has been cited that examined the vestibular contribution in a sit-to-stand task using GVS as the vestibular information manipulator in healthy young or older individuals. Similar to the significant impact of previous work that examine the effect of GVS on vestibular pathways and the subsequent understand of the it phase-dependant maneuver, this study will provide a great deal of knowledge about the phase-specific importance of the vestibular information while performing sit-to-stand task, which

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would improve our interventions toward more evidence based goal-directed approaches.

Specific aims and hypothesis

The first purpose of this study is to determine whether GVS will induce changes during sit-to-stand in normal healthy individuals. We hypothesize that GVS will cause dizziness and/or deviation toward the anodal side and we predict that GVS will affect the stability and performance during sit to stand. Furthermore, sit-to-stand is a multi-phase task which has acceleration and deceleration phases in which the body COM moves in different horizontal and vertical directions. Accordingly, the second goal of this study is to examine the phase-specific contribution of vestibular information during sit-to-stand in healthy young adults. We hypothesize that there will be more deviations from normal pattern more specifically at phase II compared to phase I of a sit-to-stand task.

Methods

Participants

- One young (n=1) (25 years old, male, 178 cm)

Inclusion/exclusion criteria

- Age: 20-30 yrs
- No previous history of motion sickness.
- No neurological or musculo-skeletal problems including no cervical/lumber complaints.
- No history of benign paraoxysmal positional vertigo or any other vestibular disorders.
- No history of overt vestibular pathology (such as vestibular neuritis) within the last 2 years.

Protocol

Task: the subject was asked to:

- Stand up from a sitting position in standard chair (height: 0.46 m).
- As quickly as possible.
- Without using the hand.
- Looking straight ahead.

Instrumentations

Vicon System (120Hz): The Vicon System was used for Center of Mass (COM) calculations. Six markers were used to measure the COM as following: C7, Left shoulder, Right Shoulder, S1, Right ASIS, LEFT ASIS.

Force plate (3000Hz): Participants were asked to sit on two force plates (Advanced Mechanical Technology, Inc.) to ascertain instantaneous center of pressure location. One of the force plates was used for the chair placement and the other one for the foot placement. The CoP excursion data were derived from raw force plate data using custom made software. During selected trials medium density foam were placed on the force plate to reduce accuracy of lower limb somatosensory input during sit-to-stand. Further, force plate data (Center of Pressure (COP)) were used to determine the phases of sit-to-stand. According to force plate data, phase one was determined as the time from the initiation of sit-to-stand till the point where the buttocks left the chair, where phase II was determine from the point from leaving the chair till finishing the sit-to-stand in an up straight position.

Phase I and phase II

The time point whenever COP data were collected by only one force plate (equation 1) (to: the force plate on which the subject placed his foot). Then, the corresponding point on the COM data was determined according to the following equation:

Cut off point (z) = (FP frame* 120)/ 3000 (equation #1)

For COM: (equations #2)

to (Starting point)= Z-120 (the zero point) ,

End point = to (COM) +360

One second before and two seconds after the cutoff point were considered as the standard time frame to finish the whole task and was calculated for each trial. (Figure 1) summarizes the main phases of sit to-stand.

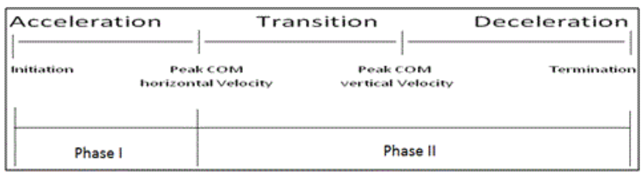

Figure 1: Phases of sit-to-stand.

Sensory Input manipulation

- Vestibular input manipulation
- Normal input: No GVS
- Inaccurate input: GVS
- Threshold (x): the threshold was determined as the following:
- The subject was asked to stand with feet together (not touching)
- Electrodes were placed over the mastoid process
- Left: anode
- Right: Cathode
- Eyes opened
- Stimulus Intensity was increased (starting from 0.05 mA) until the subject started swaying of feeling dizzy.
- Threshold reported (x=1.5 mA)
- Then 2x and 4x the threshold were calculated.

Foot placement

Before starting testing, the subject was asked to stand five times and self-select foot placement was reported. Then, the subject was asked to maintain the same foot placement throughout the whole trials. The reported foot placement was 35 cm, measured from the lateral side of one heel to the same point at the other heel.

Outcome measures

Our main outcome measures were as the following:

Medio-Lateral COM displacement (mm)(6 markers)

- Peak-to-peak (Med-Lat P_P): this will be sensitive to the extreme values (minimum and maximum) and will be a good indicator for the Stability during sit-to-stand.
- Root mean Square (Med-Lat RMS): Standard Deviation: This will be a representative for the whole values and will be a good indicator for the Performance of the subject during sit-to-stand.

Results

Table 1 is showing the results from different trials: (1) no stimulation (baseline) (2) 2x stimulation (3) 4x stimulation. Generally, Med-Lat P_P and RMS increased as the condition became more challenging (i.e. Phase II > Phase I > Baseline).

	NO	2X	4X
P-P PHASE 1	2.011641	5.929415	12.3891
RMS PHASE 1	0.553541	1.444757	2.495545
P-P PHASE 2	4.072285	7.455601	19.26001
RMS PHASE 2	1.114327	1.748273	5.384686
P-P ALL	5.929415	10.29114	19.49948
RMS ALL	1.479689	3.353213	6.184566

Table 1: Medio Lateral Peak-to-Peak and Root Mean Square (standard deviation) in three conditions: No stimulation (NO), 2x threshold stimulation and 4x threshold stimulation.

Figures 2 and 3 are histograms that are showing the differences in Med-Lat P_P and Med-Lat RMS between phase I and Phase II.

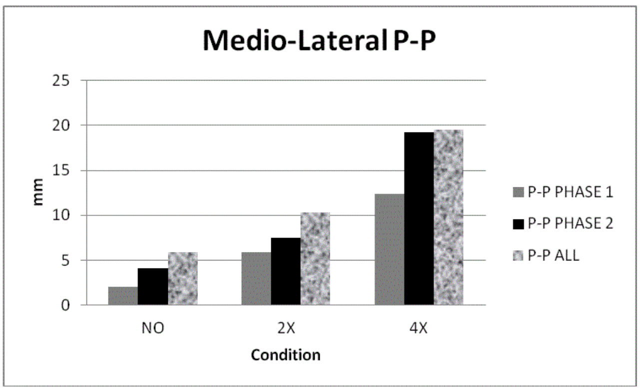

Figure 2: Med-Lat P_P comparison: Phase I, Phase II and whole trial (All).

Discussion

GVS has successfully affected the stability and the performance during sit-to-stand in phase I and II with more changes during Phase II. Since the subject did not lose his balance in any of the trials and that no change in foot placement has been reported, the changes on the Med-Lat direction was not enough to give a good judgment on the phase dependant influence of the vestibular information. Though, phase II had more MED-Lat P_P changes than Phase I. On the other hand, Med_Lat RMS showed a clearer idea about the differences between phase I and phase II.

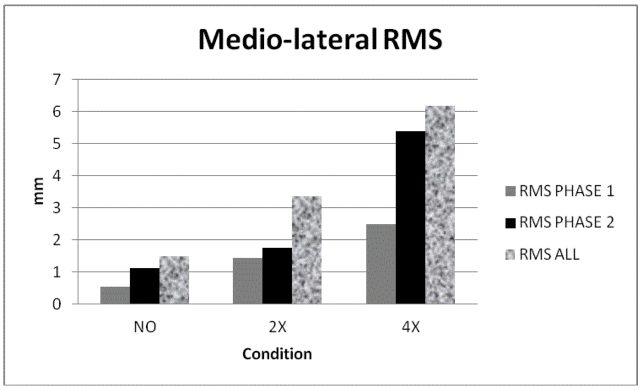

Figure 3: Med-Lat RMS comparison: Phase I, Phase II and whole trial (All).

Shumway [7] has shown that Phase II is an unstable and a highly coordinated phase that requires high coordination between the horizontal and vertical velocities especially during the transition period. During the transition phase, the body is accelerated mainly in the vertical direction however combined with movement in the horizontal direction. comparably, the body in phase I is accelerating in the horizontal direction only [7]. Based on the anatomy of our vestibular system, the otolothic organs are stimulated whenever the body is moving in a linear motion/ acceleration in both vertical and horizontal direction [8]. Accordingly, in the transition period of phase II, both of the vertical (saccule) and horizontal (utricle) components of the vestibular system becomes stimulated so that the vestibular system will be functioning at a higher level in the transition period, rather phase I in which the body will be moving in one direction. Additionally, during phase II, the body is moving over a BOS that is relatively smaller the one in phase I. Subsequently, more efforts should be provided by the vestibular system to maintain balance over the BOS created from both foot considering that, in our experiment, the foot placement was fixed throughout the whole trials. Finally, in phase II, especially upon the termination of sit-to-stand, the vestibular system becomes upregulated to ensure the successful completion of sit-to-stand, which further increases the vestibular demands during phase II of sit to stand.

The vestibular system is also functioning during phase I in which the programming of the whole sit-to-stand task is in process. Before initiating sit-to-stand, the vestibular system receives different somatosensory inputs from different parts of the body to address the critical inter-segmental coordination between the upper and lower body segments to shift the COM forward and upward [9]. Subsequently, when GVS was applied during this phase, the vestibular inputs might be corrupted which give wrong inputs about the position of the body and foot which may affect the stability and the performance in this phase I and consequently in phase II.

Conclusion

Our result of this case study are novel and showed for the first time that There is a phase dependant maneuver of the vestibular inputs during sit-to-stand. Sit-to-stand represent one commonly performed daily activities [10]. Therefore, understanding the phase dependant maneuver of the vestibular inputs during sit-to-stand add important additional information on clinically relevant aspects of physical performance especially in individuals with declined vestibular functions. In fact, clinicians have used sit-to-stand tests as Indicators of postural control [11], fall risk [12] lower extremity strength [13] and disability [2]. In addition, sit-to-stand has been used as an assessment tool to assess mobility, balance and walking ability [14]. However, our knowledge about the influence of the vestibular system during sit-to-stand is unclear. Therefore, we believe that our results are clinically significant as it adds further and deeper understanding of the vestibular influence on a commonly performed daily function like sit-to-stand could make test like timed up-and-go test and 30-second sit-to-stand test more potentially useful in clinical decision making. Clinicians could benefit from an in-depth and feasible analysis of the role of vestibular inputs during sit-to-stand and what they expect from their patients as elderly or patients with balance disorders [2,15] which could help researchers and clinicians determine the root cause of functional limitations to develop more effective assessment and interventions.

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