Standardization of Rotatory Chair Velocity Step and Sinusoidal Harmonic Acceleration Tests in Adult Population

MOHAMED F.M. AHMED, M.D.
The Department of Otolaryngology Audiology Unit, Faculty of Medicine, Mansoura University, Mansoura, Egypt

Abstract

Objective: To standardize the rotatory chair sinusoidal harmonic acceleration and velocity step tests in adult population.

Study Design: Prospective study.

Setting: Clinical tertiary care vestibular function test center.

Patients: One hundred normal participants (66 male and 34 females without suspected vestibular disorder) evaluated with bithermal binaural caloric and sinusoidal and step-velocity rotary chair (RC) tests.

Intervention: Hearing, VNG and RC tests.

Material and Methods: All participants were selected according to the following criteria: (1) No past history of dizziness; (2) Normal otological examination; (3) Normal hearing evaluation; (4) Normal VNG testing; (5) Rotational Chair Testing: The patient was positioned and secured to the rotational chair with the patient’s head restrained and adjusted so that both lateral semi-circular canals were close to the plane of stimulus (30° forward tilt). The rotational chair testing paradigms used in this study were: (A) The Rotational Sinusoidal Harmonic Acceleration (SHA) Test and (B) The Rotational Velocity Step (RVS) Test.

Results: The demographic criteria for the study group as following: the age range was 18-56 years with mean age of 36.47 years; the gender distribution was 66% for males and 34% for females. The mean, standard deviation, range and 95% confidence limits of the SHA and RVS test was calculated and compared with the manufacture normal values. It demonstrated that no significant statistical difference between our lab test results and the manufacture measured values of the rotational SHA test and the RVS; this could be attributed to the strict selection criteria of the study group.

Conclusion: In summary, the information gleaned from rotational chair testing may provide valuable information in the diagnosis and subsequent management of patients with vestibular disorders. It completes the spectrum of tests necessary for diagnosing vestibular abnormalities, assists in identification of peripheral vestibular deficits not detectable with existing procedures. The major clinical advantage of computerized rotational testing is the ability to produce angular accelerations that can be precisely controlled and repeated. Multiple stimuli of varying intensities can be applied to the vestibular system within a relatively short time.

Key Words: VNG test – Caloric test – Rotary chair test – Rotational step velocity time constant – Sinusoidal harmonic acceleration gain – Phase – Asymmetry.

Introduction

THE peripheral vestibular system consists of: 3 Semi-circular canals (SCC) that are sensitive to angular accelerations, 2 Otolith organs (Utricle and Saccule) that are sensitive to linear accelerations, and the vestibular nerve up to the root entry zone in the brain stem. The peripheral vestibular system acts through a range of intensity (acceleration) and frequency [1]. The ability to evaluate the range of physiological function using an Electронystagmography (ENG) evaluation is limited, given that the use of caloric irrigation stimulates the system in a manner equivalent to a frequency between 0.002 and 0.004Hz and accelerations of less than 10 degrees/s. These values are below the level within which the vestibulo-ocular reflex (VOR) generally functions in daily activities [2].

Therefore, rotatory chair testing has been used to expand the evaluation of the peripheral vestibular system as it can stimulate frequencies in the 0.01 to 1.28Hz which considered more physiologic frequencies [3]. The rotational chair testing is a test in which sequences of sinusoidal angular velocity signals at several test frequencies are applied for evaluation of the VOR function [1]. In 1907, Barany described a clinical test of vestibular function based on rotational response. He placed patients in a swivel chair and rotated them to the left or right for several complete cycles and then suddenly stopped the rotation while observing the
patients’ eyes. The presence of post rotatory nystagmus evoked by this test is influenced by the level of vestibular function and by the status of velocity storage mechanisms [4].

In 1948, Van Egmond described an elaboration of rotational chair testing, as the patient was slowly accelerated to a series of different rotational velocities before being suddenly stopped. The duration of the nystagmus responses were measured and “cupulogram” was then generated by plotting nystagmus response duration versus the log of stimulus magnitude [4]. In 1960, the modern era of rotational testing began when methods became available for generating precise, repeatable rotational stimuli and for making quantitative measurement of eye movements. Today, computer controls all aspects of rotational testing-including stimulus generation, response measurement, and data analysis [4].

Hamid et al., [5] reported that when the head is rotated on the vertical axis, the horizontal semicircular canal on each side of the head is stimulated simultaneously. The activity of the horizontal canals is complementary. Head movement to the right increases neural discharge from the right horizontal semicircular canal and decreases neural discharge rate for the left horizontal semicircular canal and vice versa. These changes in discharge rate induce nystagmus. By measuring the VOR response, information can be obtained concerning the activity and interaction of the right and left vestibular systems.

Studies of rotatory chair sinusoidal harmonic acceleration and velocity step tests are limited in the literature and the normal ranges for the test parameters are variable from lab to lab. Accordingly, this study was designed to standardize the rotational chair testing in our lab especially that our lab is serving very huge number of dizzy patients referred from primary, secondary, private ... etc. health care centers. So, the rationale behind this study is to standardize the rotational chair testing as an objective tool for evaluation of dizzy patient.

Material and Methods

This study was carried out in the hearing and balance clinic, ENT Department, Dubai Hospital, United Arab Emirates. From July 2011 – Dec. 2011.

This study group consisted of 100 normal healthy volunteers, 66 males and 34 females. Their ages ranged from 18-56 years with a mean age of 36.47 years. They were selected from nurses, residents, medical students, relatives accompanying patients etc. They were selected according to the following criteria:

- No history of vertigo, ear disease or intake of ototoxic drugs.
- Normal hearing sensitivity, and normal Videonystagmography Testing (VNG).
- No history of medical disease that might contribute to disequilibrium such as Diabetes Mellitus (D.M), Hypertension, severe visual loss and neurological disorders.

All participants were submitted to the following:

- Full history: Was taken from all participants with the emphasis on presence or absence of vertigo, ear diseases, ototoxic drugs, systemic diseases.
- Otological examination.
- Basic audiological evaluation: Pure tone and speech audiometry, tympanometry and acoustic reflex study.
- Videonystagmography testing (VNG): VNG test battery including: Oculomotor test, positional and positioning test and caloric test.
- Rotational chair testing: Performed using a Micromedical Technologies with the standard commercially available software (4 Channel Spectrum S 1.0.3) for test analysis. The patient was asked to refrain from use of certain medications such as antihistamines, sedatives/hypnotics and anxiolytics for 48 hours prior to rotational chair testing. Eating for two hours prior to the exam was discouraged as this may exacerbate nausea and emesis.

The patient was positioned and secured to the rotational chair with the patient’s head restrained and adjusted so that both lateral semi-circular canals were close to the plane of stimulus (30° forward tilt) [6] (Fig. 1). During rotation, the patient was instructed to keep his/her eyes open and was given appropriate mental alerting tasks. The rotational chair testing paradigms used in this study were:

A- Rotational sinusoidal harmonic acceleration (SHA) test:

The SHA test was performed at frequencies 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, and 0.64Hz. The chair was rotated with maximum velocity of 60 degrees/second at each test frequency. The program calculates the GAIN (the ratio of the amplitude of eye movement to the amplitude of head movement), PHASE (Describes the timing relationship between head movement and reflexive eye response) and Symmetry (Comparison of the slow component of the nystagmus when rotated to the right versus left for each frequency).
B- Rotational velocity step (RVS) test:

The rotational velocity step (RVS) test was composed of two sections. In the first section the chair was accelerated in one direction until it was attained a pre-set constant velocity (100 degrees/second). This velocity was maintained for a designated length of time (45 seconds). During this section, a sudden burst of nystagmus occurred as the chair was accelerated; However, the nystagmus response decays exponentially as the chair maintains rotation at a constant velocity.

At the onset of the second section the chair was decelerated to a complete stop (0 degree/second 2) while eye movements continue to be recorded. Sudden stoppage causes nystagmus in the opposite direction as the patient perceived this stoppage as motion in the opposite direction; nystagmus will again decay exponentially until eye movements stop. The entire procedure was repeated with the initial rotation in the opposite direction.

For both sections, the computer automatically performs data analysis, in which it was calculated the GAIN (average eye velocity/stimulus velocity) and time constant (time in seconds for the response to decay to 37% of its peak value).

Statistical analysis:

The SPSS® version 13.0 for Windows (SPSS Inc., Chicago, IL) was used. Results are presented as percentage, mean and standard deviation (SD). Paired t-test was used to compare results between the study group and the manufacturer normal values. Level of significance was set at p≤0.05.

Results

Table (1) demonstrates the demographic characteristics of the study group (100 participants), the age range was 18-56 years, and the gender distribution was 66 males and 34 females. Table (2) is showing the mean, standard deviation, range and 95% confidence limits of the Rotatory Sinusoidal Harmonic Acceleration (SHA) test gain, phase and symmetry in the study group. In terms of standardization of the rotatory velocity step (RVS) test, Table (3) demonstrates the mean, standard deviation, range and 95% confidence limits of the RVS gain and time constant of the study group.

Table (4) demonstrates the mean, standard deviation, t- and p-values of RVS (Gain, Time constant) for the study group in comparison to the manufacturer measured parameters (The manufacturer is the Micromedical Technologies, Inc. located at 10 Kemp Drive, Chatham, Illinois 62629, USA).

In terms of the rotational chair testing set up, Fig. (1) demonstrates that the patient was positioned and secured to the rotational chair with the patient’s head restrained and flexed 30° forward. Fig. (2) demonstrates the mean of the gain, phase and symmetry at the tested frequencies (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64Hz) in the study group as compared to the manufacturer values.
Table (3): Mean (X), Standard Deviation (SD), Range and 95% confidence limits of the Rotatory Velocity Step (RVS) test gain and time constant in the study group.

<table>
<thead>
<tr>
<th>Rotatory velocity step test</th>
<th>Mean</th>
<th>S.D</th>
<th>Range</th>
<th>95% C.L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock-wise</td>
<td>Per-rotatory Gain</td>
<td>0.62</td>
<td>0.22</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>16.2</td>
<td>2.44</td>
<td>12</td>
</tr>
<tr>
<td>Post-rotatory Gain</td>
<td>0.66</td>
<td>0.17</td>
<td>0.39</td>
<td>0.68</td>
</tr>
<tr>
<td>T.C</td>
<td>17.11</td>
<td>3.12</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Counter clock-wise</td>
<td>Per-rotatory Gain</td>
<td>0.59</td>
<td>0.22</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>15.85</td>
<td>2.64</td>
<td>12</td>
</tr>
<tr>
<td>Post-rotatory Gain</td>
<td>0.59</td>
<td>0.094</td>
<td>0.47</td>
<td>0.66</td>
</tr>
<tr>
<td>T.C</td>
<td>16.4</td>
<td>2.47</td>
<td>13</td>
<td>21</td>
</tr>
</tbody>
</table>

Table (4): Mean (X), Standard Deviation (S.D), t- and p-values of RVS (Gain, Time constant) for both the study group and the manufacturer measured values.

<table>
<thead>
<tr>
<th>Rotatory velocity step test</th>
<th>Study gp.</th>
<th>Manufacture</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gain</td>
<td>X</td>
<td>S.D</td>
<td>X</td>
</tr>
<tr>
<td>Clock-wise</td>
<td>Per-rotatory</td>
<td>0.62</td>
<td>0.22</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>16.2</td>
<td>2.44</td>
<td>14.8</td>
</tr>
<tr>
<td>Post-rotatory</td>
<td>Gain</td>
<td>0.66</td>
<td>0.17</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>17.11</td>
<td>3.12</td>
<td>15.5</td>
</tr>
<tr>
<td>Counter clock-wise</td>
<td>Per-rotatory</td>
<td>0.59</td>
<td>0.22</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>15.85</td>
<td>2.64</td>
<td>14.5</td>
</tr>
<tr>
<td>Post-rotatory</td>
<td>Gain</td>
<td>0.59</td>
<td>0.09</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>T.C</td>
<td>16.4</td>
<td>2.47</td>
<td>15.3</td>
</tr>
</tbody>
</table>

Fig. (1): Rotational chair testing set-up.

Fig. (2): Mean (X) of the gain, phase and symmetry at the tested frequencies of (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64 Hz) in the study group as compared to the normal range of the manufacture.
Discussion

The present study was conducted on 100 normal subjects with the following criteria: No previous history of dizziness or vertigo, normal hearing evaluation, normal VNG findings, no systemic, neurological or visual disorders. Table (1) demonstrates the demographic characteristics of the study group; the age range for the study group was 18 - 56 years with mean age of 36.47 years; the gender distribution was 66% for males and 34% for females. Tokumoso et al., [7] reported that peripheral vestibular disorders are more common in females than males [6]. However, Kamal et al., [8,9] found slight increase of peripheral vestibular disorders among males.

Selection of the study group based on the previously mentioned criteria demonstrated that more than 90% of the initially selected participants demonstrated normal hearing (patients with abnormal hearing was excluded from this study), this is reflect that there is strong correlation between hearing loss and vertigo/dizziness. Similarly, Asai et al., [10] reported suchassociation of hearing loss with vertigo. They demonstrated that vertigo due to labyrinthine causeis more common than non-labyrinthine cause.

Table (2) demonstrated the mean, standard deviation, range and 95% confidence limits of the SHA test. Amin (2001b) [6] defined the SHA testing as a type of angular acceleration stimulus applied to the rotational chair testing in which rotating the patient in alternating directions (sinusoidal) at a given frequency. The measured parameters in SHA testing are (Gain, Phase and Symmetry). Gain is the ratio of the amplitude of eye movement to the amplitude of head movement (stimulus) [10]. It is calculated by dividing the slow component velocity of the eye by the velocity of the head (measured by chair velocities). It gives an indication of the overall responsiveness of the system [11].

Abnormally low gain is seen in patients with bilateral vestibular weakness that will exhibit greatly reduced gain at lower frequencies of rotation. Low gain is usually a consequence of bilateral chronic vestibular weakness, but may occur in response to acute labyrinthine lesions when the cerebellum deliberately suppresses output from all vestibular nuclei to minimize symptoms of rotation, nausea and vomiting. Unilateral peripheral weakness can cause a mild reduction in gain. However, when gain is low, the vestibular system might not be stimulated sufficiently to provide meaningful data, phase and symmetry calculations therefore cannot be interpreted [12]. Abnormally high gain can be seen in cerebellar lesions due to absence of descending inhibition [13].

Phase describes the timing relationship between the initiation of head movement and reflexive eye response when the head and eyes are moving at exactly the same velocity in opposite directions. They are said to be exactly out of phase or 180°. If the reflex eye movement leads the head movement, a phase lead is present, and if the compensatory eye movement trails the head movement, a phase lag is present. Abnormal increase in phase lead (from low frequency, less than 0.04Hz, sinusoidal rotations) implies an abnormally low system time constant suggestive of peripheral system involvement (labyrinthine, VIIIth nerve), although possible involvement at the level of the vestibular nuclei must be considered [13]. Abnormal decrease in Phase lead (from low frequency less than 0.04Hz, sinusoidal rotations) implies possible central system influences eitherat the level of the brain stem or the posterior cerebellar area (nodulus) needs to be considered if the result is reliable [13].

Symmetry is a comparison of the slow component of the nystagmus when rotated to the right compared with rotation to the left [10]. Asymmetry is a measure of compensation and is calculated as the difference between the slow peak velocities of left and right beating nystagmus [14]. The peripheral vestibular pattern has a high level of asymmetry especially acute lesions which gradually decreases as symptoms improve. The central vestibular pattern has a low and variable asymmetry in conjunction with variable symptomatology [5].

Table (3) demonstrated the mean, standard deviation, range and 95% confidence limits of the RVS test. Tusa and Herdman [14] defined the RVS as a method of assessing the horizontal VOR evoked by head rotation through step changes in head velocity instead of sinusoidal rotation. The measured parameters in RVS testing are (Gain and Time constant). Gain is the ratio of peak eye velocity to head velocity; Time constant is the time in seconds for the response to decay to 37% of its peak value.

Shepard [12] studied that although both ears are involved in responses to rotary stimuli, the right periphery (horizontal semicircular canal and superior vestibular nerve) is primarily responsible for responding to accelerations to the right or decelerations from fixed velocity rotation leftward. The reverse is true for the left labyrinth.
Therefore, per- and post-rotary step tests also allow comparison of the time constant for dominant stimulation to one peripheral system. Averaging the data from multiple measures of per- or post-rotary slow component velocity would improve test reliability by reducing the impact from anxiety or drowsiness during a single trial [3]. Patient with unilateral peripheral vestibular lesion show directional asymmetries in response to velocity step stimuli.

Figure (2) demonstrated that the mean of the gain, phase and symmetry at the tested frequencies of (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64Hz) in the study group are within the normal range of the manufacture normal values; this could be attributed to the strict selection criteria of the study group. On the other hand, Table (4) demonstrated that no significant statistical difference between our lab test results and the manufacture measured values of the rotational RVS test (Gain, Time constant), this could be attributed also to the strict selection criteria of the study group.

Finally, rotational chair testing is usually well tolerated by patients. It is a physiological stimulus whose frequency and amplitude can be varied precisely. Rotatory stimulation is unrelated to physical features of the external ear or temporal bone [16]. It is useful in children who may not tolerate caloric testing and very useful in assessing patients with bilateral vestibular dysfunction and inpatients receiving vestibulotoxic drugs and in assessment of compensation [17]. Shepard [3] Suggested criteria for when chair testing may be of valuable clinical use over the ENG/VNG testing:

- When the ENG/VNG is normal; chair testing is used to expand investigation of peripheral system involvement and compensation.
- When the ENG suggest compensated status in terms of absence of spontaneous or positional nystagmus, despite the presence of a significant unilateral caloric weakness; Chair testing is used to expand the investigation of compensation in a patient with a known lesion site and complaints suggesting poor compensation [3].
- When the caloric irrigation are below 10 degrees/s, when the caloric irrigation cannot be performed, or when results in the two ears may not be compared reliably because of anatomic variability. Chair testing is used to verify and define the extend of a bilateral weakness or when caloric studies are unreliable or unavailable [3].
- When a baseline is needed to follow the natural history of the patient’s disorders (such as possible early Meniere’s) or for assessing the effectiveness of a particular treatment such as chemical-ablation of one or both peripheral vestibular-systems [3].

The Limitations of the rotational testing include that it is expensive and necessary to maintain high level of mental alertness; it can test horizontal SCC only and cannot localize the side of vestibular dysfunction [16].

Conclusion:

In summary, the information gleaned from rotational chair testing may provide valuable information in the diagnosis and subsequent management of patients with vestibular disorders. It completes the spectrum of tests necessary for diagnosing vestibular abnormalities, assists in identification of peripheral vestibular deficits not detectable with existing procedures [17]. The major clinical advantage of computerized rotational testing is the ability to produce angular accelerations that can be precisely controlled and repeated. Multiple stimuli of varying intensities can be applied to the vestibular system within a relatively short time [18].

Rotational chair testing is ideal in the assessment of patients suffering from peripheral vestibular disorders because, unlike caloric testing, higher frequencies are also tested and both labyrinths are stimulated simultaneously. This allows for accurate determination of remaining vestibular function. So, it can differentiate central from peripheral and compensated from uncompensated vestibular disorders through abnormalities detected in gain, phase, symmetry and time constant [10].

Recommendations:

Based on the current study, we recommend studying the rotational chair test in patients with unilateral versus bilateral peripheral vestibular disorders and patients with central vestibular disorders and using the rotational chair testing as an objective test to measure the outcome of the vestibular rehabilitation therapy for those groups of patients.

References