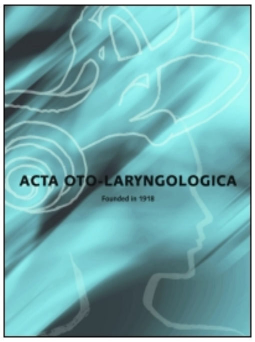

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RESEARCH ARTICLE

Evaluation and interpretation of the bucket test in healthy individuals*

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ABSTRACT
Objective: To determine and interpret the range of normal deviation of the bucket test in healthy subjects
Subjects and methods: *Study design:* Cross-sectional study in a secondary care center. Inclusion criteria: subjects ≥18 years old with no otologic or neurologic symptoms and normal complete neuro-otological examination. The subjective visual vertical was evaluated binocularly using the bucket test. Five measurements were made on the clockwise direction and five on the counterclockwise direction. The examiner selected the starting point, the patient then manipulated the bucket and it stopped when the volunteer considered the line reached the vertical position.
Results: Fifty healthy volunteers were included, 16 (32%) were men, and 34 (68%) women with a mean age of 34 years. The mean value found clockwise was 1.93° ± 2.26° and counterclockwise sense was of 0.86° ± 2.44°. Mean normal values ranged from 1.4° ± 1.9°.
Conclusions: The bucket test is easy and quick to perform; we recommend to use a range of −1.0° to +3.0° as normal values in the healthy population.

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KEYWORDS
Bucket test; subjective visual vertical; otolith organs; utricule; vestibular dysfunction

Introduction

The subjective visual vertical (SVV) is the ability of every subject to determine if an object is vertical [1,2]. A tilt of the SVV can result from lesions both in central and in peripheral vestibular pathways; diseases such as vestibular neuritis, Wallenberg syndrome, internuclear ophthalmoplegia or midbrain damage have been studied for SVV pathological deviations [3]. The direction of SVV is usually to the same side in unilateral peripheral or pontomedullary lesions and to the opposite side in unilateral pontomesencephalic lesions [3].

The bucket test was proposed by Zwergal et al. [3], as an effective and low-cost tool to measure SVV compared to other evaluation instruments with greater complexity of application. This test has been shown to be useful for the diagnosis of peripheral vestibular disturbance involving the otolithic organs [4,5].

Nonetheless, the normal range reported on previous literature of the SVV found in healthy subjects using the bucket test, is still controversial and has conflicting data that may not differentiate between healthy and diseased subjects. Additionally, the technique of the bucket test is not yet homogeneous and different techniques have been described in previous reports [3,4]. The determination of the normal range of deviation of the bucket test is capital in order to understand, apply and interpret this test. Thus, our main objective is to determine the range of normal deviation in healthy subjects and to understand how this test is performed and interpreted.

Materials and methods

A descriptive cross-sectional study was performed in a secondary care center.

Subjects

Eligible subjects were healthy volunteers ≥18 years interested in participating in clinical studies. Volunteers had no otologic or neurologic symptoms and had normal complete neuro-otological examination. Neurotologic examination included: otoscopy, visual acuity with snellen card, cerebellar tests and complete otolaryngology and cranial nerve examination. Exclusion criteria included visual impairment, neurologic or otologic disease.

An otolaryngologist evaluated all volunteers.

Bucket test technique

The subjective visual vertical was evaluated binocularly using the bucket test. An opaque plastic bucket was used with a 25 and 23 cm in diameter. Inscribed on the inside bottom of the bucket was a straight line. Inscribed on the outside was the same straight line, with a protractor and weighted plumb line to indicate degrees of rotation of the inscribed line from true vertical, which extended from −40° to +40°. The internal vertical line corresponded perfectly to the line indicating 0° on the angle protractor.

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The subject sitting in a straight position, placed his face inside the bucket. Patients attempted to align a vertical line inscribed at the inside bottom of a bucket to the true vertical in the absence of external visual cues. The subject could not see beyond the rim of the bucket, providing no cues to visual orientation. To measure the SVV, the bucket was randomly rotated by the examiner, in the clockwise or counterclockwise directions. Each time the volunteer received the bucket from the examiner and rotated the bucket until the line reached the vertical position. Ten repetitions of the procedure were performed, five consecutive attempts in the clockwise and five consecutive attempts in the anti-clockwise direction, in relation to the examiner. The angular inclinations of the vertical position were measured in degrees. The evaluator recorded the degrees of deviation for each of the attempts made. The protractor was read such as clockwise in relation to the patient was positive and counterclockwise was negative.

All subjects signed informed consent. This study was approved by our institutional review board.

Statistical analysis

The Statistical Program for Social Sciences (SPSS Inc., version 21, IBM, Chicago, IL, USA) was used for statistical analysis. A descriptive analysis was made using mean, standard deviation (SD) and maximum and minimum value of clockwise, counterclockwise direction and the total attempts with and without negative values. The effect of age and gender were performed by means comparison with *t*-test. Paired *t*-tests were used to compare clockwise and counterclockwise measurements of the same subjects.

Unpaired *t*-tests were used to compare gender and age. In order to compare our results, age was subsequently divided in two groups: <50 years and >50 years.

To know the normal range of SVV deviation, mean ±2 standard deviations were calculated.

$p < .05$ was considered significant.

Results

Fifty subjects were included, 16 (32%) were men, and 34 (68%) were women, mean age 34.36, with a range of 22–69 years. Subjects had no internal ear pathology or history of vertigo or dizziness and had normal neurological examination. Mean clockwise and counterclockwise attempts was of 1.39° with one standard deviation of 0.95° and 1.9° with two standard deviations (Table 1). No differences were found on SVV deviations and gender ($p = .86$) or age ($p = .154$). The mean of SVV deviation in the clockwise measurement was significant different from the counterclockwise measurement (1.93° (SD 1.13) vs. 0.86° (SD 1.22), $p < .0001$).

The scatter plot (Figure 1) shows the absolute degrees of deviation in the clockwise and counterclockwise direction according to age.

An average of all measurements was calculated without considering negative numbers. The average of these measurements was 1.61° (SD 0.72, 2SD 1.44.). Therefore, the range without including negative values was the following: 0.2° to 3.1°.

Discussion

The bucket test is a relatively new instrument that measures the SVV.

This test has low costs in its implementation, is practical and quick to perform. Additionally, it could improve patient care in the vestibular clinic, if proved accurate as a screening and diagnostic tool in vestibular impaired patients. Authors have described the degree of SVV deviation in both healthy and disease subjects [3,4,6–10] (Table 2). Nonetheless, it needs first to be establish accurately the normal values in the healthy population. Although there are several reports on the normal values, the range described is diverse and there is a need for new studies that can corroborate and interpret these results [5,8]. Furthermore, some authors [4] have used preset values that may not be accurate to identify healthy subjects. There are unfortunately, different ways to do and to interpret this test that leads to confusion (Table 2). There is a controversy in the use of negative or positive values, as well as many investigations differ on the way to perform the test, with the examiner or the subject rotating the bucket. Also, there has been no consensus in how many standard deviations to use in the final report of normal results.

Zwergal et al. proposed the bucket test in 2009, describing it as a reproducible, low-cost instrument of practical use and simple analysis of the results [3]. The range of normality of SVV proposed was −2° to 2°. The authors of this same study did not find differences with gender or age and SVV deviation, which agrees with the findings of our study.

The amplitude of SVV deviation found in previous reports is also similar to our study, which corresponds to less than +4° (from −1° to 3° or 0.2° to 3.1° Without considering negative values); however, our maximum negative value was −1, unlike other reports [3–5]. Interestingly, clockwise and counterclockwise measurements were significant different, being closer to 0° in counterclockwise direction.

Several studies have involved vestibular impaired subjects who have been evaluated with the bucket test; these findings

Table 1. Mean deviations in clockwise and counterclockwise directions in healthy individuals.

	Clockwise direction	Counterclockwise direction	Total	*p*
Mean ± 1 SD	1.93° ± 1.13	0.86° ± 1.22	1.39° ± 0.95	$p < .0001$
Mean ± 2 SD (range)	1.93° ± 2.26 (−0.32 to 4.2)	0.86° ± 2.44 (−1.58 to 3.3)	1.39° ± 1.9 (−0.5 to 3.3)	
Minimum value	−1.0°	−4.0°		
Maximum value	8.0°	6		

P: statistical significance; SD: standard deviation.

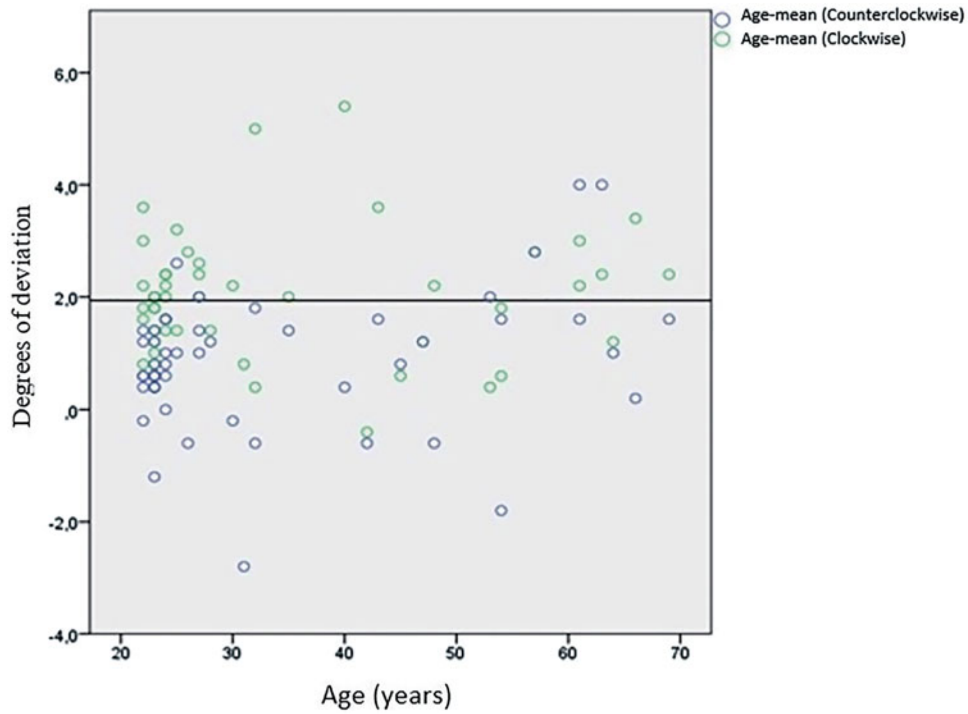

Figure 1. The scatter plot of the absolute degrees of deviation in the clockwise and counterclockwise direction according to age.

have shown that the bucket test and the data obtained are useful and reliable. Other studies used a pre-established value as in the case of Chetana et al. a study of 2015 [4]. In the same way, the study by Sun et al. through a ROC (receiver operating curve) analysis established the normal range with a sensitivity of 47% and a specificity of 85%. The normal value proposed by these authors was $0 \pm 2.0°$ in a study in healthy older adults [5]. The authors of this same study found, sensitivity of 21% and specificity of 96% at a score threshold of 3. They recommended a score threshold of 2 in order to maximize diagnostic yield.

On the other hand, Ferreira et al., established a normal deviation range of $-2°$ to $2°$ using a sample of 100 subjects, 50 men and 50 women; gender was not statistically significant [8].

In our study, we included 50 healthy subjects, the range of SVV deviation did not show a difference in the evaluation by gender or age group.

In vestibular disease patients, values of SVV deviation are reported as ipsiversive or contraversive from the affected side. This might the best form to accurately report SVV values [4,7].

Limitations of this study are the low number of controls and the absence of vestibular impaired patients. Although there are different techniques described to perform the bucket test, we decided that the volunteers could manipulate the bucket until they considered the line reached the vertical position. We chose this technique because we believe it reflects adequately the perception of the vertical line, since some studies need to repeat this test if the examiner moved the bucket too fast, not allowing for an accurate response from the patient. Nevertheless, other authors are concerned with the addition of kinesthetic information that could augment visual input [3,7]. Another limitation is the way in which both negative and positive values are read. In most studies, it is not specified to which side is positive or negative. Values are classified depending on the perspective of the examiner or the subject. Furthermore, some authors do not take into account whether the value is positive or negative: what they value is the healthy side and the pathological side [4,7]. Also, another limitation was that no other vestibular tests were performed in our healthy subjects such as electronystagmography, vestibular evoked myogenic potentials or video head impulse test.

Only 11 patients were older than 50 years; therefore, results on these patients should be considered with caution.

One of the strengths of this study is the fact that there are few reports on the normal values of SVV. Additionally, our study provides evidence that up to $3°$ of normal deviation can be expected in healthy volunteers. On the other hand, negative values have minimum range of presentation, as observed in our study ($-1°$); therefore, preset values of ± should not be use (e.g. ±2). In order to interpret adequately our results, we have used the mean and 2 standard deviations as used by Zwergal et al. to describe the range of SVV deviation.

Additionally a thorough review of the literature was performed, normal parameters described by other authors are specified on Table 2. While Zwergal et al. [3] stated their parameters using 2 standard deviations, not all authors followed this rule, and parameters should be read with caution.

More studies are needed in vestibular disease patients in order to corroborate the usefulness of the bucket test. Since there are other reports that state it is not useful for screening people with vestibular impairments [7].

Table 2. The bucket test values for the evaluation of SVV in healthy and disease individuals.

	Normal subjects			Vestibular compromised subjects			Test performance	
Study	*n*	Normal range	Condition	*n*	Abnormal deviation	Condition	Participant who rotated the bucket	Results
Zwergal et al. (2009) [3]	30	Binocular: 0 ± 2.3° Monocular: 0 ± 2.5°	Normal subjects	30	Binocular: 8.3°±5.0° Monocular: 8.7°±5.0°	Peripheral or central vestibular lesion.	Examiner	They used mean ±2 SD. Does not specify which side is positive or negative.
Čakrt et al. (2011) [6]	33	−0.04°±0.64°	Control group	33	0.86°±1.39°	Idiopathic Scoliosis	Examiner	Degrees were read off on the outside scale by the examiner. They used mean ± SD. Does not specify which side is positive or negative.
Cohen et al. (2012) [7]	50	1.2° (0.75, 0 a 3.2)[a]	Normal subjects	25	2.1° (1.5, 0–6.0)[a]	Unilateral BPPV (posterior)	Examiner	Degrees were read off on the outside scale by the examiner. They used mean ± SD.
				25	2.1° (1.7, 0–7.5)[a]	Unilateral vestibular weakness		Does not specify which side is positive or negative. Compare the values of the normal side against the abnormal side of the subject.
Sun et al. (2014) [5]	51	0 ± 2.0°*	Normal older adults	0	–		Examiner	A clockwise rotation of the vertical from the perspective of the subject was designated as a positive deviation.
Chetana et al. (2015) [4]	0	0 ± 2.0°*	Normal subjects	100	Range: >2°–7°**	Vestibular neuritis; BPPV; Ménière's disease; Labyrinthitis.	The subject holds the bucket. The examiner rotated the bucket.	They compare the values of the normal side against the abnormal side of the subject. (Authors do not use negative values).
Ferreira et al. (2015) [8]	M = 50 F = 50	2.0° (0.8042)[b] 1.65° (0.6386)[b]	Normal subjects	–			Examiner	The angular inclinations were measured in degrees and defined as positive deviations in the clockwise and negative In the counterclockwise direction, in relation to the volunteer.

*Preset value used in the study as normal range.
**The range implies 85% of all subjects with abnormal SVV.
BPPV: benign paroxysmal positional vertigo; F: women; M: men; *n*: subjects considered for the sample; SVV: subjective visual vertical.
[a]Mean (standard deviation, range).
[b]Mean (standard deviation).

In our study, we proposed a range of normal deviation in healthy subjects. In practical terms, a range of $-1.0°$ to $+3.0°$ with a mean of $1.4°$±2SD $1.9°$, (from 0 to 3 without negative parameters, with a mean of $1.61° \pm 2$SD 1.44) should be considered as normal values in the healthy population. This range could be used as a normal reference when evaluating vestibular disease patients with the bucket test.

Due to the diversity of values reported by different researches, we recommend at the moment of reading the protractor, not to use negative and positive values in future investigations, the implementation of mean and 2 standard deviations in the final result and also, we suggest the performance of the test could be by the subject or examiner (the rotation of bucket).

Conclusions

The bucket test is easy and quick to perform. The normal values of SVV deviation found were $1.4° \pm 1.9°$, with a range of -0.5 to 3.3. The average of measurements without including negative values was $1.61° \pm 1.44$. Therefore, the range without including negative values was the following: $0.2°$ and $3.1°$. In general, a range of $-1.0°$ to $+3.0°$ should be considered as normal values in the healthy population.

Disclosure statement

No potential conflict of interest was reported by the authors.

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