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## Computerized Dynamic Posturography does not detect measured CVEMP and OVEMP abnormalities<sup>☆</sup>

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### ABSTRACT

**Background:** Computerized Dynamic Posturography (CDP) was developed by the American space program to assess imbalance in astronauts, and eventually evolved into a clinical diagnostic tool. However it is not a specific measure of vestibular function. Vestibular Evoked Myogenic Potential testing (VEMPs) is a new clinical tool which is sensitive and specific for measuring otolithic pathology, especially in the atypical vestibular patient.

**Research question:** As posturography measures ability to maintain balance, and VEMP testing measures the structures responsible for this, we wondered if CDP results would correlate with VEMP abnormalities in the clinical setting.

**Methods:** We analysed 180 patients sequentially referred to our unit for vestibular complaints. All patients had a full battery of vestibular assessments. We correlated VEMP results with CDP results to look for abnormality patterns and correlations. An occasional patient's only abnormality was on CDP

**Results:** There was a high rate of VEMP abnormalities seen, which correlates with the fact that our referral base consists of patients with chronic vestibular complaints. The rate of VEMP abnormalities was the same in patients with normal CDP and those with abnormal CDP.

**Significance:** Our results do not suggest that CDP is unnecessary, but we feel that they emphasize the idea that these tests are measuring two different aspects of balance control. In some patients, all assessments are abnormal, but in some patients only one assessment is abnormal, suggesting that these modalities measure different things and are all important in the diagnostic armamentarium. Hopefully in the near future, the use of virtual reality will reduce the cost of CDP to the point where it can be made widely accessible to patients and clinicians.

### 1. Introduction

During the early years of spaceflight it was discovered by NASA researchers that on return to earth astronauts were extremely imbalanced and quite incapacitated. This has been elegantly summarized and discussed by Black et al in 1999 [1].

In order to investigate and quantify the deficit in returning astronauts, a new technology - Computerized Dynamic Posturography® (CDP) - had been devised by Nashner [2]. CDP subsequently was introduced as an effective clinical tool. (Neurocom International; Clackamas USA) [3]. This was commercialized as Equitest® in the mid 1980's (Neurocom International; Clackamas USA). It was the first generally

available investigation into the balance system that had been developed subsequent to standard caloric test, which was described by Barany about 70 years previously. At the time it was developed, it was new technology, highly complex, and extremely advanced. Although expensive, this system was acquired by many research laboratories in the balance and dizziness field. Comparison of CDP investigations from one location to another made direct collaboration between institutions possible. This was one of its main benefits over a "home-made" force plate, (the so-called "foam and dome") developed by Shumway-Cook and Horak in 1986 [4] which has the major limitation of not being precisely applicable to any other institution.

In the clinical setting, CDP can be used to measure static sway and

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also increase the overall diagnostic sensitivity of vestibular function testing. It has been shown that with CDP, abnormalities are measured in about 50% of dizzy patients referred for complaints of a vestibular nature [5]. When it first came into use, it allowed measurement of abnormalities in patients who up until this point were diagnosed based on history alone. The caloric test is not a sensitive measurement of vestibular function; only between 10–20% of dizzy patients with complaints of a vestibular nature have abnormalities on caloric testing [5]. It has also been shown that caloric tests should no longer be considered the criterion standard when the issue is the presence or absence of unilateral lateral canal damage [6]. This may be due to the fact that the caloric stimulus does not challenge the vestibular system sufficiently to reveal its defects as it only tests the VOR at a very low velocity, and is not a sufficient stimulation. [7].

The drawbacks of CDP include the fact that it is neither site specific nor side specific. As time has passed and newer tests have developed, its place in the diagnostic armamentarium is also less secure. Unfortunately, the cost for CDP remains high and is prohibitive in terms of general availability.

Complaints of dizziness which are sometimes regarded as “non-traditional” in nature are strongly suggestive of otolithic pathology and previous work has suggested that CDP is effective at picking up impairment of the otolithic structures [8,9]. However the specificity for “otolith disorders” is unclear [9]. It has been stressed that otolithic disorders affect posture, but postural tests themselves do not specifically measure otolithic function. This has become important as otolithic disorders can occur in an isolated fashion without other pathology [10]. Patients who have suffered head and neck trauma can also suffer otolithic symptoms and it has been shown that the results of assessments in these two groups of patients (i.e. vestibular dysfunction as a result of trauma and also without trauma) are the same [8,11].

Since the development of CDP, other more specific tests to evaluate each section of the balance organ of the inner ear have become available: Cervical Vestibular Evoked Myogenic Potentials (CVEMP), Ocular Vestibular Evoked Myogenic Potentials (OVEMP), Head Impulse Test (HIT) and Subjective Visual Vertical (SVV); all these assessments are carried out routinely on patients with chronic vestibular complaints.

We wondered how CDP might correlate with other vestibular assessment tests and if it might be able to detect disorders of specific otolithic structures (i.e. utricle or saccule). Specifically, we wondered if CDP results correlated with measured CVEMP or OVEMP abnormalities.

This study is not meant to serve as a guideline for carrying out CDP and VEMPs in the clinical setting. CDP techniques are well described elsewhere [e.g. [3]] and optimal clinical CVEMP and OVEMP techniques are also discussed elsewhere in the literature [e.g. [12]]

## 2. Methods and statistical analysis

Our study was approved by the Clinical Research Ethics Board of the University of British Columbia and Vancouver General Hospital (Approval number H15-00494). This study was granted an expedited approval and did not require informed consent, as it was classified as a retrospective chart review.

We analyzed 180 patients. An online *a-priori* sample size calculator for multiple regression was used. We wished to identify a medium effect size of 0.15 with a significance of  $P = 0.01$  and a desired statistical power of 0.85. We had 4 predictors/variables (CVEMP, OVEMP, Calorics, CDP). The sample size calculator suggested a minimum required sample size of 170. In order to account for incomplete data, 10 extra participants were included in the study for a total sample size of 180.

All patients enrolled in the study had been referred to our tertiary care neuro-otology unit for chronic vestibular disease (which we define as persistent symptoms for more than one year). Patients with neurologic, orthopedic or musculoskeletal involvement were excluded.

All patients had extensive histories taken, and all underwent caloric

testing, Computerized Dynamic Posturography, CVEMP and OVEMP testing, and SVV. Patients were categorized as “normal” or “abnormal” for each modality, using the standardized assessment protocols for calorics, and using the normative data base for CVEMP and OVEMP amplitudes and latencies that have been established in our lab.

We divided CDP results into three different categories which have been defined previously by us [11].

- Normal
- Vestibular abnormality patterns
- Nonspecific abnormality patterns

We correlated the rate of caloric abnormalities (defined as > 24% unilateral weakness using the Phillipszoon-Jongkees formula), CVEMP abnormalities and OVEMP abnormalities against each group of CDP abnormalities that we defined. We define caloric abnormalities with an abundance of caution; we realize that some centres use 20% as their limits of normal, and there is no accepted international standard.

When we analyzed VEMPs, we analyzed amplitudes, interaural amplitude ratio (IAR), and latencies of each wave. In each patient, VEMPs were classified as abnormal if any one parameter of measurement was abnormal. As we were trying to assess the ability of posturography to detect specific utricular or saccular disease, we purposely did not report pathology as “unilateral” or “bilateral”. Our suspicion is that a factor in many of our patients with chronic disease is the presence of bilateral pathology; this has been strongly suggested to be the case in a recent study [13].

## 3. Results

There were 111 trauma patients (who had suffered a decelerative head trauma) and 69 nontrauma patients. We carried out a preliminary analysis of test results, where we separated nontraumatic from traumatic patients, and we also separated males from females. We found no difference in test results between those groups; which agrees with our previous work done [8]. As a result, this study combined the results of traumatic and non traumatic patients, and also combined males and females.

CDP results were “normal” in 102 patients (57%), “nonspecifically abnormal” in 53 patients (29%) and showed a “vestibular abnormality pattern” in 25 patients (14%) (Table 1).

Looking at each CDP abnormality group, there was a high rate of CVEMP and OVEMP abnormalities, but the rate of abnormalities was virtually identical in both of the CDP abnormality groups (vestibular and nonspecific) as well as in the normal CDP group.

## 4. Discussion

Our rate of CVEMP and OVEMP abnormalities is very high; 70% and 90% respectively. The OVEMP abnormality rate is higher in each group, although this is not statistically significant. It is difficult to ascertain

**Table 1**  
CDP groups and test results (n = 180) caption: “correlation of CDP results with other measured abnormalities”. (results are not significantly different).

CDP abnormality pattern	No. of patients with Abnormal calorics	No. of patients with Abnormal CVEMP	No. of patients with Abnormal OVEMP
NORMAL 102(57%)	14	56	80
VEST PATTERN 25 (14%)	8	19	23
NONSPECIFIC ABNORMALITY 53 (29%)	11	35	43

what the high rate of OVEMP abnormalities in each group suggests. Keeping in mind that our patients are “atypical” (i.e. still symptomatic after a year), it is unclear to us if the high utricular abnormality rate suggests

- 1. a higher rate of utricular dysfunction,
- 2. more difficulty compensating effectively for utricular dysfunction.

Our group of patients cannot be regarded as representative of a “normal” vestibular population. The standard classifications often reported in many conditions such as “vestibular migraine” and “unilateral viral labyrinthitis” reflect expert opinions, and not diagnostic test results. This is less true in disorders such as Meniere’s syndrome, which presents with typical measurable abnormalities on investigation. As a tertiary and quaternary care centre, we see patients with non-traditional pathology (i.e. chronic persistent vestibulopathy of any cause), and with our one year waiting list, our patients are also atypical because they are still symptomatic.

Posturography is relatively non-invasive and not unpleasant for most patients. Therefore it is undertaken early in the test battery as other tests, particularly the caloric test, make the patients feel so unwell that they need time to recover.

Our “non-traditional” patients often denied true spinning, but instead had histories of “imbalance”, “walking on clouds”, feeling drunk”, feeling motion sick”, or standing on a boat dock. These symptoms are recognized as otolithic in nature [8,10]. Looking at the percentages of patients with reported pathology, it is apparent that many patients had both OVEMP and CVEMP abnormalities. We purposely reported the abnormalities of OVEMPs and CVEMPs separately. We did not report double abnormalities (i.e. as “both abnormal”) because our experiment was designed to see if posturography might possibly be “sacculic specific” or “utricle specific”. We did this because of the previous work of Basta et al [9] who were not able to pinpoint abnormalities in specific vestibular structures.

One study discussing optical counter rolling (OCR) abnormalities [14] suggested that they correlate with VEMP abnormalities. The suggestion was that OCR is a measure of utricular function. This extrapolation about utricular pathology being reflected as OCR abnormalities, which we feel is as yet unproven, may be an unjustified oversimplification. This study did not include VEMP measurements.

It is not surprising that CDP assessment, (which measures dynamic sway and is assessing vestibulospinal stability) does not correlate with OVEMP and CVEMP results, as VEMPs are related to activities involving head movement, and are not a measure of body sway. It has been known since the 19<sup>th</sup> century that vestibulospinal signals are based on otoconial function. This is not an activity which is needed for head movement and therefore results would not be expected to correlate.

CDP has been shown in this experiment, as well as by others to make an important contribution to the diagnostic armamentarium in a tertiary care vestibular lab. When initially developed, it was innovative and ahead of its time. However, as new technologies and better computerization has developed and improved, it has remained largely unchanged.

The particular development which will cause the demise of posturography in the next few years is access to virtual reality goggles, which allow more precise visual simulation of the effects of movement. Time will be necessary for normalization of populations with respect to these new virtual reality tests. Standardization of these tests so they can be used internationally is necessary, but their main advantage is that they will be cheap, and if combined with a commercially available force plate, will allow for more complex measurements than CDP, will be much cheaper and also will allow virtual reality technology to be used on a rehabilitative basis. We feel that the present paper addresses what is probably a fading technology, but one which will continue to be used until norms and standardized force plates are available everywhere.

The cost of these new systems will also increase demand for them. An opportunity for Computerized Dynamic Posturography to be used as the basis for virtual reality is at the behest of the manufacturer; we feel strongly that, until this is undertaken and standardized, there will be a period of a few years with uncertainty about the assessment and management of postural sway in relation to virtual reality and how it applies to patients.

## 5. Conclusions

Our 18 month waiting period endured by most of the patients in this study defines them as an atypical group who inexplicably have failed to compensate and recover effectively from a vestibular insult. However this study confirms earlier work [5] that shows CDP to be a sensitive vestibular assessment, but is not able to detect site-specific pathology. Our data has shown that CVEMP and OVEMP abnormalities do not correlate with CDP findings; as variables in chronically dizzy patients, they are independent of each other. As abnormal VEMPs do not make CDP assessment redundant, it is important to continue including CDP as a standard part of a vestibular assessment. Posturography does have one other benefit. In many patients who have subtle non-vertiginous vestibular symptoms, the test can also simulate their verbalized complaints, probably indicating an origin in the balance system [11]. In patients without central disease this probably means the inner ear.

It is extremely important for a clinician to be able to document organic disease. Although there is often no effective therapy, the presence of organic pathology is much more comforting to a patient than a suggestion that their non-traditional complaints are of psychiatric origin, and in itself this is very helpful and quite often therapeutic.

## Conflict of interest

This is to state that none of the authors in this paper have any conflicts of interest with respect to the research carried out and reported in this manuscript.

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