Spring 2019

Do EMG monitoring and amplitude normalization reduce cVEMP variability in a pediatric population?

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Do EMG Monitoring and Amplitude Normalization Reduce cVEMP Variability in a Pediatric

Population?

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An Honors College Project Presented to

the Faculty of the Undergraduate

College of Health and Behavioral Sciences

James Madison University

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May 2019

Accepted by the faculty of the Department of Communication Sciences and Disorders, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION
This work is accepted for presentation, in part or in full, at Honors Symposium on April 5th, 2019.

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Acknowledgements

Abstract

Untreated balance disorders can cause anxiety, social withdrawal, and even slow motor development in children, making early and accurate diagnosis crucial to patient care. One of the leading tests for the diagnosis of balance disorders is known as the cervical vestibular evoked myogenic potential (cVEMP) test. The cVEMP test is the only clinically available tool that assesses the integrity of the organ of balance known as the saccule and its afferent pathway through the inferior vestibular nerve. The test is noninvasive and easy to administer, making patient diagnosis quick and effective rendering it crucial in the assessment of vestibular function in children. This is important, as most vestibular diagnostic assessments cannot be completed in young children because they are invasive or uncomfortable. While cVEMP testing has largely been studied and practiced on the adult population, little is known about the *gold standard* best practices for performing cVEMPs on a pediatric population, especially in young children under the age of 5 as the majority of pediatric cVEMP research studies focus on older children. The primary purpose of this project is to determine if the adult gold standard protocol of using electromyography (EMG) monitoring and amplitude normalization techniques during cVEMP testing is effective in reducing the amplitude variability of cVEMPs in a pediatric population. A secondary purpose is to provide normative data for cVEMPs in young children, including amplitude, interaural amplitude asymmetry, latency, and EMG values. A population of 10 pediatric participants aged 2-5 had cVEMP testing performed, with EMG monitoring and amplitude normalization, in an effort to see if these strategies reduce amplitude variability in the cVEMP results. Our results showed that while there was no observable effect of EMG correction on cVEMP amplitude asymmetry, there is a clinical need to monitor for EMG.

Introduction

Pediatric Vestibular Disorders

In pediatric populations, undiagnosed vestibular disorders can lead to delays in language learning as well as normative developing motor functioning (De Kegel, Van Waelvelde, & Dhooge, 2013; Pereira et al., 2015). However, the prevalence of vestibular disorders, or disorders causing problems with balance or awareness of one's body in space, are often hard to quantify in a pediatric population. While it is estimated that around 1% of all pediatric audiology visits are vestibular in nature, it is possible that the actual percentage is much higher (Pereira et al., 2015). This is likely due to children's inability to express their symptoms, as children lack language in the first years of life and during preschool years may not have the vocabulary to describe their symptoms (Pereira et al., 2015). Due to this inability for self-diagnosis, the clinician must be aware of the common signs of vestibular disorders within the pediatric population, which often manifest in the form of delayed motor milestones and a loss of ability to control posture (El-Danasoury, El Sirafy, Taha, & Hegazy, 2015).

Pediatric Vestibular Testing

Many of the vestibular function tests that a clinician would perform on an adult upon suspecting vestibular dysfunction are too uncomfortable for a child to complete (Maes et al., 2013). That is, most diagnostic vestibular tests require the child to be in complete darkness, must participate with their eyes open the entire time, and may cause dizziness and discomfort. The vestibular evoked myogenic potential (cVEMP) test is one of the few objective tests of vestibular function that can be completed in very young children because it is non-invasive, quick, requires minimal participation from the child, and is easy to perform making it an optimal test for a child (Pereira et al., 2015).

Cervical Vestibular Evoked Myogenic Potentials

The cVEMP test is used to measure the functional integrity of the saccule, one of the primary organs of balance located in the inner ear, and its afferent pathway through the inferior portion of the vestibular nerve. The literature on cVEMPs extensively covers the specific protocols, in adults, that produce the most robust results giving the clinician an accurate depiction of the functioning of the saccule (Bogle et al., 2013; Isaacson, Murphy, & Cohen, 2006; McCaslin & Jacobson, 2016; Meyer, Vinck, & Heinze, 2015). The saccule is tested through electrodes placed on the contracted sternocleidomastoid muscle (SCM) of the neck (McCaslin & Jacobson, 2016). In the optimal position, patients lie supine (laying back) with their heads turned away from the test ear, as that has been identified as ideal for receiving the most robust amplitude response indicating the organ's functioning (Isaacson et al., 2006; Meyer et al., 2015). When testing the saccule through the SCM, the muscle must be contracted due to the fact that it is an inhibitory response, meaning it will not generate a response without activation through contraction (Bogle et al., 2013). If using air conduction to elicit a response, a low-frequency toneburst is played through the patient's ipsilateral ear (same ear as the side that is being tested), and the saccule response is measured through the SCM as an evoked potential displayed on a screen in front of the clinician with a positive peak (P1) and a negative peak (N1) that can be easily labeled and measured (McCaslin & Jacobson, 2016). In a recently published meta-review, Meyer et al. (2015) reviewed 66 empirical journals on the methods for performing cVEMPs and concluded that the most effective presentation of the tone into the patient's ear is in the form of short tone bursts played at a frequency of 500 Hz due to the increased amplitude that it gives the response. For these reasons, the most commonly used clinical protocol for cVEMP testing in adults is having the patient in a supine position, head turned away from the test ear

while 500 Hz air-conducted tone bursts are played in the test ear and the SCM is contracted

(Isaacson et al., 2006; McCaslin & Jacobson, 2016; Meyer et al., 2015).

In addition to stimulus characterictics, there are recording characteristics to consider

while elicitng a cVEMP, such as electromyography (EMG) monitoring of the contracted SCM.

EMG indicates how much a muscle is contracted. When EMG is monitored, the level of muscle

contraction is displayed either to the clinician or the patient in microvolts. High values indicate

high amounts of contraction from the SCM and low values indicate low amounts of contraction

(Akin et al., 2004). During cVEMP testing, the greater the EMG of the SCM the greater the

cVEMP amplitude (Akin et al., 2004). Because participants manually contract their SCMs, it is

important that they contract them equal amounts on both sides to eliminate interaural amplitude

asymmetries due to differences in muscle contraction (Akin et al., 2004; Bogle et al., 2013). An

unequal level of contraction could lead the clinician to believe there is a problem with the

saccule when really it is due to differences in contractions of the SCM (Akin et al., 2004; Bogle

et al., 2013).

In addition to monitoring EMG activity, amplitude normalization can correct for

variability in EMG after data collection. During amplitude normalization, the average EMG that

the SCM generated during the cVEMP recording is divided into the final cVEMP amplitude to

"normalize" the response based on EMG. EMG monitoring and amplitude normalization are the

two most common measures used to control for unequal muscle contraction (Bogle, Zapala,

Criter, & Burkard, 2013).

Initially, there was disagreement over the legitimacy of EMG monitoring during

cVEMPs (McCaslin, Jacobson, Hatton, Fowler, & DeLong, 2013). The early research in cVEMP

testing showed that EMG directly affected the cVEMP amplitude, and that the relationship was

linear indicating that EMG needs to be monitored in order to make accurate comparisons between subjects and within subjects when comparing an individual's right and left ear response (Akin et al., 2004). However, most clinically available equipment at the time did not include a method for monitoring EMG, so most clinics that implemented cVEMP testing simply did not monitor EMG. Several studies were published that suggested when placing patients in the "optimal" position, supine with head turned and lifted, the SCM contraction was both maximized and equal on both sides (McCaslin et al., 2013; Tillburg et al., 2014). McCaslin et al. (2013) concluded that EMG monitoring did not significantly affect the absolute amplitude of the cVEMP, nor did it affect the interaural amplitude asymmetry between ears. Tillburg et al. (2014) showed similar results in that they observed no within subject effect, but they did state that amplitude normalization reduced between subject variability. Thus, there were recommendations that EMG monitoring may not be necessary if using the optimal patient position during testing.

There were limitations in both these studies. The most significant limitation is that their participant cohort consisted of young, healthy adults. It is quite feasible that a young healthy adult can generate a maximum amount of EMG from the SCM that is equal on both the right and left side. Unfortunately, this may not generalize to a clinical population that tends to be either older or pediatric. In a clinical population, patients may not be able to contract their SCMs equal amounts on both sides resulting in amplitude variability. For that reason, the current consensus in the field of vestibular science is that EMG monitoring and amplitude normalization techniques are good techniques to use to correct for amplitude variability in cVEMP results and should be included in the "gold standard" protocol (Akin et al., 2004; McCaslin, Fowler, & Jacobson, 2014).

While it is clear what the best practices are for adult cVEMP testing, what much of the reviewed literature lacks is any discussion about EMG monitoring and amplitude normalization techniques in pediatric subjects. Few studies have included populations under age 5, and those that have were unable to test the children due to reported crying or restlessness (El-Danasoury et al., 2015) or did not use either EMG monitoring or amplitude normalization techniques (Erbek, S., Erbek, S. S., Gokmen, Ozkiraz, Tarcan, & Ozluoglu, 2007; Hsu, Wang, & Young, 2009; Kelsch, Schaefer, & Esquivel, 2006). One concrete difference between pediatric subjects and adults that has been identified is body placement during testing. It has been found that in children ages 6 and younger, it is best to position the children sitting upright on a parent's lap (Wiener-Vacher, S. 2013). The children are then enticed with a toy to get them to contract their SCM by turning their head to one side while their parents hold the children's bodies still (Wiener-Vacher, S. 2013). Other than this, no standard protocol exists in reference to the amplitude variability of the results in pediatric subjects. More research is needed to determine the best practice for cVEMP testing with EMG monitoring and amplitude normalization in the pediatric population.

This project seeks to determine if the standard protocol for EMG monitoring and amplitude normalization techniques used when testing adults is also beneficial when testing within a pediatric population. These techniques reduce the amplitude variability of the results in adults, ensuring that the responses shown are from the saccule and not from any other source of energy within the contracted SCM muscle (Bogle, Zapala, Criter, & Burkard, 2013). If it is found that these techniques do the same in pediatric subjects, a new best practice procedure could result that is efficient and accurate. This could benefit both clinicians and patients. When using these techniques, the clinicians can be sure that the results they are analyzing reflect the true functioning of the pediatric subject's saccule. An additional purpose of this project is to report on

cVEMPs in healthy, young children including their generated EMG while sitting upright on their parent's lap, as few studies report normative cVEMP data in young children in this test position.

One significant limitation that could present problems over the course of this study is young children's ability, or inability, to follow complex instructions. This could result in an inconclusive set of data points, as the children may be unable to be tested, leaving the question of EMG monitoring's significance unanswered. This challenge will be overcome by having the participants in constant contact with their parents in an effort to overcome feelings of insecurity reducing the amount of crying and restlessness. Even if inconclusive data is found, it will be a step in the right direction of bringing awareness to pediatric cVEMP testing protocols.

Design and Methods

This project utilized an experimental design in which cVEMP tests were performed on pediatric participants.

Participants

Ten pediatric participants ages 2-5 were recruited for this project. The participants for this study were found by the researcher's advisor. She sent an email blast to the James Madison University faculty stating the need for participants in this age range. Exclusionary criteria for participants include children with balance disorders and those with abnormal middle ear function tested by a tympanometry screen. Including children with pathologies could skew the results, as a baseline needs to be established by a normative population before use on a clinical population.

Methods

Data-Gathering Procedure. Data was collected from the 10 pediatric participants within the vestibular sciences lab on JMU's campus. Each child had otoscopy and tympanometry

performed to ensure a normal middle ear function before testing. Each participant had a cVEMP

test performed either in an upright sitting position on the parent's lap or sitting upright

independently, if that was what the child preferred. An alcohol wipe and nu-prep jelly was used

to clean the participant's skin in preparation for electrode placement. Disposable silver/silver-

chloride electrodes were applied to the surface of the skin using a conventional clean electrode

preparation technique. Six electrodes were placed on each participant, two vertical on both the

left and right SCM, one on the forehead and one on the sternum. The forehead electrode is the

ground and the sternum electrode is the reference to cancel out any "white noise" from the

muscle activity. Impedance was measured to ensure the electrodes effectively conducted the

muscle signal.

Figure 1: Electrode placement with SCM flexed

Figure 2: Full body placement sitting upright on parent's lap with SCM flexed

The stimulus was presented in one ear at a time through Etymotic ER-14B disposable

foam eartips designed for pediatric ears. An iPad playing children's shows was then presented to

the children in an effort to get them to turn their heads, effectively contracting the SCM muscle.

The presented stimulus was a 500 Hz Blackman-gated tone burst with a 2 ms rise/fall and 0 ms

plateau presented at a rate of 5.1/second. The stimulus level of the tone was 125 dB pSPL. This

tone burst was simultaneously played into the children's ipsilateral (same side as being tested) ear while the child's head was turned the opposite direction. If the child turned their head back to center, the stimulus and recording was paused and resumed when the child turned their head again. The stimulus stimulates the participant's saccule and the electrodes pick up the muscle activity from the SCM. The bioelectrical activity from the muscle was amplified and filtered (5 – 500 Hz) with a commercially produced neurophysiological amplifier (ChartrEP, GN Otometrics, Tasstrup, Denmark). For each recording, the EMG activity was digitized at a rate of 5000 Hz and recorded on a commercially available electrophysiological recording system (Chartr EP, GN Otometrics, Tasstrup, Denmark). An EMG monitor that is connected to the electrodes displayed how much or how little the participants contracted their SCMs.

cVEMPs were recorded from both the left and right side. During recording, all levels of EMG, regardless of the amount of muscle contraction, were accepted in the protocol. The children were not asked to monitor their own EMG, but the EMG they generated was measured and recorded. The resulting EMG value is the average EMG collected over the duration of the recording. The cVEMP results were then analyzed between the original uncorrected results and the corrected results where the measured EMG value or that participant was used for amplitude normalization.

This is a method commonly used in adult populations. The P1 (positive peak level), N1 (negative peak level), and EMG amount were recorded for each trial. Each condition ran for a duration of 80 accepts or 80 data points within the desired contraction zone. The participant was then brought to a state of relaxation in the SCM by removing the iPad from their sight allowing the participant to relax their neck.
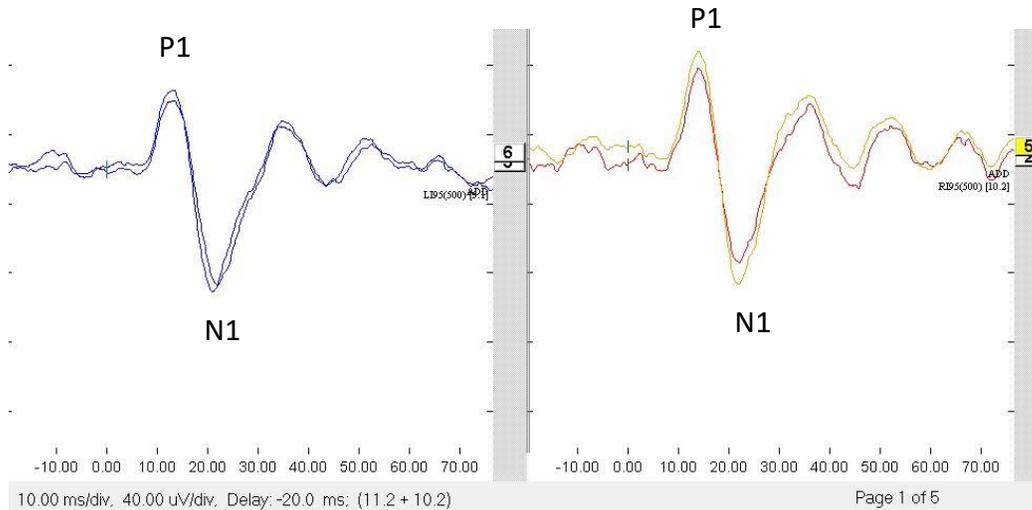
Figure 3: Pediatric cVEMP waveform example

Figure 3 shows a pediatric cVEMP waveform. The blue waveform on the left is the cVEMP for the left ear and the red waveform on the right is the cVEMP for the right ear. The first peak on each side labled P1 depicts the first positive peak and N1 depicts the first negative peak. The amplitude is calculated as the distance between the P1 and N1 values.

Data Analysis and Interpretation. cVEMP variables of latency (amount of time it takes for the first peak to appear), interaural latency difference (left and right ear latency difference), EMG, raw peak-to-peak amplitude, normalized peak-to-peak amplitude, uncorrected interaural amplitude asymmetry (left and right ear amplitude differences), and corrected interaural amplitude asymmetry were calculated. Descriptive statistics were calculated for the means and standard deviations for each outcome variable. Statistical tests were run on SPSS. A repeated measure analysis of variance (ANOVA) was used to assess the variance between the means of the variables tested when the same measure is collected from participants under two or more different conditions. In this case the two conditions are uncorrected and corrected (or normalized) results.

Other considerations.

In order to maintain credibility and validity, the exact same procedure was implemented for each participant. Because the participants are all minors, their parents provided written consent for the child's participation as well as remained present for the duration of the study. In addition to this, the study is IRB approved, establishing that the study is safe and will not cause any harm to the participants ensuring their safety and well-being. Bias was avoided by strictly using the numerical results during analysis, there was no subjective means of data collection during the course of this study.

Results

All subjects were able to complete the cVEMP testing with the exception of one who found the electrodes too uncomfortable, resulting in a total participant completion number of 9. Further, one of those who completed the test produced cVEMP responses that were abnormal from one ear and therefore excluded from the study, leaving 8 total participants included in data analysis.

An initial analysis was completed to determine whether there were ear effects (i.e. right or left ear) on the cVEMP amplitude, EMG, corrected amplitude, or latency. A series of paired sample t-tests were completed, and results showed no significant effect of ear ($p > 0.05$). As such, data from the right ear only was used for all subsequent analyses unless the outcome variable was a measure of inter-aural amplitude asymmetry (IAA) or interaural latency difference (ILD), in which data from both the right and left ears is used.

Descriptives

The average amplitude of the cVEMP, EMG, interaural amplitude asymmetry (IAA), and the corrected IAA are shown in Table 1.

Amplitude (µV)	EMG (µV)	IAA (%)	Corrected IAA (%)
103.29 (41.07)	89.43 (34.33)	16.69 (15.8)	17.8 (11)

Table 1: Mean (standard deviation) of cVEMP amplitude and EMG data

The average EMG produced by the pediatric participants was 89.43 microvolts, but there was a range in values across participants between 48-145 µV. Observing such a large average EMG production from pediatric participants in a seated position was impressive and the range in EMG values showed significant variability in the EMG capabilities of young participants. In addition to the range in EMG, there was a range in amplitudes between participants between 42.76-162.95 µV with a mean of 103.29 µV. Finally, the mean IAA indicates that the average asymmetry between the right and left ears was 16%. The mean corrected IAA was very similar at 17.8%.

The average P1 latency and interaural latency difference (ILD) was calculated along with the standard deviation. The results can be seen below in Table 2.

P1 Latency Mean (SD)	ILD (SD)
14.4 (1.7)	1.9 (1.1)

Table 2: Latency values including mean and standard deviation

The average P1 latency for the right ear was calculated to be 14.4 ms with a standard deviation of 1.7 ms. This shows low variability within the latency data indicating that most of the participants tested have relatively similar latency responses for the P1 value. The mean difference between the P1 latency between the right and left ears was 1.9 ms.
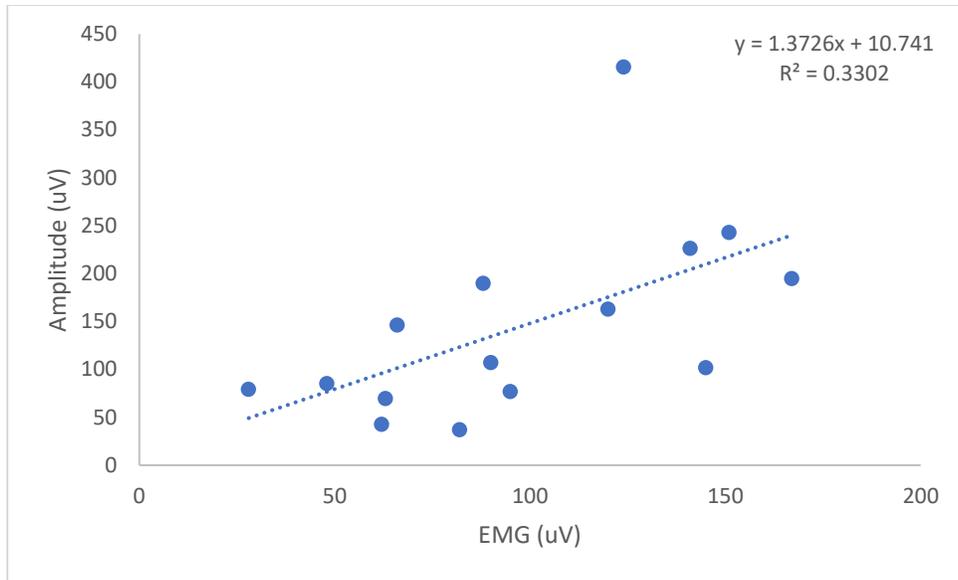
EMG and cVEMP Amplitude

Figure 4: cVEMP amplitude as a function of EMG from each participant's left and right ears

Figure 4 demonstrates the linear relationship between cVEMP amplitude and EMG. As the EMG produced increases, so does the amplitude of the resulting cVEMP wave. Nearly all participants followed this trend, with the exception of one outlier. This helps to highlight the importance of monitoring for EMG, as its presence or absence can have an effect on the resulting cVEMP amplitude. Low EMG results in a low cVEMP amplitude, and high EMG results in a high cVEMP amplitude.

Effects of EMG correction on amplitude asymmetry

To determine whether IAA significantly differed between the EMG corrected and uncorrected conditions (i.e. raw amplitude vs normalized amplitude), a repeated measures ANOVA was conducted where the within subject variable was the recording condition (i.e. 2 recording conditions, with and without amplitude normalization). Results showed no main effect of recording condition ($F = .690$, df $= 1$, p $= .415$) on IAA indicating that amplitude normalization did not significantly affect the subsequent IAA.

Clinical utility of EMG monitoring and amplitude normalization

In a typical clinic or lab, a cut-off value for the cVEMP IAA is calculated as the mean ±

two standard deviations for the mean. An IAA value greater than this would be considered

abnormally asymmetrical, a P1 latency longer than this would be abnormally late, and an ILD

between ears that is greater than this value would be considered abnormal. The following table

shows the cut-off values for the pediatric cohort in this study.

Uncorrected IAA Cut-off (%)	Corrected IAA Cut-off (%)	P1 Latency Cut-off (ms)	ILD Cut-off (ms)
48.2	39.8	17.8	4.1

Table 3: The calculated cut-off values for this cohort, designated by the mean + 2 SD

Statistically, there was no significant difference in mean IAA when comparing the raw,

uncorrected IAA versus the corrected IAA. However, the variability in the corrected condition

was reduced and this holds clinical relevance. Reducing the standard deviation resulted in a

clinical cut-off of 39.8% (i.e. 95% of the normal distribution should be under this value). This is

lower than the uncorrected cut-off of 48.2% and may possibly yield a more sensitive clinical test.

Although there was no significant difference of EMG correction on measures of amplitude

asymmetry, correcting for EMG did lower the cut-off value for the pediatric group.

Discussion and Conclusion

In general, very little data exists of normal cVEMPs in children younger than 5 years of

age and EMG monitoring and amplitude normalization has not been thoroughly studied in this

age group. In adults and older children, previous studies show no main effect of EMG correction

on IAA, even though the direct effect of EMG on the amplitude of the cVEMP is widely

accepted. In adults and older children, the tonic EMG between sides is symmetrical and

participants are able to maintain the EMG for the duration of the recording, thus canceling out

the effects of EMG correction on asymmetry measures. This is consistent with the current study

findings. We hypothesized that there would be a significant effect of EMG correction on

amplitude asymmetry in a sample of young patients, between ages 2 – 5, secondary to children having difficulty maintaining a tonic contraction in their SCM. Our hypothesis was proven incorrect. Children produced adequate EMG that was very symmetrical between the right and left side and they were able to maintain EMG for the duration of the cVEMP recording. There was no significant difference between recording conditions, that is no difference in IAA between when the amplitude was normalized based on EMG and in the uncorrected condition. This indicates that EMG correction and amplitude normalization did not reduce the IAA ratio. However, EMG correction did reduce the IAA variability, resulting in a lower cut-off of normal that has clinical implications. Further, these findings only apply to the group mean data. There were individuals where amplitude normalization had a significant effect.

Although we did not observe any significant effects of EMG correction on the main cVEMP outcome of IAA at a group level, an examination of individuals shows the need for monitoring EMG. That is, there are cases where not monitoring EMG, and not correcting the subsequent cVEMP amplitude, produced asymmetry results that were either erroneously normal or abnormal. The pediatric group subject number PCV 7 showed that correcting for EMG changed the IAA from 67% (abnormal) down to 39% (within normal limits in most labs). In this case, a patient's initial test results may be interpreted as abnormal indicating an impairment of the saccule on one side, when in fact the vestibular system is normal, but the EMG asymmetry resulted in a cVEMP amplitude asymmetry. Conversely, there was an example where correcting for EMG increased the IAA, putting it in, or close to, an abnormal range. Pediatric group subject number PCV 6 initially had an IAA value of 30% and correcting for EMG increased that value to 50%. In this example, the patient's initial results may have been interpreted as normal when in fact there may be a significant vestibular asymmetry.

The IAA cut-off value in this study cohort are consistent with other pediatric cVEMP studies. For example, McCaslin et al. (2013) reported a mean IAA of 12.8% with a cut-off of 33.75%. Althought this is slightly lower than our data, McCaslin et al. studied a pediatric group with a mean age of 10 years, much older than our cohort, and it is possible that older children show less variability in IAA yielding smaller cut-off values.

In terms of the average latency and peak-to-peak amplitude in pediatric studies, the current study is very consistent with what other studies have reported. Typically most pediatric studies reported an average P1 latency of 11.3ms-16.13ms (El-Danasoury, 2015; Hsu, 2009; Kelsch, 2006; McCaslin, 2013; Picciotti, 2006; Rodriquez, 2018; Valente, 2007; & Zhou, 2014). The current study recorded an average P1 latency of 14.4 ms which is well within the average range of values reported by comparable pediatric cVEMP studies. The same can be said for the average amplitude reported. Typical pediatric values that have been reported ranged from 14.2 µV to 301 microvolts, which is quite a large range (El-Danasoury, 2015; Hsu, 2009; Kelsch, 2006; McCaslin, 2013; Picciotti, 2006; Rodriquez, 2018; Valente, 2007; & Zhou, 2014). The current study reported an average amplitude of 103.29 µV which again is well within the range of values that have been reported in the past.

Many pediatric studies do not monitor for EMG, and if they do, the average EMG is not reported in the results. For example, the 2009 Hsu study and 2018 Rodriguez study monitored for EMG during data collection to ensure contraction remained within their desired range, but the average EMG was not reported. One of the few studies reporting average EMG in a pediatric group was McCaslin et al. (2013) who reported an RMS EMG value of 350 µV collected over a 100 mse prestimulus interval. As stated previously, thier average population age was older at 10.81 years. Additionally, their participants were supine, with the head lifted and turned, and

thus yielded much larger EMG values. Finally, the 2007 Valente study reported that it was not feasible to monitor for EMG in children under the age of 5 years due to limited space on the SCM as well as children's limited attention spans. The current study proves that this assertion is incorrect, as the participants tested had no problems tolerating an extra electrode and many of those tested were younger than age 5, and to our knowledge is the only study reporting the mean EMG of young children in an upright seated positon with the head turned.

Of the cVEMP studies conducted on young children, the youngest mean age was 5.5 years old (El-Danasoury, 2015; Hsu, 2009; Kelsch, 2006; McCaslin, 2013; Picciotti, 2006; Rodriquez, 2018; Valente, 2007; & Zhou, 2014). This differs from the mean age of 3.3 years found in this study. Thus, this study is unique in that we assessed very young children and we monitored EMG and recorded the EMG value in a seated condition. Few studies attempted to monitor EMG in children under age 5, let alone report the level of EMG (El-Danasoury, 2015; Hsu, 2009; Kelsch, 2006; McCaslin, 2013; Picciotti, 2006; Rodriquez, 2018; Valente, 2007; & Zhou ,2014). In addition, the position of the participants during data collection was fairly unique to this study was well. Typically, most studies have the children either supine or semirecumbent while the current study had the children sitting, either independently or in their parent's lap, with their heads turned (Kelsch, 2006; McCaslin, 2013; Picciotti, 2006; & Rodriguez, 2018). Clinically, this is the most effective position for very young children and is the most commonly used position in pediatric vestibular clinics (A. Rodriguez, personal communication, 2018)

A limitation to this study is the small sample size. Data collection is ongoing to increase the number of participants in the pediatric group. In future studies we would like to examine the variability of EMG over the duration of the recording in young children. That is, does EMG fluctuate throughout the recording? Anecdotally, most adults were very steady during the

recording with little visible changes in the tonic contraction of their SCM. Similarly, many children were very steady during the recording as they stared intently at the iPad. However, some children had a tendency to wiggle or readjust as their base of support shifted while they were sitting on the parent's lap.

In conclusion, although we did not observe a significant effect of amplitude normalization on the cVEMP amplitude of young children, we did observe individual effects. In some individuals there is a negative consequence to not monitoring. Further, there does not appear to be a drawback to EMG monitoring as all children easily tolerated an extra electrode on their SCM and young children can produce adequate EMG in a seated position. Our study also serves as preliminary normative data of the cVEMP in this testing position. Our recommendation is for best practices cVEMP testing in children to include amplitude normalization based on EMG and to compare results to normative data in the same, or close, testing position.

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