Pediatrics Norms for Visual Contrast Sensitivity Using an APT VCS Tester

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Abstract

Chronic inflammatory response syndrome (CIRS) is an acute and chronic, systemic inflammatory response syndrome usually acquired following exposure to the interior environment of water-damaged buildings (WDB). Capillary hypoperfusion is a principle mechanism of injury in CIRS patients. Visual contrast sensitivity (VCS) testing is affected by capillary hypoperfusion and has been used to screen patients and track treatment results in CIRS cases. Adult VCS norms for the APT VCS Tester were developed by its manufacturer but pediatric norms have not been made available. This study evaluated VCS testing, using an APT VCS tester, on 157 consecutive pediatric patients presenting for wellness checks at a local pediatric clinic. Thirty children were excluded. For the remaining 127 controls, means for left eyes at each CPD (cycles per degree of visual arc) were the same as for right eyes at the same testing frequency. The mean visual contrast raw score at 1.5 CPD was 8.1 out of a possible 9 (stdev = 0.534). The mean for 3 CPD was 8.2 (stdev = 0.531). The mean for 6 CPD was 8.2 (stdev = 0.450). The mean for 12 CPD was 7.8 (stdev = 0.835). The mean for 18 CPD was 1.8 (stdev = 2.40). Further analysis showed there was no significant difference between boys and girls, between well controlled asthmatics and those without asthma or between the cohort of ages 7-8 and any other age grouping. The pediatric VCS norms calculated were the same as the manufacturer's reported norms for adults. Pediatric CIRS prevalence in this cohort was calculated as a minimum of 7.6% and a maximum of 12.7%. Pediatric CIRS prevalence is on the same order as pediatric asthma.

Abbreviations used:

CIRS	chronic inflammatory response syndrome
CPD	cycles per degree of visual arc
VCS	visual contrast sensitivity
WDB	water-damaged buildings

1. Introduction

"The ability to detect objects at low contrast (contrast sensitivity) is a fundamental aspect of visual performance and is closely related to the ability to perform everyday tasks, such as driving, reading, and navigation" (Thayaparan et al.2007). VCS, or visual contrast sensitivity, has been a key factor in determining and tracking the potent effects of toxins that have been introduced to the human body (Hudnell et al., 2001; Shoemaker et al., 2001; Thomas et al., 2010; New York State Department of Health, 2010). Chronic inflammatory response syndrome (CIRS), a genetic disorder with an environmental component, is one illness where VCS testing has been successfully used diagnostically (Shoemaker, Rash and Simon, 2006) and in monitoring treatment effectiveness (Shoemaker et al., 2001; Shoemaker et al., 2004). CIRS (due to WDB) is defined as "an acute and chronic, systemic inflammatory response syndrome acquired following exposure to the interior environment of a water-damaged building with resident toxigenic organisms, including, but not limited to fungi, bacteria, actinomycetes and mycobacteria as well as inflammagens such as endotoxins, beta glucans, hemolysins, proteinases, mannans and possibly spirocyclic drimanes; as well as volatile organic compounds" (Shoemaker, www.surviving mold.com). The prevalence of CIRS in the general pediatric population was recently reported at a minimum of 7.01% (McMahon, 2017). Symptoms of this syndrome include chronic fatigue, recurrent headaches, chronic abdominal pain, frequent diarrhea, sinus problems, cognitive dysfunction, respiratory symptoms, neurologic abnormalities, ophthalmic issues, endocrine dysregulation and more (Shoemaker et al., 2004).

Rather than using traditional measures of visual testing, such as visual acuity, high-contrast stimuli testing of visual contrast sensitivity has presented better appraisals of visual dysfunction resulting from chemical exposures (Hitchcock, 2004). Chronic exposure to inhaled toxins, inflammagens and microbes routinely found in water-damaged buildings (Berndston et al., 2016), in Lyme disease after tick bite (Shoemaker, Hudnell, House, van Kempen and Pakes, 2006), in Ciguatera (Shoemaker et al., 2010) and Pfiesteria toxin exposures (Shoemaker, 1998) and contact with cyanobacteria (Shoemaker et al., 2009) trigger immune dysregulation leading to multi-system and multi-symptom illness (Shoemaker and House, 2006) typically in genetically predisposed persons. One mechanism of injury seen in most CIRS patients is capillary hypoperfusion at multiple sites. Visual contrast testing deficits and visual field losses may occur prior to decreases in visual acuity in glaucoma patients (Wilensky et al., 2001) and VCS changes are thought to be due to hypoperfusion at the optic nerve head. As such, VCS testing has been used for over 15 years to screen potential CIRS patients and to follow the progress of CIRS treatment. One common method of testing Visual Contrast Sensitivity uses the VCS APTitude Test, also known as the APT VCS Tester kit. Currently, there are no published norms for pediatric patients using this instrument. The purpose of this study is to establish such norms.

2. Methods

One hundred fifty-seven (157) consecutive children presenting for routine wellness checks or sports physicals at a local pediatric clinic (FHL Pediatrics) were recruited to participate in this study. Inclusion criteria included youth between the ages of seven and eighteen years without a history of uncontrolled chronic illness, such as diabetes or asthma, and the ability to

distinguish left from right. Subjects were excluded if they demonstrated a history suggestive of CIRS or an inability to follow the test instructions. This study was IRB approved and parental informed consent for all subjects (with informed assent for all children ten years and older) was obtained.

A health questionnaire of eight items was administered to screen for children for uncontrolled chronic illness or the possibility of CIRS. Questions touched on specific illnesses, such as asthma and diabetes, and more vague complaints (frequent headaches, joint pains, constant congestion, memory loss, recurrent diarrhea and other abdominal issues). Qualitative and quantitative data were obtained to assess for chronicity of symptoms, severity of potential occult chronic disease and likelihood of having previously undiagnosed CIRS. No child reported prolonged exposure to solvents, petrochemicals or hydrocarbons.

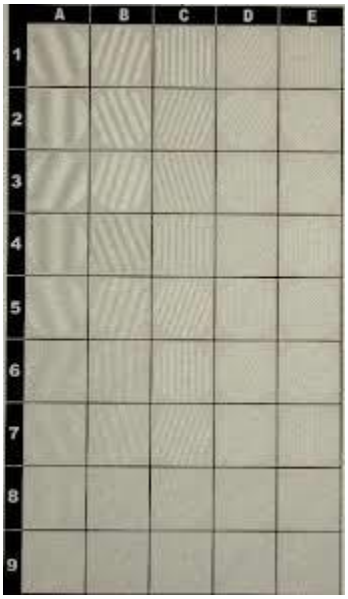
Two children or their parents refused the study, seven demonstrated an inability to perform VCS testing, five were known CIRS patients, one had autoimmune iritis and fifteen were excluded because their health questionnaire suggested possible CIRS, i.e., having three or more chronic symptoms in three different body systems. In all, thirty children were excluded; one hundred twenty-seven children met criteria and were tested.

Testing took place in one of four exam rooms or one private triage room. Illuminance measurements were taken in each room with a High Accuracy 50,000 Lux Digital LCD Light Meter Photometer 3 Range Luxmeter. The minimum recording of 411 lux units over a surface area of 1 m^2 yielded a measure of 411 lumens. This illuminance taken with an apex angle of ~60 degrees converted to 488 candelas or 143 foot-lamberts as the minimum illuminance of any testing area.

Testing was performed using a VCS APTitude Test kit (www.survivingmold.com). A standard near vision visual acuity test and visual contrast sensitivity were performed per the manufacturer's instructions for each subject and following the procedure outlined in Shoemaker et al., 2001. A minimum vision of 20/50 with each eye was required to proceed. One patient failed this screening in one eye (after an eye surgery), and only the passing eye was tested for VCS. No patient scored better than 20/20 as this was the limit of the testing instrument. Measurements were recorded monocularly for each eye for five different spatial frequencies in cycles per degree of visual arc (CPD). Five measurements for each eye (at 1.5, 3, 6, 12 and 18 CPD) were recorded (see Diagram 1). An average of the raw scores for each CPD for each eye was calculated and the standard deviations were devised. Raw scores were converted to contrast sensitivity using the scale on the vertical axis of the manufacturer supplied test recording sheet, and a VCS conversion table created by the manufacturer (also used in the adult validation testing of this instrument). Pediatric conversion replicated adult conversion. By report of the manufacturer (personal communication), the APT VCS Tester was previously validated for adults by simultaneous direct comparison of patients' VCS using the APT VCS Tester and the previously standardized FACT® (Stereo-Optical, Chicago, Illinois) VCS tester. A passing score for adults was determined to correctly ascertain the first ≥7 correct answers in the 6 CPD column and the first ≥6 correct responses in the 12 CPD column.

Statistical analysis consisted of calculations of means, standard deviations and two-tailed t-tests using Excel (Office365) software. An $\alpha = 0.05$ was used to determine significance.

Diagram 1

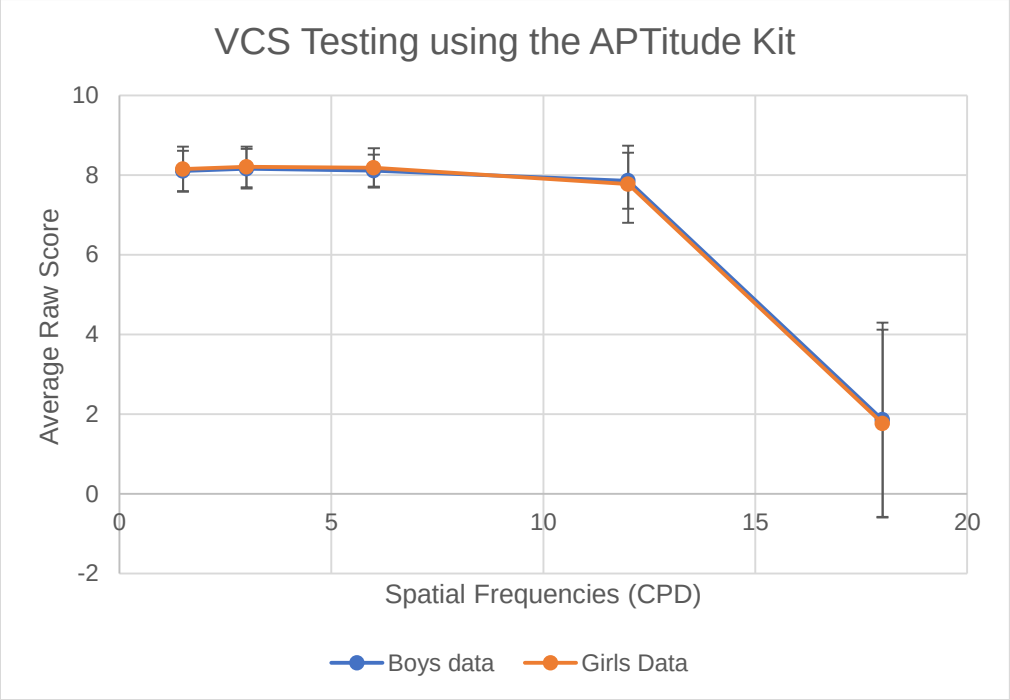


Key: A sample of the score card demonstrating columns A-E and rows 1-9. Each column portrays a specific CPD value (1.5, 3, 6, 12 and 18, respectively) and in each row the sinusoidal markings are more faint than the previous in a descending manner.

3. Results

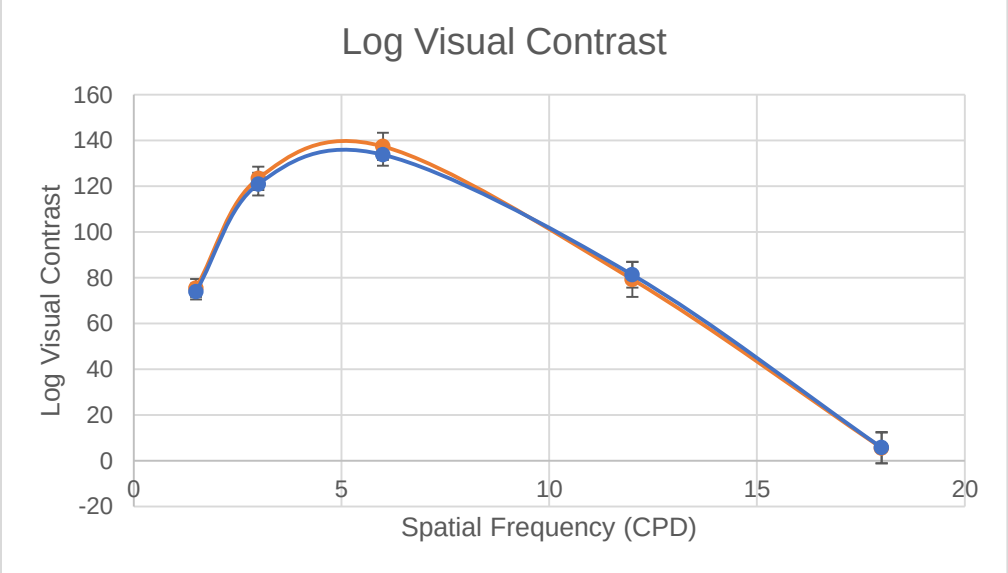
One hundred twenty-seven healthy children (59 girls, 68 boys) between the ages of seven and eighteen years were tested for visual contrast sensitivity. All passed near vision visual acuity other than one teen with previous monocular eye surgery who did pass with the unaffected eye. Means were calculated for each eye and the averages for each eye at each CPD were identical. The reported means for each CPD were then calculated using the data for both eyes combined. The mean raw score for column A, or 1.5 CPD, was 8.1 out of a possible 9 (stdev = 0.534). The mean for 3 CPD was 8.2 (stdev = 0.531). The mean for column C (6 CPD) was 8.2 (stdev = 0.450). The mean for 12 CPD was 7.8 (stdev = 0.835). The mean for 18 CPD (column E) was 1.8 (stdev = 2.40). Conversion to visual contrast sensitivity (log CS) was as follows: 1.5 CPD, 75; 3 CPD, 125; 6 CPD, 143; 12 CPD, 73; and 18 CPD, 4.8, respectively. The normal ranges of raw data at each CPD were established at the mean ± 2 stdev. The ranges were calculated as follows (see Diagrams 2 and 3): 1.5 CPD, 7.1-9; 3 CPD, 7.1-9; 6 CPD, 7.3-9; 12 CPD, 6.1-9; and 18 CPD, 0-6.6, respectively.

Diagram 2



Key: This graph plots spatial frequency measured in CPD (cycles per degree of visual arc) against the average number of correct responses before an error (raw score) in each frequency. "I" designates 1 and 2 standard deviations at each CPD.

Diagram 3



Key: This graph plots spatial frequency measured in CPD (cycles per degree of visual arc) for boys and girls against the log of the contrast sensitivity at each frequency. "I" designates 1 and 2 standard deviations at each CPD.

Previous reports indicated that VCS might reach adult levels by 9 years and may be significantly different at 7-8 years of age (Adams 2002). Only 22 subjects aged 7-8 years and only 17 subjects 16-18 years were tested. There was no significant difference between these small groups (p = 0.711). There were also no significant differences comparing VCS between patients aged 7-8 years with 14-18 years (p = .944) and 9-18 years (p = .721).

The VCS of boys was compared to that of the girls (see Diagrams 2 and 3). There were no significant differences of mean VCS except in the 6 CPD measure (girls 8.2, stdev 0.422; boys 8.1, stdev 0.463, p = 0.0424). The difference between 8.1 and 8.2 is trivial as individual readings in this range are discrete data – either 8 or 9 – so no meaningful significant difference was noted between the boys' and girls' VCS testing.

The VCS of 32 well controlled asthmatics was compared to that of non-asthmatics. There were no significant differences at any CPD measure.

4. Discussion

Our purpose was to determine the normal ranges of visual contrast sensitivity in children using the VCS APTitude Test kit. The ranges established correlate with known norms for adult patients. This suggests that there may not be a great deal of difference between VCS patients of younger age (7-8 years old) and older patients as adult VCS typically remains stable until the 6th decade (Owsley et al. 1983.)

While retinopathies and other ocular diseases which directly alter visual acuity can indirectly affect VCS, CIRS is an illness which affects capillary perfusion. Reportedly, contrast sensitivity is very sensitive to the presence of capillary hypoperfusion at the optic nerve head (Wilensky et al., 2001). VCS testing is used diagnostically for CIRS patients and to evaluate treatment responses. Differences in sex and with illnesses which do not alter perfusion, such as controlled asthma, should not cause significant variance in VCS. Our results demonstrate this.

5. Conclusions

Pediatric VCS norms for the VCS APTitude Test kit at 1.5 CPD were ≥ 7, at 3 CPD were ≥7, at 6 CPD were ≥7, at 12 CPD were ≥6 and at 18 CPD were 0-7, for each eye. These correlate with previously reported adult norms for this test kit. Continued data collection may give these findings more power. There was no difference in VCS measurements between girls and boys. Controlled asthma does not alter VCS testing.

Twenty children were excluded because of known CIRS (5) or describing 3 or more symptoms in varying systems (15) indicating a positive screen for pediatric CIRS. Multi-system disease is considered rare in children, although CIRS is not rare, just usually missed by unaware practitioners. Recent published work demonstrated a minimum prevalence of CIRS in the pediatric population as 7.01% (McMahon, 2017). Minimum prevalence was stressed as the cited study only included known CIRS cases (screening was not performed on the entire population). At the time of this writing, 7 of the 15 children with multi-system symptoms had been evaluated for CIRS and all 7 were found to be CIRS cases. The other 8 of 15 had not completed the work up. In total, there were 12 confirmed cases of CIRS amongst the 157 random patients screened at their well check. This suggests a minimum pediatric prevalence of 7.6% in this population. It is highly likely that more of the other 8 children will also

have CIRS after their evaluation is complete. If all of the other 8 children were also proven to be CIRS patients, the prevalence for this population would be 12.7% (which is greater than the prevalence of childhood asthma). Therefore, the range of CIRS in this group of children is, at minimum, 7.6%, and, at maximum, 12.7%. CIRS is a progressive illness so prevalence in adults is likely higher. CIRS is an important emerging illness and funding should be appropriated to study CIRS in children and adults.

The 8-question health screen briefly self-evaluated 5 body systems. It detected 20 children out of 157, presenting for well checks, with multi-system problems. Twelve of those 20 have confirmed CIRS, the other 8 have not had a completed evaluation. Not including chronic fatigue as a symptom in the screen was an oversight as most CIRS patients suffer from this symptom.

Two of the major strengths of this study were that it was the first to evaluate VCS in children with this instrument and, secondly, efforts were taken to remove potential CIRS patients. Up to 25% of the population (Shoemaker, Rash and Simon, 2006) carries one (or two) CIRS predisposing HLA haplotype(s), it is likely that most previous studies of VCS norms were influenced by an unknown number (up to 25%) of undiagnosed CIRS patients. In addition, agreement in normal ranges between left and right eyes at all CPD values created an internal validation. A major weakness of this study was the relatively low numbers of subjects, particularly in the oldest and youngest age groups.

Further studies using larger numbers should confirm these findings and look more deeply at VCS in 7-8 year old patients vs. older children. A prospective study should compare VCS in pediatric control subjects with known CIRS patients. More work should be done with the screening questionnaire and it should be validated. Sensitivity and specificity should be evaluated as it could be used globally as an easy to administer CIRS screen in children and teens.

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