Article ▸ Prevalence of Accommodative and Non-Strabismic Binocular Anomalies in a Puerto Rican Pediatric Population

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ABSTRACT

Background: There exists a considerable void in the literature of studies that examine the prevalence of non-strabismic binocular and accommodative disorders in the pediatric population of Puerto Rico. The purpose of this retrospective study was to fill this void by performing a comprehensive record review of the pediatric clinical population of the InterAmerican University College of Optometry satellite clinics.

Methods: This study was performed using a random selection of 593 existing health records of patients between the ages of 5 and 20 years. Patients had participated in a complete optometric assessment between the years 2004 and 2012. The criteria for selection were the absence of strabismus, amblyopia, nystagmus, vertical deviation, corneal pathology, retinal pathology, lens pathology, or any other parameter outside of population requirements.

Results: Statistical analysis was performed using the IBM SPSS program. Results of this study indicate that the most common non-strabismic and accommodative anomalies in the studied population are accommodative insufficiency (39.0%), convergence insufficiency (12.6%), convergence excess (9.1%), and accommodative infacility (7.6%).

Conclusions: Accommodative and non-strabismic binocular vision problems are prevalent in the pediatric population of the InterAmerican satellite clinics. This is the first epidemiologic study about the prevalence of these conditions in Puerto Rico. Due to the possibility of these non-strabismic and accommodative anomalies resulting in a reduced quality of life for children and affecting school performance, sports performance, and play activities, an appropriate vision evaluation, diagnosis, and treatment is important. Lastly, further comprehensive studies should be conducted in Puerto Rico using this study as a base for data collection and analysis.

Keywords: accommodative infacility, accommodative insufficiency, convergence excess, convergence insufficiency, non-strabismic binocular anomalies, Puerto Rico

Introduction

The impact of accommodative and non-strabismic binocular anomalies on academic performance and quality of life has been well documented within the optometric and ophthalmologic literature. Epidemiologic studies such as this one create awareness and educate health care providers about the frequency and prevalence of the conditions to be expected in their patient base.

In Australia, Canada, England, South Korea, Spain, and the United States, epidemiologic studies on the prevalence of accommodative and non-strabismic binocular vision anomalies in the school-aged population have been completed, as well as the correlation to learning difficulties.[1-13] Other studies have established the correlation of accommodative and non-strabismic binocular anomalies to learning difficulties.[13-20] All of these studies provide practitioners in these countries the basic information on the frequency of these conditions in order to better assess their patients and implement the most appropriate treatment and management strategies when necessary.

In Puerto Rico, such epidemiologic studies on accommodative and non-strabismic binocular anomalies are lacking. This study is a retrospective review of data from patients aged 5 to 20 years according to National Institute of Child Health and Human Development who have had a comprehensive visual assessment within the InterAmerican University of Puerto Rico School of Optometry's Eye Institute between the years 2004-2012.[21] Diagnostic data was compiled, and the prevalence of accommodative and non-strabismic binocular anomalies in this population was established. This is the first attempt in Puerto Rico to begin the necessary task of providing valid epidemiologic information about the ocular characteristics of the Puerto Rican pediatric population.

Statement of the Problem

Sensory-motor integrative visual conditions are those that may result in accommodative and/or non-strabismic binocular anomalies. These conditions have been documented to affect learning in children of all ages. Therefore, emphasis on early

diagnosis is essential in order to implement the appropriate treatment and management. There have been epidemiologic studies performed in other countries such as the United States, England, Australia, South Korea, and Spain that have determined the prevalence of accommodative and binocular anomalies in the pediatric population.[1-13] There have not been any studies conducted in Puerto Rico that address these conditions. There is a lack of reliable epidemiologic studies based in Puerto Rico to better prepare visual health care service providers to understand the needs of their patients. This paper helps to determine the prevalence of these various conditions from a sample population of existing pediatric health records within the InterAmerican University of Puerto Rico School of Optometry Eye Institute. The clinical system included in the study is composed of the Bayamón main clinic and the Santurce, Rio Piedras, Caguas, Hato Rey, and Juana Diaz satellite clinics.

Purpose of the Study

This study reviews existing clinical health records of patients between the ages of 5 and 20 years who had a comprehensive visual assessment between the years 2004 and 2012. The purpose of this study is to determine the prevalence of accommodative insufficiency (AI), accommodative infacility, accommodative excess (AE), convergence excess (CE), convergence insufficiency (CI), basic exophoria, basic esophoria, and fusional vergence dysfunction within this population.

Review of the Literature

The clinical assessment of binocular vision function and the accommodative system is an integral part of the comprehensive optometric examination. Often, patients will not present with a complaint of decreased visual acuity but rather often report headache, eye strain (asthenopia), blurred vision while performing near tasks, double vision (diplopia), a lack of concentration, and poor reading comprehension. These symptoms often have a negative impact on academic performance.[5,13,16] Although accommodative and non-strabismic binocular anomaly prevalence studies have not been carried out in the Puerto Rican pediatric population, a careful literature review provides studies that have been completed in other countries.

The question of the distribution and frequency of ocular disease and visual anomalies in children has been addressed by Ganz and colleagues Their purpose was to present a method for using a large and ongoing nationally representative survey of the health care experiences of US residents (the Medical Expenditure Panel Survey) to identify children younger than 18 years of age with diagnosed or treated eye and vision conditions.[1] They determined that approximately 6.8% of children less than 18 years of age have a diagnosed eye or visual condition.

The prevalence of ocular conditions and visual impairment and their association with social and biological factors was studied by Cumberland et al. in the United Kingdom.[2] They determined that at 3 years of age, 5.7% of children had at least one eye condition. Cumberland and colleagues also concluded that disorders without visual impairment were independently associated with lower socioeconomic status, decreased birth weight, and prematurity. Visual impairment was more likely to be found in those with low birth weight for gestational age and those born in an ethnic minority group.

Accommodative and non-strabismic vergence dysfunction prevalence amongst school-aged children was reported by Scheiman et al.[3] In their prospective study, they performed a large-scale and comprehensive assessment of the prevalence of vision disorders in a clinical pediatric population. Included in the study were specific diagnostic criteria consisting of 35 categories. The investigators concluded that non-strabismic binocular vision anomalies and accommodative dysfunctions were the most prevalent conditions affecting vision in school-aged children other than refractive error. Other studies carried out in the United States include those by Hokoda, Borsting et al., and Rouse et al.[4-6] Hokoda found that 21% of the patients studied had general binocular dysfunction.[4] Borsting et al. investigated the association of symptoms with accommodative insufficiency and CI in children from grades 3 through 8. They concluded that approximately 45% of the children studied had a general binocular dysfunction which was associated with increased symptoms.[5] Rouse et al. studied the frequency of CI in the clinics associated with the Southern California College of Optometry and the State University of New York College of Optometry. They concluded that 17.6% of the children studied had clinically significant CI.[6]

Utilizing previously published normative data from Australia, Dwyer reported the prevalence of vergence-accommodation disorders in a school-age population. Dwyer acknowledged that although the study did not establish a definitive incidence of vergence-accommodation disorders, it did make a useful contribution to establishing relative incidence of these disorders in a school-age clinical population using a normative clinical application of data. He concluded that 77% of those patients studied had a vergence-accommodative disorder.[7]

Studies have not been limited to pediatric clinical populations. Lara et al. investigated the prevalence of non-strabismic accommodative and binocular dysfunctions in a Spanish clinical population. They found that 22.3% of subjects were classified as having an accommodative and/or binocular disorder.[8] Again in Spain, Porcar studied the prevalence of binocular vision dysfunctions in university students. It was determined that 32.3% had accommodative and non-strabismic binocular anomalies.[9]

Studies by García et al. have also established epidemiologic statistics in the Spanish population. In the first study, they found that 27% had accommodative dysfunction, 23% had binocular dysfunction, and 25% had accommodative and binocular dysfunction.[10] In an additional study by García, it was

noted that 45% of the population studied had accommodative dysfunction, 27% had binocular anomalies, and 27% had combined accommodative and binocular disorders.[11]

In Canada, Letourneau et al. studied the prevalence of CI in elementary school children. They concluded that 8.3% of the population studied had CI.[12] In South Korea, Shin and colleagues found that 71.9% of the children studied had accommodative and/or vergence dysfunction. They also discovered a significant relationship between the diagnosed dysfunctions and poor academic performance.[13]

Other studies have been completed that provide scientific evidence of a correlation between deficient visual skills and learning difficulties. Studies in the United States have been carried out by Hoffman,[14] Buzzelli,[15] Grisham,[16] and Maples.[17] Motsch and Mühlendick studied the same correlation in Germany,[18] and Evans conducted studies in the United Kingdom.[19,20]

There have been only two studies addressing ocular and visual characteristics in the Puerto Rican population. Gordon published the refractive conditions in the Patillas population.[21] His study had an age range of 5 to 81 years. The other study was carried out by Emanuelli and colleagues and investigated eye diseases in the adult population of the San Juan metropolitan area.[23] No studies have specifically evaluated the number of children with significant accommodative and binocular vision anomalies in Puerto Rico.

Methodology

Study Population

This was a retrospective study of patients seen at the InterAmerican University School of Optometry's eye care clinics located in different counties between the years of 2004 and 2012. The counties were: Santurce, Rio Piedras, Bayamón, Caguas, and Hato Rey. The investigators collected data from 593 patient files retrieved by systematic random selection in order to generate a representative sample for the study. No direct contact was made between the subjects and the investigators.

Following IRB approval, data collection began with record file number 110, and every fifth file was retrieved thereafter. A number was assigned to each file that was different from the subject record number to ensure the anonymity of the actual subject. Data was collected in a private office located at each of the InterAmerican Eye Institute clinics. Investigators complied with all HIPAA requirements.

Inclusion Characteristics of the Study

This retrospective study was performed for all patients presenting for a comprehensive examination at the InterAmerican University School of Optometry. Two examiners participated in the study and classified vision disorders for each patient by following a detailed, specific list of criteria. The patient age range of existing health records for review was 5 years to 20 years of age. Data from the existing clinical health records included best-corrected distance visual acuities of 20/20 in each eye. The inclusion criteria to be considered for each condition are the same as set forth by Scheiman et al. for the prevalence of accommodative and non-strabismic binocular anomalies.[3] The criteria are found in Appendix A.

Exclusion Characteristics of the Study

Patients who were specifically excluded from this retrospective study were those who had ocular pathology, disease, or anomalies other than or in addition to binocular vision and accommodative anomalies. These exclusions were as follows:

- Strabismus or previous surgery to correct strabismus
- Amblyopia
- Nystagmus
- Vertical deviation >1$^{\Delta}$
- Best corrected VA not equal to 20/20 in each eye
- Cataracts
- Corneal pathology
- Retinal pathology
- Other ocular condition or surgery that may affect the accommodation-vergence relationship and its data
- Previous vision therapy before the last complete visual assessment within the InterAmerican University School of Optometry's Eye Institute clinical system
- Contact lens use

Data Collection and Analysis

Descriptive statistics were used to analyze the diagnostic data gathered from the existing patient health records. The data was placed into an Excel spreadsheet, and an analysis was performed with the SPSS (Statistical Product and Service Solutions) program.

Results

Overview

All 593 records included in this investigation had sufficient data available to determine eligibility. There were 143 records more than anticipated in the original sample size calculations. This higher number was due to the larger number of charts available that met the eligibility criteria and had complete data for statistical analysis. Table 1 summarizes the testing necessary to be considered an eligible record for inclusion.

Data Analysis

Statistical significance was performed using the bootstrapping method, which assigns a measure of accuracy to sample estimates. The bootstrapping method of statistical analysis is useful for this investigation because it provides a solution to account for distortions caused by a sample that may not be fully representative of the entire population.[22] Overestimation with this type of analysis is possible, therefore the sample size was increased in attempts to reduce the effects of random sampling errors.

Table 1: Tests Administered

Entering visual acuity at distance and near
Pupil evaluation
External evaluation of eye structures and health
Versions
Observations of ocular motility
Near point of convergence
Cover test at distance and near
Stereopsis evaluation using the Randot stereotest
Color vision
Static retinoscopy
Subjective refraction
NRA/PRA
Amplitude of accommodation (push-up method)
Binocular and monocular accommodative facility testing
Biomicroscopy
Intraocular pressure measurement
Direct ophthalmoscopy
Indirect ophthalmoscopy
Horizontal and vertical phoria testing in phoropter

Table 2: Prevalence of Specific Binocular Vision Anomalies in the IAUPR Clinical Pediatric Population

Condition	Prevalence (%)
Accommodative Insufficiency	39
Convergence Insufficiency	12.6
Convergence Excess	9.1
Accommodative Infacility	7.6
Accommodative Excess	5.1
Basic Esophoria	5.1
Fusional Vergence Dysfunction	4.7
Basic Exophoria	3.5
Divergence Insufficiency	2.7
Divergence Excess	1.3
Ill-Sustained Accommodation	0.2

Table 2 lists the results for prevalence of the various conditions for the entire pediatric population investigated. The conditions with the highest prevalence were AI (39%), CI (12.6%), CE (9.1%), and accommodative infacility (7.6%). In addition, accommodative excess was diagnosed in 5.1% of the population, ill-sustained accommodation in 0.2%, basic exophoria in 3.5%, basic esophoria in 5.1%, fusional vergence dysfunction in 4.7%, divergence excess in 1.3%, and divergence insufficiency in 2.7%. A 95% confidence interval was constructed using the percentile bootstrap, and all results reported are within this interval.

Of the 593 records evaluated, 156 children did not have any binocular or accommodative vision anomaly, 335 children had at least one anomaly, and 102 children had two anomalies. Table 3 represents the percentages related to

Table 3: Overall Prevalence of Binocular and Accommodative Vision Anomalies (BAVA)

Number of BAVA present (n = 593)	Prevalence (%)
0 BAVA	26.3
1 BAVA	56.5
2 BAVA	17.2

Table 4: Total Number within Population with Binocular Vision and/or Accommodative Anomalies

IAUPR (n = 593)	Prevalence (%)
Absent	26.3
Present	73.7

incidence of binocular and accommodative vision anomalies. The study resulted in a total number of 437 children (73.7%) with binocular and/or accommodative anomalies. Table 4 shows percentages within the population for any binocular anomalies.

Discussion

This is the first retrospective study using strict diagnostic criteria and a comprehensive optometric evaluation of the prevalence of non-strabismic and accommodative anomalies in a pediatric clinical population in Puerto Rico. As this is a clinical population study, the prevalence of anomalies is expected to be higher than the population as a whole. The study has its limitations, most notably that it was restricted to the clinical pediatric patients of the InterAmerican University School of Optometry satellite clinics. The statistical results found in the study must be used with discretion when applied to the general pediatric clinical population of Puerto Rico in its entirety.

An important result of this study is that other than refractive errors such as hyperopia, myopia, and astigmatism, the optometrist will most likely encounter binocular and accommodative dysfunctions in the pediatric population. Most notably, according to this study, the optometrist will encounter AI, CI, accommodative infacility, and CE. Optometrists routinely evaluate and treat accommodative problems; however, there are no large-scale studies published on the prevalence of these anomalies in Puerto Rico.

The high prevalence determined here gives credence to previously published literature indicating that besides refractive error, binocular and accommodative anomalies will be the most frequent source of visual complaints in pediatric populations.

Prevalence of Non-Strabismic Binocular Disorders

In the pediatric clinical population studied, approximately three in four patients presenting to the satellite clinics displayed an anomaly of accommodation or binocularity. Amongst the anomalies studied, CI is the most widely reported and studied non-strabismic dysfunction reported in current literature. The

classic description of CI is exophoria that is greater for near than distance, a remote near point of convergence, decreased positive fusional vergence (PFV) at near, and normal negative fusional vergence (NFV).[6] According to the results of this investigation, the prevalence of CI in the pediatric clinical population of IAUPR clinic system is 12.6% (p = 0.05). In the literature, the frequency of CI in a pediatric clinical population differs greatly, with Scheiman et al. reporting 4.6%, Rouse et al. reporting 6.0%, Borsting et al. reporting 4.2%, Shin et al. reporting 28.0%, and Dwyer reporting 33%. Although numbers vary considerably between studies, it is important to note that the commonality amongst them is that CI accounts for a significant percentage of non-strabismic binocular anomalies in the pediatric clinical population.

Another notable result from this study is that AI has the highest prevalence of all non-strabismic binocular anomalies investigated. AI is a sensory motor anomaly of the visual system characterized by an inability to focus or to sustain focus at near. This can be demonstrated clinically by reduced amplitude of accommodation based on age-expected norms. These results, as well as those of other studies,[5,10,11,13] suggest that AI is common in school-age children. The high prevalence could be the result of significant latent hyperopia that would lead to a 2.00D or greater reduction in amplitude of accommodation. Latent hyperopia may be a factor, considering that non-cycloplegic refraction was performed.

As shown in this sample of children, accommodative and binocular dysfunctions were frequently present at the same time, with 17.2% of children diagnosed with two conditions (p = 0.05). Over half of the children studied, 56.5% specifically, had one binocular or accommodative disorder (p = 0.05). According to Borsting et al. and Shin et al., accommodative and convergence insufficiencies were frequently present at the same time in school children, with values of 78% and 30.5%, respectively. Of the disorders considered in their studies, both investigations concluded that CI and AI were found in greatest frequency. Although this study does not support previous literature on the topic through statistical analysis, it can be inferred that if two dysfunctions were present, a combination of accommodative and binocular vision dysfunctions were the culprit. Furthermore, this study resulted in a prevalence of 12.6% of the pediatric population with CI and 39% with AI (p = 0.05). These outcomes are impressive in that numerous studies have correlated AI and CI as impacting the performance of school-age children.[5,7,12-14,17,20]

The high prevalence of CI in the pediatric clinical population of IAUPR's School of Optometry in comparison to other literature may be explained by the lack of distinction between a "true CI" and a "pseudo CI" made in the current study. An individual experiencing difficulty accommodating will most likely under-accommodate, leading to a greater degree of exophoria at near and a receded near point of convergence (NPC). Sometimes, repeating the cover test and NPC using +2.00D lenses will lead to a decrease in the exophoria at near and an improved NPC. This would confirm a diagnosis of pseudo-convergence insufficiency. These tests should be repeated when a CI is associated with an AI. The tests were not repeated in the cases included in this study; therefore, it is possible that what appears here as a CI may be misdiagnosed.

Conclusion

The results of this study demonstrating the high prevalence of accommodative and binocular vergence dysfunctions in a clinical pediatric population are significant in that optometric clinicians, health care providers, ophthalmologists, and academic institutions can better prepare for the examination of pediatric patients. In addition to the necessity for proper and complete visual evaluations, children are often misdiagnosed as having learning or reading disorders when, in fact, they may be suffering from an accommodative or non-strabismic binocular anomaly.

As this is the first epidemiologic study of its kind in Puerto Rico, a better understanding of the visual sensory-motor integrative status of a portion of the general pediatric population has been achieved. Further comprehensive large-scale studies should be completed in Puerto Rico, utilizing this study as a foundation for data collection and analysis. Also, future analyses in the clinical pediatric population of Puerto Rico should include prevalence of accommodative and binocular dysfunctions in specific age groups as well as any significant prevalence of these dysfunctions in males and females.

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Paniccia SM, Ayala AR. Prevalence of accommodative and non-strabismic binocular anomalies in a Puerto Rican pediatric population. Optom Vis Perf 2015;3(3):158-64.

The online version of this article contains digital enhancements.

Appendix A

- **Accommodative insufficiency**
  - Symptoms associated with near work PLUS signs 1-2 need to be present and one sign of 3-4.
    1. Reduced amplitude of accommodation. Push-up monocular accommodative amplitude at least 2.00D below Hofstetter's calculation for minimum amplitude: 15 – (0.25 x age of patient)
    2. Fails monocular accommodative facility with -2.00D, ≤ 4.5 cycles per minute (CPM)
    3. Fails binocular accommodative facility with -2.00D, ≤ 2.5 CPM
    4. Low positive relative accommodation (PRA) of ≤ 1.25D

- **Accommodative infacility**
  - Symptoms associated with near work PLUS signs 1-3 need to be present; sign 4 may or may not be present.
    1. Normal amplitude of accommodation. Push-up monocular accommodative amplitude meets Hofstetter's calculation for minimum amplitude: 15 – (0.25 x age of patient)
    2. Fails monocular accommodative facility with ±2.00D, ≤ 4.5 CPM
    3. Fails binocular accommodative facility with ±2.00D, ≤ 2.5 CPM
    4. Low PRA and negative relative accommodation (NRA); PRA ≤ 1.25D and NRA ≤ 1.50D

- **Accommodative excess**
  - Symptoms associated with near work PLUS signs 1-3 need to be present, and one sign of either 4 or 5 must be present.
    1. Variable visual acuity findings
    2. Variable objective and subjective refraction
    3. Fails monocular accommodative facility with +2.00D, ≤ 4.5 CPM
    4. Fails binocular accommodative facility with +2.00D, ≤ 2.5 CPM
    5. Low NRA, ≤ 1.50D

- **Ill-sustained accommodation**
  - Symptoms associated with near work PLUS signs 1-4 need to be present, and one sign of 5-7 must be present.
    1. Normal accommodative amplitude if administered once; the amplitude decreases if repeated 5 to 10 times
    2. Normal near point of convergence (NPC)
    3. Low PRA, ≤ 1.25D
    4. Fails monocular accommodative facility with -2.00D, ≤ 4.5 CPM
    5. Fails binocular accommodative facility with -2.00D, ≤ 2.5 CPM
    6. Esophoria at near
    7. High Monocular Estimation Method (MEM)

- **Convergence insufficiency**
  - Symptoms associated with near work PLUS signs 1-4 need to be present, and one of 5-7 must be present.
    1. Moderate to high exophoria at near > 6^{Δ}
    2. Exophoria at near greater than measured at distance, ≥ 4^{Δ}
    3. Receded near point of convergence, ≥ 6 cm for break point
    4. Reduced positive fusional vergence (PFV) at near: failing Sheard's criterion or minimum normative PFV ≤ 12/15/4 for blur, break, and recovery (at least one of three)
    5. Low calculated AC/A ratio, < 3/1
    6. Fails binocular accommodative facility with +2.00D, ≤ 2.5 CPM
    7. Low NRA, ≤ 1.50D

- **Basic exophoria**
  - Symptoms associated with near and distance work PLUS signs 1-2 need to be present, and one of 3-4 must be present.
    1. Exophoria of approximately equal amount at near and distance
    2. Reduced PFV at near; failing Sheard's criterion or minimum normative PFV: ≤ 12/15/4 for blur, break, recovery (at least one of three)
    3. Normal AC/A ratio
    4. Fails binocular accommodative facility with +2.00D lenses, ≤ 2.5 CPM
    5. Low NRA, ≤ 1.50D

- **Divergence excess**
  - Associated symptoms such as photophobia or poor cosmesis and signs 1-4 need to be present
    1. High AC/A ratio (calculated method)
    2. Frequency of exodeviation worse at distance than at near
    3. Normal PFV at distance and near
    4. No significant refractive error

- **Convergence excess**
  - Symptoms associated with near work PLUS signs 1-2 need to be present, and one of 3-5 must be present.
    1. Esophoria at near is greater than measured at distance, ≥ 3^{Δ}
    2. Reduced negative fusional vergence (NFV) at near: failing Sheard's criterion or minimum normative NFV ≤ 9/17/8 for blur, break, and recovery (at least one of three)
    3. High calculated AC/A ratio, ≥ 7/1
    4. Fails binocular accommodative facility with -2.00D lenses, ≤ 2.5 CPM
    5. Low PRA, ≤ 1.25D

- **Basic esophoria**
  - Symptoms associated with distance and near tasks PLUS signs 1-2 need to be present, and one of 3-4 must be present.
    1. Esophoria of approximately equal magnitude at near and distance
    2. Normal AC/A ratio
    3. Reduced NFV at near; failing Sheard's criterion or minimum normative NFV ≤ 9/17/8 for blur, break, recovery (at least one of three)
    4. Fails binocular accommodative facility with -2.00D lenses, ≤ 2.5 CPM
    5. Low PRA, ≤ 1.25D

- **Divergence insufficiency**
  - Symptoms associated with distance tasks PLUS signs 1-4 must be present.
    1. Esophoria greater at distance than at near
    2. Reduced NFV at distance
    3. Reduced vergence facility at distance with BI prism
    4. Eso fixation disparity at distance

- **Fusional Vergence Dysfunction**
  - Symptoms associated with reading PLUS signs 1-3 must be present.
    1. Orthophoria at distance and near, or low degree of exophoria or esophoria at distance and near
    2. Normal AC/A ratio
    3. Reduced NFV and PFV at near and distance: minimum normative NFV ≤ 9/17/8 for blur, break, recovery (at least one of three), and minimum normative PFV ≤ 12/15/4 for blur, break, and recovery (at least one of three)