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REVIEW

Do we really know the prevalence of accomodative and nonstrabismic binocular dysfunctions?

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Abstract
Purpose: To determine the scientific evidence about the prevalence of accommodative and nonstrabismic binocular anomalies.
Methods: We carried out a systematic review of studies published between 1986 and 2009, analysing the MEDLINE, CINAHL, FRANCIS and PsycINFO databases. We considered admitting those papers related to prevalence in paediatric and adult populations. We identified 660 articles and 10 papers met the inclusion criteria.
Results: There is a wide range of prevalence, particularly for accommodative insufficiency (2%-61.7%) and convergence insufficiency (2.25%-33%). More studies are available for children (7) compared with adults (3). Most of studies examine clinical population (5 studies) with 3 assessed at schools and 1 at University with samples that vary from 65 to 2048 patients. There is great variability regarding the number of diagnostic signs ranging from 1 to 5 clinical signs. We found a relation between the number of clinical signs used and prevalence values for convergence insufficiency although this relationship cannot be confirmed for other conditions.
Conclusion: There is a lack of proper epidemiological studies about the prevalence of accommodative and nonstrabismic binocular anomalies. Studies reviewed examine consecutive or selected patients in clinical settings and schools but in any case they are randomized and representative of their populations with no data for general population. The wide discrepancies in prevalence figures are due to both sample population and the lack of uniformity in diagnostic criteria so that it makes difficult to compile results. Biases and limitations of reports determine that prevalence rates offered are only estimations from selected populations.

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PALABRAS CLAVE
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Trastornos de la visión

¿Conocemos realmente la prevalencia de disfunciones binoculares no estrábicas y de acomodación?

Resumen

Objetivo: Determinar la evidencia científica acerca de las anomalías acomodativas y binoculares no estrábicas.

Métodos: Llevamos a cabo una revisión sistemática de estudios publicados entre 1986 y 2009 analizando las bases de datos MEDLINE, CINAHL, FRANCIS y PsycINFO. Decidimos admitir las publicaciones relacionadas con la prevalencia en poblaciones pediátricas y adultas. Identificamos 660 artículos, y 10 publicaciones cumplieron los criterios de inclusión.

Resultados: Hay un amplio intervalo de prevalencias, sobre todo para la insuficiencia acomodativa (2-61,7%) y la insuficiencia de convergencia (2,25-33%). Hay más estudios dedicados a niños (7) que a adultos (3). La mayoría de los estudios examinan la población clínica (5 estudios), 3 realizados en escuelas y 1 en la universidad, con muestras que varían desde 65 hasta 2.048 pacientes. Hay una gran variabilidad respecto al número de signos diagnósticos, entre 1 y 5 signos clínicos. Encontramos relación entre el número de signos clínicos utilizados y los valores de prevalencia para la insuficiencia de convergencia, aunque esta relación no puede confirmarse para otras anomalías.

Conclusión: Faltan estudios epidemiológicos adecuados acerca de la prevalencia de las anomalías acomodativas y binoculares no estrábicas. Los estudios revisados examinan a pacientes consecutivos o seleccionados de ámbitos clínicos y escuelas, pero en ningún caso están aleatorizados ni son representativos de sus poblaciones, y no hay datos para la población general. Las amplias divergencias en los valores de prevalencia existentes se deben tanto a la población de la muestra como a la falta de uniformidad en los criterios del diagnóstico, de modo que se hace difícil la recopilación de resultados. Los sesgos y las limitaciones de las investigaciones determinan que los valores de prevalencia ofrecidos sean únicamente estimaciones de las poblaciones seleccionadas.

Introduction

Accommodative anomalies and nonstrabismic binocular dysfunctions are vision disorders which affect the binocularity and visual performance of subjects, particularly when close vision is needed. Although there have been several classifications to categorize binocular disorders,[1-3] the most common[4] refers to convergence insufficiency (CI), divergence insufficiency (DI), convergence excess (CE), divergence excess (DE), basic exophoria, basic esophoria, fusional vergence dysfunction (FVD) and vertical deviations. According to accommodative anomalies, the classification includes the anomalies of accommodative insufficiency (AI), accommodative excess (AE) and accommodative infacility.[5-8]

There are several symptoms and signs of accommodative and binocular disorders. The signs refer to the findings of accommodative and binocular tests which may be altered and symptoms may include blurred far or near vision, headaches, diplopia, difficulty in reading and in many cases, impossibility to maintain clear vision for a reasonable period of time.[9-12] Characteristics of accommodative and vergence anomalies by means of definitions of each condition, symptoms and signs are summarized in Table 1.[13] As it can be observed, there are several symptoms and signs that may be used for diagnosing these conditions. However, there is a lack of consensus in the scientific literature on what diagnostic criteria should be used to define each anomaly, existing large differences between them.[14-22]

Regardless of these differences, there are several grounds to understand that the prevalence of these visual conditions is important to know. Prevalence of a disorder refers to the total number of cases of a disorder/ disease that exists in the population, either during a period of time or at a specific point in time.[23] In this way, prevalence studies examine persons who form a part of a population looking for the condition of interest. In this point of time some members of the population suffer the condition and other does not so that the proportion of the population who has the condition is the prevalence of the disorder. Thus, the process used by many visual health clinicians[24] requires the use of information on prevalence in order to reach a hypothesis on the possible diagnosis of the condition and a decision regarding the process to be followed, so that information about prevalence should be essential for clinical purposes. Moreover, as with refractive errors,[25] proper epidemiological information based on scientific evidence can help in many areas such as decision-making in certain clinical initiatives, for instance, vision screening for detection, research projects or political visual health care strategies. In this regard, prevalence studies are essential for health policy purposes as governments make decisions about vision care coverage based, among others, on the available prevalence data.

Certainly, several studies have suggested that these dysfunctions are commonly found in optometric practice[26,27] but there is certain disparity with regard to the prevalence values offered by different authors. Several examples may be seen for accommodative insufficiency for which

Table 1 Classification of accommodative and nonstrabismic binocular anomalies[13]

Disorder	Definition	Characteristics	
		Symptoms	Signs
ACCOMMODATIVE ANOMALIES			
Accommodative insufficiency	Condition in which the patient has difficulty stimulating accommodation.	Very similar to those associated with presbyopia. Are associated with near tasks, May include: blurred near vision, discomfort and strain, fatigue and difficulty with attention and concentration when reading.	• Low accommodative amplitude (AA). • Low positive relative accommodation (PRA). • Fails monocular and binocular accommodative facility (MAF, BAF) with −2.00 D. • High MEM or fused cross-cylinder (FCC) findings.
Accommodative excess	Condition in which the patient has difficulty with relaxation of accommodation.	Asthenopia and headaches associated with near tasks and intermittent blurred distance vision.	• Variable visual acuity findings. • Variable static and subjective. • Low degree of against-the rule- cylinder • Low MEM or FCC findings. • Low negative relative accommodative (NRA). • Fails MAF and BAF facility with + 2.00 D.
Accommodative infacility	Condition in which the patient has difficulty in changing the accommodative response level.	Difficulty focusing from distance to near and near to distance, asthenopia associated with near tasks, difficulty with attention and concentration when reading, intermittent blur associated with near tasks.	• Fails MAF and BAF with ± 2.00 D. • Low PRA and NRA.
NONSTRABISMC BINOCULAR ANOMALIES			
Convergence insufficiency	Patient with orthophoria or exophoria at distance, low AC/A ratio and significant exophoria at near greater than the distance phoria.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, intermittent diplopia, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, words move on the page, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Greater exophoria at near than at distance. • Reduced positive fusional vergence (PFV) at near. • Reduced vergence facility at near with base-out prisms. • Intermittent suppression at near. • If suppression is significant, stereopsis may be reduced. • Receded near point of convergence. • Low AC/A ratio. • Fails BAF with + 2.00 D. • Low MEM or FCC. • Low NRA. • Exofixation disparity.
Divergence insufficiency	Patient with esophoria at distance, low AC/A ratio and distance phoria will be significantly greater than the near phoria.	Asthenopia associated with distance tasks. May include: intermittent blur or diplopia at distance, symptoms worse at the end of day, symptoms are generally longstanding, in contrast to a recent history of acute symptoms.	• Esophoria greater at distance than at near. • Reduced negative fusional vergence (NFV). • Reduced vergence facility at distance with base-in prism. • Esofixation disparity at distance.

Table 1 Classification of accommodative and nonstrabismic binocular anomalies[13] *(Continuation)*

Disorder	Definition	Characteristics: Symptoms	Characteristics: Signs
Convergence excess	Patient with orthophoria or moderate degree of esophoria at distance, high AC/A ratio and esophoria at near significantly greater than that at distance.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, intermittent diplopia, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, words move on the page, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Significant esophoria at near, greater than at distance. • Reduced negative fusional vergence (NFV) at near. • Reduced vergence facility at near with base-in prisms. • Low PRA. • Fails BAF with −2.00 D. • High MEM or FCC. • Esofixation disparity.
Divergence excess	Patient with a low to moderate degree of exophoria at distance and a high AC/A ratio, with a degree of exophoria at near significantly less than that at distance.	Associated with distance tasks: complain of eye turning out, occasional near point asthenopia, patient closes one eye in bright light.	• Greater exophoria at distance than at near. • High AC/A ratio. • Suppression at far. • Limited NFV, adequate PFV. • Difficulty with first and second degree of fusion.
Fusional vergence dysfunction	Patient with orthophoria at distance and near or a low degree of phoria at far and near, with fusional vergence ranges reduced in both base-in and base-out directions.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Ortophoria or low degree of eso- or exophoria at distance and near. • Reduced PFV and NFV at far and near. • Reduced vergence facility with both base-out and base-in prism. • Low PRA and NRA. • Fails BAF with ±2.00 D.
Basic esophoria	Patient with esophoria at distance and a normal AC/A ratio, with near phoria approximately equal to the distance phoria.	Associated with distance and near tasks. May include: asthenopia, intermittent blur, intermittent diplopia and symptoms worse at the end of day.	• Esophoria of approximately equal magnitude at near and at distance. • Reduced NFV at far and near. • Reduced vergence facility at distance and near with base-in prism. • Low PRA. • Fails BAF with −2.00 D. • High MEM or FCC findings. • Esofixation disparity at far and near.
Basic exophoria	Patient with exophoria at distance and a normal AC/A ratio, with near phoria approximately equal to the distance phoria.	Associated with distance and near tasks. May include: asthenopia, intermittent blur, intermittent diplopia and symptoms worse at the end of day.	• Exophoria of approximately equal magnitude at near and at distance. • Reduced PFV at far and near. • Reduced vergence facility at distance and near with base-out prism. • Low NRA. • Fails BAF with +2.00 D. • Low MEM or FCC findings. • Exofixation disparity at near and distance.
Vertical deviations	Patient with either hyper or hypophoria.	Blurred vision, headaches, asthenopia, diplopia, car and motion sickness, inability to attend and concentrate during sustained visual tasks, sleepiness, loses place when reading.	• Anomalous head position. • Hyperphoria. • Reduced PFV y NFV. • Reduced vergence facility at distance and near with base-out and base-in prism. • Vertical fusional vergence may be reduced or unusually large, depending on the duration of the vertical deviation.

Source Scheiman M, et al[13].

prevalence values may vary between authors from 9.24%[28] to 80%.[9] Other examples of prevalence disparities can be found for convergence insufficiency, with published values ranging from 24.6%[29] to 8.3%.[30]

To achieve an estimate of the population prevalence of accommodative and nonstrabismic binocular dysfunctions, we have systematically reviewed studies of the prevalence of these visual disorders. Therefore, this study concentrates on establishing the scientific evidence on the prevalence of accommodative and nonstrabismic binocular anomalies from 1986-2009. We decided to study this large time frame for not losing possible relevant information about these anomalies.

Methods

We carried out an exhaustive search on content published in health-science databases from 1986 to 2009. The search was carried out using MEDLINE, CINAHL, FRANCIS and PsycINFO databases. The visual disorders we wanted to examine were: accommodative excess, accommodative insufficiency, accommodative infacility, convergence insufficiency, convergence excess, divergence excess, divergence insufficiency, basic esophoria, basic exophoria, fusional vergence dysfunction and vertical deviations. For that reason, the search strategy was based on the use of terms in free language related to these visual anomalies, searching in all fields of the databases. The search equation included boolean operators, truncated symbols and wildcard characters which are specific signs used in information sciences and in databases selected. Table 2 shows the search strategy.

The inclusion criteria for articles were the recovery of original articles published in English, whose purpose were to study the prevalence of accommodative and nonstrabismic binocular dysfunctions, with study populations including all ages from children to adults. Therefore, the exclusion criteria were articles not concerned with accommodative and nonstrabismic binocular disorders; publications regarding to assessment of optometric tests but not related to prevalence of these anomalies; studies about diagnosis and/or treatment of these dysfunctions; non original articles; studies on strabismic binocular disorders or ocular pathologies and papers in other languages.

We found 660 articles. Upon analysis, and following the inclusion and exclusion criteria, we selected 10 articles[24,31-39] which complied with the inclusion criteria. We excluded the remaining 650 publications for different reasons. 205 studies (31.6%) were not related to disorders, mentioning accommodative and binocular dysfunctions secondarily but not being the subject of research; 160 (24.6%) dealt with strabismic anomalies; 105 (16.2%) with ocular pathologies; 54 (8.3%) were studies about assessment of tests; 49 (7.5%) were related to treatment; 41 (6.3%) were publications about diagnosis and 36 (5.5%) not written in English.

We analysed the selected studies through different variables: characteristics of the sample studied, clinical signs used by different authors to diagnose accommodative and binocular anomalies, prevalence values obtained and biases and limitations within the studies.

Table 2 Search strategy used in databases

#1	(Accommodative excess) OR (excess of accommodation)
#2	(Accommodative spasm) OR (spasm of accommodation)
#3	(Accommodative insufficiency) OR (insufficiency of accommodation)
#4	(Accommodative infacility) OR (infacility of accommodation)
#5	(Accommodative disorder*) OR (accommodative anomal*) OR (accommodative dysfunction*)
#6	(Disorder* of accommodation) OR (anomal* of accommodation) OR (dysfunction* of accommodation)
#7	#1 OR #2 OR #3 OR #4 OR#5 OR #6
#8	(Convergence insufficiency) OR (insufficiency of convergence)
#9	(Convergence excess) OR (excess of convergence)
#10	(Convergence spasm) OR (spasm of convergence)
#11	(Divergence excess) OR (excess of divergence)
#12	(Divergence insufficiency) OR (insufficiency of divergence)
#13	Basic e?ophoria
#14	(Vergence disorder*) OR (vergence anomal*) OR (vergence dysfunction*)
#15	(Binocular disorder*) OR (binocular anomal*) OR (binocular dysfunction*)
#16	(Vergence infacility) OR (reduced fusional vergence) OR (fusional vergence dysfunction*) or (fusional vergence anomal*) OR (fusional vergence disorder*)
#17	Hyperdeviation* OR hypodeviation* OR hypophoria* OR hyperphoria* OR (vertical deviation*) OR (vertical disorder*) OR (vertical anomal*) OR (vertical dysfunction*) NOT surgery
#18	#8 OR #9 OR #10 OR #11 OR#12 OR #13 #14 OR #15 OR#16 OR #17
#19	#7 OR #18

Results

Table 3 summarise the selected 10 publications showing the most outstanding characteristics of each of them. It exhibits the information about methodological characteristics of the articles showing the sample type and size, country of study and the diagnostic criteria used by the authors of each study. As we can see, all papers refer to studies in which a sample is selected and assessed an optometric exam with several tests obtaining the prevalence values for each condition. It highlights the greater number of studies (7) on children compared with adults (3 papers). There are also more surveys on clinical populations, 5 studies, compared with those referred to schools, 3 papers, being one study which does not specify the type of population and other that examines university students. We can also see that there is no study focusing adult healthy general population. Likewise, Table 3 reveals the existence of different diagnostic criteria used by different authors for these anomalies. It also highlights the great disparity of sample size of each study which fluctuates from 65 to 2048 patients.

Table 4 shows the minimum and maximum prevalence values for accommodative and binocular disorders studied,

Table 3 Methodological characteristics of articles

Author and year of publication	Sample type and size	Study population	Country of study	Dysfunction	Diagnostic criteria
Abdi, 2005[31]	120 children Urban population 61 female, 59 male Age: 6-16 years Mean age: 11	Not specified	Sweden	CI AI	*CI Diagnosis* • NPC ≥ 10 cm. Push-up method. Mild CI: NPC of 10-14 cm; Moderate CI: NPC of 15-19 cm; Marked CI: NPC of 20-25 cm *AI Diagnosis*. • Near point of accommodation (NPA) ≥ 10 cm (AA ≤ 10 D). Push-up method Mild AI: NPA: 10-15 cm; Moderate AI: NPA: 16-20 cm; Marked AI: NPA > 21-25 cm
Borsting, 2003[32]	392 children Type of population not specified 199 female, 93 mele Age: 7.6-14.8 years Mean age: 10.46 ± 1.41	2 private elementary schools and 2 public elementary schools	USA	CI AI	*AI Diagnosis*: • AA 2 D below Hofstetter's minimum age formula: 15-0.25 (age). Push-up method. *CI Diagnosis*: 2 or 3 signs: • Greater exophoria at near than distance (≥ 4 Δ). Cover test at 3 m/30 cm • PFV at near ≤ 7 Δ break or 3 Δ recovery or fails Sheard's criteria. Prism bar at 30 cm • NPC receded: > 6 cm. Push-up method.
Lara, 2001[34]	265 patients Urban population Sex not specified Age: 10-35 years Mean age: 20.75 ± 5.78	Optometry clinic	Spain	AI, AE, Accommodative infacility CI, CE, Basic exophoria	*AI Diagnosis:* signs 1-2 fundamental and two signs from 3-5 • (1) AA reduced: 2 D below Hofstetter's minimum age formula: 15-0.25 (age). Monocular push-up method • (2) MAF ≤ 6 cpm with −2 D • (3) BAF ≤ 3 cpm with −2 D • (4) MEM > +0.75 D • (5) PRA ≤ 1.25 D *Accommodative infacility Diagnosis* • MAF ≤ 6 cpm with −2 D and FAB ≤ 3 cpm with −2 D • PRA ≤ 1.25 D and NRA ≤ 1.50 D *AE Diagnosis* signs 1-3 fundamental and two signs from 4-6 • (1) Variable visual acuity • (2) Variable static retinoscopy and subjective refraction • (3) MAF ≤ 6 cpm with + 2 D • (4) BAF ≤ 3 cpm with + 2 D • (5) MEM ≤ 0 D • (6) NRA ≤ 1.50 D *CE Diagnosis:* signs 1-2 fundamental and two signs from 3-6 • (1) Significant esophoria at near, > 2 Δ. Cover test. • (2) NFV ≤ 8/16/7 Δ, at least one of three made at near distance • (3) calculated AC/A > 7/1 • (4) BAF ≤ 3 cpm with −2 D • (5) MEM > +0.75 D • (6) PRA ≤ 1.25 D

					CI Diagnosis: signs 1-3 fundamental and two signs from 4-7 • (1) Exophoria at near > 6 Δ. Cover test • (2) PVF ≤ 11/ 14/ 3 Δ, at least one of three made at near distance • (3) Receded NPC, > 10 cm break, > 17.5 recovery. Push-up method • (4) Calculated AC/ A < 3/ 1 • (5) BAF ≤ 3 cpm with + 2 D • (6) MEM ≤ 0 D • (7) NRA ≤ 1.50 *Basic exo Diagnosis:* signs 1-2 and two from 3-6 • (1) Exophoria of approximately of equal magnitude at near and distance (within 5 Δ). Cover test • (2) PFV ≤ 11/ 14/ 3 Δ at near and ≤ 4/ 8/ 5 Δ at far, at least one of three • (3) Normal AC/ A ratio • (4) BAF ≤ 3 cpm with + 2 D • (5) MEM ≤ 0 D • (6) NRA ≤ 1.50 D
Rouse, 1999[39]	453 children Urban and rural population Sex not specified Age: 9-13 years Mean age: 11.3 ± 0.6	2 public school children and 1 parochial school children	USA	CI AI	*CI Diagnosis:* • (1) Exophoria at near ≥ 4 Δ than at far. Von Graeffe for 3 m and 30 cm, with VA of 20/ 30 • (2) Failing Sheard's criterion or minimum normative PFV at near of 12/ 15 (blur/ break). At 30 cm with VA of 20/ 30 • (3) Receded NPC of ≥ 7.5 cm or ≥ 10.5 cm recovery. Push-up method Low suspect CI: sign 1; High suspect CI: sign 1 and 2 or 3; Definite CI: signs 1, 2 and 3 *AI Diagnosis:* sign 1 or sign 2 • (1) AA less than Hofstetter's minimum age formula (15-0.25xage). Monocular Push-up method • (2) MEM > +1.00 D. At 30 cm, VA 20/ 60
Rouse, 1998[38]	415 children Type of population not specified Sex not specified Age: 8-12 years Mean age: 10.2 ± 1.2	2 optometry clinics	USA	CI	*Diagnosis CI:* • Exophoria at near ≥ 4 Δ than at far. Von Graeffe method. • Failing Sheard's criterion or minimum normative PFV at near of 12/ 15 (blur/ break) • Receded NPC of ≥ 7.5 cm or ≥ 10.5 cm recovery. Push-up method Low suspect CI: exophoria at near and 1 sign. High suspect CI: exophoria at near and 2 signs. Definite CI: exophoria at near and 3 signs

(Continues)

Table 3 Methodological characteristics of articles (Continuation)

Author and year of publication	Sample type and size	Study population	Country of study	Dysfunction	Diagnostic criteria
Porcar, 1997[37]	65 university students Type of population not specified Sex not specified Range of age not specified Mean age: 22 ± 3 years	University	Spain	AI, AE, Accommodative infacility CI, CE, Basic exo, Basic eso FVD	*AI Diagnosis* • AA 2 D below Hofstetter's minimum age formula: 15-0.25 (age). Push-up method • PRA ≤ 1.25 D • MAF ≤ 6 cpm with −2 D and BAF ≤ 3 cpm with −2 D • MEM ≥ + 0.75 D • Fused cross-cylinder ≥ + 1.00 D *Accommodative infacility Diagnosis* • MAF ≤ 6 cpm with ± 2 D and BAF ≤ 3 cpm with ± 2 D • PRA ≤ 1.25 D and NRA ≤ 1.50 D *AE Diagnosis* • Variable static and subjective • Possibly low degree of against-the rule- cylinder • Variable VA findings • MAF ≤ 6 cpm with + 2 D and BAF ≤ 3 cpm con with + 2 D • MEM ≤ 0.25 D • Fused cross-cylinder ≤ 0 D *CI Diagnosis* • Exophoria at near > 6 Δ. Von Graeffe method • AC/A < 3/1 (gradient ratio) • PFV reduced at near (no values specified) • Receded NPC (no values and method specified) *CE Diagnosis* • Esophoria at near > 2 Δ • AC/A > 7/1 • NFV reduced at near (no values specified) *Basic exophoria Diagnosis* • Exophoria of equal magnitude at far and near • AC/A 4/1 ± 2 • PFV reduced at far and near (no values specified) *Basic esophoria Diagnosis* • Esophoria of equal magnitude at far and near • AC/A 4/1 ± 2 • NFV reduced at far and near (no values specified) *Fusional Vergence Dysfunction Diagnosis* • Orthophoria or a low degree of exophoria or esophoria at far and near • AC/A 4/1 ± 2 • PFV and NFV reduced at far and near (no values specified)

Scheiman, 1996[24]	2023 children Urban population 971 female, 1052 male Age: 6 months-18 years Mean age: 8.25 years	Optometry clinic	USA	AI, AE, Accommodative infacility CI, CE, DI, DE, Basic exophoria, Basic esophoria, FVD, Hyperphoria	*CI Diagnosis*: Sign 1 and at least three signs from 2-11 • (1) Receded NPC. Break > 10 cm or Recovery > 17.5 cm. Penlight target • (2) PFV blur < 11 Δ • (3) PFV break < 14 Δ • (4) PFV recovery < 3 Δ • (5) NRA: < 1.50 D • (6) BAF: can't clear with + 2.00 D in less than 10 seconds • (7) Exophoria at near > than distance (no values specified). Cover test • (8) AC/A ≤ 2/1 • (9) MEM < 0 • (10) Fails Sheard's criterion • (11) Exofixation disparity with type I curve or type III curve *AI Diagnosis*. Sign 1 and at least two signs from 2-5 • (1) AA > 2 D from mean for age (15-0.25 age) • (2) PRA ≤ 1.25 D • (3) BAF can't clear —2.00 D • (4) MAF can't clear —2.00 D • (5) MEM ≥ 1.00 D
Dwyer, 1992[33]	144 children Type of population not specified Sex no specified Age: 7-18 years Mean age: 11.5 ± 3.19	Optometry clinic	Australia	IA, EA, Accommodative infacility, CI, CE, DI, DE, Basic exophoria, Basic esophoria, FVD	Diagnostic criteria not specified in the article
Letourneau, 1988[35]	2048 children Urban population Sex no specified Age: 6-13 years Mean age no specified	6 elementary schools	Canada	CI	*CI Diagnosis* • NPC > 10 cm on three trials. Objective observation of the deviation on one eye • Exophoria at near greater than exophoria at far. Cover test
Pickwel, 1986[36]	643 patients Rural population Sex no specified 374 patients under 50 years and 269 patients over 50 Mean age no specified	Optometry clinic	UK	CI	*CI Diagnosis*: at least 1 sign from 1-3 • NPC > 20 cm. Push up method • The eyes either failed to convergence or made a versional movement on the jump-convergence test, fixating an object at 6 m and then fixating to an object at 15 cm • NPC between 10-20 cm and the jump convergence slow or hesitant

AA: accommodative amplitude; AE: accommodative excess; AI: accommodative insufficiency; BAF: binocular accommodative facility; CE: convergence excess; CI: convergence insufficiency; DE: divergence excess; DI: divergence insufficiency; FVD: fusional vergence dysfunction; MAF: monocular accommodative facility; NFV: negative fusional vergence; NPA: near point of accommodation; NPC: near point of convergence; NRA: negative relative accommodation; PFV: positive fusional vergence; PRA: positive relative accommodation; VA: visual acuity.

Table 4 Relation between prevalence of anomalies, population type of each study and number of diagnostic signs used for diagnosing dysfunctions

	Dysfunction	Prevalence (%)	Prevalence (%) for each study	Study population	Population type	N.º of signs
Binocular anomalies	Convergence insufficiency	2.25%33%	3.5[34]	Optometry clinic	Adults	5
			7.7[37]	University	Adults	4
			4.6[24]	Optometry clinic	Children	4
			2.25[35]	School	Children	2
			13[39]	School	Children	2
			17.3[32]	School	Children	2
			17.6[38]	Optometry clinic	Children	2
			14[36]	Optometry clinic	Adults	1
			18.3[31]	NR	Children	1
			33[33]	Optometry clinic	Children	NR
	Convergence excess	1.5%15%	9[34]	Optometry clinic	Adults	4
			1.5[37]	University	Adults	3
			15[33]	Optometry clinic	Children	NR
			7.1[24]	Optometry clinic	Children	NR
	Divergence insufficiency	0.1%0.7%	0.1[24]	Optometry clinic	Children	NR
			0.7[33]	Optometry clinic	Children	NR
	Divergence excess	0.8%	0.8[24]	Optometry clinic	Children	NR
	Basic Exophoria	0.3%3.1%	0.4[34]	Optometry clinic	Adults	4
			3.1[37]	University	Adults	3
			0.3[24]	Optometry clinic	Children	NR
	Basic Esophoria	0.6%9%	1.5[37]	University	Adults	3
			0.6[24]	Optometry clinic	Children	NR
			9[33]	Optometry clinic	Children	NR
	Fusional vergence dysfunction	0.4%1.5%	1.5[37]	University	Adults	3
			0.4[24]	Optometry clinic	Children	NR
	Hyperphoria	0.2%	0.2[24]	Optometry clinic	Children	NR
Accommodative anomalies	Accommodative insufficiency	2%61.7%	6.2[37]	University	Adults	5
			4.9[34]	Optometry clinic	Adults	4
			2[24]	Optometry clinic	Children	3
			9.9[39]	School	Children	2
			61.7[31]	NR	Children	1
			17.3[32]	School	Children	1
			8[33]	Optometry clinic	Children	NR
	Accommodative excess	1.8%10.8%	9[34]	Optometry clinic	Adults	5
			10.8[37]	University	Adults	5
			1.8[37]	Optometry clinic	Children	NR
			8[33]	Optometry clinic	Children	NR
	Accommodative infacility	0.4%5%	0.4[34]	Optometry clinic	Adults	2
			1.2[24]	Optometry clinic	Children	NR
			5[33]	Optometry clinic	Children	NR

NR: not reported.

the prevalence for each study, study population, type of population and the number of signs used to diagnose the anomalies. In general, there is a great variability regarding the prevalence, the type of population studied and the number of diagnostic signs for each condition. As we can see in Table 4, most of studies examine clinical population and there are more studies available for school-age population. In fact there are several conditions lacking information in scientific literature regarding to their prevalence in adults.

Particularly when considering binocular conditions, the main differences are for convergence insufficiency with prevalence values between 2.25%and 33% There is also disparity according to authors in relation to the number of tests used for diagnosing the same disorder, ranging from 1 to 5 clinical signs. Figure 1 plots the relationship between the number of signs and prevalence of convergence insufficiency where we can observe that the higher prevalence is related to the lower number of clinical signs.

When considering accommodative anomalies, it highlights that the main differences occur for accommodative insufficiency with the greater variability of prevalence, ranging from 2%to 61.7% There are also discrepancies about the number of clinical signs used for diagnostic criteria, ranging from 1 to 5 signs in accommodative insufficiency. Figure 2 plots the relationship between the number of signs and prevalence of accommodative insufficiency.

Discussion

The studies reviewed fail to provide clear information on the prevalence of accommodative and nonstrabismic binocular disorders. There is lack of consensus between authors due to the different population characteristics and diagnostic criteria used by each author with an important limitation of the lack of good epidemiological studies for different populations. There are several studies reporting the frequency of these visual conditions but they only represent specific clinical populations.

We should take into account that we may only apply these arguments within the framework of this study. The information covers the past 20 years, and the articles analysed are taken from scientific journals in the languages considered. Accordingly, there may be data in other publications which we could have not been found in our review.

The reasons of discrepancies about prevalence results found by different authors are due to the population characteristics of the studies and the diagnostic criteria used. According to population characteristics, the review represents 6568 patients examined. In addition to the wide dispersion of the sample size used in different studies which may difficult comparisons, another issue is the lack of homogeneity of the population studied. When it is tried to provide the prevalence to the scientific community by means of synthesising the international evidence base it is necessary to have studies with uniformity in diagnostic criteria and sample populations. But this review shows that this is not the case for accommodative and binocular disorders so that we can only establish ranges of prevalence for adult and children populations. Thus, of the 10 articles reviewed most of them provide scientific information regarding children compared with adults. The differentiation of patients according to their age is important when considering prevalence values. It must be taken into account that in young children subjective responses of several tests may be not as reliable as those responses of adults. Obviously, most of clinical accommodative and binocular tests used for diagnosing these anomalies are made based upon subjective responses, as accommodative amplitude, monocular and binocular accommodative facility, near point of convergence, fusional vergences, etc. Nevertheless, this point of view must be taken into account to understand why we cannot compare prevalence of both different populations.

The most important issue related to population characteristics is the patient selection. When considering prevalence studies the sample must be randomized with sufficient number of subjects to be representative of the population examined so that prevalence results could be extrapolated to this population (Fletcher and Fletcher, 2007). However, this is not the case of the articles reviewed. Of the 10 studies analysed, 5 of them included consecutive patients of clinical settings.[24,33,34,36,38] Although using consecutive patients is the method preferred by different authors as it is easy to find subjects for a research,[23] they do not represent a particular population as they are not

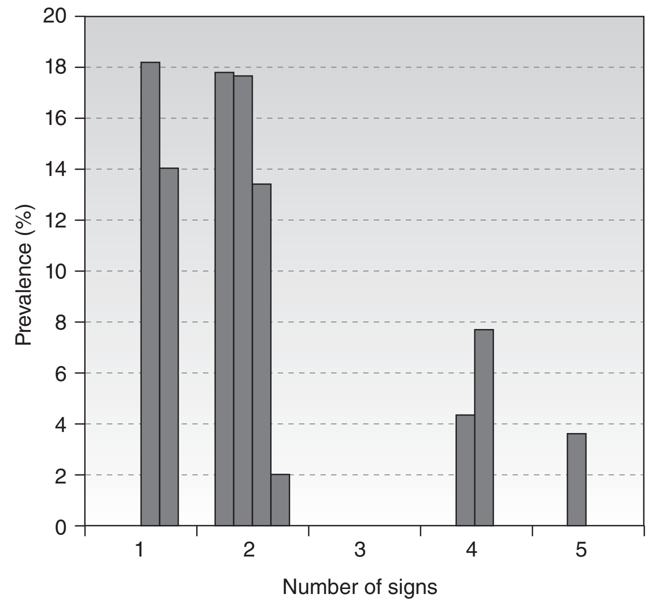

Figure 1 Relationship between the number of signs and prevalence of convergence insufficiency.

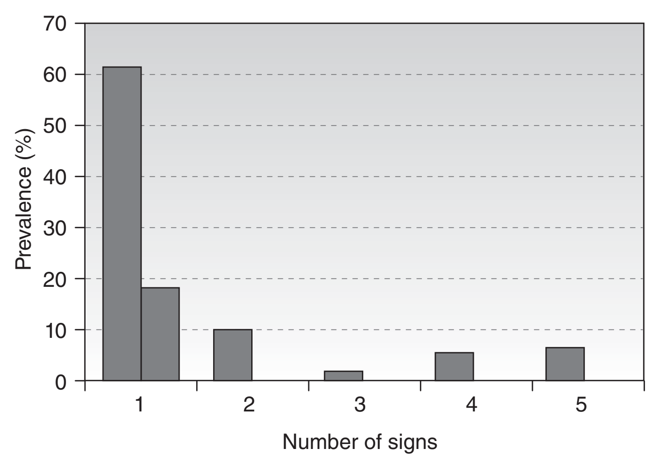

Figure 2 Relationship between the number of signs and prevalence of accommodative insufficiency.

selected in a randomized way. Furthermore, of these 5 studies, we can see in Table 3 that there are 2 reports[33,34] which examine small samples of patients that cannot be considered representative of the population examined.

Selected patients are less representative of population for prevalence purposes and this review shows that there are 2 studies in which patients were selected. One of them selected students who complained of asthenopia[31] so that the probability of having these conditions may increase the prevalence obtained in this study. The other report[37] selected a group of 2nd year university students without establishing why were selected those students and no others. They both also have the bias that the low number of patients examined cannot be considered representative of the population assessed.

The other 3 studies which are related to school-age populations[32,35,39] cannot also be considered representative for children. Certainly the population analysed at school is very similar to the general paediatric population. However to be representative, schools should also be randomized[23] and it has not been the case. These research studies not only do not mention this bias but even they establish their prevalence as values that may be applied to the general children population. We must consider however that they have examined a sufficient number of patients to be considered a representative sample for prevalence purposes.

Another issue related to patient selection is that there is no study about prevalence of general population as it has been done for other visual conditions as refractive errors.[25,40-42] Most of the studies reviewed examine particular samples of children or adult populations in clinical settings.[24,33,34,36,38] However prevalence values obtained from optometric clinics are biased data as patients have been selected. Patients who visit an optometry clinic are more likely to have complaints of a visual anomaly than if they would have been selected at random from general population. So this may contributes to an increase of prevalence values being therefore less representative of the general population. We can observe an example in Table 4 when considering data for school-age population. For convergence insufficiency, the greater prevalence value[33] is offered for children examined in clinical settings and the less value is referred to elementary schools.[35]

In spite of the lack of studies for general population, this bias is not often mentioned by the authors. Only two reports[24,33] refer to this issue as a limitation of their results and the other authors discuss other limitations. Two studies[36,37] only concentrate their conclusions in the samples examined, supporting that binocular vision problems are prevalent in their rural sample[36] and university populations[37], without discussing that their results cannot be valid for general university or rural population. Other authors[34,38] discuss their results as clinical prevalence values giving confusion in their conclusions. And even there is one study[31] in which is not specified if the sample is derived from clinical setting or schools. Anyway, both studies of prevalence in the general population and clinical population provide information to the clinician. Prevalence studies in the general population provide information of these conditions in a country or area so that their results will be more important for public health purposes. However, prevalence studies in the clinical population will offer information about how common or rare are these conditions for those subjects who usually present to clinical setting.

In addition to the limitations of both studies of prevalence and clinical population including different ages of sample populations and patient selection by consecutive or randomization methods, the limitation of both types of studies is the lack of uniformity of diagnostic criteria which limits the ability to compile and compare results of different studies. The review shows that different diagnostic criteria are used for each anomaly, not only in the tests but also in the number of signs with the limitation that they use different cut-offs to establish when a patient fails a particular test. Examples of these discrepancies occur with the conditions which show greater differences of prevalence: accommodative insufficiency and convergence insufficiency.

As we can observe in Table 3, several authors diagnose accommodative insufficiency simply on the basis of a below accommodative amplitude for the age[31,32] while others use 5 different signs[37] and even using different cut-offs for each test. Similarly, when diagnosing convergence insufficiency the authors apply a wide range of clinical signs ranging between 1 and 5 clinical signs. It also highlights the six different cut-offs used for near point of convergence or the three different cut-offs for the exophoria at near. These discrepancies in both cutt-offs and number of signs used may cause that patients could be differently diagnosed depending on the study in which they were included. This fact should be considered one of the main factors which had accounted for these varying prevalence figures between studies. In this regard, we could expect a relationship between the number of signs used and the prevalence of the anomaly, so that as mentioned by some authors,[34] the greater number of clinical diagnostic signs used, the lower prevalence. This review shows that it only occurs for convergence insufficiency for which there is a tendency to relate greater prevalence to a lower number of signs used. Although the lower prevalence does not coincide with the use of a higher number of signs, we can see in Table 4 that the second highest value is obtained with a single diagnostic sign.[31] This relationship cannot be established for other conditions because several studies do not report the number of clinical signs used. For accommodative insufficiency although we observe that the highest value of prevalence is obtained with only the criterion of failing accommodative amplitude,[31] prevalence results do not seem to confirm this relationship. Nevertheless we must take into account that the small number of studies for this anomaly may difficult this assertion.

Other biases and limitations according to the methodology used by different studies may also affect prevalence results. They are related to clinical tests assessed in a non-normalised way. There is one study in which accommodative amplitude is considered binocularly instead of monocular result.[31] And there are two reports[32,39] in which the authors assess the positive fusional vergence at distances not normalised.

As a result of the biases and limitations of designs discussed above we can conclude that there is a lack of clear information about the prevalence of accommodative and nonstrabismic binocular anomalies. Existing epidemiological studies are only estimations of selected clinical or school populations with no data being representative of their populations. Prevalence results vary due to the sample population and the lack of uniformity in diagnostic criteria so that it is difficult to compile the prevalence. More research is needed following well-designed epidemiological studies and uniform diagnostic criteria. Prevalence information of these binocular vision anomalies would enable optometrists to help and support health policies with the aim of improving visual health of patients.

Conflict of interests

None of the authors have a conflict of interests about the manuscript.

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