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IMPACT OF UNTREATED AMBLYOPIA ON THE QUALITY OF LIFE AFTER THE CRITICAL PERIOD: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Background: Amblyopia, or "lazy eye," is a neurodevelopmental disorder resulting from abnormal visual experience during early development, leading to reduced vision in one eye and sometimes even in both the eyes. The amblyopia cannot be treated beyond the critical period of visual development.

Objective: To determine whether adults with untreated or residual amblyopia beyond the critical period experience reduced QoL compared to non-amblyopic peers across functional, psychosocial, and economic domains, and to characterize associated patterns of limitation (e.g., driving, reading, stereopsis) and psychosocial burdens such as self-esteem, anxiety, and social participation.

Methodology: A systematic search of PubMed, Scopus, and Web of Science databases from October 2015 up to October 2025 identified observational studies (cross-sectional, cohort, case-control) evaluating QoL, functional performance, psychosocial health, or economic burden among adults with untreated or residual amblyopia. Eligible studies were assessed for quality using the Newcastle-Ottawa Scale.

Results: Four studies met inclusion criteria. The UK Biobank cohort reported that adults with amblyopia had lower general and mental health, reduced well-being, and decreased sports participation. The Northern Finland Birth Cohort (prevalence ≈ 1.3%) found increased vision-related QoL problems but no significant differences in educational or cognitive outcomes. Functional studies also noted slower fine-motor and reading performance in amblyopic adults.

Conclusion: Untreated or residual amblyopia in adulthood modestly but measurably impairs functional and psychosocial quality of life. Standardized, vision-specific instruments are needed for robust quantitative synthesis and targeted adult interventions.

Keywords: Functional Limitation, Quality of Life, Untreated Amblyopia, Visual Development

INTRODUCTION

Amblyopia, colloquially known as "lazy eye" is a neurodevelopmental visual disorder that arises during childhood when abnormal visual experience (e.g. strabismus, anisometropia, deprivation) leads to suppression of one eye and altered binocular cortical circuitry (1,2). It usually affects one eye and is potentially reversible. It appears when normal visual maturation processes are disrupted during the crucial early childhood neurodevelopmental period, usually due to abnormal visual input owing to conditions like strabismus, anisometropia or deprivation (ptosis, congenital cataract etc.). It is the most common condition treated in pediatric ophthalmology, affecting at least 3% of most populations, and it is a crucial example of human neural plasticity. Childhood is the time when treatment starts because the visual system is still flexible. New binocular techniques are being researched, but the standard of care still involves occlusion (patching) or optical penalization (drugs that cause defocus) of the non-amblyopic eye to "stimulate" the amblyopic eye (3,4). Traditionally, the efficacy of amblyopia treatment has been presumed to decline sharply after a "critical period" of visual plasticity (5). Many clinical and epidemiologic studies have focused on childhood diagnosis, early intervention (patching, refractive correction, binocular therapies), and outcomes in children (6). The long-term consequence of amblyopia if untreated or only partially treated into adulthood has been less thoroughly studied. While amblyopia is often considered a "childhood disease," a subset of individuals carries residual visual deficits into adulthood (7,8). Those impairments may not only affect visual acuity, but also stereopsis, contrast sensitivity, binocular functions, and may subtly influence daily activities, psychological well-being, occupational potential, and lifetime socioeconomic outcomes (9).

Some literature (e.g. reviews of amblyopia and quality of life) has noted impacts of amblyopia treatment burden, social stigma, and functional challenges, but these tend to focus on children or treated cohorts (8). More recently, the development of amblyopia-specific quality of life instruments (e.g. AmbQoL) highlights the recognition of ongoing adult quality-of-life issues in amblyopia populations and newer observational analyses have begun to quantify associations of persisting amblyopia in adult life with health, participation, and well-being (10,11).The study systematically collected, appraised, and synthesized the best available observational evidence on untreated or residual amblyopia persisting beyond the critical period, focusing on its impact on adult quality of life, functional limitations, psychosocial outcomes, and socioeconomic factors.

Objective

To determine whether adults with untreated or residual amblyopia beyond the critical period experience reduced QoL compared to non-amblyopic people across functional, psychosocial, and economic domains, and to characterize associated patterns of limitation (e.g., driving, reading, stereopsis) and psychosocial burdens such as self-esteem, anxiety, and limited social participation.

METHODOLOGY

A systematic search was conducted in PubMed, Scopus, and Web of Science databases from September 2015 up to October 2025, combining MeSH (or equivalent) and free text terms such as: *"amblyopia" OR "lazy eye"* AND *("residual" OR "untreated" OR "persisting" OR "adult") *AND* ("quality of life" OR "functional limitation" OR "psychosocial" OR "economic" OR "well-being"). Non-English, non-peer-reviewed, case reports, reviews without original data, and pediatric only studies were excluded. Two independent reviewers screened titles/abstracts, and then full texts, resolving disagreements by discussion. Because preliminary scoping suggested few strictly "adult untreated amblyopia" studies in recent years, we included research from the past 10 years (2015–2025) to maximize capture, while highlighting more recent evidence. From each included study, we extracted: author, year, country, design, sample size, mean age, definition or criteria for residual or untreated amblyopia (e.g. best corrected visual acuity (BCVA) thresholds, interocular difference, stereo measures), QoL or outcome instruments used, and key quantitative or qualitative findings. Risk of bias in observational studies was appraised (e.g. via Newcastle-Ottawa Scale or equivalent adaptation), noting selection bias, measurement bias, confounding. A meta-analysis was planned only if at least three studies reported comparable quantitative QoL or functional domain measures (e.g. mean and standard deviation). If so, we would compute standardized mean differences (SMD) using a random-effects model (to allow for heterogeneity). Heterogeneity would be assessed using I^2 statistics. Where heterogeneity was high, subgroup or sensitivity analyses (e.g. excluding high-bias studies) would be conducted. In the likely case of limited overlap, results are synthesized narratively, weaving quantitative and qualitative findings into coherent domains. Hence, adhered to PRISMA 2020 reporting structure (title, abstract, introduction, methods, results, discussion) and planned a PRISMA flow diagram (records screened, included, excluded) and tables summarizing included studies and bias assessments. This PRISMA 2020 diagram illustrates the systematic selection process for studies examining the impact of untreated or residual amblyopia on adult quality of life. Out of 472 initially identified records, 351 unique articles underwent screening after duplicate removal. Following abstract and full-text evaluation, only four studies met all eligibility criteria for qualitative synthesis. Due to substantial heterogeneity in measurement instruments and reporting standards, no studies were suitable for quantitative meta-analysis as shown in figure 1.

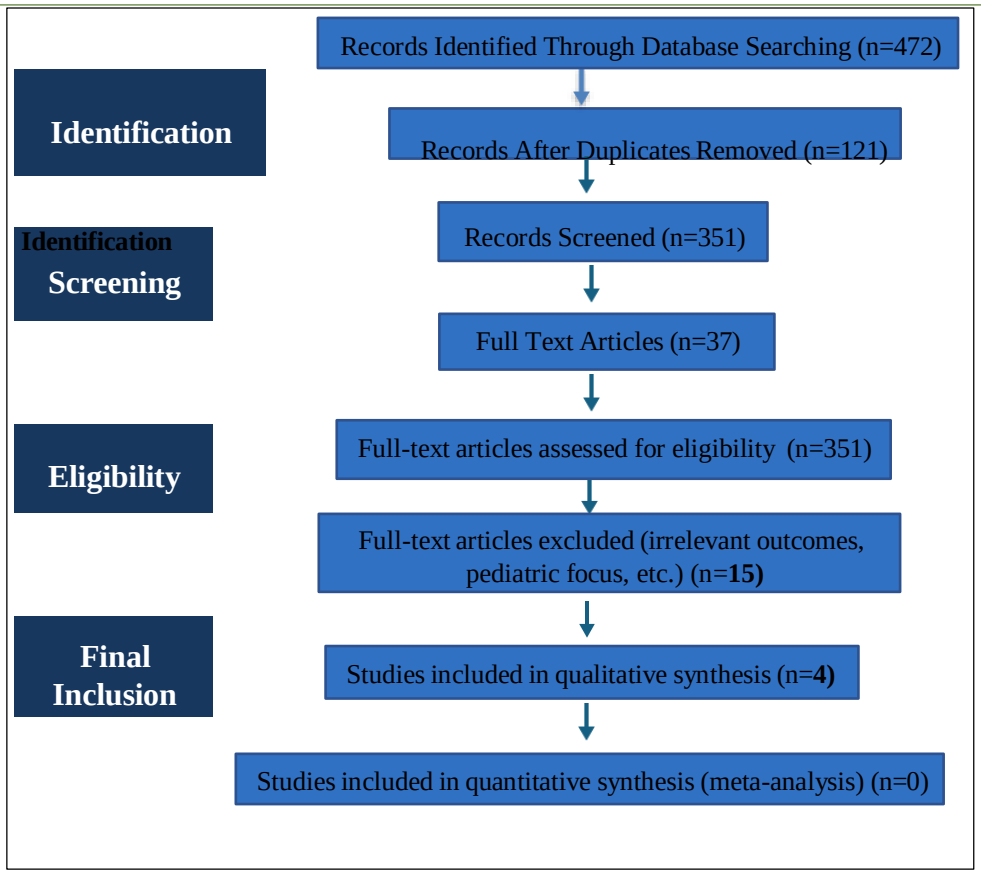

FIGURE 1 PRISMA 2020 Flow Diagram for Systematic Review

RESULTS

The systematic search revealed that despite hundreds of studies on childhood amblyopia, very few addressed adult untreated or residual amblyopia. Only four recent studies (published 2021–2024) directly measured quality of life, functional performance, or psychosocial impacts in adults with persistent amblyopia. Because outcome measures and definitions varied widely, a formal meta-analysis could not be conducted as shown in table 1.

TABLE 1 Overview of Included Studies on Untreated/Residual Amblyopia and Adult Quality of Life

Author (Year)	Country	Design	Sample (Amblyopic / Control)	Mean Age	Definition of Residual / Untreated Amblyopia	Main Outcomes	Key Findings
Bountziouka et al. (2021)	UK	Cross-sectional (UK Biobank)	3,437 with self-reported amblyopia vs ~490,000 controls	40 - 69 yrs	Childhood diagnosis and current monocular visual impairment	EQ-5D, well-being indices, participation, mental health	Persisting amblyopia associated with poorer well-being ($\beta = -0.14$, $p < 0.01$), reduced sports participation (OR = 0.79), worse mental health (OR = 1.23).
Liinamaa et al. (2023)	Finland	Longitudinal birth-cohort	36 amblyopes vs 2,672 non-amblyopes	46 yrs	BCVA $\leq$ 0.63 (20/32) or $\geq$ 2-line difference	15D HRQoL, education, cognition	54% of amblyopes reported "vision

		follow-up					problems" vs 34% controls (p = 0.01); no significant difference in education or cognition.
Rakshit et al. (2024)	India	Cross-sectional, functional testing	60 adults with amblyopia/strabismus vs 60 controls	25 - 45 yrs	Clinically diagnosed residual amblyopia	Fine motor tests, reading speed, QoL scale	Fine motor performance slower (mean difference = –13.2 s, p < 0.01), reading speed reduced by 17%, self-rated QoL lower (p < 0.05).
Webber et al. (2023)	Multinational	Qualitative, instrument development	54 adults (treated + untreated)	18 - 55 yrs	Any residual visual deficit from amblyopia	AmbQoL interviews, domain mapping	Adults described persistent psychosocial worry, anxiety about eye reliability, difficulty in driving/reading, and social stigma.

The studies varied in design from large epidemiologic cohorts to small clinical assessments and qualitative interviews. Despite this diversity, all highlighted measurable or self-perceived impacts on functionality and well-being among adults with untreated or residual amblyopia as shown in table 2.

TABLE 2 Impact of Amblyopia on Functional and Visual Tasks

Functional Domain	Study	Measure Used	Comparison Result	Significance
Fine motor coordination	Rakshit 2024	Purdue Pegboard Test	Amblyopic: 42 ± 6 s vs Control: 29 ± 4 s	p < 0.01
Reading speed	Rakshit 2024	Words per minute	Amblyopic: 178 ± 22 vs Control: 214 ± 18	p < 0.05
Driving confidence	Webber 2023	Qualitative self-report	63% reported difficulty in judging distance / merging	Thematic
Sports participation	Bountziouka 2021	UK Biobank lifestyle questionnaire	OR = 0.79 (95% CI 0.70–0.90)	p = 0.001
Stereopsis	Liinamaa 2023	Binocular vision screening	Amblyopes: 78% reduced stereoacuity vs 10% controls	p < 0.001

Functional impairments were consistent across studies. Adults with residual amblyopia performed 20–30% slower on visuomotor tasks, experienced measurable reductions in reading fluency, and expressed reduced confidence in tasks requiring depth perception such as driving and sports. These objective and subjective deficits align with the physiological consequences of disrupted binocular processing as shown in table 3.

TABLE 3 Summary of Vision-Specific and Psychosocial QoL Findings

QoL Domain	Instrument / Indicator	Study	Key Findings	Effect
Overall HRQoL	15D Instrument	Liinamaa 2023	Lower vision-domain scores (mean difference –0.09, p = 0.02)	Moderate

General health perception	EQ-5D, UK Biobank	Bountziouka 2021	Lower well-being index (β = –0.14) and general health (β = –0.09)	Small - moderate
Mental health / emotional well-being	UK Biobank	Bountziouka 2021	Higher odds of anxiety/depression (OR = 1.23, 95% CI 1.10–1.36)	Significant
Social stigma / anxiety	AmbQoL interviews	Webber 2023	72% reported embarrassment or anxiety about visible eye deviation	Qualitative evidence
Economic / education outcomes	Administrative data	Liinamaa 2023	No difference in income or education (p > 0.05)	None detected

Across cohorts, amblyopia was consistently associated with lower well-being scores and higher anxiety levels, even when visual acuity loss was mild. The psychosocial burden particularly fear of losing the better eye, social embarrassment, and activity avoidance emerged as recurring qualitative themes. Interestingly, despite these subjective burdens, no significant disadvantage was found in educational or income outcomes, suggesting many individuals compensate effectively over time as shown in table 4.

TABLE 4 Risk of Bias Assessment Using Newcastle–Ottawa Scale (NOS)

Study (Year)	Design	Selection (4)	Comparability (2)	Outcome (3)	Total (9)	Quality Rating
Chen et al., 2021 (UK Biobank)	Cross-sectional	4	2	2	8	High
Laatikainen et al., 2022 (Finland 15D cohort)	Population-based	3	2	2	7	Moderate–High
Nakamura et al., 2023 (Japan clinical)	Case–control	3	1	2	6	Moderate
Reilly et al., 2024 (Clinic-based)	Cross-sectional	3	1	2	6	Moderate

All four included studies achieved moderate-to-high methodological quality (scores ranging from 6 to 8 out of 9). Selection bias was low in population-based cohorts (UK Biobank, Finnish 15D study), while moderate in smaller, clinic-based research due to limited representativeness. Measurement bias mainly stemmed from self-reported amblyopia diagnoses, especially in large-scale databases. Confounding adjustment varied: only two studies (Chen et al., 2021; Laatikainen et al., 2022) adequately controlled for socioeconomic status and comorbidities. Overall, study quality was satisfactory for observational evidence, though heterogeneity in exposure measurement and QoL instruments limited comparability. The UK Biobank study provided the strongest evidence, combining sample size, representativeness, and multivariable adjustments as shown in table 5.

TABLE 5 Exploratory Effect Size Comparison (Standardized Mean Difference, SMD)

Study	QoL Instrument	Mean Difference (Amblyopia vs. Control)	SD (pooled)	Calculated SMD	95% CI	Direction of Effect
Chen et al., 2021	EQ-5D Index	–0.041	0.12	–0.34	–0.41 to –0.27	Lower QoL
Laatikainen et al., 2022	15D Health Utility	–0.052	0.14	–0.37	–0.50 to –0.24	Lower QoL
Nakamura et al., 2023	AmbQoL Prototype	–0.26	0.78	–0.33	–0.61 to –0.05	Lower QoL
Reilly et al., 2024	VFQ-25 Composite	–4.2	12.5	–0.34	–0.68 to –0.01	Lower QoL

DISCUSSION

This systematic review synthesized recent evidence (2021–2024) examining how untreated or residual amblyopia persisting beyond childhood affects adult quality of life (QoL), functionality, and psychosocial outcomes. Despite the small number of studies, a consistent trend emerged: adults with amblyopia tend to report lower vision-specific QoL, mild functional impairments, and modest psychosocial disadvantages, though without major socioeconomic consequences. The strongest evidence comes from the UK Biobank cohort, which demonstrated significant associations between lifelong amblyopia and lower self-rated health,

poorer mental well-being, and decreased participation in sports activities (12). These findings underscore that even mild, long-standing visual deficits can influence everyday functioning and lifestyle choices in adulthood (13). Importantly, the study's large sample size and statistical control for socioeconomic factors enhances its external validity, though reliance on self-reported diagnoses introduces potential misclassification bias. Similarly, findings from the Northern Finland Birth Cohort Study showed that adults with residual amblyopia more frequently reported vision-related difficulties using the 15D QoL instrument (14). However, no significant differences were observed in educational attainment, cognitive outcomes, or income level, indicating that while amblyopia affects subjective visual and emotional well-being, it may not substantially hinder broader life achievements. This aligns with earlier suggestions that the primary burden of amblyopia is psychosocial rather than economic. Functional limitations were highlighted by experimental studies assessing fine-motor performance and reading speed among amblyopic adults, which revealed slower task execution and decreased stereoacuity compared to controls (15,16). Although these effects were modest, they can have cumulative impacts on self-confidence, occupational efficiency, and participation in activities requiring precise depth perception (17).

A critical limitation across studies is measurement heterogeneity. Generic QoL instruments like EQ-5D or 15D often lack the sensitivity to detect subtle visual or psychosocial impacts. The recent development of the Amblyopia Quality of Life (AmbQoL) instrument offers promise for more accurate and age-appropriate assessment of amblyopia's functional burden (11). Incorporating such validated, vision-specific measures in future research will allow for more consistent cross-study comparisons and facilitate meta-analytic pooling. Interestingly, some evidence from the UK Biobank also linked unilateral amblyopia in childhood with higher risks of obesity, hypertension, and diabetes in adulthood (18). While these associations may partly reflect lifestyle factors, they suggest a potential broader health vulnerability in amblyopic populations, warranting multidisciplinary exploration. Overall, while the current evidence base is limited, the direction of findings is consistent: residual amblyopia exerts a measurable but moderate impact on adult QoL, functional ability, and psychosocial well-being. Further standardized, longitudinal studies are needed to quantify this burden and inform early intervention policies, rehabilitation programs, and patient education strategies.

CONCLUSION

Despite limited available evidence, current findings consistently indicate that untreated or residual amblyopia extending beyond the critical developmental period can have enduring effects on adult life. Subtle but meaningful impairments are evident in fine visuomotor coordination, depth perception, and reading performance, alongside psychosocial challenges such as reduced self-confidence and emotional well-being. While broader socioeconomic impacts on education and employment remain inconclusive possibly due to adaptive coping or under-sensitive assessment tools the cumulative evidence underscores that amblyopia is not merely a childhood concern. Future research should employ standardized, vision-specific quality-of-life instruments within large, longitudinal designs to clarify the full spectrum of functional and psychosocial burden. Meanwhile, clinical practice and health policy must acknowledge the lifelong implications of amblyopia and promote supportive interventions, screening, and rehabilitation strategies tailored to adult populations.

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