Visual function and quality of life in adolescents with visual impairment: a case study of the Arthur Blaxall School in Pietermaritzburg

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DECLARATION

I, Shivani Naipal, hereby declare that the work described in this thesis is as a result of my own investigation and has not been submitted to the University of KwaZulu-Natal or other tertiary institution for purposes of obtaining an academic qualification, whether by myself or any other party.

_____ _____

Signed Date

DEDICATION

To my parents and brothers

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ACRONYMS

CVAQC	Cardiff Visual Ability Questionnaire for Children
OCA	Oculocutaneous albinism
QoL	Quality of life
ROP	Retinopathy of prematurity
RP	Retinitis pigmentosa
VA	Visual acuity
VI	Visual impairment
WHO	World Health Organisation

ABSTRACT

Background: Visual impairment (VI) may affect the lives of children, adolescents and adults although the effects of VI on the former two groups may be taken for granted as they account for less than half the population affected by VI. Affected children and adolescents may endure a lifetime of vision related difficulties that may affect their education, social interactions and possible future employment.

Aim: To investigate visual function and quality of life (QoL) in adolescents with VI at the Arthur Blaxall School in Pietermaritzburg.

Methods: This study followed a descriptive case study research design. Students registered at Arthur Blaxall School aged 10 years to 19 years were recruited using convenience sampling. Visual function was quantified by distance visual acuity (VA) and refractive error, contrast sensitivity, colour vision and central visual field. The QoL was assessed with the Cardiff Visual Ability Questionnaire for Children (CVAQC). Data were analysed using differential and inferential statistics.

Results: The sample consisted of 70 participants with a mean age of 13.83 ± 2.28 years. The most common cause of VI was oculocutaneous albinism (OCA) followed by posterior segment disorders. The mean best-corrected VA ranged from 0.79 ± 0.16 logMAR to 0.91 ± 0.22 logMAR in the right, left and both eyes. Only 16 participants presented with spectacles and an additional 18 participants required spectacles following refraction. More than 40% of participants had moderate loss of contrast sensitivity in each eye. The majority of participants did not have any colour vision or central visual field defects. The mean visual ability score was −0.27 ± 0.74 log units, and the most difficult tasks were reading smallest print in textbooks and the board in the classroom for near and distance respectively. Participants with OCA had the best monocular best-corrected VA and contrast sensitivity. The most common colour vision defects among participants with anterior and posterior segment disorders were tritan and deutan colour vision defects respectively. Participants with anterior segment disorders had the poorest QoL while those with OCA had the best QoL.

Conclusion: The results of this study showed that visual function varied among adolescents with VI. Furthermore, both visual function and QoL differed between each of the main causes of VI.

Key words: visual impairment, visual function, quality of life, adolescents, Cardiff Visual Ability Questionnaire for Children (CVAQC)

CHAPTER 1. INTRODUCTION

1.1 Introduction

Visual impairment (VI) is a global health concern that is likely to increase with the growing global population and prolonged life expectancies. Visual impairment may impact the lives of both adults and children, although the effects may not be the same. The effects of VI on the lives of children and adolescents may be taken for granted, as they account for less than half of those affected by the condition. This is evident as few studies have investigated its impact on the lives of affected children and adolescents. The purpose of this study was therefore to explore visual function and quality of life (QoL) in adolescents with VI. This study further compares the cause of VI with both visual function and QoL in adolescents with VI.

This chapter begins by providing an overview of VI and describes the evolution of its definition. It also reviews the global and local prevalence of VI in both adult and children populations, the impact of VI in the lives of affected individuals, the clinical characteristics and its effects on QoL. Thereafter, the study aim, objectives and problem statement are presented. The chapter concludes with the significance of the study, an outline of the chapters in this thesis and a summary of the key points in this chapter.

1.2 Background to the study

1.2.1 Visual impairment

Visual impairment refers to a condition of reduced visual performance that cannot be remedied by surgery, medical methods or refractive correction (DeCarlo, Woo & Woo 2006, p. 1591). This implies that the loss of vision is severe enough to limit the performance of daily tasks (Bailey & Hall 1989, p. 2). Consequently, it results in functional limitations of the visual system that may be characterised by irreversible vision loss, restricted visual fields and decreased contrast sensitivity (DeCarlo, Woo & Woo 2006, p. 1591).

Individuals with VI have measurable vision yet experience difficulty accomplishing daily tasks even with the use of corrective lenses (Corn & Lusk 2010, pp. 4-5). These individuals are sometimes capable of enhancing their visual ability to perform visual tasks by using compensatory low vision aids and/or environmental adjustments (Corn & Lusk 2010, pp. 4-5). Individuals with VI may not always display predictable clinical changes in visual function, and changes in functional vision may not always correlate to measurable changes in clinical findings (Corn & Lusk 2010, p. 8).

1.2.2 Definitions

The terms disorder, impairment, disability and handicap may be used to describe different aspects that result from a disruption of normal human function, although these terms are neither synonymous nor can they be used interchangeably (Jackson 2007a, p. 8). The International Classification of Impairment, Disability and Handicap (ICIDH-2/1980) was introduced by the World Health Organisation (WHO) in 1980 to standardise the definition of these terms (Jackson 2007a, p. 8).

According to ICIDH-2/1980, the term 'disorder' describes the effect of a disease or injury on the anatomy of the organ (Jackson 2007a, p. 8). This implies that an ocular disorder is the deviation from the normal anatomical structure of visual function, and may result from disease, injury or congenital anomalies (Corn & Koenig 1996, p. 6; DeCarlo, Woo & Woo 2006, p. 1591). The term 'impairment' refers to the functional consequence or the physical loss of function of the organ affected by the disorder, and implies that the affected organ does not function optimally as a result of the disorder (Macnaughton 2005, pp. 8-11; Jackson 2007a, p. 8). Within this context, visual impairment refers to the measurable reduction in visual function (DeCarlo, Woo & Woo 2006, p. 1591).

The term 'disability' refers to a restriction or inability to perform activities in a manner that is considered normal for any individual (Gray & Hendershot 2000; Macnaughton 2005, pp. 8-11; Jackson 2007a, p. 8). Consequently, the term disability represents the disruption at the individual level. Furthermore, a disability is present if an impairment affects an individual's ability to perform certain tasks, although not all impairments result in a disability (Corn & Koenig 1996, p. 6; Macnaughton 2005, pp. 8-11). A visual disability may affect the lifestyle of an affected individual, as it may limit that individual's ability to perform visual tasks (DeCarlo, Woo & Woo 2006, p. 1591). The term 'handicap' is a perceived disadvantage that prevents an individual from fulfilling a role that is considered normal for that individual when age, gender, social and cultural factors are considered (Corn & Koenig 1996, p. 6; Macnaughton 2005, pp. 8-11). Consequently, a handicap describes the effect of a disability on an individual's ability to interact and adapt to society, although not all disabilities result in handicaps (Gray & Hendershot 2000; Macnaughton 2005, pp. 8-11). An individual with a visual handicap may also experience psychosocial and economic disadvantages (DeCarlo, Woo & Woo 2006, p. 1591).

1.2.3 Definition of visual impairment

The definition of VI has evolved over time, and is considered an umbrella term that encompasses a broad spectrum of vision loss, including moderate to severe VI and

blindness. The term ‘low vision’ was previously used to refer to moderate and severe VI, and can be used to describe vision loss that is so severe that it disrupts the performance of daily tasks, but still permits some degree of visual discrimination (Bailey & Hall 1989, p. 2). In 1934, the American Medical Association (AMA) formulated the following definition of VI (Corn & Koenig 1996, p. 6):

> Central acuity of 20/200 or less in the better eye with corrective glasses or central visual acuity (VA) of more than 20/200 if there is a visual field defect in which the peripheral field is contracted to such an extent that the widest diameter of the visual field subtends an angular distance no greater than 20 degrees in the better eye.

This definition does not consider other aspects of vision that may significantly impact an individual’s ability to use their vision, such as contrast sensitivity (Corn & Koenig 1996, p. 7). Another definition of VI was coined by Jose in 1992 (cited in Corn & Koenig 1996, p. 7) and is stated as:

> Vision loss severe enough to interfere with the ability to perform everyday tasks or activities and that cannot be corrected to normal by conventional eyeglasses or contact lenses.

As VI implies a functional loss of vision, a functional definition may have more value than a purely clinical definition (Corn & Koenig 1996, p. 6). This was considered in 1992, when the WHO added a functional dimension to the definition of VI. According to the WHO (2014), an individual with VI is defined as:

> One who has impairment of visual functioning even after treatment and/or standard refractive correction, and has VA of less than 6/18 to light perception, or a visual field of less than 10 degrees from the point of fixation, but who uses, or is potentially able to use, vision for the planning and/or execution of a task.

According to the International Classification of Diseases, 10th revision (ICD-10), VI may be classified into four levels, namely: mild or no VI, moderate VI, severe VI and blindness, as shown in Table 1.1 (WHO 2016). The term ‘low vision’ has been replaced with moderate and severe VI, and are collectively categorised as VA of less than 6/18, but equal to or better than 6/120 in the better eye with the best refractive correction (WHO 2016). When considering the degree of visual field loss, a visual field radius of no more than 10 degrees around the central point of fixation in the better eye is classified as category three, blindness (WHO 2016).

Table 1.1: ICD-10 classification of visual impairment

Category	Presenting distance visual acuity	
	Worse than:	**Equal to or better than:**
0 Mild or no visual impairment	-	6/18 3/10 (0.3) 20/70
1 Moderate visual impairment	6/18 3/10 (0.3) 20/70	6/60 1/10 (0.1) 20/200
2 Severe visual impairment	6/60 1/10 (0.1) 20/200	3/60 1/20 (0.05) 20/400
3 Blindness	3/60 1/20 (0.05) 20/400	1/60* 1/50 (0.02) 5/300 (20/1200)
4 Blindness	1/60* 1/50 (0.02) 5/300 (20/1200)	Light perception
5 Blindness	No light perception	
9	Undetermined or unspecified	

*or counts fingers (CF) at 1 metre

Source: WHO. International statistical classification of diseases and related health problems 10th revision (ICD-10) [homepage on the Internet]. 2016 [cited 2017 Jan 16]. Available from: http://apps.who.int/classifications/icd10/browse/2015/en#/H54

1.2.4 Prevalence of visual impairment

Visual impairment is not equally distributed across the world, with approximately 90% of affected individuals living in developing countries (Watkins 2001; Oduntan 2005). This geographical disparity may be as a result of various factors in developing countries including but not limited to poverty, environmental conditions, lack of education and poor health care services (Watkins 2001; Oduntan 2005; Naidoo 2007). This is further compounded by the higher prevalence of untreatable degenerative causes of VI related to ageing in developed countries and the higher prevalence of preventable causes of VI in developing countries (Jackson 2007a, p. 14).

There is an interesting relationship between gender and VI and/or blindness. The literature suggests that the global prevalence of blindness is greater in females than in males, with females being at higher risk of VI due to their longer life expectancies and limited access to health care services in rural areas (WHO 2007; Stevens et al. 2013). Interestingly, Stevens et al. (2013) and Bourne, Resnikoff and Ackland (2017a) reported that the gender disparity for VI is greatest in high income regions (such as Asia Pacific and Western Europe) and lowest in developing regions (such as Sub-Saharan Africa, Central Latin America and Central Asia). Stevens et al. (2013) hypothesised that this may be as a result of onchocerciasis being more prevalent in males than females in endemic

African regions. Bourne, Resnikoff and Ackland (2017a) attributed this gender disparity to the longer lifespan of females, particularly in high income regions. Furthermore, the accessibility and use of eye care services differ according to the culture and socioeconomic development of different regions, which may also explain these gender disparities in VI prevalence (Stevens et al. 2013).

1.2.5 Impact of visual impairment

Visual impairment has severe debilitating consequences that decrease the ability of affected individuals to function independently and perform tasks of daily living (West et al. 2002). Vision is fundamental to learning and integrating information received from the other senses, as approximately 80% of the information about the world is obtained through the sense of sight (Raj 2007; Khadka et al. 2012). Good vision is essential to acquiring cognitive and functional skills, especially during childhood development (Rainey et al. 2016). Therefore, development may be adversely affected if VI is present at birth, or develops shortly thereafter. This may result in individuals being developmentally delayed in gross and fine motor skills in addition to visual perception (Abdullah, Jani & Abdullah 2012; Rainey et al. 2016).

According to the WHO, 'health' is defined as a state of "complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 1948). In addition to negatively influencing sensorial development, VI also impacts the physical, social and psychological well-being of children and adolescents (Rainey et al. 2016). Furthermore, it has been shown that children and adolescents with VI experience poorer QoL (Chadha & Subramanian 2010). Visual impairment increases the socioeconomic burden on society due to loss in education, career opportunities and economic gain for the affected individual and their families (Khanna, Raman & Rao 2007; Resnikoff et al. 2008). The socioeconomic and physical barriers that deprive individuals with VI of an education include discrimination, stigmatisation, limited accessible schools and an inability to cope with the impairment (WHO 2007).

1.2.6 Visual impairment and visual function

While VI is a functional loss of vision, clinical aspects still need to be considered when diagnosing its severity. Clinically, evaluating VA, contrast sensitivity, colour vision and the extent of the visual field may provide an indication of visual function (DeCarlo, Woo & Woo 2006, p. 1591; Elliott & Flanagan 2007, p. 48). Therefore, reduced visual function may be characterised by a decrease in VA and/or restricted visual fields as well as abnormal contrast sensitivity (DeCarlo, Woo & Woo 2006, p. 1591). Assessing contrast

sensitivity in individuals with VI is beneficial as there may be preferential loss at specific spatial frequencies (DeCarlo, Woo & Woo 2006, p.1601). Some ocular conditions may cause little reduction in VA but produce significant deficits in central vision, such as centrocaecal scotomas, metamorphopsia and/or impaired colour vision (Elliott & Flanagan 2007, p. 43). Additionally, the mobility of individuals with VI may be better predicted by contrast sensitivity and visual fields than VA alone (Marron & Bailey 1982).

1.2.7 Visual impairment and quality of life

The WHO defines QoL as:

> An individual's perception of their position in life in context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns (Jackson 2007b, p. 169).

Based on this definition, it is apparent that QoL is not solely influenced by the actual nature and severity of the impairment, as the effect of the impairment on an individual's ability to function within their environment also plays a role (Jackson 2007b, p. 169). Quality of life also depends on the individual, specifically their attitude towards the impairment, and their perception of themselves in relation to society (Jackson 2007b, p. 169).

1.3 Problem statement

Several studies have investigated visual function and QoL in adults with VI (Broman et al. 2002; Gyawali, Paudel & Adhikari 2012; Kempen et al. 2012). However, there is little evidence to suggest that these results may be generalised to adolescents with VI, as few studies have assessed visual function and QoL in adolescents with VI. As VI is a lifelong impairment, affected adolescents may endure a lifetime of vision related difficulties that are likely to affect their education, social interactions and possible future employment. Therefore, interventions aimed at understanding and improving visual function and QoL in adolescents with VI are essential. Furthermore, there is limited information available on VI in adolescents in South Africa. As the prevalence of VI is greater in developing countries, more data is required on the impact of VI in the lives of affected individuals.

1.4 Aim and objectives

The study aimed to investigate visual function and quality of life in adolescents with visual impairment at the Arthur Blaxall School in Pietermaritzburg.

The objectives of the study were to:

1. determine distance visual acuity and refractive error in adolescents with visual impairment.
2. measure contrast sensitivity in adolescents with visual impairment.
3. assess colour vision in adolescents with visual impairment.
4. assess central visual field in adolescents with visual impairment.
5. explore quality of life experienced by adolescents with visual impairment.
6. compare visual function according to the main cause of visual impairment.
7. compare quality of life according to the main cause of visual impairment.

1.5 Significance of the study

Despite the majority of individuals with VI residing in developing countries, such as South Africa, very little information is available on the impact of VI in the lives of affected individuals. Previous international studies have focused on either visual function or QoL in adults with VI with little emphasis on adolescents. Few studies assessed both visual function and QoL in individuals with VI. This study assesses both visual function and QoL in adolescents with VI. Furthermore this study also determines whether a relationship exists between either visual function or QoL and the main cause of VI. Consequently, the results of this study will add to current knowledge of adolescents with VI. Based on the results of this study, current management of individuals, specifically adolescents, with VI may be adjusted in a holistic manner to improve the QoL of these individuals. This includes implementing changes in schools for individuals with VI, such as using large font textbooks and high contrast worksheets.

1.6 Type of study and methods

This study followed an observational, descriptive study design involving case reports and used both quantitative and qualitative data collection methods. The study sample included adolescents with VI at a school that caters for children and adolescents with VI. The study sample, aged between 10 years and 19 years, were recruited using convenience sampling. Quantitative data collection involved assessing the various aspects of visual function, and included distance VA and refractive error, contrast sensitivity, colour vision and central visual field. Qualitative data collection involved an assessment of the QoL using a recommended QoL questionnaire specific for use in adolescents with VI (Khadka, McAlinden & Pesudovs 2013).

1.7 Outline of the study chapters

This thesis has been organised into six chapters. Following chapter one (introduction), chapter two describes previous research that has been conducted in the form of a literature review. Chapter three explains the methodology adopted in this research study. The results and discussion of the study are presented in chapters four and five respectively. Finally, the limitations, recommendations and conclusion are addressed in chapter six. This is followed by a list of references and appendices used in the study.

1.8 Conclusion

This chapter presented an overview of VI and the evolution of the definition of VI. The global and local prevalence of VI in adults and children were also reviewed. The chapter also briefly discussed the impact of VI in the lives of affected individuals and the clinical characteristics of VI as well as the effects on QoL. The aim, objectives, problem statement and significance of the study were also presented. The next chapter discusses literature that was reviewed for this study.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter reviews the development of vision and the main causes of visual impairment (VI) both globally and locally. It also presents a review of studies that have examined visual function, including visual acuity (VA) and refractive error, contrast sensitivity, colour vision and central visual field in individuals with VI. Studies that have reported on the effect of VI on quality of life (QoL) are also reviewed.

2.2 Development of vision

Visual acuity, as well as contrast and brightness sensitivities, are typically reduced in neonates, with the perception of colour also not being optimal, such that colour appears desaturated (McCulloch 1998). The VA of a neonate is estimated to be 6/120, while in terms of refractive error, approximately two to three dioptres of hyperopia is usually present at birth and may be accompanied by astigmatism (Olitsky & Nelson 2003, p. 2083; Silvestri 2007, p. 27). Although the retina is well developed at full term, the neural pathways are still immature, with the foveal region only reaching adult levels of maturity four months after birth (Silvestri 2007, p. 28). Furthermore, the optic nerve becomes completely myelinated at seven months, while the cells in the lateral geniculate nucleus only reach adult size at the age of two years (Silvestri 2007, p. 28).

During the first three to six months of life, there are rapid improvements in several visual functions, including VA, contrast sensitivity, extent of the visual field, scotopic sensitivity, colour vision and sensitivity to orientation, motion and direction (McCulloch 1998). Any hindrances to the formation of a clear retinal image during the developmental period may result in amblyopia (Olitsky & Nelson 2003, p. 2088). The development of VA proceeds at a rapid pace during infancy and childhood, reaching VA levels of 6/9 to 6/6 by age two to three years, while in conjunction with the maturation of the visual system, the amount of hyperopia also reduces at a steady rate (Olitsky & Nelson 2003, p. 2083; Silvestri 2007, p. 28). However, this normal maturation of the visual system and its associated visual functions may be delayed in individuals with VI (McCulloch 1998; Healey et al. 2010).

2.3 Prevalence of visual impairment

2.3.1 Global prevalence of visual impairment

The prevalence of VI may vary depending on whether presenting or best-corrected vision is reported (Murthy & Johnson 2012, p. 5). In 2002, with best-corrected vision, the global prevalence of individuals with VI was reported to be 161 million (Resnikoff et al. 2004).

This value increased significantly to 314 million individuals with VI when uncorrected refractive error was considered (Resnikoff et al. 2008). This significant increase implies that an additional 153 million individuals were visually impaired as a result of uncorrected refractive error alone (Resnikoff et al. 2008). However, by the year 2010, the global prevalence of VI decreased by approximately 10%, from 314 million to 285 million, of which an estimated 6.60% comprised children younger than 14 years (Pascolini & Mariotti 2012). A recent report by Bourne, Resnikoff and Ackland (2017) showed that the global prevalence of VI decreased further by approximately 11% to 253 million in 2015. In terms of the levels of VI, the prevalence of moderate and severe VI also decreased by approximately 10% from 269 million in 2004 to 246 million in 2010 (Resnikoff et al. 2004, 2008; Pascolini & Mariotti 2012). Since then, the number of individuals with moderate and severe VI decreased further to 217 million in 2015, of which 47 million and 170 million could be classified as having severe and moderate VI respectively (Bourne, Resnikoff & Ackland 2017b). Globally, an estimated 17.5 million children aged zero to 14 years have moderate and severe VI, and of the global estimate of 1.4 million blind children, an estimated one million are in Asia and 300 000 in Africa (WHO 2007; Pascolini & Mariotti 2012).

2.3.2 Visual impairment in Africa

There was a slight decline in the number of individuals with VI in Africa from 26.8 million in 2002 to 26.3 million in 2010 (Resnikoff et al. 2004; Pascolini & Mariotti 2012). This decrease in the prevalence of VI both globally and in Africa may be accredited to the achievements of the VISION 2020: Right to Sight initiative that was established by the WHO and the International Agency for the Prevention of Blindness (IAPB) in 1999 (Ackland 2010). In terms of the levels of VI, 20.4 million and 16-18 million individuals were reported to have moderate and severe VI in Africa and sub-Saharan Africa respectively (Sacharowitz 2005; Pascolini & Mariotti 2012). Specifically in South Africa, the prevalence of moderate and severe VI decreased from 2.86% (876 779 of 48.4 million) in 2005 to 2.66% (950 943 of 51.6 million) in 2010 (Bourne 2017). Bourne (2017) reported a further decrease in 2015 to 2.45% (954 240 of 54.5 million). This is projected to decline by 0.14% to 2.31% (984 002 of 56.7 million) by the year 2020 (Bourne 2017).

2.4 Causes of visual impairment

Table 2.1 summarises the studies that have reported on the major causes of VI both globally and in each World Health Organisation (WHO) region, as well as in children and adolescents. Although five studies reported on the major causes of VI globally, only one noted the major causes of VI in children and adolescents worldwide (WHO 2007). While

studies have been conducted in each of the six WHO regions, there is considerable attention focused on VI in Africa (Table 2.1). This may be due to the higher prevalence of VI in developing countries and the need to create an accurate and updated database, particularly in Africa. The greater number of studies conducted in Africa may also be a method of establishing whether the goal of VISION 2020 will be achieved within the designated timeframe.

Overall, the leading causes of VI worldwide, and in each WHO region, include cataract, uncorrected refractive error and glaucoma (Table 2.1). Although trachoma was previously noted as one of the leading causes of VI globally, its prevalence has decreased in recent years and may be attributed to the efforts of the VISION 2020 initiative in eliminating avoidable blindness (Resnikoff et al. 2004; Ackland 2010; Flaxman et al. 2017). Age-related macular degeneration (ARMD) remains as one of the leading causes of VI worldwide, while posterior segment disorders (such as glaucoma, diabetic and hypertensive retinopathy), in addition to cataracts and uncorrected refractive errors, are the most common causes of VI in Africa (Cockburn et al. 2012; Naidoo et al. 2013; Maake & Oduntan 2015; Flaxman et al. 2017).

In the Americas and Eastern Mediterranean, the major causes of VI include uncorrected refractive error, cataract, glaucoma and ARMD (Schellini et al. 2009; Duerksen et al. 2013; Mousa et al. 2014; Hashemi et al. 2017). In South-East Asia, cataract and uncorrected refractive error predominate, while in the Western Pacific, cataract, choroidal, retinal and corneal disorders, as well as glaucoma, constitute the main causes of VI (Gupta et al. 2015; Guo et al. 2017; Sapkota & Kim 2017). There have been no recent studies conducted in Europe on the major causes of VI in the general population, which may be due to its reduced prevalence in developed regions, such as Europe.

Some studies have reported on the causes of VI primarily in children and adolescents, as shown in Table 2.1 (WHO 2007; Schellini et al. 2009; Heijthuijsen et al. 2013; Santos-Bueso et al. 2015; Haugen, Bredrup & Rødahl 2016; Asferaw, Woodruff & Gilbert 2017; Awad et al. 2017; Hashemi et al. 2017). Although individuals aged 50 years and older account for the majority of individuals affected by VI, childhood blindness and VI remain a major concern due to the greater life expectancy (Pascolini & Mariotti 2012; WHO 2014). Globally, the main causes of VI in children and adolescents include uncorrected refractive error, cataract, glaucoma, retinopathy of prematurity (ROP) and corneal scarring (WHO 2007).

Most of the studies investigating VI in children and adolescents shown in Table 2.1 were conducted in developing countries, with the exception of only one, which was from Norway, thus indicating that the majority of children and adolescents with VI live in developing countries (Oduntan 2005). The leading causes of VI in children and adolescents in developing countries include cataract, uncorrected refractive error, corneal diseases, glaucoma and amblyopia (Schellini et al. 2009; Santos-Bueso et al. 2015; Asferaw, Woodruff & Gilbert 2017; Awad et al. 2017; Hashemi et al. 2017). The major causes of VI in children and adolescents in Norway include cerebral VI, optic atrophy, retinitis pigmentosa (RP), ROP, albinism and high myopia (Haugen, Bredrup & Rødahl 2016). This demonstrates that VI in developed countries is mainly attributed to genetic causes, whereas in the developing world, it is mainly due to avoidable causes, such as infections (Jackson 2007, p.15).

Table 2.1: Summary of studies reporting on the major causes of VI

Author	WHO Region	Study area	Cause of VI	Cause of VI in children and adolescents
Resnikoff et al. (2004)	Global	Global	Cataract, glaucoma, ARMD, trachoma, corneal opacity and diabetic retinopathy	NR
WHO (2007)	Global	Global	Cataract, URE, glaucoma and ARMD	URE, cataract, glaucoma, corneal scarring and ROP
Pascolini and Mariotti (2012)	Global	Global	URE and cataract	NR
Bourne et al. (2013)	Global	Global	Cataract, URE and ARMD	NR
Flaxman et al. (2017)	Global	Global	URE, cataract, ARMD, glaucoma, diabetic retinopathy and corneal opacity	NR
Cockburn et al. (2012)	Africa	Cape Town, South Africa	Posterior segment diseases (diabetic retinopathy, glaucoma and ARMD), cataract and URE	NR
Naidoo et al. (2013)	Africa	KwaZulu-Natal, South Africa	URE, cataract, glaucoma, hypertensive retinopathy and diabetic retinopathy	NR
Maake and Oduntan (2015)	Africa	Limpopo, South Africa	URE, cataract and glaucoma	NR
Asferaw, Woodruff and Gilbert (2017)	Africa	Ethiopia	NR	Corneal disease (due to measles, vitamin A deficiency and infection/ ulcer), microphthalmos, anophthalmos and cataract
Santos-Bueso et al. (2015)	Africa Eastern Mediterranean	Ethiopia Morocco	NR NR	Corneal disease and trauma Hereditary disease and myopia
Mousa et al. (2014)	Eastern Mediterranean	Egypt	Cataract, URE, trachomatous corneal opacities, other corneal opacities and retinal detachment	NR

WHO, World Health Organisation; VI, visual impairment; NR, not reported; ARMD, age-related macular degeneration; URE, uncorrected refractive error; ROP, retinopathy of prematurity; RP, retinitis pigmentosa

Table 2.1: Summary of studies reporting on the major causes of VI (continued)

Awad et al. (2017)	Eastern Mediterranean	Palestine	NR	Aged 0-5 years: amblyopia, RP, macular dystrophy, congenital glaucoma and optic atrophy Aged 6-12 years: RP, cataract, macular dystrophy and amblyopia Aged 13-18 years: ocular albinism, macular dystrophy, cataract, congenital glaucoma and amblyopia
Hashemi et al. (2017)	Eastern Mediterranean	Iran	URE, cataract, ARMD, glaucoma and amblyopia	URE and amblyopia
Schellini et al. (2009)	Americas	Brazil	URE, cataract, ARMD and glaucoma	URE and retinopathy
Duerksen et al. (2013)	Americas	Paraguay	Cataract, URE, glaucoma, diabetic retinopathy and ARMD	NR
Heijthuijsen et al. (2013)	Americas	Republic of Suriname	NR	Retinal disorders (including ROP, dystrophy and albinism), cataract, idiopathic nystagmus and optic nerve disorders
Haugen, Bredrup and Rødahl (2016)	Europe	Norway	NR	Cerebral VI, optic atrophy, RP, ROP, albinism and high myopia
Gupta et al. (2015)	South-East Asia	India	Cataract, URE, posterior segment diseases, corneal opacity and aphakia	NR
Sapkota and Kim (2017)	South-East Asia	Nepal	Nystagmus, high refractive error, cataract, RP, amblyopia, ARMD, retinal/uveal coloboma, macular scar/hole, albinism, optic atrophy, microphthalmos, Stargardt's disease, drug toxicity and glaucoma	NR
Guo et al. (2017)	Western Pacific	China	Cataract, disorders of the choroid and retina, corneal disorders, glaucoma and hereditary and congenital abnormalities	NR

WHO, World Health Organisation; VI, visual impairment; NR, not reported; ARMD, age-related macular degeneration; URE, uncorrected refractive error; ROP, retinopathy of prematurity; RP, retinitis pigmentosa

2.5 Distance visual acuity and refractive error

2.5.1 Distance visual acuity

Visual acuity is the measurable ability of the visual system to resolve fine details and may be restricted by optical and/or neural factors or a combination (Bailey 2006, p. 217; Elliott & Flanagan 2007, p. 30). In individuals with VI, reduced visual function commonly manifests as a reduction in VA (DeCarlo, Woo & Woo 2006, p. 1591). Few studies have assessed VA in individuals with VI, as shown in Table 2.2. Overall, the sample sizes in these studies ranged from 19 participants to 365 participants, with the majority having samples sizes equal to or less than 50, and only three studies including 120 or more (Sampath & Bedell 2002; Lee et al. 2010; Schwering et al. 2015; Tunay et al. 2016).

The majority of studies included both adult and adolescent participants, based on the age range reported (Table 2.2). In three studies, the sample consisted of only children and adolescents, as their age ranged from five years to 18 years (Labib et al. 2009; Ganesh et al. 2013; Tunay et al. 2016). Overall, the mean age of the participants ranged from 10.50 years to 38.00 years (Lee et al. 2010; Ganesh et al. 2013). Although the study by Lee et al. (2010) included a larger number of participants (n = 365) with a wide age range (81 years), the standard deviation of the mean age reported was similar to that reported in the study by Wildsoet, Oswald and Clark (2000). Furthermore, the mean age of study participants reported by Lee et al. (2010) was more than twice that reported by Wildsoet, Oswald and Clark (2000).

Only two studies used the Landolt C chart to measure VA, while the majority of studies used the Bailey-Lovie LogMAR chart. Table 2.2 shows that the overall mean VA ranged from 0.68 ± 0.17 logMAR to 1.03 ± 0.48 logMAR (Sampath & Bedell 2002; Khanal, Pokharel & Kandel 2016). Of the four studies that reported similar mean VA results of 0.90 logMAR, only Labib et al. (2009) used a Landolt C chart, while the other three studies used Bailey-Lovie LogMAR charts (Wildsoet, Oswald & Clark 2000; Lee et al. 2010; Ganesh et al. 2013). This similarity in mean VA is notable because the causes of VI varied between the four studies, as although the predominant cause of VI in each was posterior segment disorders, the major cause of VI in one study was hereditary maculopathy, while in another it was RP (Labib et al. 2009; Lee et al. 2010).

A large variation in mean VA (range from 0.68 ± 0.17 logMAR to 1.03 ± 0.48 logMAR) was found in the studies that included only individuals with albinism (Sampath & Bedell 2002; Khanal, Pokharel & Kandel 2016). This variation in mean VA may be accounted for by different sample sizes and differences in the mean ages of the participants. The study by

Sampath and Bedell (2002) had the smallest sample size and reported a better mean VA of 0.68 ± 0.17 logMAR, which may also be due to the use of the Landolt C chart. The studies by Wildsoet, Oswald and Clark (2000) and Khanal, Pokharel and Kandel (2016) consisted of identical sample sizes (n = 25) and used the same chart (Bailey-Lovie LogMAR Chart). While the age range of the participants differed, both studies reported similar mean ages and VA measurements (Wildsoet, Oswald & Clark 2000; Khanal, Pokharel & Kandel 2016). Only the study by Schwering et al. (2015) had a sample size greater than 100 participants, which also included those with albinism, and reported a mean VA of 0.77 ± 0.15 logMAR, which is different from the mean in other studies that included individuals with albinism (Table 2.2).

Of all the studies indicated in Table 2.2, four each reported on VA in individuals with posterior segment disorders (Labib et al. 2009; Lee et al. 2010; Ganesh et al. 2013; Tunay et al. 2016) and albinism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016) as the predominant cause of VI. Consequently, there is limited information on VA in individuals with anterior segment disorders as the primary cause of VI.

Table 2.2: Visual acuity in individuals with VI

Author (year)	Sample size	Age (years)		VA Chart	Mean VA (logMAR)	Cause of VI
		Mean	Range			
Wildsoet, Oswald and Clark (2000)	25	17.40 ± 13.50	3 – 51	Bailey-Lovie LogMAR Chart	Right: 0.90 ± 0.23 Left: 0.88 ± 0.22	Albinism
Sampath and Bedell (2002)	19	NR	10 – 35	Landolt C	0.68 ± 0.17	OCA
Labib et al. (2009)	50	11.04 ± 2.58	5 – 15	Landolt C	0.90	Hereditary maculopathy 44%, RP 22%, optic atrophy 18%, congenital anomalies 16%
Lee et al. (2010)	365	38.00 ± 13.10	4 – 85	Bailey-Lovie LogMAR Chart	0.90 ± 1.03	RP
Ganesh et al. (2013)	35	10.50 ± 3.20	6 – 15	Bailey-Lovie LogMAR Chart	0.90 ± 0.05	Retinal dystrophy 37.1%, amblyopia 22.9%, OCA 17.2%, congenital developmental defects 14.2%, congenital idiopathic nystagmus 8.6%
Schwering et al. (2015)	120	NR	4 – 25	Bailey-Lovie LogMAR Chart	0.77 ± 0.15	OCA
Khanal, Pokharel and Kandel (2016)	25	16.00 ± 8.40	5 – 37	Bailey-Lovie LogMAR Chart	1.03 ± 0.48	OCA
Tunay et al. (2016)	150	10.60 ± 3.00	6 – 18	Bailey-Lovie LogMAR Chart	1.02 ± 0.31	Hereditary macular dystrophy 36%, cortical VI 18%, OCA 10.7%, optic atrophy 10%

VA, visual acuity; VI, visual impairment; NR, not reported; OCA, oculocutaneous albinism; RP, Retinitis pigmentosa

2.5.2 Refractive error

Table 2.3 summarises the studies that have reported on refractive error in individuals with VI. Overall, the sample sizes ranged from 19 participants to 365 participants, where half of the studies had less than 100 participants (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Khanal, Pokharel & Kandel 2016) and the other half had more (Lee et al. 2010; Mokaya et al. 2014; Schwering et al. 2015). None of the studies were specific to only children and adolescents, as all the studies also included adults in the study samples (Table 2.3). The age of the participants differed in the various studies, with a minimum of three years and a maximum of 85 years, while the overall mean age ranged from 12.59 years to 38.00 years (Wildsoet, Oswald & Clark 2000; Lee et al. 2010; Mokaya et al. 2014). The studies by Sampath and Bedell (2002) and Schwering et al. (2015) did not report a mean age, but rather a median age of 18 years and 12 years respectively. Mokaya et al. (2014) had the narrowest age range of participants (17 years), while Lee et al. (2010) had the widest age range (81 years).

Both subjective and objective (autorefraction, cycloplegic refraction and retinoscopy) methods of refraction were used to determine the refractive error (Table 2.3). Three studies used a combination of both objective and subjective refraction (Wildsoet, Oswald & Clark 2000; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016), and two studies made use of only objective refraction (Lee et al. 2010; Mokaya et al. 2014). The study by Sampath and Bedell (2002) used only subjective refraction, which may be due to the youngest participants in this study being older than the minimum age of participants reported in all the other studies.

Although there was some overlap between the studies regarding the methods used to determine the refractive error, the results reported varied and may be due to differences in sample sizes and mean age of participants (Table 2.3). The majority of the studies reported the mean spherical equivalent, while only two studies reported the mean best sphere (Wildsoet, Oswald & Clark 2000; Schwering et al. 2015). Overall, four of the studies reported a mean myopic refractive error (Sampath & Bedell 2002; Lee et al. 2010; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016), and only two reported a mean hyperopic refractive error (Wildsoet, Oswald & Clark 2000; Mokaya et al. 2014). The mean myopic refractive error ranged from −4.54 D to −0.65 D in individuals aged four years to 35 years (Sampath & Bedell 2002; Schwering et al. 2015), while the mean hyperopic refractive error ranged from +0.31 D to +1.45 D in individuals aged three years to 51 years (Wildsoet, Oswald & Clark 2000; Mokaya et al. 2014). This inclination toward hyperopia may be related to the age of the participants as the study by Wildsoet, Oswald and Clark

(2000) also included presbyopic participants. The mean spherical equivalent refractive error ranged from −2.97 D to +0.31 D (Lee et al. 2010; Mokaya et al. 2014) and the mean best sphere ranged from −4.54 D to +1.45 D (Wildsoet, Oswald & Clark 2000; Schwering et al. 2015). All the studies in Table 2.3 reported standard deviations greater than the mean best sphere or spherical equivalent, thus implying that refractive error varies in individuals with VI. This assumption is also supported by the large range of refractive errors reported (range from very high myopia of −30.00 D to high hyperopia of +16.00 D) (Schwering et al. 2015).

The variability in mean refractive error is notable as five out of the six studies were conducted in individuals with albinism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Mokaya et al. 2014; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Two of the studies that included individuals with albinism had the same sample size (n = 25) and used both objective and subjective methods of refraction, but reported different mean refractive errors (Wildsoet, Oswald & Clark 2000; Khanal, Pokharel & Kandel 2016). Khanal, Pokharel and Kandel (2016) reported a mean myopic spherical equivalent, while Wildsoet, Oswald and Clark (2000) reported a mean hyperopic best sphere. This difference may be due to Wildsoet, Oswald and Clark (2000) including presbyopic participants in their study sample, who are likely to show a hyperopic shift in refractive error after the age of 45 years (Goss 2006, pp. 79-80).

The distribution of refractive error varies in individuals with albinism, such that some studies suggest that myopia is the more common refractive error (Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016), while others suggest that hyperopia is more common (Wildsoet, Oswald & Clark 2000; Mokaya et al. 2014). While either a myopic or hyperopic mean refractive error was reported in the studies in Table 2.3, the ranges suggest that both myopia and hyperopia were found in the study participants (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Mokaya et al. 2014; Schwering et al. 2015). The magnitude of myopia and hyperopia may reach up to −30.00 D and +16.00 D respectively (Schwering et al. 2015), with only one of the studies further reporting on the mean myopia and hyperopia, which were −6.56 ± 4.52 D and +1.53 ± 1.26 D respectively (Khanal, Pokharel & Kandel 2016).

Four of the studies reported on the magnitude of astigmatism, with a range of −3.26 DC to −1.09 DC (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). The majority of participants in each of these studies had with-the-rule (WTR) astigmatism, while only a few had against-the-rule (ATR)

and oblique astigmatism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Two studies reported a similar mean astigmatism with a difference of less than 0.50 DC, which may be due to both having the same sample size (n = 25) and similar mean age of study participants, as well as both being conducted on individuals with albinism (Wildsoet, Oswald & Clark 2000; Khanal, Pokharel & Kandel 2016).

Five of the studies measured refractive error in individuals with albinism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Mokaya et al. 2014; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016) and only one determined the refractive error in individuals with a posterior segment disorder (Lee et al. 2010). Consequently, there is limited information on refractive error in individuals with primarily anterior segment disorders as the cause of VI.

Table 2.3: Refractive error in individuals with VI

Author (year)	Sample size	Age (years)		Method	Refractive error (D)			Cause of VI
		Mean	Range		Mean	Range	Mean astigmatism	
Wildsoet, Oswald and Clark (2000)	25	17.40 ± 13.50	3 – 51	Autorefraction and subjective refraction	Best sphere: Right: +1.07 ± 4.67 Left: +1.45 ± 4.62	−10.50 to +9.13	Right: −2.37 ± 1.54 Left: −2.15 ± 1.32	Albinism
Sampath and Bedell (2002)	19	NR	10 – 35	Subjective refraction	Spherical equivalent: −0.65 ± 4.56	−13.75 to +7.30	−3.26 ± 1.76	OCA
Lee et al. (2010)	365	38.00 ± 13.10	4 – 85	Autorefraction	Spherical equivalent: −2.97 ± 3.37	NR	NR	RP
Mokaya et al. (2014)	101	12.59 ± 4.16	4 – 21	Cycloplegic refraction	Spherical equivalent: +0.31 ± 4.58	−16.00 to +10.00	NR	OCA
Schwering et al. (2015)	120	NR	4 – 25	Retinoscopy, cycloplegic refraction and subjective refraction	Best sphere: Right: −4.54 ± 5.77 Left: −4.37 ± 5.47	−30.00 to +16.00	Right: −1.09 ± 1.43 Left: −1.23 ± 1.40	OCA
Khanal, Pokharel and Kandel (2016)	25	16.00 ± 8.40	5 – 37	Retinoscopy, cycloplegic refraction and subjective refraction	Spherical equivalent: −1.59 ± 5.39	NR	−1.93 ± 1.00	OCA

VI, visual impairment; NR, not reported; OCA, oculocutaneous albinism; RP, retinitis pigmentosa

2.6 Contrast sensitivity

Measuring VA alone may not accurately reflect an individual's functional vision, as reduced visual function may also occur as a result of decreased contrast sensitivity (DeCarlo, Woo & Woo 2006, p. 1591). Contrast sensitivity is related to the visibility of real-world targets, thereby providing useful information about functional vision that may not be evident from the measurement of VA (Owsley & Sloane 1987; Elliott & Flanagan 2007, p. 48). Furthermore, contrast sensitivity testing is more sensitive to subtle vision loss, as there may be preferential losses at specific spatial frequencies, especially in individuals with VI (DeCarlo, Woo & Woo 2006, p. 1601; Elliott & Flanagan 2007, p. 48).

Only two studies assessed contrast sensitivity in individuals with VI and both differed in sample size and mean age of participants (Table 2.4). Haymes et al. (1996) studied a smaller (n = 18) and older sample with a mean age of 44 years, while Labib et al. (2009) studied a slightly larger (n = 50) and younger sample, with a mean age of 11.04 ± 2.58 years. The studies used different tests to measure contrast sensitivity, with Haymes et al. (1996) using the Pelli-Robson chart and the Melbourne Edge Test to measure contrast sensitivity at low spatial frequencies in log CS units and decibels (dB) respectively, while Labib et al. (2009) used the Vision Contrast Test System (VCTS 6000) to measure contrast sensitivity at all spatial frequencies.

With the Pelli-Robson chart, Haymes et al. (1996) reported that contrast sensitivity ranged from poor (0.00 log CS) to good (1.80 log CS), and peak contrast sensitivity ranged from 3 dB to 21 dB with the Melbourne Edge Test. This variation from mild to severe loss of contrast sensitivity may be attributed to the main cause of VI being RP, where the results were likely to depend on the severity of this ocular condition and the presence of macular involvement. Another possible explanation for this finding may be accounted for by the inclusion of both young and old participants, as there is a decrease in contrast sensitivity with increasing age (Haymes et al. 1996; Elliott 2006, p. 267). Different to the findings of Haymes et al. (1996), Labib et al. (2009) reported that contrast sensitivity at all spatial frequencies were impaired with the VCTS 6000. Both studies were conducted in individuals with predominantly posterior segment disorders with limited information available on contrast sensitivity in those with VI due to anterior segment disorders and OCA.

Table 2.4: Contrast sensitivity in individuals with VI

Author (year)	Sample size	Age (years)		Method	Results	Cause of VI
		Mean	Range			
Haymes et al. (1996)	18	44	17 – 75	Pelli-Robson, Melbourne Edge Test	Range: 0.00-1.80 log CS 3 to 21 dB	RP
Labib et al. (2009)	50	11.04 ± 2.58	5 – 15	VCTS 6000	Impaired for all spatial frequencies	Hereditary maculopathy 44%, RP 22%, optic atrophy 18%, congenital anomalies 16%

VI, visual impairment; RP, retinitis pigmentosa; VCTS 6000, vision contrast testing system

2.7 Colour vision

Colour vision defects may have educational, vocational and avocational implications in the lives of affected individuals (DeCarlo, Woo & Woo 2006, p. 1602). Colour vision defects may be classified according to the minimum number of primary colours used to match perceived colours (Pease 2006, p. 291). Normal trichromacy entails the ability to match any perceived colour using an appropriate proportion of the three primary colours, whereas anomalous trichomacy requires a different intensity of primary colours in order to match a perceived colour (Pease 2006, p. 292). The three types of anomalous trichromacy are protanomaly (more red light is required to match standard yellow), deuteranomaly (more green light is required to match standard yellow) and tritanomaly (more blue light is required to match standard cyan) (Pease 2006, p. 292). In dichromatic individuals, only two photopigments are present in the retina. In protanopia, the L-cone photopigment that responds to long wavelengths of light is missing, while in deuteranopia and tritanopia the M- and S-cone photopigments, which respond to medium and short wavelengths, respectively are lacking (Pease 2006, p. 292). Protan and deutan colour vision defects may be collectively referred to as red-green colour vision defects while tritan colour vision defects may be described as blue-yellow colour vision defects. The inability to discriminate between different wavelengths is referred to as monochromacy or achromacy whereby the visible spectrum is perceived as shades of grey of differing brightness (Pease 2006, p. 293). This may be related to either the rod or cone photoreceptors, i.e. typical rod monochromats or cone monochromats.

Colour vision defects may be further classified as either inherited or acquired. Acquired colour vision defects may obey Köllner's rule, although it is only useful in the early stages of a condition as the diagnosis of the type of colour vision defect becomes difficult with the progression of certain diseases (Pease 2006, p. 297). Köllner's rule states that acquired blue-yellow colour vision defects are as a result of diseases affecting the outer retinal layers, ocular media and choroid, while acquired red-green colour vision defects are as a

result of diseases affecting the inner retinal layers, including the optic nerve and proximal parts of the visual pathway (Pease 2006, p. 297). Exceptions to Köllner's rule include Stargardt's disease, which presents as a red-green colour vision defect, and glaucoma, papilloedema and hereditary autosomal dominant optic atrophy, which present with blue-yellow colour vision defects (Pease 2006, p. 297).

Four studies have assessed colour vision in individuals with VI (Table 2.5), their sample sizes ranging from 25 participants to 365 participants, and the mean age ranging from 11.04 ± 2.58 years to 38.00 ± 13.10 years (Labib et al. 2009; Lee et al. 2010; Khanal, Pokharel & Kandel 2016). Labib et al. (2009) assessed colour vision in children and adolescents, while Kalloniatis and Johnston (1990) assessed it in school-going children. The other two studies included adults in their samples, which may explain why the standard deviation of the mean age associated with their findings is larger (Table 2.5) (Lee et al. 2010; Khanal, Pokharel & Kandel 2016). Three of the studies were conducted in individuals with primarily posterior segment disorders (Kalloniatis & Johnston 1990; Labib et al. 2009; Lee et al. 2010), while only one assessed colour vision in individuals with albinism (Khanal, Pokharel & Kandel 2016). The Ishihara colour vision test was used to assess colour vision in three of the studies (Kalloniatis & Johnston 1990; Labib et al. 2009; Khanal, Pokharel & Kandel 2016), while the fourth used the Hardy-Rand-Rittler (HRR) colour vision test (Lee et al. 2010). In addition to the Ishihara colour vision test, Kalloniatis and Johnston (1990) used the Farnsworth F2, Farnsworth Panel D-15 and L'Anthony's desaturated D-15 colour vision tests.

The results varied among the four studies that reported on colour vision defects in individuals with VI (Table 2.5). Some studies only reported on whether the participants failed or passed the colour vision test, whereas the others noted the percentage of those who presented with the different types of colour vision defects. Only two studies reported on the prevalence of achromatopsia, which were 62% and 16.90% in the studies by Labib et al. (2009) and Lee et al. (2010) respectively. Overall, the varying results reported in Table 2.5 may be attributed to each study using different sample sizes, which consisted of participants with different ocular conditions.

Kalloniatis and Johnston (1990) reported that of the 75% of participants who failed at least one colour vision test, 24% also failed the Farnsworth Panel D-15, which indicates the presence of a moderate to severe colour vision defect, although the axes of these colour vision defects were not reported. Furthermore, the colour vision defects in participants with RP and primary optic atrophy obeyed Köllner's rule and were blue-yellow and red-

green respectively (Kalloniatis & Johnston 1990). In the same study, two cases were exceptions to Köllner's rule, where one case of inherited juvenile optic atrophy presented with a blue-yellow colour vision defect and one of Stargardt's disease presented with a red-green colour vision defect (Kalloniatis & Johnston 1990). In the study of individuals with RP by Lee et al. (2010), 29% of participants had red-green colour vision defects and 13.70% had blue-yellow colour vision defects. These results do not comply with Köllner's rule regarding colour vision defects in individuals with RP and are in contrast with the results reported by Kalloniatis and Johnston (1990).

In the study that assessed colour vision in individuals with albinism, 76% of the participants had no colour vision defects, 12% had red-green colour vision defects while colour vision could not be assessed in 12% of participants (Khanal, Pokharel & Kandel 2016). Furthermore, this study did not report on any blue-yellow colour vision defects, which may be due to the test used being insensitive to these types of colour vision defects. The study by Kalloniatis and Johnston (1990) included participants with OCA and reported that only 22.20% of the participants with OCA presented with red-green colour vision defects.

Table 2.5: Colour vision in individuals with VI

Author (year)	Sample size	Age (years)		Method	Results	Cause of VI
		Mean	Range			
Kalloniatis and Johnston (1990)	66	NR	NR	Ishihara, Farnsworth F2, Farnsworth Panel D-15, L'Anthony's desaturated D-15	75% failed one or more tests 24% (of the 75%) failed the Panel D-15	RP, optic atrophy, Stargardt's disease, OCA
Labib et al. (2009)	50	11.04 ± 2.58	5 – 15	Ishihara	62% achromatopsia 24% impaired colour perception 14% no colour vision defect	Hereditary maculopathy 44%, RP 22%, optic atrophy 18%, congenital anomalies 16%
Lee et al. (2010)	365	38.00 ± 13.10	4 – 85	HRR	33.9% no colour vision defect 29% red-green defect 16.9% achromatopsia 13.7% blue-yellow defect 6.5% unclassified	RP
Khanal, Pokharel and Kandel (2016)	25	16.00 ± 8.40	5 – 37	Ishihara	76% no colour vision defect 12% red-green defect 12% could not be assessed	OCA

VI, visual impairment; NR, not reported; RP, retinitis pigmentosa; OCA, oculocutaneous albinism; HRR, Hardy-Rand-Rittler

2.8 Central visual field

Only two studies have assessed and reported on the central visual field in individuals with VI and both differed in their sample sizes and mean age of participants (Table 2.6). Haymes et al. (1996) assessed a small sample of only 18 participants, while the study by Mokaya et al. (2014) consisted of a larger sample of 101 individuals. The mean age of participants in the study by Haymes et al. (1996) was 44 years, with a range of 17 years to 75 years, while Mokaya et al. (2014) included younger participants (mean age of 12.59 ± 4.16 years) with a narrower age range (4 years to 21 years).

Both studies used an Amsler grid to assess the central visual field, while Haymes et al. (1996) also used a Goldmann perimeter to measure the magnitude of the visual field radius. Haymes et al. (1996) reported the magnitude of the residual central visual field, while the study by Mokaya et al. (2014) reported on whether a visual field defect was present and the type of visual field defect. All participants in the study by Haymes et al. (1996) experienced some degree of visual field loss, ranging from midperipheral loss to considerable peripheral field loss, with extension into the central visual field (Table 2.6). In contrast, Mokaya et al. (2014) reported that majority of participants (79%) presented with no visual field defect, while of those who had a visual field defect, 15.50% and 5.50% presented with central scotomas and metamorphopsia respectively. It is likely that their varying results may be due to the different causes of VI. Haymes et al. (1996) studied individuals with RP, while Mokaya et al. (2014) studied individuals with OCA. To the best of the researcher's knowledge, there are no studies that have assessed the central visual field in individuals with anterior segment disorders as the predominant cause of VI.

Table 2.6: Central visual field in individuals with VI

Author (year)	Sample size	Age (years)		Method	Results	Cause of VI
		Mean	Range			
Haymes et al. (1996)	18	44	17 – 75	Goldmann perimeter, Amsler grid	11.10% intact CVF with peripheral field loss 33.30% VF radius of 10° 27.80% VF radius of 4° 16.70% VF radius of 1.6° 11.10% VF loss that extended into entire CVF	RP
Mokaya et al. (2014)	101	12.59 ± 4.16	4 – 21	Amsler grid	79% no defects 15.5% central scotoma 5.5% metamorphopsia	OCA

VI, visual impairment; CVF, central visual field; VF, visual field; RP, retinitis pigmentosa; OCA, oculocutaneous albinism

2.9 Quality of life

Overall, few studies have investigated QoL in individuals with VI. This review includes only studies that followed the WHO classification of VI and included children and adolescents in the study sample (Table 2.7). All of the studies consisted of sample sizes equal to or less than 50 participants and ranged from a minimum of 19 to a maximum of 50, while the mean age of participants ranged from 10.50 ± 3.20 years to 49.00 ± 20.80 years (Burstedt & Mönestam 2010; El Byoumi & Mousa 2010; Ganesh et al. 2013; Tončić et al. 2016). The majority of studies consisted of children and adolescents aged five years to 18 years (El Byoumi & Mousa 2010; Ganesh et al. 2013; Tončić et al. 2016), while only the study by Burstedt and Mönestam (2010) also included adults in the sample, where the age of participants ranged from five years to 80 years.

Two studies used the LV Prasad-Functional Vision Questionnaire (LVP-FVQ) to assess QoL in individuals with VI (El Byoumi & Mousa 2010; Ganesh et al. 2013), while the studies by Burstedt and Mönestam (2010) and Tončić et al. (2016) assessed QoL by using the National Eye Institute Visual Function Questionnaire-25 (NEI VFQ-25) and the Cardiff Visual Ability Questionnaire for Children (CVAQC) respectively. In a study assessing the quality of available ophthalmic questionnaires, the CVAQC was found to have the highest quality in terms of content, psychometric properties, validity and reliability (Khadka, McAlinden & Pesudovs 2013). The CVAQC consists of 25 items that are divided into seven domains, namely distance vision, near vision, getting around, education, sports, social interaction and entertainment. This instrument was developed by obtaining information provided by focus group discussions with children and adolescents who were both normally sighted and visually impaired (Khadka et al. 2010). These focus group discussions initially identified 121 items, however items that were repeated or ambiguous were removed (Khadka et al. 2010). In addition, Rasch analysis was used to improve measurement validity of the instrument as well as to determine the optimum number of response categories, which reduced the number of items to 25 (Khadka et al. 2010). The test-retest reliability was confirmed using a group of 39 participants and a test-retest time period of two to three weeks (Khadka et al. 2010).

The LVP-FVQ is designed for use in developing countries and does not possess adequate psychometric properties, while the NEI VFQ-25 is recommended for adults with VI (Khadka, McAlinden & Pesudovs 2013). Of these three QoL questionnaires, the NEI VFQ-25 assesses the highest number of domains and the LVP-FVQ the least (Table 2.7). Despite this, all the questionnaires assessed both distance and near vision, with the

results indicating that individuals with VI had difficulty with distance and near vision and consequently experienced reduced QoL.

Burstedt and Mönestam (2010) used the NEI VFQ-25 and reported that individuals with VI experienced the most difficulty with the general, near, distance and colour vision domains, while the least difficulty was reported with ocular pain, general and mental health. Furthermore, all domains were negatively affected by an increase in age, except for mental health, where the authors postulated that this may be due to older individuals being more accustomed to their diagnosis and living with the condition (Burstedt & Mönestam 2010).

The two studies that used the LVP-FVQ reported similar results of reduced distance and near vision, especially when related to education (El Byoumi & Mousa 2010; Ganesh et al. 2013). In both studies, the participants reported difficulty with copying from the blackboard and reading a textbook at an arm's length distance (El Byoumi & Mousa 2010; Ganesh et al. 2013), while the results reported by El Byoumi and Mousa (2010) also indicated that seeing a person across the road and identifying colours were difficult. El Byoumi and Mousa (2010) further reported that there was no significant difference between male and female participants regarding the QoL.

Only one study used the CVAQC in adolescents with amblyopia and reported an overall mean visual ability score of 1.29 ± 1.26 log units, indicating poor QoL (Tončić et al. 2016). The study further reported that as a result of the VI, the majority of participants had never watched a film at the cinema and only used public transport with a companion (Tončić et al. 2016). With regard to entertainment, all participants found listening to music, playing computer games and using mobile phones to be very easy, while swimming was the preferred choice rather than ball games and athletics (Tončić et al. 2016). When education was considered, language lessons were reported to be very easy and maths the most difficult (Tončić et al. 2016). The study also reported that while reading small print in textbooks were reported to be very difficult, drawing, colouring or painting were easy or very easy. Reading the blackboard in class was also reported to be difficult, this being similar to the results reported by El Byoumi and Mousa (2010) and Ganesh et al. (2013).

Table 2.7: Quality of life in individuals with VI

Author (year)	Sample size	Age (years)		Questionnaire		Results	Cause of VI
		Mean	Range	Tool	Domains		
Burstedt and Mönestam (2010)	49	49.00 ± 20.80	5 – 80	NEI VFQ-25	General health, general vision, ocular pain, near vision, distance vision, social function, mental health, role functioning, dependency, driving, peripheral vision and colour vision	Difficulty with general, near, distance & colour vision Least difficulty with ocular pain, general and mental health	RP
El Byoumi and Mousa (2010)	50	11.28 ± 3.50	5 – 18	LVP-FVQ	Distance vision, near vision, colour vision and visual field	Difficulty with distance, near and colour vision	OCA 44%, hereditary retinal dystrophy 36%, cone dystrophy 12%, amblyopia 4%, congenital coloboma 4%
Ganesh et al. (2013)	35	10.50 ± 3.20	6 – 15	LVP-FVQ	Distance vision, near vision, colour vision and visual field	Difficulty with distance and near vision	Retinal dystrophy 37.10%, amblyopia 22.90%, OCA 17.20%, congenital developmental defects 14.20%, nystagmus 8.60%
Tončić et al. (2016)	19	13.20 ± 4.10	9 – 18	CVAQC	Education, near vision, distance vision, mobility, social interaction, entertainment and sports	Reduced quality of life in children with VI	Amblyopia

VI, visual impairment; NEI VFQ-25, National Eye Institute Visual Function Questionnaire-25; RP, retinitis pigmentosa; LVP-FVQ, LV Prasad-Functional Vision Questionnaire; OCA, oculocutaneous albinism; CVAQC, Cardiff Visual Ability Questionnaire for Children

2.10 Conclusion

This chapter briefly described the development of vision and presented the main causes of VI both globally and locally. Few studies have assessed visual function and/or QoL in individuals with VI and of the studies that assessed visual function, most focused on VA and refractive error with very few also including contrast sensitivity, colour vision and central visual field. These studies highlighted the variability of visual function in individuals with VI and reported that these individuals have relatively poorer QoL. Furthermore, most of these studies included children younger than 10 years and adults in the study samples therefore the results may not be generalised to adolescents with VI. The next chapter addresses the methodology used in this study and describes the data collection tools and procedures.

CHAPTER 3. METHODOLOGY

3.1 Introduction

The research methodology is distinguished from the research methods in that it refers to the path used to solve the research problem systematically while the research methods refers to the techniques employed in performing the research (Kothari 2004, pp. 7-8). The methodology explores the logic behind the decisions made and ensures that the techniques employed are relevant to the research question (Kothari 2004, pp. 7-8). This chapter provides an overview of the methodology used to evaluate visual function and quality of life (QoL) in adolescents with visual impairment (VI).

3.2 Research design

Case study research focuses on understanding the dynamics of a particular setting thereby exploring an occurrence within the context in which it appears with both quantitative and qualitative data collection methods (Baxter & Jack 2008). This study followed an observational, descriptive study design involving case reports and used both quantitative and qualitative data collection methods.

3.3 Study setting

The study location was the Arthur Blaxall School for children and adolescents with VI. The school, which currently accommodates students with VI from across South Africa, is located in Mountain Rise in Pietermaritzburg (South Africa) with coordinates 29.59° S and 30.41° E and was founded by Reverend Arthur Blaxall in 1954.

3.4 Study population

The study population included adolescent students with VI enrolled at the Arthur Blaxall School. According to the World Health Organisation (WHO), an adolescent refers to an individual aged between 10 years and 19 years (WHO 2014). The WHO (2014) further categorises ‘adolescence’ into early adolescence (aged 10 years to 13 years) and middle to late adolescence (aged 14 years to 19 years). When conceptualising the study, there were 213 students enrolled at the Arthur Blaxall School (Govender, V 2017, pers. comm., 15 March).

3.5 Sampling method and sample size

Study participants were recruited using convenience sampling between January 2017 and March 2017 in order not to disrupt the examinations or the academic programme of the school. The sample size was determined in consultation with the faculty statistician, and

based on the study design, objectives and a 95% confidence level, a sample of approximately 80 participants was recommended by the statistician (Brown, P 2016, pers. comm., 22 September).

3.6 Inclusion and exclusion criteria

Participants with moderate and severe VI (visual acuity (VA) less than 6/18 (0.48 logMAR) but greater than or equal to 6/120 (1.30 logMAR)), aged between 10 years and 19 years, of both genders and all races were included. Participants were excluded if they did not fall within the required age and VA ranges and had any existing comorbidities including hearing, mental and/or physical impairments.

3.7 Data collection instruments

In this study, visual function was quantified by distance VA and refractive error, contrast sensitivity, colour vision as well as central visual field. The instruments used were standard optometric equipment, which included a distance ETDRS LogMAR VA chart, Mars contrast sensitivity test, Panel 16 colour vision test, Amsler grid, vertometer, a trial case and trial frame, while QoL was assessed using the Cardiff Visual Ability Questionnaire for Children (CVAQC). The tests and instruments that were used for data collection will be outlined below.

3.7.1 Distance visual acuity

Visual acuity is a measure of the ability of the visual system to resolve fine details and is the most commonly used measurement of visual function (DeCarlo, Woo & Woo 2006, p. 1601; Elliott & Flanagan 2007, p. 30). The distance ETDRS LogMAR chart is designed according to the Bailey-Lovie principle and is considered as the gold standard for VA assessment (Bailey & Lovie-Kitchin 2013). This design of the LogMAR chart ensures that the visual task is not altered when the viewing distance is altered. The chart consists of five optotypes on each row with a constant logarithmic size progression ratio of 1.2589 where the spacing between two adjacent rows is equal to the width of the letter of the superseding row (Bailey & Lovie-Kitchin 2013). Each letter on a row is assigned a score which provides more accurate and consistent results (Hussain et al. 2006). Furthermore, the space between adjacent letters is equal to the width of a letter in that row which controls for contour interaction and the crowding phenomenon (Bailey & Lovie-Kitchin 2013). Visual acuity on a distance ETDRS LogMAR chart ranges from −0.3 logMAR to 1.0 logMAR, making this chart suitable for assessing VA in individuals with VI (Dougherty, Flom & Bullimore 2005; DeCarlo, Woo & Woo 2006, p.1595; Elliott & Flanagan 2007, p. 49).

3.7.2 Refractive error

The purpose of refraction is to measure the refractive status of the eye and to determine the dioptric power of corrective lenses required to provide maximum VA (Borish & Benjamin 2006, p. 794). Subjective refraction determines the corrective lenses required for an individual based on their responses (Elliott 2007a, p. 104).

3.7.3 Contrast sensitivity

Contrast sensitivity measures the ability of the visual system to perceive changes in luminance and provides information about functional, real-world vision that may not be evident from a VA measurement (DeCarlo, Woo & Woo 2006, p. 1601; Elliott & Flanagan 2007, p. 48; Milling, O'Connor & Newsham 2014). The Mars letter contrast sensitivity test has good validity and similar repeatability to the Pelli-Robson contrast sensitivity test in individuals with VI (Dougherty, Flom & Bullimore 2005; DeCarlo, Woo & Woo 2006, p. 1602; Thayaparan, Crossland & Rubin 2007; Sukha & Rubin 2013). Thus, the Mars letter contrast sensitivity test may be a viable alternative to the Pelli-Robson contrast sensitivity test for clinical research and is suitable for individuals with VI (Dougherty, Flom & Bullimore 2005; DeCarlo, Woo & Woo 2006, p. 1595; Elliott & Flanagan 2007, p. 49; Thayaparan, Crossland & Rubin 2007; Sukha & Rubin 2013). The contrast sensitivity on the Mars chart ranges from 91% to 1.2% (0.04 to 1.92 log units), and each letter represents an increment of 0.04 log units (Dougherty, Flom & Bullimore 2005; Thayaparan, Crossland & Rubin 2007). At the recommended test distance of 50 cm, each letter subtends 2° which is equivalent to 20/480 (≈ 6/150) (Arditi 2005; Dougherty, Flom & Bullimore 2005). The contrast sensitivity measurement corresponds to the final letter read correctly less 0.04 (for any previous errors) after two consecutive errors are made (Arditi 2005).

3.7.4 Colour vision

An assessment of colour vision allows for the detection of colour vision deficiencies that may be present in individuals with VI which may be either inherited or acquired. Colour vision testing requires adequate VA, therefore a reduction in VA may adversely affect the colour vision test results (Wilkinson 1996, p. 162; Sehlapelo & Oduntan 2007).The Panel D15 arrangement test is less sensitive to decreased VA compared with the Ishihara or HRR colour plates, is accurate up to a VA of 6/150 (1.40 logMAR) and has good test-retest reliability (DeCarlo, Woo & Woo 2006, pp. 1602-1603; McCulley et al. 2006; Cole 2007). The Panel 16 colour vision test is similar to the Panel D15 arrangement test and consists of the same hues with 16 (15 test and 1 pilot) caps except that each cap has a

larger stimulus area of 3.30 cm, thus making the Panel 16 colour vision test suitable for children and adolescents with VI.

3.7.5 Central visual field

Central visual field testing evaluates the integrity of the macula region and detects abnormalities that may not be present in a VA measurement (Elliott & Flanagan 2007, p. 43). The Amsler grid is suitable for qualitatively evaluating the central 10° radius of the visual field (Elliott & Flanagan 2007, p. 44; Bhattacharyya 2009, p. 274). Moreover, the Amsler grid is an inexpensive and reliable technique that allows for a rapid detection of abnormalities that may not be detected by other methods of perimetry (Bhattacharyya 2009, p. 274). At the standard test distance of 30 cm, each 5 mm square on the grid subtends approximately 1° (Elliott & Flanagan 2007, p. 44).

3.7.6 Cardiff Visual Ability Questionnaire for Children

The CVAQC is recommended for assessing QoL in adolescents with VI and has high quality content, superior psychometric properties, and good validity and reliability (Khadka, McAlinden & Pesudovs 2013). The CVAQC consists of 25 questions divided into seven domains which include distance vision, near vision, getting around, education, sports, social interaction and entertainment. Every question uses a five point rating scale where participants have the option of choosing a response (very easy [1], easy [2], difficult [3], very difficult [4] or not interested in doing this/ do not do for other reasons [5]) to the question where each response has a unique log unit score.

3.8 Data collection procedure

The data collection procedure consisted of an initial screening followed by data gathering (Figure 3.1). Data gathering involved the collection of demographic information and procedures to assess distance VA, refractive error, contrast sensitivity, colour vision, central visual field and QoL.

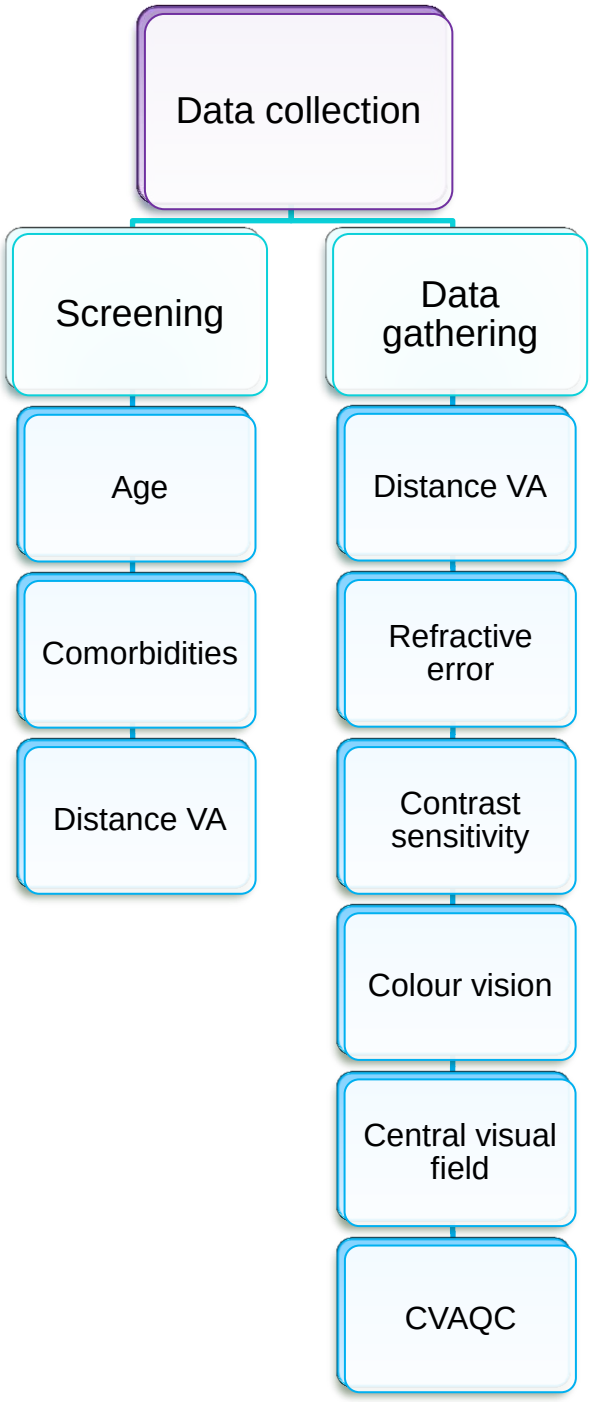

Figure 3.1: Data collection procedure

3.8.1 Screening

Each participant was required to return their consent and assent forms prior to participation in the study. The screening procedures involved administering a questionnaire to ascertain the participant's age and presence of comorbidities as well as measuring distance aided or pinhole VA with a LogMAR chart (Figure 3.1). The age of each participant was further confirmed by reviewing the participant's 'pupil particulars'

provided by the school secretary. Each participant underwent screening to ensure that the requirements of the inclusion criteria were met prior to data gathering. This involved filtering out participants who were not within the required age and/or VA range as well as those with existing comorbidities.

3.8.2 Data gathering

If the requirements of the inclusion criteria were met, a questionnaire was utilised to determine demographic information (age, race, gender and level of education) while the cause of VI was obtained by reviewing the participant's 'pupil particulars' provided by the school secretary.

3.8.2.1 Distance visual acuity

Each participant's presenting distance VA was measured again with the ETDRS LogMAR chart at a four meter testing distance under normal room illumination. If the participant was unable to read the letters at four meters, the distance was reduced to two meters or one meter and the resulting VA was adjusted by adding 0.3 or 0.6 logMAR respectively. Visual acuity was measured both monocularly, starting with the right eye followed by the left eye, and binocularly, and if the participant wore spectacles, the aided VA of the right, left and both eyes was also measured.

3.8.2.2 Refractive error

If a participant wore spectacles, the spectacle prescription was measured with a vertometer thereafter a subjective refraction was performed on all participants according to the procedure described by Borish and Benjamin (2006, pp. 795-847) and the best-corrected VA was measured both monocularly and binocularly. The subjective refractive error was classified according to Obstfeld (1982, pp. 43-49) where ametropia was described as a phenomenon whereby a distant object is not imaged on the retina but rather in front (myopia) or behind (hyperopia) the retina. Astigmatism implies that a distant point object does not form a point image on the retina but rather two perpendicular line foci that are separated by a distance (Obstfeld 1982, pp. 43-49). If one focal line lies on the retina and the other lies either in front of or behind the retina, this is referred to as simple myopia and simple hyperopia respectively (Obstfeld 1982, pp. 43-49). Compound myopia and compound hyperopia imply that both line foci lie either in front of or behind the retina respectively, while mixed astigmatism is described as one focal line lying in front of the retina and the other behind the retina (Obstfeld 1982, pp. 43-49). Refractive astigmatism was further classified as with-the-rule (WTR), against-the-rule (ATR) or oblique astigmatism based on the axis of the refractive cylinder. With-the-rule refers to the

more powerful meridian being along the vertical plane or 15 degrees on either side while ATR refers to the most powerful meridian being along the horizontal plane or 15 degrees on either side (Obstfeld 1982, p. 43-49; Paik et al. 2016). Astigmatism was classified as oblique if the most powerful meridian did not lie on the vertical or horizontal plane or within 15 degrees on either side of each plane (i.e. astigmatism was classified as oblique if the most powerful meridian was between 16 to 74 degrees and between 106 to 164 degrees) (Obstfeld 1982, p. 43-49; Paik et al. 2016).

3.8.2.3 Contrast sensitivity

The Mars letter contrast sensitivity test was used to measure contrast sensitivity with the best-corrected spectacle prescription worn by each participant at a test distance of 50 cm. Each participant was required to read all the letters from left to right across each line before moving to the next line. Participants were encouraged to guess even when they reported that the letter appeared too faint. On the record sheet, an X was allocated to each letter that was incorrectly identified and the test was stopped when two consecutive errors were made or the end of the chart was reached. The contrast sensitivity measurement was calculated as the last correctly identified letter less the value of any previous errors (each letter was valued as 0.04 log CS) and recorded in log contrast sensitivity (log CS). This was then classified as normal (1.52 log CS to 1.92 log CS), moderate loss (1.04 log CS to 1.48 log CS), severe loss (0.52 log CS to 1.00 log CS) and profound loss (< 0.48 log CS) according to the grading system provided with the Mars letter contrast sensitivity test. The three Mars letter contrast sensitivity charts available were used for each the right, left and both eyes in order to minimise the effects of letter sequence memorisation by the participants.

3.8.2.4 Colour vision

The Panel 16 colour vision test was used to assess monocular colour vision with the best-corrected spectacle prescription worn by each participant. Each participant was asked to order the caps such that there was a progressive change in the appearance of the colours. Upon completion, each participant was asked if they were satisfied with the order of the caps and if so, the numerical order on the reverse of the caps was recorded on a circular diagram. Two or more diametrical crossings constituted a fail and indicated the presence of either a moderate or severe colour vision defect while a pass indicated mild or no colour vision defect (Atchison, Bowman & Vingrys 1991; Cole 2007). The diagnosis of the type of colour vision defect was based on the orientation of the crossings and were recorded as protan, deutan or tritan colour vision defects (Cole 2007). Protan and deutan

colour vision defects were also collectively described as red-green colour vision defects while tritan defects were described as blue-yellow colour vision defects.

3.8.2.5 Central visual field

The central 20° of visual field was evaluated with the Amsler grid at 30 cm, where the first plate in the Amsler chart manual was used initially, however if the participant experienced difficulty locating the central white dot the second plate in the Amsler chart manual was used. The first plate of the Amsler chart manual consists of a standard white grid with a central white fixation target (i.e. the central white dot) against a black background. The second plate of the Amsler chart manual also consists of a standard white grid against a black background however there are also two white diagonal lines that cross in the centre of the grid to assist with steady, central fixation in individuals with a central scotoma (Elliott & Flanagan 2007, p. 44). A fail indicated the presence of a defect within the central visual field and were categorised as either a scotoma (absolute or relative and central or paracentral) or metamorphopsia. Reduced retinal sensitivity results in a scotoma which is described as absolute when there is no sensitivity to light within the borders of the defect and relative when there is some sensitivity to light within the borders of the defect, while metamorphopsia is described as a distortion of the perceived image (Comer 2006, p. 533; Kulp, Raasch & Polasky 2006, p. 1496; Kanski & Bowling 2011, p. 595). Central visual field testing was performed monocularly, first on the right eye followed by the left eye.

3.8.2.6 Quality of life

Following completion of the visual function assessment, QoL was assessed with the CVAQC which was verbally administered to each participant while the results were recorded on the questionnaire by the researcher. The rating scale, in large font, was displayed in front of each participant. The participants were each given adequate time in which to complete the questionnaire, and questions were clarified by the researcher when necessary.

3.9 Data management

Data were initially recorded on the data record sheet (Appendix I) and the CVAQC form with the associated scoring instruction sheet (Appendix II). The data were then captured using the Statistical Package for Social Sciences (SPSS) version 24. All record sheets and questionnaires were stored in a locked room and will be kept for a minimum of five years, after which they will be destroyed. The record sheets did not contain the identities of the participants and data were subsequently analysed as group findings so as not to identify any one participant.

3.10 Data analysis

Data were captured and analysed with descriptive and inferential statistics using the SPSS version 24. Descriptive statistics included means, standard deviations, ranges and frequencies. The independent sample *t*-test was used to compare age, distance VA, refractive error, contrast sensitivity and the visual ability score for the QoL in the two gender groups. The independent sample *t*-test was also used to compare the visual ability score for QoL in the two age categories (aged 10 years to 13 years and aged 14 years to 19 years). The chi-square test was used to determine the association between gender and the categories of VI, categories of contrast sensitivity loss, colour vision and central visual field defects. The correlation between unaided and best-corrected VA was assessed using the Pearson correlation coefficient. The one-way ANOVA test with a LSD post hoc test and the chi-square test were used to compare visual function and QoL according to the main causes of VI. A probability (p) value of less than or equal to 0.05 was considered statistically significant.

3.11 Validity and reliability

Validity implies that the method of measurement is accurate and measures exactly what was intended to be measured (Golafshani 2003; Elliott 2007b, pp. 2-4). The use of standard optometric visual function tests and a recommended QoL questionnaire ensured the validity of this study. Moreover, a pilot study was used to validate the data collection procedures and instruments prior to data gathering. Reliability refers to the repeatability and consistency of the results obtained during repeated measurements (Golafshani 2003; Elliott 2007b, pp. 2-4). To promote standardisation and maintain reliability, all procedures were performed under the same environmental conditions in consistent illumination by only one researcher.

3.12 Ethical considerations and confidentiality

Ethical clearance to conduct this study was obtained from the Biomedical Research and Ethics Committee (BREC) of the University of KwaZulu-Natal (BREC reference: BE457/16, Appendix III). Permission to conduct research at the Arthur Blaxall School was obtained from the provincial Department of Education and the principal of the school (Appendices IV and V). Permission to utilise equipment belonging to the Department of Optometry was obtained from the Academic Leader (Appendix VI). Each participant was given an information document, in English and isiZulu, informing them of the purpose of the study (Appendix VII). Written informed consent and assent were acquired from both the parents/guardians and the participants respectively (Appendix VIII). If a parent/guardian was unable to sign the consent form, as was the case of students living at

the hostel, the school principal signed in the capacity of the guardian. Each participant was informed that participation is voluntary and they may withdraw from the study at any time with no consequences. Confidentiality of data was maintained and participants were not identified in the presentation of the results.

3.13 Conclusion

This chapter outlined the methodology and methods used in this study to assess visual function and QoL of adolescents with VI. Only adolescents with VI who were registered at Arthur Blaxall School and who met the requirements of the inclusion criteria were included in this study. Visual function was quantified by distance VA and refractive error, contrast sensitivity, colour vision and central visual field, while QoL was assessed with the CVAQC. Data were analysed as group findings using SPSS version 24 in order not to identify any one participant and confidentiality was maintained throughout the duration of the study. The results of the study are presented in the next chapter and will be discussed in chapter five.

CHAPTER 4. RESULTS

4.1 Introduction

The results of the study will be presented in this chapter in the following order: demographic and ocular characteristics, visual function and quality of life (QoL). Visual function consists of distance visual acuity (VA) and refractive error, contrast sensitivity, colour vision and central visual field. Visual function and QoL were also analysed according to gender and the main cause of visual impairment (VI).

4.2 Demographic and ocular characteristics

The study sample consisted of 70 participants ranging from 10 years to 19 years, with a mean and median age of 13.83 ± 2.28 years and 14 years respectively. Of the 70 participants, 54.29% (n = 38) were female and 45.71% (n = 32) were male. The mean age of the female and male participants were 13.74 ± 2.15 years and 13.94 ± 2.46 years respectively. Despite males being slightly older, there was no significant difference in mean age between females and males (p = 0.717). The majority of the participants were Black (95.71%, n = 67), while only 2.86% (n = 2) and 1.43% (n = 1) were Indian and Coloured respectively.

Table 4.1 shows the causes of VI in the study sample where oculocutaneous albinism (OCA) was the most common cause of VI affecting 40% of the sample. Overall, there was a higher frequency of posterior segment disorders that caused VI compared with anterior segment disorders (Table 4.1). Of those that had posterior segment disorders, the most common cause was glaucoma (n = 5), high myopia (n = 4) and three participants each with retinitis pigmentosa (RP) and optic atrophy. Only six participants (8.57%) presented with anterior segment disorders, the most common of which was cataract (n = 2) followed by an equal presentation of aniridia, aphakia, corneal opacity and conjunctivitis. Amblyopia (n = 1) and phthisis bulbi (n = 1) were noted as the causes of VI in only two participants. The cause of VI was not known to either the participants or noted in the school records for 13 participants (18.57%) in the sample.

Table 4.1: Cause of VI with frequencies and percentages

Cause of VI	Frequency	Percentage
Anterior segment disorders		
Cataract	2	2.86
Anirida	1	1.43
Aphakia	1	1.43
Corneal opacity	1	1.43
Conjunctivitis	1	1.43
Posterior segment disorders		
Glaucoma	5	7.14
High myopia	4	5.71
Retinitis pigmentosa	3	4.29
Optic atrophy	3	4.29
Toxoplasmosis	2	2.86
Macular scarring	2	2.86
Retinopathy of prematurity	1	1.43
Stargardt's disease	1	1.43
Oculocutaneous albinism (OCA)	28	40.00
Other		
Amblyopia	1	1.43
Phthisis bulbi	1	1.43
Unknown	13	18.57

Table 4.2 shows the distribution of the cause of VI by gender where the most common cause of VI was OCA which was present in approximately 40% of male and female participants. There was an equal presentation of anterior segment disorders in both male (n = 3) and female (n = 3) participants. Only male participants had RP (n = 3) and Stargardt's disease (n = 1). Only one female participant each presented with amblyopia and phthisis bulbi. This distribution of the cause of VI by gender was not statistically significant (p = 0.573).

Table 4.2: Distribution of cause of VI by gender

	Male (n = 32)		Female (n = 38)	
Cause of VI	Frequency	Percentage	Frequency	Percentage
Anterior segment disorders				
Cataract	1	3.13	1	2.63
Anirida	1	3.13	-	-
Aphakia	1	3.13	-	-
Corneal opacity	-	-	1	2.63
Conjunctivitis	-	-	1	2.63
Posterior segment disorders				
Glaucoma	2	6.25	3	7.89
High myopia	1	3.13	3	7.89
Retinitis pigmentosa	3	9.38	-	-
Optic atrophy	2	6.25	1	2.63
Toxoplasmosis	1	3.13	1	2.63
Macular scarring	-	-	2	5.26
Retinopathy of prematurity	-	-	1	2.63
Stargardt's disease	1	3.13	-	-
Oculocutaneous albinism (OCA)	13	40.63	15	39.47
Other				
Amblyopia	-	-	1	2.63
Phthisis bulbi	-	-	1	2.63
Unknown	6	18.75	7	18.42

In terms of presenting signs, almost two-thirds of the participants had nystagmus (n = 43). Cutaneous hypopigmentation was present in 28 (40%) participants while thirteen (18.57%) and five (7.14%) participants had a strabismus and a head turn respectively. Corneal anomalies were observed in six participants where three participants (4.29%) each presented with corneal opacities and microcornea.

Table 4.3 shows the distribution of presenting signs among male and female participants. Overall, the distribution of presenting signs was similar among male and female participants except for nystagmus. Almost 70% (n = 26) of the female participants had nystagmus and just over 50% (n = 17) of the male participants had nystagmus.

Table 4.3: Distribution of presenting signs by gender

	Male (n = 32)		Female (n = 38)	
Presenting signs	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Corneal opacity	2	6.25	1	2.63
Cutaneous hypopigmentation	13	40.63	15	39.47
Strabismus	7	21.88	6	15.79
Head turn	2	6.25	3	7.89
Microcornea	1	3.13	2	5.26
Nystagmus	17	53.13	26	68.42
Ptosis	-	-	1	2.63

4.3 Objective one: distance visual acuity and refractive error

4.3.1 Distance visual acuity

The majority of the participants had measurable vision in the right eye (92.86%, n = 65) and left eye (90%, n = 63) as shown in Table 4.4. Almost one-third of the participants (n = 25) lacked binocularity due either to strabismus or blindness (categories 3, 4 and 5 of VI outlined by the World Health Organisation (WHO)) in one eye. The mean unaided VA for the right, left and both eyes were 0.98 ± 0.23 logMAR, 0.94 ± 0.24 logMAR and 0.86 ± 0.21 logMAR respectively (Table 4.4). The mean best-corrected VA for the right, left and both eyes were 0.91 ± 0.22 logMAR, 0.88 ± 0.22 logMAR and 0.79 ± 0.16 logMAR respectively. When comparing the unaided and best-corrected minimum and maximum VA, only the maximum binocular VA improved from 1.50 logMAR to 1.10 logMAR (Table 4.4). The unaided and best-corrected VA were correlated in the right eye ($r = 0.83$, $p < 0.001$), left eye ($r = 0.81$, $p < 0.001$) and both eyes ($r = 0.59$, $p < 0.001$).

Table 4.4: Unaided and best-corrected logMAR VA in the right, left and both eyes

	Right eye (n = 65)		Left eye (n = 63)		Both eyes (n = 45)	
	Unaided	**Best-corrected**	**Unaided**	**Best-corrected**	**Unaided**	**Best-corrected**
Mean ± SD	0.98 ± 0.23	0.91 ± 0.22	0.94 ± 0.24	0.88 ± 0.22	0.86 ± 0.21	0.79 ± 0.16
Minimum	0.58	0.58	0.52	0.52	0.50	0.50
Maximum	1.54	1.54	1.68	1.68	1.50	1.10

Table 4.5 shows the mean unaided and best-corrected VA according to gender. For both the unaided and best-corrected VA in the right and left eyes, males had slightly better mean VA than females though these differences were not statistically significant ($p \geq 0.552$). Male and female participants had similar mean unaided and best-corrected binocular VA ($p \geq 0.448$).

Table 4.5: Unaided and best-corrected logMAR VA in the right, left and both eyes according to gender

	Right eye (n = 65)		Left eye (n = 63)		Both eyes (n = 45)	
	Unaided	Best-corrected	Unaided	Best-corrected	Unaided	Best-corrected
Male	0.96 ± 0.23	0.90 ± 0.20	0.92 ± 0.23	0.86 ± 0.18	0.87 ± 0.22	0.81 ± 0.16
Female	0.99 ±0.23	0.93 ± 0.24	0.96 ± 0.26	0.89 ± 0.25	0.86 ± 0.20	0.77 ± 0.17

Table 4.6 shows the frequency of the participants' unaided and best-corrected VA in the right, left and both eyes according to the categories of VI outlined by the WHO. Based on the unaided VA, 43 (61.43%) and 45 (64.29%) participants had VA worse than 6/18 but better than or equal to 6/60 in the right and left eye respectively. Nineteen (27.14%) and 15 (21.43%) participants had VA worse than 6/60 but better than or equal to 3/60 in the right and left eye respectively. When the best-corrected VA was considered, 51 (72.86%) and 52 (74.29%) participants had VA worse than 6/18 but better than or equal to 6/60 in the right and left eye respectively. Twelve (17.14%) and 10 (14.29%) participants had VA worse than 6/60 but better than or equal to 3/60 in the right and left eye respectively. Overall for the best-corrected VA, there was an increase in the number of participants who had VA between 6/18 and 6/60 since the number of participants with VA less than or equal to 3/60 decreased.

Table 4.6: Frequency of unaided and best-corrected VA in the right, left and both eyes according to the WHO classification

Visual acuity	Right eye		Left eye		Both eyes	
	Unaided	Best-corrected	Unaided	Best-corrected	Unaided	Best-corrected
6/18 > VA ≥ 6/60	43	51	45	52	37	42
6/60 > VA ≥ 3/60	19	12	15	10	7	3
3/60 > VA ≥ 1/60	3	2	3	1	1	-
1/60 > VA ≥ light perception (LP)	2	2	2	2	-	-
No light perception (NLP)	3	3	5	5	-	-

Using the unaided VA of the better-seeing eye, 75.71% (n = 53) of the participants had moderate VI and almost a quarter (n = 16) had severe VI according to the WHO classification of VI (Figure 4.1). Only one participant had category 3 blindness (VA between 3/60 and 1/60). For the best-corrected VA of the better-seeing eye, 85.71% (n = 60) of the participants had moderate VI and only 14.29% (n = 10) had severe VI (Figure 4.1). After subjective refraction, there was a decrease in the number of

participants with severe VI which corresponded to the increase in the number of participants with moderate VI (Figure 4.1).

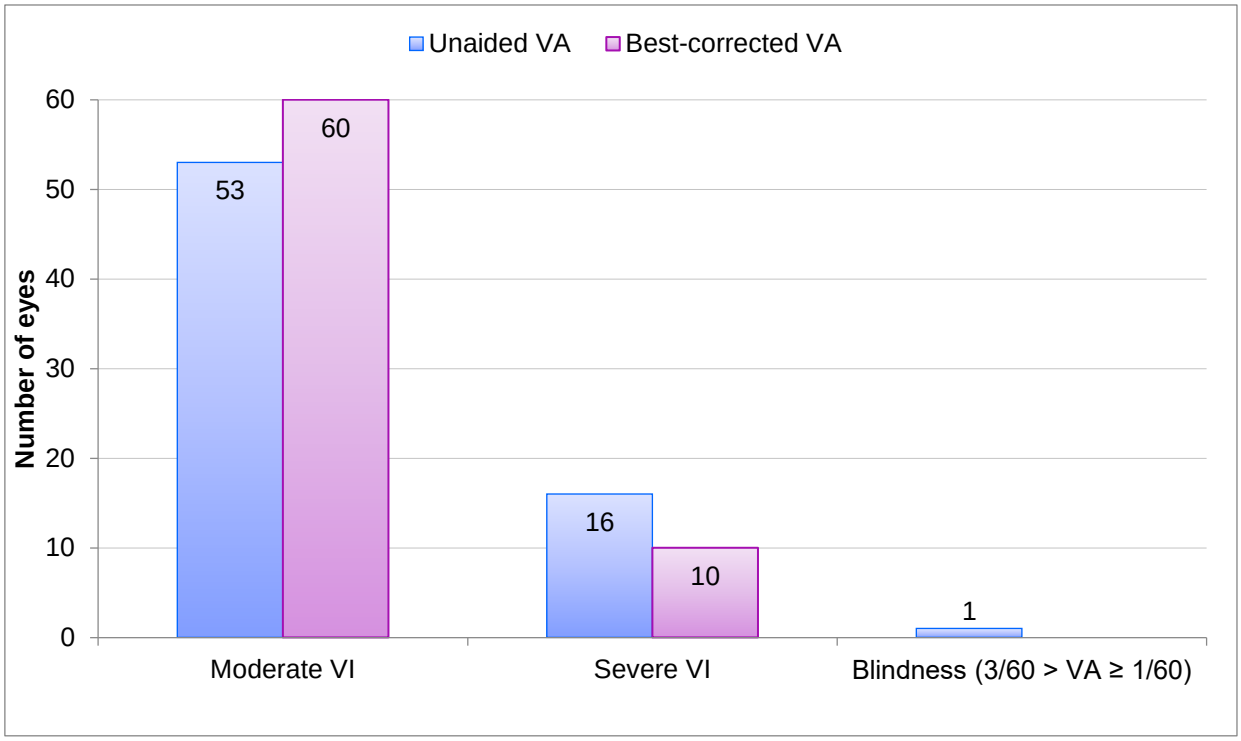

Figure 4.1: Categories of VI based on unaided and best-corrected VA in the better-seeing eye

Figure 4.2 shows the frequency of the categories of VI among male and female participants based on unaided and best-corrected VA of the better-seeing eye. The number of males and females with moderate VI based on the unaided and best-corrected VA was similar. For both unaided and best-corrected VA, slightly more females had severe VI than males although this gender difference was not statistically significant ($p \geq 0.281$). For both males and females, the number of participants with moderate VI increased since the number of participants with severe VI and blindness decreased after subjective refraction.

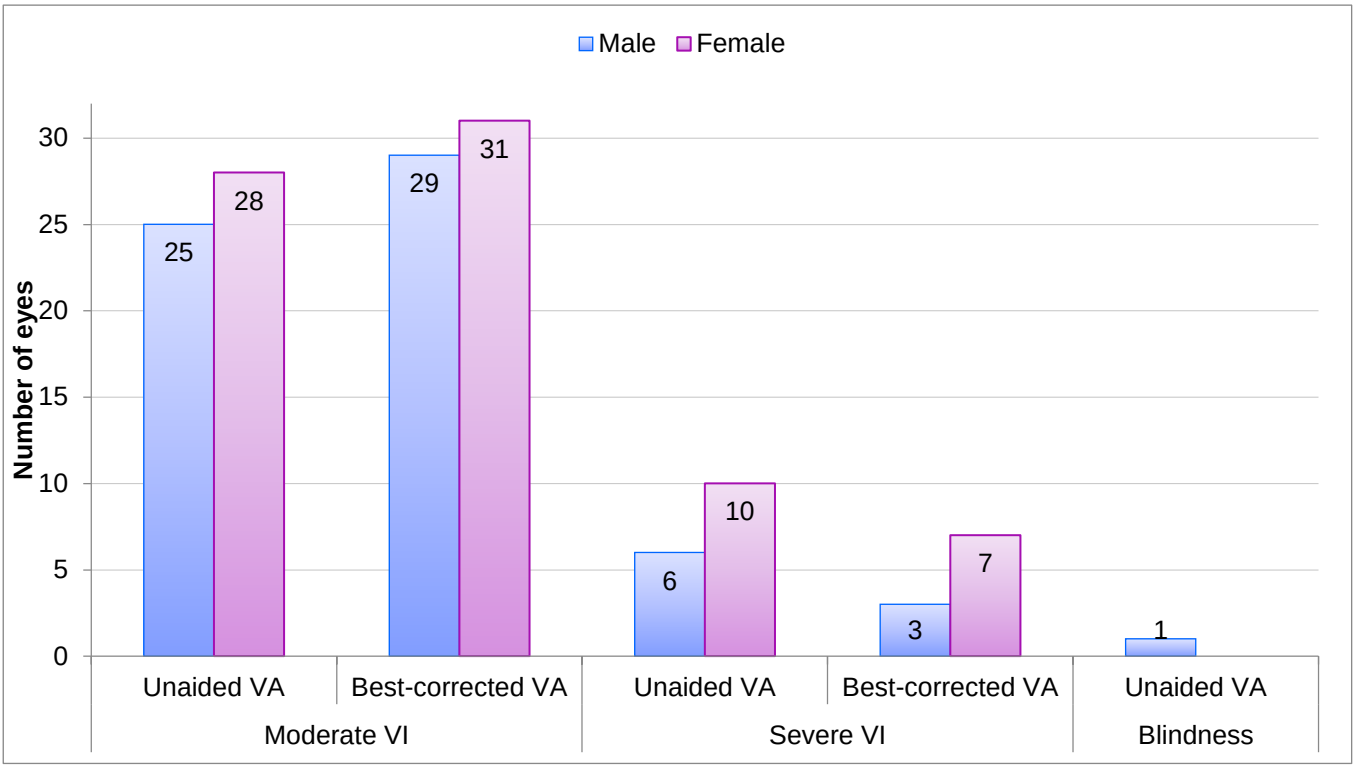

Figure 4.2: Frequency of VI based on unaided and best-corrected VA in the better-seeing eye in males and females

4.3.2 Refractive error

4.3.2.1 Presenting refractive error

Only 16 participants (22.86%) presented with spectacles and of this, eight were males and eight were females. For all participants, the overall mean sphere and cylindrical powers for the right eye were −2.22 ± 8.50 D and −2.06 ± 1.11 DC respectively. The overall mean sphere and cylindrical powers for the left eye were −1.11 ± 10.11 D and −2.30 ± 0.84 DC respectively. The median sphere was −2.00 D for both the right and left eyes, while the interquartile range was from −5.00 D to +1.75 D in the right eye and from −5.25 D to +4.75 D in the left eye. For males the mean sphere was −3.25 ± 8.75 D and −0.68 ± 11.39 D in the right and left eye respectively. For females the mean sphere was −1.31 ± 8.79 D and −1.54 ± 9.55 D in the right and left eye respectively. There were no significant gender differences in the mean sphere values for the right ($p = 0.677$) and left ($p = 0.881$) eyes. Females had slightly higher mean cylindrical powers in the right (−2.09 DC versus −2.00 DC) and in the left (−2.54 DC versus −2.00 DC) eyes, although these gender differences were not statistically significant ($p \geq 0.308$). Figure 4.3 shows the categories of the presenting refractive error for the right and left eyes. The most common presenting refractive error for the right and left eyes was compound myopia. For the participants with myopia, the mean myopic prescription was −7.69 ± 7.02 D and

−7.38 ± 7.25 D in the right and left eyes respectively. The myopic prescription ranged between −2.00 D and −22.00 D for the right and −1.50 D and −22.00 D for the left eyes. For those participants with hyperopia, the mean hyperopic prescription was +4.04 ± 5.11 D in the right eye and +7.25 ± 6.74 D in the left eye. The hyperopic prescription ranged between +0.50 D and +15.00 D for the right eye and +0.50 D and +16.00 D for the left eye. The majority of participants presented with astigmatism in the right (n = 13) and left (n = 11) eyes. Overall, with-the-rule (WTR) astigmatism was most common in the right (n = 7) and left (n = 6) eyes, followed by oblique astigmatism in the right (n = 5) and left (n = 5) eyes, and against-the-rule (ATR) astigmatism in the right eye (n = 1).

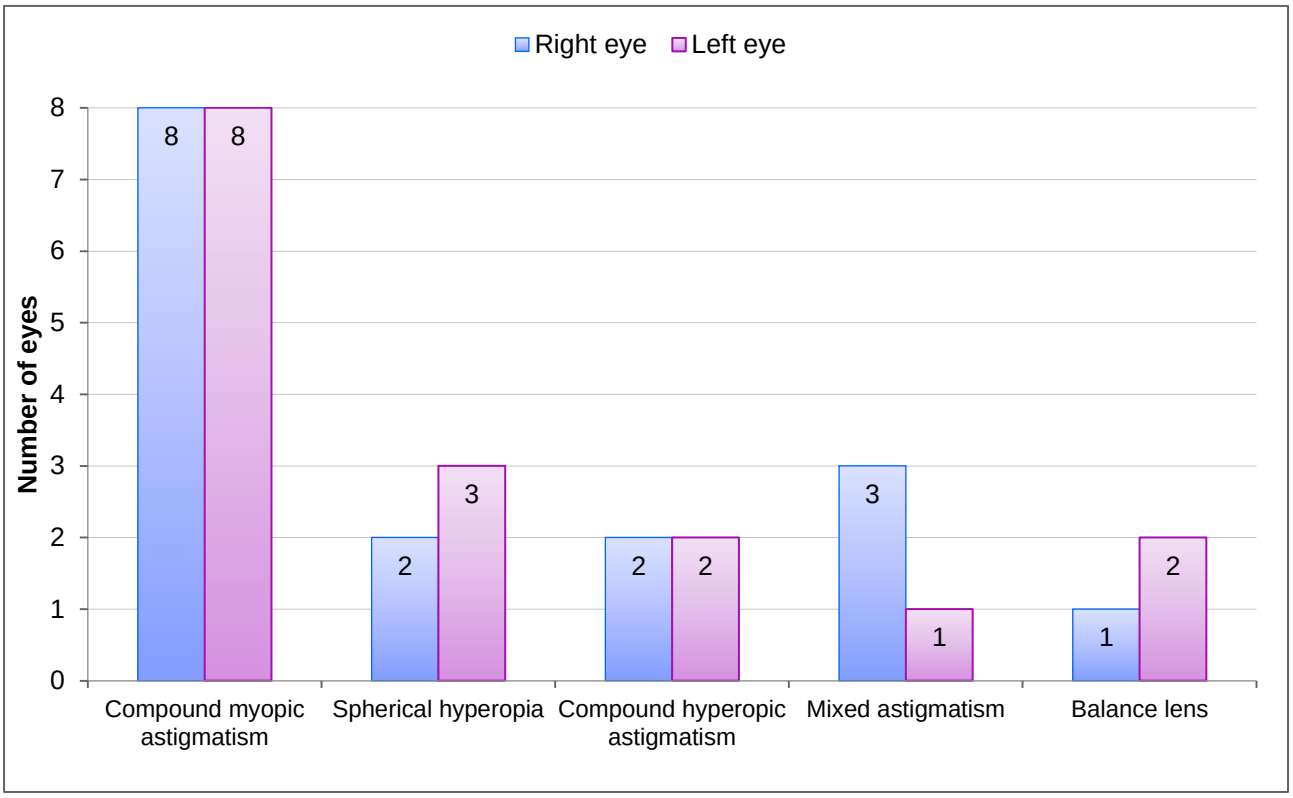

Figure 4.3: Category of presenting refractive error for the right and left eye

Table 4.7 shows the frequency of the presenting refractive error according to gender. More females than males presented with compound myopic astigmatism in the right and left eyes. In contrast, more males presented with spherical hyperopia and mixed astigmatism in the right and left eyes. Astigmatism was more common in females than males with WTR astigmatism being most common among female participants.

Table 4.7: Categories of presenting refractive error according to gender

	Right eye (n = 16)		Left eye (n = 16)	
Category	**Male (n = 8)**	**Female (n = 8)**	**Male (n = 8)**	**Female (n = 8)**
Compound myopic astigmatism	3	5	3	5
Spherical hyperopia	2	-	2	1
Compound hyperopic astigmatism	-	2	1	1
Mixed astigmatism	2	1	1	-
Balance lens	1	-	1	1
	Right eye (n = 13)		**Left eye (n = 11)**	
Astigmatism	**Male (n = 5)**	**Female (n = 8)**	**Male (n = 5)**	**Female (n = 6)**
WTR	2	5	2	4
ATR	-	1	-	-
Oblique	3	2	3	2

WTR, with-the-rule; ATR, against-the-rule

4.3.2.2 Best-corrected refractive error

Thirty-four participants required spectacles after subjective refraction, implying that 25.71% (n = 18) of the participants had uncorrected refractive error. Of the 34 participants that required spectacles, there were two more females (n = 18) than males (n = 16). For the right eye, the overall mean sphere and cylindrical powers were −1.61 ± 6.06 D and −1.83 ± 1.12 DC respectively. For the left eye, the overall mean sphere and cylindrical powers were −0.89 ± 6.75 D and −2.30 ± 0.84 DC respectively. The median sphere was −1.13 D and −1.25 D in the right and left eyes respectively. The interquartile range was from −3.38 D to +1.00 D in the right eye and from −2.50 D to +0.50 D in the left eye. For males, the mean sphere was −2.29 ± 6.26 D and −0.89 ± 7.20 D in the right and left eye respectively. For females, the mean sphere was −1.02 ± 6.03 D and −0.89 ± 6.55 D in the right and left eyes respectively. There were no significant gender differences in the mean sphere values for the right ($p = 0.576$) and left ($p = 1.000$) eyes. Females had slightly higher mean cylindrical powers in the right (−2.00 DC versus −1.61 DC) and in the left (−2.54 DC versus −2.00 DC) eyes, although these gender differences were not statistically significant ($p \geq 0.308$).

Table 4.8 categorises the frequency of best-corrected refractive error for the right and left eyes. More than 50% of the participants had myopia with spherical and compound myopia being most common. For those participants with myopia, the mean myopic prescription was −4.24 ± 5.41 D and −3.71 ± 4.99 D in the right and left eyes respectively. The range of the myopic prescription was similar in the right (−0.50 D to −22.00 D) and left (−0.25 D to −19.25 D) eyes. Of those participants that had hyperopia, spherical hyperopia was most

common. For those participants with hyperopia, the mean hyperopic prescription was +3.23 ± 4.38 D in the right eye and +5.06 ± 6.26 D in the left eye. The range of the hyperopic prescription was similar in the right (+0.50 D to +15.00 D) and left (+0.50 D to +16.00 D) eyes.

Table 4.8: Categories of best-corrected refractive error for the right and left eyes

Category	Right eye (n = 34)	Left eye (n = 34)
Spherical myopia	9	11
Compound myopic astigmatism	10	8
Simple myopic astigmatism	1	-
Spherical hyperopia	5	6
Compound hyperopic astigmatism	2	2
Mixed astigmatism	3	1
Balance lens	4	6

Less than half of the 34 participants that required spectacles had astigmatism in the right (n = 16) and left (n = 11) eyes. Overall, WTR astigmatism was the most common followed by oblique astigmatism and ATR astigmatism (Figure 4.4).

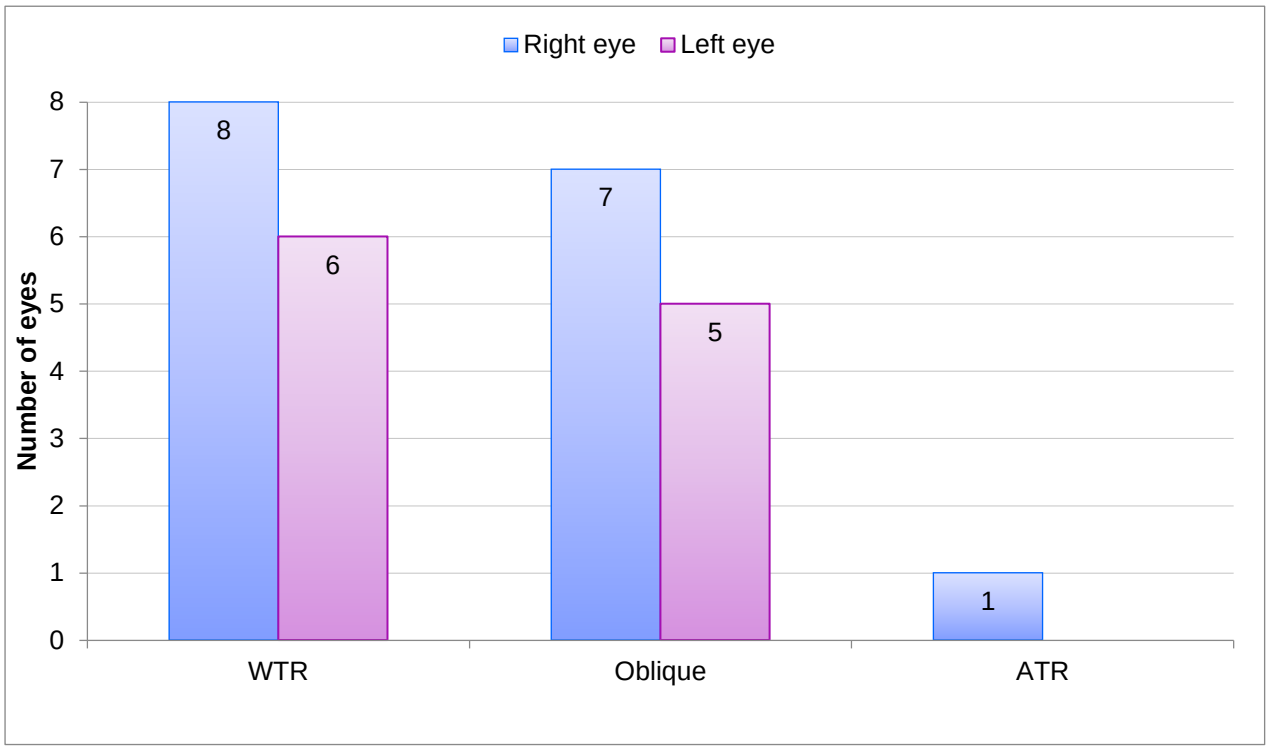

Figure 4.4: Category of astigmatism for best-corrected refractive error

Table 4.9 categorises the best-corrected refractive error according to gender. Among the male participants, spherical myopia was most common followed by compound myopic astigmatism and spherical hyperopia. Compound myopic astigmatism and spherical myopia were most common among female participants followed by spherical hyperopia. Oblique astigmatism was slightly more common among male participants and WTR astigmatism was most common among female participants. Against-the-rule astigmatism was found in the right eye of only one female participant.

Table 4.9: Categories of best-corrected refractive error according to gender

	Right eye (n = 34)		Left eye (n = 34)	
Category	**Male (n = 16)**	**Female (n = 18)**	**Male (n = 16)**	**Female (n = 18)**
Spherical myopia	3	6	7	4
Compound myopic astigmatism	5	5	3	5
Simple myopic astigmatism	-	1	-	-
Spherical hyperopia	4	1	2	4
Compound hyperopic astigmatism	-	2	1	1
Mixed astigmatism	2	1	1	-
Balance lens	2	2	2	4
	Right eye (n = 16)		**Left eye (n = 11)**	
Category	**Male (n = 7)**	**Female (n = 9)**	**Male (n = 5)**	**Female (n = 6)**
WTR	3	5	2	4
ATR	-	1	-	-
Oblique	4	3	3	2

WTR, with-the-rule; ATR, against-the-rule

4.4 Objective two: contrast sensitivity

Table 4.10 shows the contrast sensitivity of the right, left and both eyes in log CS units. The mean contrast sensitivity for the right, left and both eyes were 0.95 ± 0.47 log CS, 1.08 ± 0.41 log CS and 1.24 ± 0.36 log CS respectively (Table 4.10). The minimum contrast sensitivity ranged from 0.00 log CS to 0.56 log CS and the maximum contrast sensitivity ranged from 1.80 log CS to 1.88 log CS. The male and female participants had similar mean contrast sensitivity in the right (male 0.90 ± 0.40 log CS and female 1.00 ± 0.51 log CS; p = 0.400) and left (male 1.03 ± 0.41 log CS and female 1.12 ± 0.41 log CS; p = 0.406) eyes. When tested binocularly, females (1.34 ± 0.37 log CS) had slightly better contrast sensitivity than males (1.12 ± 0.32 log CS) and this difference was statistically significant (p = 0.036).

Table 4.10: Contrast sensitivity (log CS) in the right, left and both eyes

	Right eye (n = 65)	Left eye (n = 63)	Both eyes (n = 45)
Mean ± SD	0.95 ± 0.47	1.08 ± 0.41	1.24 ± 0.36
Minimum	0.00	0.00	0.56
Maximum	1.84	1.80	1.88

Figure 4.5 shows the categories of contrast sensitivity loss for the right and left eyes of the participants. More than 40% of the participants had moderate contrast sensitivity loss for the right and left eyes. Almost one-third of the participants had severe contrast sensitivity loss in the right and left eyes. Only 13 (20%) and five (7.94%) participants had profound contrast sensitivity loss in the right and left eyes respectively. Few participants had normal contrast sensitivity (four in the right eye and seven in the left eye). When contrast sensitivity was tested binocularly, almost 50% (n = 22) of the participants had moderate contrast sensitivity loss and one-third (n = 14) of the participants had severe contrast sensitivity loss. Only nine (20%) participants had no loss of contrast sensitivity when tested binocularly.

Figure 4.5: Categories of contrast sensitivity loss in the right and left eyes

Table 4.11 shows the frequency of the contrast sensitivity categories according to gender. Overall, majority of the male and female participants had moderate contrast sensitivity loss when considering the right, left and both eyes ($p \geq 0.057$). The frequency of male and female participants with severe contrast sensitivity loss was greater than those with

normal contrast sensitivity. When contrast sensitivity was tested binocularly, no male or female participants had profound contrast sensitivity loss (p = 0.057).

Table 4.11: Contrast sensitivity categories in the right, left and both eyes according to gender

Category	Right eye (n = 65)		Left eye (n = 63)		Both eyes (n = 45)	
	Male (n = 29)	Female (n = 36)	Male (n = 29)	Female (n = 34)	Male (n = 21)	Female (n = 24)
Normal	1	3	2	5	1	8
Moderate	12	15	14	16	12	10
Severe	11	10	10	11	8	6
Profound	5	8	3	2	0	0

4.5 Objective three: colour vision

Colour vision was assessed monocularly for each participant (Table 4.12). Overall, more than 50% of the participants passed the Panel 16 colour vision test with less than or equal to one crossing indicating either a mild or no colour vision defect. Of those who failed (≥ 2 crossings), the most common type of colour vision defect was red-green in both the right (n = 16) and left (n = 15) eyes. A deutan colour vision defect was most common in 15 (23.08%) and 10 (15.87%) participants for the right and left eyes respectively. One (1.54%) and five (7.94%) participants had a protan colour vision defect in the right and left eyes respectively. Only 13 (20%) and 10 (15.87%) participants had a blue-yellow (tritan) colour vision defect in the right and left eyes respectively.

Table 4.12: Colour vision in the right and left eyes

	Right eye (n = 65)		Left eye (n = 63)	
	Frequency	Percentage	Frequency	Percentage
No/ mild defect	36	55.38	38	60.32
Deutan	15	23.08	10	15.87
Protan	1	1.54	5	7.94
Tritan	13	20.00	10	15.87

Table 4.13 shows the frequency of colour vision defects according to gender. Overall, majority of the male and female participants passed the Panel 16 colour vision test. A red-green colour vision defect was most common among those who failed. There was no significant gender difference in the colour vision defects in the right (p = 0.379) and left (p = 0.860) eyes. Two times more females (n = 10) had a deutan colour vision defect in the right eye than males (n = 5). The distribution of blue-yellow colour vision defects in

males and females was similar with slightly more males (n = 8) having a tritan colour vision defect in the right eye than females (n = 5).

Table 4.13: Colour vision in the right and left eyes according to gender

	Right eye (n = 65)		Left eye (n = 63)	
	Male (n = 29)	**Female (n = 36)**	**Male (n = 29)**	**Female (n = 34)**
No/ mild defect	16	20	16	22
Deutan	5	10	5	5
Protan	-	1	3	2
Tritan	8	5	5	5

Of the participants that had RP (n = 3), only two right eyes and two left eyes followed Köllner's rule and presented with blue-yellow colour vision defects. Of the two participants with cataracts, only one right eye and one left eye followed Köllner's rule and presented with blue-yellow defects. The one participant with Stargardt's disease was the exception to Köllner's rule and presented with a red-green (deutan) colour vision defect in both the right and left eyes.

4.6 Objective four: central visual field

Almost 80% of the participants did not have central visual field defects in either eye (Table 4.14). Of the central visual field defects found in the right eye, metamorphopsia (n = 7) was most common followed by an absolute paracentral scotoma (n = 4). In contrast, an absolute paracentral scotoma (n = 6) was the most common finding in the left eye followed by metamorphopsia (n = 5). One participant each presented with a relative paracentral scotoma and a relative central scotoma in the right and left eyes respectively and only one participant had an absolute central scotoma in the right eye.

Table 4.14: Central visual field in the right and left eyes

	Right eye (n = 65)		Left eye (n = 63)	
	Frequency	**Percentage**	**Frequency**	**Percentage**
No defect	52	80.00	51	80.95
Metamorphopsia	7	10.77	5	7.94
Absolute central scotoma	1	1.54	-	-
Absolute paracentral scotoma	4	6.15	6	9.52
Relative central scotoma	-	-	1	1.59
Relative paracentral scotoma	1	1.54	-	-

Table 4.15 shows the frequency of central visual field defects according to gender. The majority of both male and female participants did not have any defects in the central visual field. There was no significant gender difference in the central visual field defects in the right (p = 0.716) and left (p = 0.352) eyes. For the male participants, the most common central visual field defect was metamorphopsia in the right eye (n = 3) and an absolute paracentral scotoma in the left eye (n = 4). For the female participants, the most common visual field defect was metamorphopsia followed by an absolute paracentral scotoma in both the right and left eyes. Only one male participant had a relative paracentral scotoma in the right eye and only one female participant had a relative central scotoma in the left eye (Table 4.15).

Table 4.15: Central visual field in the right and left eye according to gender

	Right eye (n = 65)		Left eye (n = 63)	
	Male (n = 29)	**Female (n = 36)**	**Male (n = 29)**	**Female (n = 34)**
No defect	23	29	24	27
Metamorphopsia	3	4	1	4
Absolute central scotoma	-	1	-	-
Absolute paracentral scotoma	2	2	4	2
Relative central scotoma	-	-	-	1
Relative paracentral scotoma	1	-	-	-

4.7 Objective five: quality of life

Table 4.16 shows the frequency of responses for each question in the seven domains that are assessed in the Cardiff Visual Ability Questionnaire for Children (CVAQC). Over 50% of the participants reported that their school lessons were ‘easy’ and ‘very easy’. More than 80% (n = 59) of the participants reported that their language lessons were ‘easy’ and ‘very easy’ and only 4% (n = 3) reported that it was ‘difficult’. The most difficult lessons were science and geography as more than 30% of participants reported that each lesson was ‘difficult’ and ‘very difficult’. The majority of participants reported ‘easy’ for each question in the near vision domain except for ‘reading the smallest print in text books’ and ‘reading restaurant menus’. Forty-three percent (n = 30) and 38.57% (n = 27) of participants reported that ‘reading the smallest print in text books’ and ‘reading restaurant menus’ respectively was ‘difficult’.

More than one-third (n = 26) of the participants reported that ‘reading the board in the class room’ was ‘difficult’ and only three participants reported that it was ‘very easy’. Seventy percent (n = 49) indicated that ‘watching television’ was ‘easy’ and/or ‘very easy’

and seven participants reported that it was ‘very difficult’. Over 40% (n = 31) reported that watching a film at the cinema was ‘difficult’ and ‘very difficult’, and 8.57% (n = 6) did not visit a cinema. In the fourth domain (getting around) more than 60% of the participants reported that ‘going out alone in the day light’ and ‘using public transport’ was ‘easy’ and/or ‘very easy’. Almost 60% (n = 41) found that ‘walking in a crowded place’ was ‘difficult’ and/or ‘very difficult’. ‘Reading bus or train time tables on a screen at a station’ was reported as either ‘difficult’ and/or ‘very difficult’ for three-quarters of the participants (n = 52).

With regard to social interaction, the majority of participants found that ‘chatting with friends’ was ‘easy’ and only two reported that it was ‘very difficult’. A quarter (n = 17) of the participants found that ‘recognizing faces or identifying friends sitting close by or at arm length’ was ‘difficult’ and/or ‘very difficult’. Less than half (n = 31) of the participants reported ‘seeing your friends in a playground’ as ‘difficult’ and ‘very difficult’. The majority of participants reported that performing each task in domain six (entertainment) was ‘easy’. Almost 60% (n = 40) found that ‘using a playstation’ was ‘easy’ and/or ‘very easy’ and only six participants reported that this task was ‘very difficult’. Nearly one-third (n = 21) of the participants stated that ‘playing computer games’ and ‘using an IPOD/MP3/MP4 player’ was ‘difficult’ and ‘very difficult’. The most common response for the questions in domain seven (sports) was ‘easy’. Almost 70% of participants found that ‘swimming’ and ‘taking part in athletics’ was ‘easy’ and/or ‘very easy’. ‘Playing ball games’ was reported as ‘difficult’ and/or ‘very difficult’ in 35.71% (n = 25) of the participants.

The overall visual ability score for the participants was −0.27 ± 0.74 log units with a minimum of −1.91 log units and maximum of 1.28 log units. Males had significantly better QoL than females (−0.46 ± 0.71 log units versus −0.10 ± 0.72 log units, p = 0.036). The mean visual ability score was further analysed according to the two age categories defined by the WHO. Participants aged 10 years to 13 years (n = 29) had a visual ability score of −0.06 ± 0.79 log units and participants aged 14 years to 19 years (n = 41) had a visual ability score of −0.41 ± 0.66 log units. Participants aged 14 years to 19 years had significantly better visual ability scores than those aged 10 years to 13 years (p = 0.050).

Table 4.16: Frequency and percentages of responses for questions in the CVAQC

Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find:	Very easy (%)	Easy (%)	Difficult (%)	Very difficult (%)	Don't do for other reason/ not interested in doing this (%)
DOMAIN 1: EDUCATION					
1. your maths lessons?	13 (18.57)	37 (52.86)	12 (17.14)	8 (11.43)	-
2. your science lessons?	7 (10.00)	30 (42.86)	19 (27.14)	4 (5.71)	10 (14.29)
3. your geography lessons?	8 (11.43)	35 (50.00)	18 (25.71)	4 (5.71)	5 (7.14)
4. your language lessons?	20 (28.57)	39 (55.71)	3 (4.29)	7 (10.00)	1 (1.43)
DOMAIN 2: NEAR VISION					
5. reading text books and work sheets you are given in your school?	16 (22.86)	35 (50.00)	17 (24.29)	1 (1.43)	1 (1.43)
6. reading the smallest print in your text books?	6 (8.57)	11 (15.71)	30 (42.86)	21 (30.00)	2 (2.86)
7. drawing, colouring or painting?	19 (27.14)	33 (47.14)	11 (15.71)	6 (8.57)	1 (1.43)
8. reading text messages on your mobile phone?	12 (17.14)	32 (45.71)	19 (27.14)	4 (5.71)	3 (4.29)
9. reading restaurant menus?	4 (5.71)	26 (37.14)	27 (38.57)	7 (10.00)	6 (8.57)
DOMAIN 3: DISTANCE VISION					
10. reading the board in your class room?	3 (4.29)	26 (37.14)	26 (37.14)	15 (21.43)	-
11. watching television?	13 (18.57)	36 (51.43)	14 (20.00)	7 (10.00)	-
12. watching film at the cinema?	8 (11.43)	25 (35.71)	26 (37.14)	5 (7.14)	6 (8.57)
DOMAIN 4: GETTING AROUND					
13. going out alone in the day light?	10 (14.29)	35 (50.00)	16 (22.86)	5 (7.14)	4 (5.71)
14. walking in a crowded place?	5 (7.14)	23 (32.86)	30 (42.86)	11 (15.71)	1 (1.43)
15. using public transport (bus/train)?	8 (11.43)	35 (50.00)	18 (25.71)	6 (8.57)	3 (4.29)
16. reading bus or train time tables on a screen at a station?	2 (2.86)	10 (14.29)	35 (50.00)	17 (24.29)	6 (8.57)

Table 4.16: Frequency and percentages of responses for questions in the CVAQC (continued)

	Very easy (%)	Easy (%)	Difficult (%)	Very difficult (%)	Don't do for other reason/ not interested in doing this (%)
DOMAIN 5: SOCIAL INTERACTION					
17. chatting with your friends?	13 (18.57)	44 (62.86)	11 (15.71)	2 (2.86)	-
18. recognizing faces or identifying your friends sitting close by or at your arm length?	15 (21.43)	38 (54.29)	11 (15.71)	6 (8.57)	-
19. seeing your friends in a playground?	8 (11.43)	30 (42.86)	22 (31.43)	9 (12.86)	1 (1.43)
DOMAIN 6: ENTERTAINMENT					
20. using a playstation?	9 (12.86)	31 (44.29)	17 (24.29)	6 (8.57)	7 (10.00)
21. playing computer games	7 (10.00)	37 (52.86)	18 (25.71)	3 (4.29)	5 (7.14)
22. using your IPOD/MP3/MP4 players?	10 (14.29)	29 (41.43)	12 (17.14)	9 (12.86)	10 (14.29)
DOMAIN 7: SPORTS					
23. swimming?	13 (18.57)	34 (48.57)	15 (21.43)	5 (7.14)	3 (4.29)
24. taking part in athletics?	11 (15.71)	36 (51.43)	13 (18.57)	4 (5.71)	6 (8.57)
25. playing ball games?	11 (15.71)	29 (41.43)	19 (27.14)	6 (8.57)	5 (7.14)

4.8 Objective six: visual function according to the main cause of visual impairment

4.8.1 Distance visual acuity

Table 4.17 shows the mean unaided and best-corrected VA for the right, left and both eyes according to the main cause of VI. The mean unaided VA for the right eye ranged from 0.85 ± 0.17 logMAR to 1.13 ± 0.25 logMAR. There was a significant difference in mean unaided VA for the right eye for all causes of VI ($p < 0.001$) (Table 4.17). Participants with OCA had significantly better unaided VA in the right eye than participants with anterior segment disorders ($p = 0.034$), posterior segment disorders ($p = 0.007$) and participants with VI due to other causes ($p < 0.001$). The mean unaided VA for the left eye ranged from 0.83 ± 0.20 logMAR to 1.15 ± 0.30 logMAR. There was a significant difference in mean unaided VA for the left eye for all causes of VI ($p = 0.004$) (Table 4.17). Participants with OCA had significantly better unaided VA in the left eye than participants with anterior segment disorders ($p = 0.005$) and participants with VI due to other causes ($p = 0.003$). The mean unaided binocular VA ranged from 0.81 ± 0.16 logMAR to 0.98 ± 0.24 logMAR and was not statistically significant based on the main cause of VI ($p = 0.201$).

The mean best-corrected VA for the right eye ranged from 0.81 ± 0.17 logMAR to 1.06 ± 0.26 logMAR and was significantly different for all the causes of VI ($p = 0.005$). Participants with OCA had significantly better best-corrected VA in the right eye than participants with anterior segment disorders ($p = 0.014$) and participants with VI due to other causes ($p = 0.002$). The mean best-corrected VA for the left eye ranged from 0.81 ± 0.18 logMAR to 1.14 ± 0.30 logMAR and was significantly different for all the causes of VI ($p = 0.005$). Participants with anterior segment disorders had significantly poorer best-corrected VA in the left eye than participants with posterior segment disorders ($p = 0.006$) and OCA ($p = 0.001$). In addition, participants with OCA had significantly better best-corrected VA in the left eye than participants with VI due to other causes ($p = 0.033$). The mean best-corrected binocular VA ranged from 0.70 logMAR to 0.98 logMAR.

Table 4.17: Mean unaided and best-corrected VA for the right, left and both eyes according to the main cause of VI

		ASD	PSD	OCA	Other	p value
Unaided	Right eye	1.07 ± 0.26	1.03 ± 0.19	0.85 ± 0.17	1.13 ± 0.25	< 0.001
	Left eye	1.15 ± 0.30	0.95 ± 0.25	0.83 ± 0.20	1.06 ± 0.21	0.004
	Both eyes	0.98	0.88 ± 0.28	0.81 ± 0.16	0.98 ± 0.24	0.201
Best-corrected	Right eye	1.06 ± 0.26	0.94 ± 0.20	0.81 ± 0.17	1.03 ± 0.25	0.005
	Left eye	1.14 ± 0.30	0.85 ± 0.24	0.81 ± 0.18	0.95 ± 0.14	0.005
	Both eyes	0.98	0.70 ± 0.19	0.79 ± 0.15	0.85 ± 0.14	0.124

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, oculocutaneous albinism

Table 4.18 categorises the level of VI based on the best-corrected VA in the better-seeing eye according to the main cause of VI. Overall for each cause of VI, the majority of participants had moderate VI. Two-thirds (n = 4) of the participants with anterior segment disorders had moderate VI. Of the participants with posterior segment disorders 90.48% (n = 19) and 9.52% (n = 2) had moderate and severe VI respectively. Of the participants with OCA, 92.86% (n = 26) had moderate VI and 7.14% (n = 2) had severe VI. Eleven participants with VI due to other causes had moderate VI and four had severe VI (Table 4.18).

Table 4.18: Category of VI based on the best-corrected VA in the better-seeing eye according to the main cause of VI

	N	Moderate VI (%)	Severe VI (%)
Anterior segment disorders	6	4 (66.67)	2 (33.33)
Posterior segment disorders	21	19 (90.48)	2 (9.52)
OCA	28	26 (92.86)	2 (7.14)
Other	15	11 (73.33)	4 (26.67)

VI, visual impairment; OCA, oculocutaneous albinism

4.8.2 Refractive error

Of the 34 participants that required spectacles, only one had an anterior segment disorder, 13 had posterior segment disorders, 11 had OCA and nine had VI due to other causes. Table 4.19 shows the mean sphere and cylindrical powers for the right and left eyes for each of the four main causes of VI. Overall for the right eyes of the participants, those with anterior segment disorders had a mean hyperopic sphere power and those with posterior segment disorders, OCA and VI due to other causes had a mean myopic sphere power. For the left eyes, participants with anterior and posterior segment disorders had a

mean hyperopic sphere power and those with OCA and VI due to other causes had a mean myopic sphere power.

When the cylindrical component was considered, only participants with anterior segment disorders did not have astigmatism (Table 4.19). Participants with OCA had significantly higher amounts of astigmatism in the right (−2.95 ± 0.94 DC) and left (−2.85 ± 0.68 DC) eyes ($p \leq 0.041$). Participants with VI due to other causes had the least amount of astigmatism for the right (−1.00 ± 0.64 DC) and left (−1.25 ± 1.06 DC) eyes.

Table 4.19: Mean sphere and cylindrical powers for the right and left eyes according to the main cause of VI

		ASD (n = 1)	PSD (n = 13)	OCA (n = 11)	Other (n = 9)	p value
Sphere power	**Right eye**	+3.00	−0.80 ± 7.12	−1.00 ± 3.00	−4.06 ± 7.55	0.557
	Left eye	+4.50	+1.00 ± 9.00	−0.98 ± 2.81	−4.25 ± 6.96	0.385
Cylindrical power	**Right eye**	-	−1.58 ± 0.85	−2.95 ± 0.94	−1.00 ± 0.64	0.007
	Left eye	-	−2.13 ± 0.25	−2.85 ± 0.68	−1.25 ± 1.06	0.041

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

Table 4.20 shows the categories of refractive error for the right and left eyes of participants according to the main cause of VI. Spherical myopia and compound myopic astigmatism were the most common categories of refractive error for the different causes of VI. The most common category of refractive error for participants with posterior segment disorders was spherical myopia for both the right and left eyes. This was followed by mixed astigmatism in the right eye and an equal presentation of compound myopic astigmatism and spherical hyperopia in the left eye. The most common categories of refractive error in participants with OCA were compound myopic astigmatism followed by spherical myopia and spherical hyperopia in both the right and left eyes. The most common categories of refractive error in participants with VI due to other causes were compound myopic astigmatism and spherical myopia in both the right and left eyes. Only one participant with an anterior segment disorder had spherical hyperopia in both the right and left eyes.

Table 4.20: Categories of refractive error for the right and left eyes according to the main cause of VI

Category	ASD		PSD		OCA		Other	
	Right	Left	Right	Left	Right	Left	Right	Left
Spherical myopia	-	-	4	4	3	3	2	4
Compound myopic astigmatism	-	-	2	2	4	4	4	2
Simple myopic astigmatism	-	-	-	-	-	-	1	-
Spherical hyperopia	1	1	1	2	2	2	1	1
Compound hyperopic astigmatism	-	-	1	1	1	1	-	-
Mixed astigmatism	-	-	3	1	-	-	-	-
Balance lens	-	-	1	2	1	1	1	2

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

Only participants with posterior segment disorders, OCA and VI due to other causes had astigmatism (Figure 4.6). For the participants with posterior segment disorders, the majority had oblique astigmatism followed by WTR and ATR astigmatism in the right and left eyes. For the participants with OCA, the majority had WTR astigmatism followed by oblique astigmatism in the right and left eyes. Overall for the participants with VI due to other causes, oblique astigmatism was most common followed by WTR astigmatism in the right and left eyes.

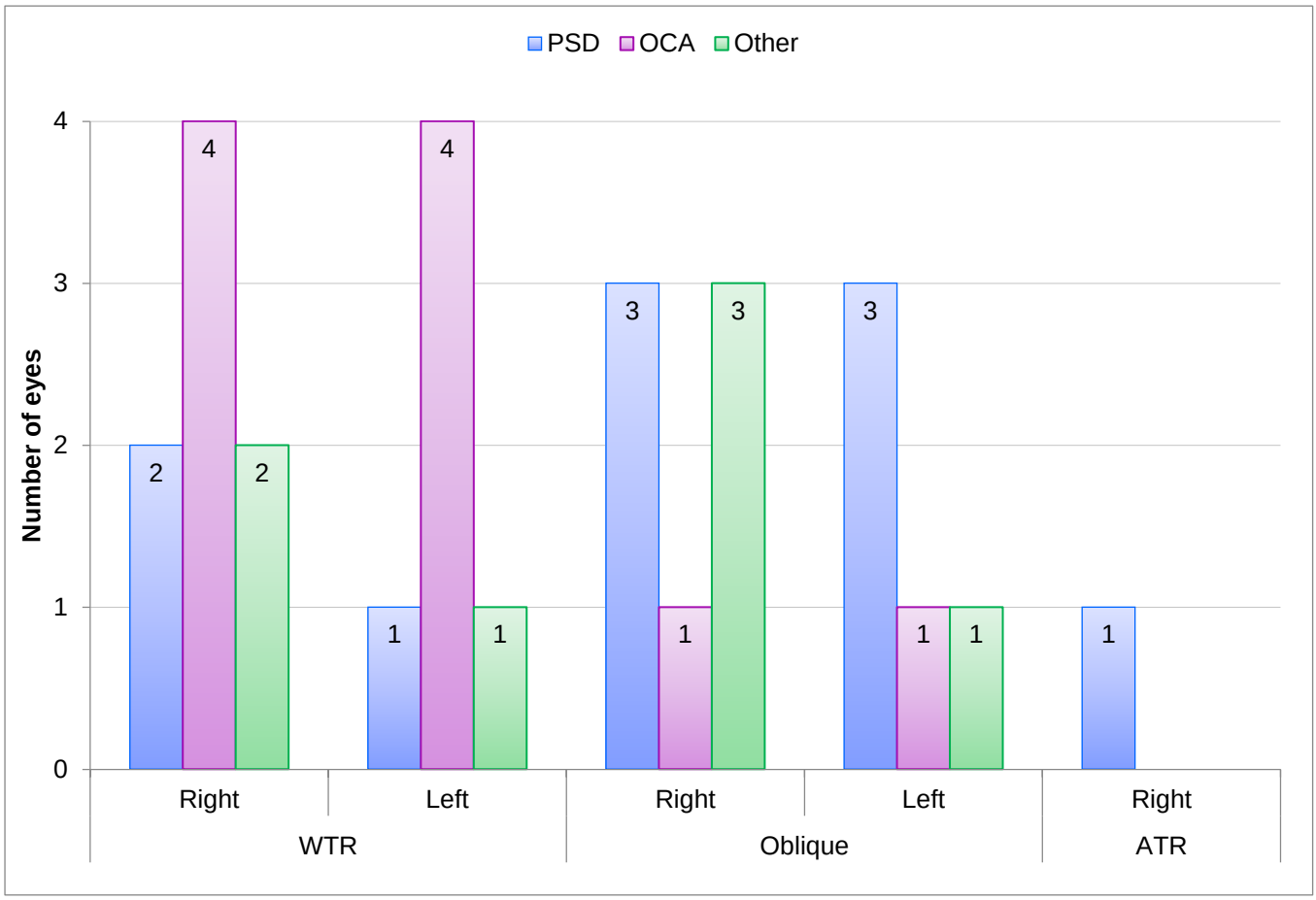

Figure 4.6: Categories of astigmatism for the right and left eyes according to the main cause of VI

4.8.3 Contrast sensitivity

Table 4.21 shows the mean contrast sensitivity in the right, left and both eyes according to the main cause of VI. Overall, participants with OCA had better contrast sensitivity in the right, left and both eyes. The mean contrast sensitivity in the right eye ranged from 0.70 ± 0.46 log CS to 1.23 ± 0.33 log CS ($p < 0.001$). The mean contrast sensitivity in the left eye ranged from 0.83 ± 0.27 log CS to 1.29 ± 0.33 log CS ($p = 0.001$). Participants with OCA had significantly better contrast sensitivity in the right and left eyes than participants with posterior segment disorders ($p \leq 0.004$) and VI due to other causes ($p < 0.001$). The mean binocular contrast sensitivity ranged from 0.93 ± 0.26 log CS to 1.43 ± 0.30 log CS and was significantly different according to the main causes of VI ($p < 0.001$).

Table 4.21: Contrast sensitivity (log CS) in the right, left and both eyes according to the main cause of VI

	ASD	PSD	OCA	Other	p value
Right eye (n = 65)	0.92 ± 0.62	0.73 ± 0.40	1.23 ± 0.33	0.70 ± 0.46	< 0.001
Left eye (n = 63)	1.00 ± 0.60	0.95 ± 0.41	1.29 ± 0.33	0.83 ± 0.27	0.001
Both eyes (n = 45)	0.96	0.93 ± 0.26	1.43 ± 0.30	1.00 ± 0.23	< 0.001

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

Table 4.22 shows the categories of contrast sensitivity loss according to the main cause of VI. The majority of participants with posterior segment disorders had severe loss of contrast sensitivity in the right eye and binocularly, and moderate loss of contrast sensitivity in the left eye. For participants with OCA, the majority had moderate loss of contrast sensitivity in the right, left and both eyes. For participants with VI due to other causes, there was an equal presentation of moderate, severe and profound loss of contrast sensitivity in the right eye. For the left eye and both eyes of participants with VI due to other causes, the most common contrast sensitivity category was severe loss followed by moderate loss.

Table 4.22: Frequency of contrast sensitivity categories according to the main cause of VI in the right, left and both eyes

	Category	ASD	PSD	OCA	Other	p value
Right (n = 65)	**No loss**	1	-	3	-	0.011
	Moderate loss	1	3	18	5	
	Severe loss	1	9	6	5	
	Profound loss	2	5	1	5	
Left (n = 63)	**No loss**	1	-	6	-	0.003
	Moderate loss	2	7	18	3	
	Severe loss	1	6	4	10	
	Profound loss	1	3	-	1	
Both (n = 45)	**No loss**	-	-	9	-	0.017
	Moderate loss	-	4	14	4	
	Severe loss	1	5	3	5	
	Profound loss	-	-	-	-	

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

4.8.4 Colour vision

Table 4.23 shows the frequency of colour vision defects according to the main cause of VI. Overall, 60% of participants with anterior segment disorders had tritan colour vision

defects in the right and left eyes. The majority of participants with posterior segment disorders had no colour vision defects in the right eye (n = 7) and deutan colour vision defects in the left eye (n = 7). More than 75% of participants with OCA did not have colour vision defects in both the right (n = 22) and left (n = 21) eyes. The majority of participants with VI due to other causes did not have colour vision defects for both the right and left eyes.

Table 4.23: Colour vision according to the main cause of VI in the right and left eyes

		ASD	PSD	OCA	Other	p value
Right (n = 65)	No defect	-	7	22	7	0.037
	Deutan	2	5	4	4	
	Protan	-	1	-	-	
	Tritan	3	4	2	4	
Left (n = 63)	No defect	2	5	21	10	0.004
	Deutan	-	7	3	-	
	Protan	-	2	2	1	
	Tritan	3	2	2	3	

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

4.8.5 Central visual field

Table 4.24 shows the frequency of central visual field defects according to the main cause of VI. Only participants with anterior segment disorders did not have central visual field defects in the right eye. Overall, less than 40% of participants with posterior segment disorders, OCA and VI due to other causes had central visual field defects in the right eye. For the left eye, less than half of the participants with anterior segment disorders, posterior segment disorders and VI due to other causes had central visual field defects. Only participants with OCA did not have central visual field defects in the left eye. Overall for participants with posterior segment disorders, the most common type of central visual field defect was an absolute paracentral scotoma in the right (n = 3) and left (n = 4) eyes. Only three participants with OCA had central visual field defects in the right eye. Of this metamorphopsia was most common (n = 2) followed by a relative paracentral scotoma (n = 1). For participants with VI due to other causes, the two most common central visual field defects were metamorphopsia and an absolute paracentral scotoma in both eyes.

Table 4.24: Central visual field according to the main cause of VI in the right and left eyes

		ASD	PSD	OCA	Other	p value
Right (n = 65)	No defect	5	11	25	11	0.366
	Metamorphopsia	-	2	2	3	
	Absolute central scotoma	-	1	-	-	
	Absolute paracentral scotoma	-	3	-	1	
	Relative paracentral scotoma	-	-	1	-	
Left (n = 63)	No defect	4	9	28	10	0.044
	Metamorphopsia	1	2	-	2	
	Absolute paracentral scotoma	-	4	-	2	
	Relative central scotoma	-	1	-	-	

ASD, anterior segment disorders; PSD, posterior segment disorders; OCA, Oculocutaneous albinism

4.9 Objective seven: quality of life according to the main cause of visual impairment

Table 4.25 shows the mean, minimum and maximum visual ability scores according to the main cause of VI. Visual ability scores ranged from −0.37 ± 0.79 log units to −0.11 ± 0.79 log units. There was no statistically significant difference in the mean visual ability score according to the main cause of VI (p = 0.809). Overall, participants with OCA had slightly better QoL and participants with anterior segment disorders had relatively worse QoL.

Table 4.25: Visual ability score according to the main cause of VI

Cause of VI	N	Mean	Minimum	Maximum
Anterior segment disorders	6	−0.11 ± 0.79	−1.57	0.71
Posterior segment disorders	21	−0.23 ± 0.76	−1.47	1.08
Oculocutaneous albinism	28	−0.37 ± 0.79	−1.91	1.28
Other	15	−0.19 ± 0.62	−1.49	0.67

4.10 Conclusion

This chapter presented the results of the study according to the objectives stated in chapter one. This chapter also included a description of the demographic and ocular characteristics of the sample. Visual function (distance VA, refractive error, contrast sensitivity, colour vision as well as central visual field) and QoL were analysed in objectives one to five. Visual function and QoL were further analysed according to gender for these objectives. Objectives six and seven presented a comparison of visual function and QoL respectively according to the main causes of VI.

CHAPTER 5. DISCUSSION

5.1 Introduction

This chapter discusses the results presented in the previous chapter in relation to the literature reviewed in chapter two. The discussion begins with the demographic and ocular characteristics of the participants including the sample size, age, gender and cause of visual impairment (VI). This is followed by a discussion of the results according to each objective presented in chapter one. Objectives one to four relate to visual function and consist of distance visual acuity (VA) and refractive error, contrast sensitivity, colour vision as well as central visual field, while quality of life (QoL) is discussed in objective five. Objectives six and seven compared visual function and QoL according to the main causes of VI.

5.2 Demographic and ocular characteristics

5.2.1 Sample size

A total of 70 participants out of the estimated 80 participated in the study. Only 213 students were registered at Arthur Blaxall School at the time of data collection (Govender, V 2017, pers. comm., 15 March). Together with the relatively small number of students registered at the school, the study inclusion criteria significantly limited the eligibility of most students from participating in the study. However, these factors do not limit the credibility of the study since the number of participants included in this study is still larger than that of previous studies that assessed visual function and/or QoL in adolescents with VI (Kalloniatis & Johnston 1990; Haymes et al. 1996; Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Labib et al. 2009; Burstedt & Mönestam 2010; El Byoumi & Mousa 2010; Ganesh et al. 2013; Khanal, Pokharel & Kandel 2016; Tončić et al. 2016).

5.2.2 Age

The World Health Organisation (WHO) describes an adolescent as an individual aged between 10 years and 19 years (WHO 2014). Consequently, only individuals aged between 10 years and 19 years were included in the sample as this study used a case report research study design and focused on adolescents with VI. Moreover, this age range was chosen since few studies have focused specifically on adolescents with VI. Previous studies that reported on visual function and/or QoL in individuals with VI included children younger than 10 years as well as adults in the study samples (Haymes et al. 1996; Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Labib et al. 2009; Burstedt & Mönestam 2010; Lee et al. 2010; El Byoumi & Mousa 2010; Ganesh et al. 2013; Mokaya et al. 2014; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016; Tončić et al.

2016; Tunay et al. 2016). The age range in this study is similar to that of Tončić et al. (2016) who reported an age range of nine years to 18 years.

The mean age of the participants in this study was 13.83 ± 2.28 years, which is similar to the mean age of participants in six other studies. Ganesh et al. (2013) and Tunay et al. (2016) reported mean ages of 10.50 ± 3.20 years and 10.60 ± 3.00 years respectively. El Byoumi and Mousa (2010) and Labib et al. (2009) reported mean ages of 11.28 ± 3.50 years and 11.04 ± 2.58 years respectively. Mokaya et al. (2014) reported a mean age of 12.59 ± 4.16 years and Tončić et al. (2016) reported a mean age of 13.20 ± 4.10 years.

5.2.3 Gender

The study sample consisted of slightly more female participants (54.29%) than male participants (45.71%). This pattern of gender allocations is similar to the studies by Sampath and Bedell (2002), Burstedt and Mönestam (2010), El Byoumi and Mousa (2010) and Mokaya et al. (2014) who also reported slightly more female than male participants. This unequal gender distribution also adds to the evidence that females may be at a higher risk for VI than males (Resnikoff et al. 2004; WHO 2007; Schellini et al. 2009). However, there are some studies that have consisted of more male participants than female participants (Labib et al. 2009; Lee et al. 2010; Ganesh et al. 2013; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016; Tunay et al. 2016). This finding may be explained by the social and/or cultural barriers that prevent females from accessing health care services (Lewallen & Courtright 2001; Guo et al. 2017). Even though there were slightly more female than male participants in this study, the mean age of each gender was similar and this facilitated a comparison of both visual function and QoL for each gender.

5.2.4 Race

Arthur Blaxall School is a government funded school that registers students of all races. Despite this, the majority of students registered at Arthur Blaxall School are Black, with only a small percentage consisting of students of other races. As a result, more than 95% of participants in the study sample were Black. Consequently, this unequal distribution prevented a comparison of visual function and QoL according to race.

5.2.5 Cause of visual impairment

The most common cause of VI in this study was oculocutaneous albinism (OCA) followed by posterior segment disorders, anterior segment disorders and VI due to other causes that did not fall within the previously mentioned categories. These findings are similar to

results reported by Awad et al. (2017) who found that ocular albinism was most common in individuals with VI aged 13 years to 18 years followed by posterior segment disorders (such as macular dystrophy) and anterior segment disorders (such as cataract) in individuals with VI aged zero years to 18 years. In contrast, the WHO (2007) reported that the most common causes of VI in children and adolescents following uncorrected refractive errors were posterior segment disorders (such as retinopathy of prematurity (ROP) and glaucoma) and anterior segment disorders (such as cataract and corneal scarring). The discrepancy may be due to the fact that the WHO (2007) reported on the global prevalence of VI in children and adolescents whereas this study was conducted in a school specifically for children and adolescents with VI in a developing country.

Individuals with OCA are more likely to attend special schools rather than mainstream schools as, in addition to their poor vision, these individuals also require palliative care for physiological problems such as sun protection (Gaigher, Lund & Makuya 2002; Lund & Gaigher 2002). This may explain the larger number of participants with OCA in this study. In addition, individuals with posterior segment disorders are expected to have poorer vision as either the optic nerve, macula or both may be affected. Consequently, these individuals are more likely to have VI in categories three to five and thus may have been underrepresented in the sample due to the study exclusion criteria. The cause of VI was unknown in 13 participants despite reviewing the school records of these participants. It is possible that these participants may have also had posterior segment disorders as the main cause of VI however this could not be confirmed.

Anterior segment disorders were the least common cause of VI in this study. In contrast, Santos-Bueso et al. (2015) and Asferaw, Woodruff and Gilbert (2017) reported that anterior segment disorders were the major cause of VI in children and adolescents in two studies conducted in Ethiopia. This discrepancy may be since the anterior segment disorders (corneal disease) were due to nutritional disorders (vitamin A deficiency) and infection (measles) in the Ethiopian studies. In this study, VI due to nutritional and/or infectious disorders occurred in less than 10% of the participants and may be attributed to the efforts of the VISION 2020 initiative. In the year 2000, VISION 2020 was launched in Pretoria, South Africa, and later adopted in Durban in the year 2002 (Pizzarello et al. 2004). This initiative has since progressively reduced VI due to avoidable causes such as nutritional and infectious disorders.

Even though there were slightly more female than male participants, there was no significant gender difference in the cause of VI. This finding is similar to a recent study by

Hashemi et al. (2017) who also reported no significant gender distribution of the cause of VI. The most common presenting signs in this sample were nystagmus, cutaneous hypopigmentation and strabismus. This is similar to findings reported by Khanal, Pokharel and Kandel (2016) where 84% of participants had nystagmus and Tunay et al. (2016) where the most common presenting signs were nystagmus and strabismus. The distribution of presenting signs was similar in the male and female participants in this study.

5.3 Objective one: distance visual acuity and refractive error

5.3.1 Distance visual acuity

The mean unaided VA ranged from 0.86 logMAR to 0.98 logMAR (Snellen 6/48 to 6/60) and the mean best-corrected VA ranged from 0.79 logMAR to 0.91 logMAR (Snellen 6/38 to 6/48) for the right, left and both eyes. The difference between the mean unaided and best-corrected VA showed an improvement of at least one logMAR line in each the right, left and both eyes. This improvement in mean best-corrected VA is similar to that reported by Schwering et al. (2015) where the majority of participants also showed an improvement of one logMAR line and Khanal, Pokharel and Kandel (2016) who reported a mean improvement of two logMAR lines following refraction. In this study, the unaided and best-corrected VA were correlated in the right, left and both eyes for all participants. This corresponds with Khanal, Pokharel and Kandel (2016) who also reported a positive correlation between unaided and best-corrected distance VA.

The mean best-corrected VA was similar to the mean VA reported by Wildsoet, Oswald and Clark (2000), Labib et al. (2009), Lee et al. (2010), Ganesh et al. (2013) and Schwering et al. (2015). This is notable as these studies included individuals with moderate to severe VI (VA worse than 0.48 logMAR (6/18) to equal to or better than 1.30 logMAR (6/120)) however the mean best-corrected VA in each of these studies was in the range of 0.77 logMAR to 0.90 logMAR (6/38 to 6/48).

When comparing the category of VI based on unaided and best-corrected VA, the number of participants with unaided VA classified as severe VI or worse decreased following refraction. This implies that refraction had improved the VA of these participants such that the number of participants in that classification of VI was altered. The increase in the number of participants with moderate VI based on best-corrected VA confirms this inference. A similar trend was reported by Khanal, Pokharel and Kandel (2016) who found that refraction improved the VA of participants from a category of worse impairment based on presenting VA to a category of less impairment based on best-corrected VA.

Even though the results show that males had slightly better unaided and best-corrected VA in the right and left eyes, this was not significant. Both male and female participants had similar unaided and best-corrected binocular VA and both showed an improvement of at least one logMAR line from unaided to best-corrected binocular VA. Many of the studies that assessed VA in individuals with VI reported the results for the entire sample and not according to the two gender groups which limits the comparison of the VA findings for the male and female participants observed in this study.

Since this study included participants with moderate and severe VI, the majority of the participants had either moderate or severe VI in at least one eye. Overall, the majority of participants had moderate VI followed by severe VI. This is similar to Khanal, Pokharel and Kandel (2016) who reported that more than 50% of participants had moderate VI followed by severe VI. In contrast, Ganesh et al. (2013) reported severe VI to be most common followed by moderate VI. This disparity in findings may be attributed to the different causes of VI in each study. In this study, the majority of participants had OCA and is similar to Khanal, Pokharel and Kandel (2016) who included only individuals with OCA in their study. Conversely, Ganesh et al. (2013) included individuals with primarily posterior segment disorders (such as retinal dystrophy). Individuals with posterior segment disorders are expected to have more severe impairment of vision as the retina is affected (Bastawrous et al. 2014).

5.3.2 Refractive error

In this study, only 16 participants presented with spectacles while an additional 18 participants required spectacles as there was an improvement in VA following subjective refraction. Two other studies also reported that VA improved in more than 50% of participants following refraction (Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). This implies that routine refraction is necessary in children and adolescents with VI as any improvement in VA is beneficial in these individuals (DeCarlo, Woo & Woo 2006, p. 1597; Schwering et al. 2015).

The mean best-corrected sphere for the right and left eyes were −1.61 ± 6.06 D and −0.89 ± 6.75 D respectively and is similar to other studies that also reported mean myopic refractive errors (Sampath & Bedell 2002; Lee et al. 2010; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Interestingly, the mean best-corrected sphere and cylindrical powers for the right eye as well as the sphere for the left eye were less myopic than the mean presenting refractive error while the cylindrical power for the left eye remained the same. A similar trend has not been reported in the literature as previous studies reported

only the best-corrected refractive error. The mean best-corrected sphere was similar for both male and female participants in this study and showed no significant gender difference. The mean myopic prescription was −4.24 ± 5.41 D and −3.71 ± 4.99 D in the right and left eyes respectively. This is similar to the results reported by Schwering et al. (2015) who included participants of a similar age range (aged four years to 25 years). The mean hyperopic prescription was +3.23 ± 4.38 D and +5.06 ± 6.26 D in the right and left eyes. This is slightly greater than that reported by Wildsoet, Oswald and Clark (2000) which is interesting as the study by Wildsoet, Oswald and Clark (2000) included presbyopic participants who are expected to have a higher degree of hyperopia.

Although the mean refractive error for each eye was myopic, the large standard deviation demonstrated the variability of refractive error among the participants. Other studies that measured refractive error in individuals with VI also reported large standard deviations for the mean sphere and/or spherical equivalent (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Lee et al. 2010; Mokaya et al. 2014; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). The large range of refractive errors in this study (from −22.00 D to +16.00 D) further validates the variability of refractive errors among individuals with VI as noted in previous studies (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Mokaya et al. 2014; Schwering et al. 2015).

The majority of participants in this study had myopia (spherical and compound) followed by hyperopia (spherical and compound) and mixed astigmatism. This finding is consistent with other studies that have reported that the majority of participants (aged between four years to 85 years) in their studies also had myopia (Lee et al. 2010; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Khanal, Pokharel and Kandel (2016) further reported that myopic astigmatism was most common followed by mixed astigmatism. In contrast, Wildsoet, Oswald and Clark (2000) reported that hyperopia was more common than myopia, which may be since that study also included presbyopic participants (age of participants ranged from three years to 51 years), while Mokaya et al. (2014) reported a higher prevalence of hyperopic astigmatism followed by myopic astigmatism and mixed astigmatism. Taken together, these findings suggest that refractive error varies among individuals with VI and that the latter may not necessarily be associated with only one specific type of refractive error.

In this study, the mean best-corrected cylindrical powers for the right and left eyes were −1.83 ± 1.12 DC and −2.30 ± 0.84 DC respectively. This is similar to the mean best-corrected cylindrical powers reported in two other studies (Wildsoet, Oswald &Clark 2000;

Khanal, Pokharel & Kandel 2016). Even though females had slightly higher mean cylindrical powers than males, these differences were not statistically significant. This finding is similar to other studies that also reported no significant gender differences in the magnitude of astigmatism (Naidoo et al. 2003; Siddiqui et al. 2017).

In this study, less than 50% of the participants that required spectacles had astigmatism. This is comparable to Schwering et al. (2015) who also reported that less than 50% of participants in their sample had astigmatism. In contrast, the majority of participants in other studies were reported to have astigmatism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Khanal, Pokharel & Kandel 2016). This discrepancy may be accounted for by the inclusion of only individuals with OCA in these three studies as OCA is associated with high levels of astigmatism (Healey et al. 2010). Even though the most common cause of VI in this study was OCA, this cause of VI was present in only four out of every 10 participants which may explain the limited number of participants with astigmatism. Of the participants with astigmatism, the majority had with-the-rule (WTR) astigmatism followed by oblique and against-the-rule (ATR) astigmatism. This finding is consistent with other studies that have also reported that WTR astigmatism is more common than oblique and ATR astigmatism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Furthermore, previous studies have indicated that WTR astigmatism is most common among younger individuals and is likely as a result of steepening of the vertical meridian caused by eyelid tension (Elliott 2007a, p. 89; Read, Collins & Carney 2007). There is a significant shift toward ATR astigmatism with an increase in age which is most likely due to a relaxation of eyelid tension (Elliott 2007a, p. 89; Read, Collins & Carney 2007).

5.4 Objective two: contrast sensitivity

Tests for contrast sensitivity vary in the design as well as targets and therefore results may not be directly comparable between different tests (Elliott 2006, p. 267). However, the results of the Mars letter contrast sensitivity test used in this study is comparable to that of the Pelli-Robson contrast sensitivity test (Dougherty, Flom & Bullimore 2005; DeCarlo, Woo & Woo 2006, p. 1602; Thayaparan, Crossland & Rubin 2007; Sukha & Rubin 2013). Consequently, the contrast sensitivity range in this study (0.00 log CS to 1.88 log CS) is comparable to the range reported by Haymes et al. (1996) (0.00 log CS to 1.80 log CS) who used the Pelli-Robson contrast sensitivity test. This range from profound loss of contrast sensitivity (0.00 log CS) to normal contrast sensitivity (1.88 log CS) demonstrates the variability of contrast sensitivity in individuals with VI.

The mean contrast sensitivity for the right, left and both eyes of the participants were 0.95 ± 0.47 log CS, 1.08 ± 0.41 log CS and 1.24 ± 0.36 log CS respectively. This indicates that there was a severe loss of contrast sensitivity in the right eyes of the participants as well as a moderate loss in the left eyes and binocularly. According to Elliott (2006, p. 253), binocular contrast sensitivity is 42% better than monocular contrast sensitivity as a result of binocular summation, however this decreases with increasing differences in monocular contrast sensitivity values. In this study, the mean binocular contrast sensitivity was not much better than the mean monocular contrast sensitivity as a result of the reduced binocular summation that is expected in individuals with VI (Elliott 2006, p. 253).

The mean contrast sensitivity was similar in the right and left eyes of both male and female participants. Only the binocular contrast sensitivity value was significantly better in females than males. However, this was still categorised as a moderate loss for both genders and is unlikely to be clinically significant. Previous studies have not compared contrast sensitivity between both genders which limits the comparison of the results found in this study.

Although contrast sensitivity varies among individuals with VI, the majority of participants in this study had a moderate loss of contrast sensitivity followed by a severe loss of contrast sensitivity in each eye and binocularly. None of the participants showed any profound loss of contrast sensitivity when tested binocularly which may be explained by binocular summation.

5.5 Objective three: colour vision

Colour vision defects may adversely affect education of adolescents with VI as it may cause difficulties with tasks requiring colour discrimination (Wilkinson 1996, p. 162). In this study, more than 50% of participants passed the Panel 16 colour vision test in both the right and left eyes. This is comparable to Khanal, Pokharel and Kandel (2016) who reported that 76% of participants passed the colour vision test in their study while two other studies reported that less than 50% of participants passed (Labib et al. 2009; Lee et al. 2010). Of those who failed the Panel 16 colour vision test in this study, the majority had red-green colour vision defects followed by blue-yellow colour vision defects. Although this is similar to Lee et al. (2010), who also reported that red-green colour vision defects were more common than blue-yellow colour vision defects, these results are not comparable to other studies (Labib et al. 2009; Khanal, Pokharel & Kandel 2016) that used the Ishihara colour vision test which is insensitive to blue-yellow colour vision defects.

Most of the male and female participants in this study passed the Panel 16 colour vision test, indicating either mild or no colour vision defects, while of those who failed, red-green colour vision defects were most common among both genders. There were twice as many females with deutan colour vision defects in the right eye and slightly more males with tritan colour vision defects in the right eye. Overall, there was no significant gender difference in the distribution of colour vision defects. Previous studies have not compared the distribution of colour vision defects between both genders.

The majority of participants with retinitis pigmentosa (RP) and cataracts followed Köllner's rule and presented with blue-yellow colour vision defects. The progression of the ocular condition may explain why some did not obey Köllner's rule as the latter is most useful in the early stages of an acquired condition. The one participant with Stargardt's disease was the exception to Köllner's rule and presented with red-green colour vision defects in both eyes. This finding is comparable to the study by Kalloniatis and Johnston (1990) where the participants with RP obeyed Köllner's rule and those with Stargardt's disease were exceptions.

5.6 Objective four: central visual field

In this study, almost four out of every five participants had no central visual field defects in both the right and left eyes. This is comparable to Mokaya et al. (2014) who reported that 79% of participants had no central visual field defects in their study. In contrast, Haymes et al. (1996) reported that only 11.10% had an intact central visual field. The most common cause of VI in this study was OCA which may explain the similarity of the central visual field findings to the study by Mokaya et al. (2014) which included only individuals with OCA in their study.

Of the participants who had central visual field defects in this study, metamorphopsia and an absolute paracentral scotoma were most common. In contrast, Mokaya et al. (2014) reported that a central scotoma was most common followed by metamorphopsia, while Haymes et al. (1996) found that the majority of participants had restricted central visual fields. This disparity may be related to the cause of VI as Haymes et al. (1996) included only individuals with RP in their sample. It is well known that restriction of the visual field is expected with RP where there is associated involvement of the central visual field as the condition progresses.

The majority of male and female participants did not have any central visual field defects. In those participants with central visual field defects, metamorphopsia and an absolute

paracentral scotoma were most common. Slightly more females had metamorphopsia in the right and left eyes while twice as many males had an absolute paracentral scotoma in the left eye. However, this distribution of central visual field defects according to gender was not significant. Previous studies have not reported on the distribution of central visual field defects according to gender.

5.7 Objective five: quality of life

The Cardiff Visual Ability Questionnaire for Children (CVAQC) has five possible responses for each question, namely ‘very easy’, ‘easy’, ‘difficult’, ‘very difficult’ and ‘not interested in doing this/ don’t do for other reasons’. In this study, participants were more likely to select ‘easy’ between the options ‘very easy’ and ‘easy’ or ‘difficult’ between the options ‘difficult’ and ‘very difficult’. This implies that some adolescents with VI may not be able to judge the level of ease or difficulty associated with certain tasks. This may be more evident in those participants who have had VI since birth as they may not have experienced deterioration in the ability to perform certain tasks thereby having no reference of ease and/or difficulty. Those participants who selected either ‘very easy’ or ‘very difficult’ may have experienced either an improvement in the ability to perform tasks due to the development of coping methods or a progressive worsening of the ability to perform the same tasks. A similar pattern where participants dichotomised results was reported by Ganesh et al. (2013), where the authors affirmed that individuals with VI were unable to judge the level of difficulty with accomplishing certain tasks.

The CVAQC consists of seven domains, namely education, near vision, distance vision, getting around, social interaction, entertainment and sports. For the domain related to education, more than 50% of the participants reported that each of the lessons was either ‘easy’ or ‘very easy’. This is notable as VI has an adverse effect on the development of cognitive skills and because approximately 80% of information is achieved through the sense of sight, education is most affected (Raj 2007; Ganesh et al. 2013). In this study, the majority of participants reported that language lessons were either ‘easy’ or ‘very easy’ which is similar to results reported by Tončić et al. (2016). In contrast to Tončić et al. (2016) who reported that maths lessons were most difficult, participants in this study reported that science and geography lessons were most difficult. The science lessons at the Arthur Blaxall School do not entail laboratory work however it is possible that the participants in this study may have encountered difficulties with resolving fine details in the science textbooks. In the same way, participants in this study may have encountered difficulties in the geography lessons possibly when studying fine details in maps. This

reason is plausible as the majority of participants reported reading the smallest print in textbooks was most difficult for near work.

For distance vision, the majority of participants reported difficulty reading the board in the classroom which is similar to results reported in other studies (El Byoumi & Mousa 2010; Ganesh et al. 2013; Tončić et al. 2016). More than 40% of participants in this study reported that watching a film at the cinema was difficult. Some participants (n = 6) did not visit a cinema which may be related to either poor distance vision or lack of access to such amenities. Similar findings were reported by Tončić et al. (2016) who also found that the majority of participants had difficulty with or had never watched a film at the cinema. When the 'getting around' domain was considered, the most difficult task was 'walking in a crowded place' which may be more evident among those participants with visual field defects. The majority of participants reported that each of the tasks listed under the domain of entertainment were either 'easy' or 'very easy' and is comparable to results reported by Tončić et al. (2016) where all participants reported that performing each of these tasks was 'very easy'. The majority of participants reported that using an IPOD/MP3/MP4 player as either 'easy' or 'very easy'. Therefore, it is likely that these individuals would report a similar ease of use with a cellular phone or iPad/Tablet because these devices are similar. Furthermore, the use of a cellular phone or iPad/Tablet may be easier as the user has control over the font size, contrast and brightness of the screen. Swimming was the preferred sport rather than ball games and athletics and is similar to results reported by Tončić et al. (2016). Swimming does not rely as heavily on visual cues which may explain this preference. Furthermore, ball games rely on the ability to perceive visual cues as well as require adequate eye-hand and/or eye-foot coordination which may be compromised or limited in individuals with VI.

The overall visual ability score for participants in this study was −0.27 ± 0.74 log units, implying relatively good QoL. In contrast, Tončić et al. (2016) reported an overall visual ability score of 1.29 ± 1.26 log units implying that those individuals had considerably poorer QoL. One possible explanation may be related to the number of participants with moderate and severe VI. The quantity of participants with moderate and severe VI were not specified in the study by Tončić et al. (2016) and it is likely that there were more participants with severe VI than moderate VI thereby resulting in a poorer visual ability score. In contrast, the majority of participants in this study had moderate VI which may explain the relatively better mean visual ability score. The disparity in findings may also be related to the difference in sample sizes, whereby Tončić et al. (2016) included only 19 participants, as well as differences in the age range of participants. The participants in this

study were aged from 10 years to 19 years whereas the participants in the study by Tončić et al. (2016) were aged from six years to 18 years. This is relevant as the older participants in this study (aged 14 years to 19 years) had significantly better QoL than younger participants (aged 10 years to 13 years). Possible reasons for this finding may include a longer duration of living with the condition and the development of adaptive abilities that may not yet be present in the younger participants, as well as the burden of biological changes experienced by the younger participants in addition to learning to cope with the VI. This is supported by Burstedt and Mönestam (2010) who also found that older individuals may be more accustomed to their diagnosis. Conversely, Chadha and Subramanian (2010) reported that older participants had poorer QoL than their younger counterparts, although this was not statistically significant. The authors postulated that the inability to meet the increased demands on the visual system that occur with an increase in age may result in poorer QoL in older individuals. However, a more recent study by Freedman et al. (2014) reported no association between age and QoL.

In this study, male participants had significantly better QoL than females and is comparable to results reported by Khorrami-Nejad et al. (2016) who reported that females had poorer QoL than males. Conversely, El Byoumi and Mousa (2010) reported no significant gender difference in QoL among their participants. Furthermore, the questionnaire was administered by the researcher to the participants without a parent/ guardian being present. Consequently, it is likely that the responses by the participants were accurate as a previous study reported that the parent/ guardian, as a proxy, tended to provide more exaggerated responses thereby creating an impression of poorer QoL than that actually experienced by the participant (Chadha & Subramanian 2010).

5.8 Objective six: visual function according to the main cause of visual impairment

5.8.1 Distance visual acuity

In this study, participants with anterior segment disorders and VI due to other causes had the worst unaided VA while the former had the worst best-corrected VA both monocularly and binocularly. Participants with OCA had the best unaided and best-corrected VA in the right and left eyes. Participants with posterior segment disorders achieved the highest binocular best-corrected VA although this was not statistically significant when compared with the binocular best-corrected VA of all the other participants. This is notable as individuals with posterior segment disorders are expected to have poorer VA as the retina is affected (Bastawrous et al. 2014). For each cause of VI, the mean binocular unaided and best-corrected VA was better than the mean monocular VA which may be accounted

for by the process of binocular summation that may exist even in individuals with VI (Rubin et al. 2000).

For participants with posterior segment disorders, the mean best-corrected VA were 0.94 ± 0.20 logMAR and 0.85 ± 0.24 logMAR in the right and left eyes respectively which is similar to other studies that included individuals with primarily posterior segment disorders (Labib et al. 2009; Lee et al. 2010; Ganesh et al. 2013). However, these studies only reported the mean best-corrected monocular VA therefore the mean best-corrected binocular VA could not be compared between the studies. In this study, the mean best-corrected VA for participants with OCA were 0.81 ± 0.17 logMAR and 0.81 ± 0.18 logMAR in the right and left eyes respectively and is similar to results of other studies that also included only individuals with OCA in their study samples (Wildsoet, Oswald & Clark 2000; Schwering et al. 2015). The finding that participants with OCA had the best mean best-corrected monocular VA is noteworthy as individuals with OCA are expected to have poor VA as a result of foveal hypoplasia, retinal hypopigmentation and degradation of the retinal image due to iris transillumination (Healey et al. 2010). Furthermore, individuals with OCA are more likely to have amblyopia, which may be refractive or meridional due to the presence of astigmatism (Healey et al. 2010). The mean binocular best-corrected VA for participants with OCA was only slightly better than the mean best-corrected monocular VA. This finding is notable as monocular occlusion usually exacerbates the nystagmus resulting in an increase in retinal blur and poorer monocular VA (Healey et al. 2010).

Based on the best-corrected VA of the better-seeing eye, the majority of participants for each of the main causes of VI had moderate VI. Similarly, Khanal, Pokharel and Kandel (2016), who included only individuals with OCA, also reported that the majority of participants had moderate VI. In contrast, Ganesh et al. (2013), who included participants with primarily posterior segment disorders, reported that majority of participants in their study had severe VI followed by moderate VI which is expected as the retina is usually affected in posterior segment disorders (Bastawrous et al. 2014).

5.8.2 Refractive error

Of the 34 participants that required spectacles after subjective refraction, the majority had posterior segment disorders. Overall, more than 60% of the participants with posterior segment disorders (13 out of 21 participants) and VI due to other causes (9 out of 15 participants) required spectacles. This is similar to the results reported by Lee et al. (2010) where the majority of participants with posterior segment disorders required spectacles. In this study, only 40% of the participants with OCA (11 out of 28 participants) required

spectacles which is unexpected as OCA is usually associated with high refractive errors (Healey et al. 2010). This implies that the results of this study are in contrast to Schwering et al. (2015) who noted that only 24% of their participants with OCA did not require spectacles as there was no improvement in VA.

Only one participant with an anterior segment disorder required spectacles after subjective refraction and presented with a mean hyperopic refractive error. Participants with posterior segment disorders had a mean myopic refractive error in the right eye and a mean hyperopic refractive error in the left eye. A mean myopic refractive error was reported in a study of individuals with RP, although some participants also had hyperopia (Lee et al. 2010). The participants with OCA had mean myopic refractive errors in both the right and left eyes which is similar to results reported in three other studies (Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). In contrast, two studies reported that individuals with OCA had mean hyperopic refractive errors (Wildsoet, Oswald & Clark 2000; Mokaya et al. 2014). The participants with VI due to other causes had mean myopic refractive errors in both eyes.

Spherical myopia and compound myopic astigmatism were the most common categories of refractive error for each of the main causes of VI. Spherical myopia was most common among participants with posterior segment disorders which is similar to results reported by Lee et al. (2010) who also found that myopia was most common among these individuals, however the type of myopia was not reported. Among participants with OCA, compound myopic astigmatism was most common which is comparable to the study by Khanal, Pokharel and Kandel (2016) where a greater prevalence of myopic astigmatism was reported. Schwering et al. (2015) also found that myopia was most common among individuals with OCA, however, the type was not reported. Conversely, two studies found that hyperopia was most common in these individuals with OCA (Wildsoet, Oswald & Clark 2000; Mokaya et al. 2014).

Astigmatism is most often either corneal (unequal curvature of the anterior or posterior surfaces of the cornea) or lenticular (unequal curvature of the anterior or posterior surfaces, unequal refractive indices or tilting/ decentration of the crystalline lens) in origin (Rosenfield 2006, p. 12; Read, Collins & Carney 2007). Flüeler and Guyton (1995) further stated that astigmatism does not result from a tilted retina. Based on this, it may be presumed that astigmatism may be induced by anterior segment disorders but not necessarily posterior segment disorders. The presence of astigmatism in individuals with posterior segment disorders may be related to etiologies other than the condition itself,

such as genetics, mechanical pressure (eyelid tension or pathology, such as a chalazion) or an associated condition (Read, Collins & Carney 2007).

In this study, none of the participants with anterior segment disorders had astigmatism. Approximately 25% of participants with posterior segment disorders had astigmatism with oblique astigmatism being the most common. Of the participants with VI due to other causes, oblique astigmatism was most common followed by WTR astigmatism. Less than one-fifth of the participants with OCA had astigmatism in either the right or left eye. This is notable as the majority of participants with OCA in other studies had astigmatism (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Khanal, Pokharel & Kandel 2016). Only one study of individuals with OCA reported that the majority of participants did not have astigmatism (Schwering et al. 2015).

In this study, WTR astigmatism was most common in participants with OCA followed by oblique astigmatism. Similarly, other studies also reported that WTR astigmatism is most prevalent in individuals with OCA while oblique and ATR astigmatism are relatively uncommon (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Khanal, Pokharel and Kandel (2016) further reported that the WTR astigmatism was corneal in origin and suggested it may be related to mechanical pressure due to eyelid tension as well as the nystagmus. Nystagmus is characterised by rapid oscillatory movements of the eye typically along the horizontal meridian. It has been suggested that this constant, involuntary movement of the eyes increases the interaction between the taut eyelids and the cornea (Read, Collins & Carney 2007). Consequently, the eyelids exert a band-like pressure on the cornea causing the vertical meridian to steepen which results in WTR astigmatism (Wildsoet, Oswald & Clark 2000; Read, Collins & Carney 2007; Healey et al. 2010; Khanal, Pokharel & Kandel 2016). It has been further suggested that the presence of nystagmus decreases the corneal rigidity thereby allowing the mechanical pressure of the eyelids to steepen the vertical meridian (Wildsoet, Oswald & Clark 2000).

5.8.3 Contrast sensitivity

In this study, participants with OCA had the best mean contrast sensitivity both monocularly and binocularly which were significantly better when compared to the contrast sensitivity in participants with anterior segment disorders, posterior segment disorders and VI due to other causes. This is noteworthy as individuals with OCA are expected to have poorer contrast sensitivity as a result of the clinical features associated with OCA, namely foveal hypoplasia, retinal hypopigmentation, iris transillumination and

nystagmus (Loshin & Browning 1983; Healey et al. 2010). Participants with VI due to other causes had the worst monocular contrast sensitivity for the right and left eyes while participants with posterior segment disorders had the worst binocular contrast sensitivity. Furthermore, participants with anterior segment disorders had slightly better contrast sensitivity than those with posterior segment disorders. However, this was not significant as both showed severe loss of contrast sensitivity. Labib et al. (2009) also reported that individuals with posterior segment disorders have poor contrast sensitivity.

Participants with OCA and VI due to other causes had better binocular than monocular contrast sensitivity, which may be due to binocular summation (Elliott 2006, p. 253). Participants with anterior segment disorders and posterior segment disorders had poorer binocular than monocular contrast sensitivity. This may be due to a decrease in binocular summation in which the binocular contrast sensitivity is poorer than monocular contrast sensitivity (Rubin et al. 2000; Elliott 2006, p. 253). In these participants, the binocular contrast sensitivity value was similar to the better monocular contrast sensitivity value.

When the categories of contrast sensitivity loss were considered, the majority of participants with OCA had a moderate loss of contrast sensitivity. In participants with VI due to other causes, slightly more participants had a severe loss of contrast sensitivity. For participants with anterior segment disorders, there was an almost equal distribution of participants in the different categories of contrast sensitivity loss. The frequency of participants with posterior segment disorders in each category of contrast sensitivity loss differed in the right, left and both eyes, however, the majority had severe loss of contrast sensitivity. Similarly, two studies conducted in individuals with posterior segment disorders also reported that contrast sensitivity varied from normal to profound loss (Haymes et al. 1996; Labib et al. 2009). This indicates the variability of contrast sensitivity in individuals with VI and may be related to the progression of the condition causing the VI.

5.8.4 Colour vision

In this study, 60% of participants with anterior segment disorders had tritan colour vision defects in the right and left eyes. This is not unusual as, of those with anterior segment disorders, two participants had cataracts and presented with blue-yellow colour vision defects thereby obeying Köllner's rule. Individuals with anterior segment disorders are usually not expected to have colour vision defects unless the condition affects the clarity of the ocular media (including the cornea and crystalline lens) or the colour vision defect is related to genetics, an associated condition or medication (Pease 2006, p. 290).

Of the participants with posterior segment disorders, the majority had no colour vision defects in the right eye and deutan colour vision defects in the left eye. This is similar to results reported by Lee et al. (2010) where the majority of participants did not have colour vision defects and of those who did, red-green colour vision defects were most common. Lee et al. (2010) further reported that blue-yellow colour vision defects were the least common. The findings of deutan colour vision defects being more common is noteworthy as, of the participants with posterior segment disorders, the most common were glaucoma and RP which are associated with tritan colour vision defects (Pease 2006, p. 297). In contrast to the results of this study, Kalloniatis and Johnston (1990) reported that three-quarters of their participants with posterior segment disorders failed at least one colour vision test although the type of colour vision defect was not reported. Labib et al. (2009) also reported that colour vision defects were present in the majority of participants with posterior segment disorders while only 14% had normal colour vision. These findings may be related to the progression of the condition and macula involvement, as the main causes of VI in these studies were RP and hereditary maculopathy respectively.

In this study, the majority of participants with OCA did not have any colour vision defects in either eye, while deutan defects were most common among those who did have colour vision defects. This is similar to another study that included individuals with OCA where 76% did not have any colour vision defects and of those who did, red-green colour vision defects were most common (Khanal, Pokharel & Kandel 2016). Overall, individuals with OCA have normal colour vision (Healey et al. 2010). However, if a colour vision defect does exist in individuals with OCA, it may be more likely owing to poor VA rather than reduced colour perception (Healey et al. 2010).

5.8.5 Central visual field

The majority of participants with anterior segment disorders had an intact central visual field in both the right and left eyes. Only one participant had metamorphopsia in the left eye, however this may be related to degradation of the retinal image due to the presence of a corneal opacity rather than a reflection of macula integrity. Individuals with anterior segment disorders are generally not expected to present with central visual field defects unless the presence of a media opacity degrades the retinal image or the visual field defect is due to an associated condition. This is because assessment of the central visual field evaluates the integrity of the macula (Elliott & Flanagan 2007, p. 43).

Most of the participants with posterior segment disorders did not have any central visual field defects and of those who did, the most common was an absolute paracentral

scotoma in each eye. This finding is in contrast to Haymes et al. (1996) who reported that only 11% of their participants had an intact central visual field with the majority showing restricted central visual fields. This may be explained by the cause of VI (RP) and the progression of the condition to involve the macula.

In this study, almost all of the participants with OCA did not have any central visual field defects in either eye, except for two participants who had metamorphopsia in the right eye. Similarly, Mokaya et al. (2014) also reported that the majority of participants with OCA did not have any central visual field defects, and of those who did, a central scotoma was most common followed by metamorphopsia. These findings are in agreement with other studies that also noted intact central visual fields in individuals with OCA (Creel, Witkop & King 1974; Healey et al. 2010). Despite an abnormal decussation of retinal nerves in the optic chiasm, this does not result in visual field defects in individuals with OCA (Hoffmann, Seufert & Schmidtborn 2007).

5.9 Objective seven: quality of life according to the main cause of visual impairment

Participants with anterior segment disorders had the least negative visual ability score indicating that they had the poorest QoL than participants with posterior segment disorders, OCA and VI due to other causes. A previous study that included individuals with anterior segment disorders, namely corneal diseases, also reported that these individuals had poorer QoL (Vashist et al. 2016). There are a few possible explanations, in addition to the VI, which may account for the poor QoL in individuals with anterior segment disorders. One possible explanation is that any disorder of the anterior surface of the eye, namely the cornea, may disrupt the tear film thereby resulting in keratoconjunctivitis sicca which may cause further blurring of vision and discomfort (Uchino & Schaumberg 2013). Another possible explanation is that anterior segment disorders, such as corneal scarring, may sometimes be more noticeable than posterior segment disorders. Consequently, this could lead to affected individuals being more conscious of the cosmetic appearance of their condition thereby increasing the distress associated with the condition and possibly decreasing their QoL.

Participants with posterior segment disorders had a slightly better visual ability score than participants with anterior segment disorders and VI due to other causes. This implies that the participants with posterior segment disorders had relatively better QoL. It is possible that QoL varies among individuals with posterior segment disorders and could be dependent on the type of condition. However, Evans et al. (2009) reported that the impact of VI on QoL is comparable between individuals with peripheral vision loss and those with

central vision loss. In a study comparing the impact of central and peripheral vision loss on QoL, it was reported that physical activities are more affected than mental health in individuals with central vision loss and vice versa in those with peripheral vision loss (Evans et al. 2009). This is because central vision loss negatively impacts the performance of daily tasks, while peripheral vision loss has less of an effect on the performance of daily tasks (Evans et al. 2009). Moreover, individuals with peripheral vision loss may be more concerned about the future impact of their condition and the potential for blindness (Evans et al. 2009).

In this study, participants with OCA had the most negative visual ability score and therefore the best QoL. This is in contrast to Maia et al. (2015) who reported that QoL is negatively affected in individuals with OCA as a result of poor vision and sensitive skin. A previous study reported that children and adolescents with OCA attempt to behave as normal as their peers without OCA, and therefore may respond positively in order to remain inconspicuous (Lund & Gaigher 2002). This is noteworthy as, in addition to VI, individuals with OCA also experience physiological and social difficulties. As a result of the poor vision and sensitivity to light, individuals with OCA may be restricted from performing certain activities, such as sports or athletics, which seem normal for individuals without OCA of the same age. This may influence their ability to adapt to society, and may result in feelings of social isolation (Lund & Gaigher 2002). There are also psychological implications of OCA as a result of the stigmatisation and superstition that still exists (Lund & Gaigher 2002). Despite the difficulties associated with OCA, affected individuals may be more accepting of their condition and may be more likely to attend special schools rather than mainstream schools (Lund & Gaigher 2002).

5.10 Conclusion

This chapter discussed the objectives of this study in relation to the results reported in the previous chapter. The overall results indicate that visual function and QoL varied among the participants, and even between each of the main causes of VI. The next chapter will provide the conclusion for this study in the form of a summary of the main findings as well as the limitations of the study and recommendations for future research.

CHAPTER 6. CONCLUSION

6.1 Introduction

Visual impairment (VI) is a global health concern that affects the lives of both adults and children although the effects may not be the same in these individuals. Even though individuals aged 50 years and older account for the majority of those affected with VI, blindness and VI in children and adolescents are major concerns because of the greater life expectancy. The severe consequences of VI decreases the ability of affected individuals to live independently and perform tasks of daily living. Vision is fundamental to learning and integration therefore if VI is present at birth, or develops shortly thereafter, it may result in affected individuals being developmentally delayed.

Although several studies have investigated visual function and quality of life (QoL) in individuals with VI, these studies involved adults with VI and as such the results of these studies may not be generalised to adolescents with VI. Visual impairment is a lifelong condition that may negatively affect the education of affected adolescents in addition to their social interactions and possible future employment. This study investigated visual function and QoL in adolescents with VI, and also compared both visual function and QoL according to the main causes of VI. The results of this study were presented in chapter four and were discussed in the previous chapter. This chapter concludes the study and presents the limitations of the study together with recommendations for future research.

6.2 Summary of findings

The study sample consisted of slightly more female than male participants which adds to the evidence that females may be at higher risk for VI than males (Resnikoff et al. 2004; WHO 2007; Schellini et al. 2009). The most common cause of VI in this study was oculocutaneous albinism (OCA), followed by posterior segment disorders, anterior segment disorders and VI due to other causes that did not belong to any of the previously mentioned categories. Individuals with OCA are more likely to attend special rather than mainstream schools, which may explain the greater prevalence of OCA in this study. Furthermore, individuals with posterior segment disorders are more likely to have poorer vision and may have been underrepresented in this study due to the study exclusion criteria. The most common presenting sign among the study participants was nystagmus, which is similar to other studies (Khanal, Pokharel & Kandel 2016; Tunay et al. 2016).

With respect to the first study objective which focused on distance visual acuity (VA) and refractive error, the VA of participants improved by at least one logMAR line following

refraction. This emphasises the importance of routine refraction as it improved the VA of participants from a category of worse impairment, based on the unaided VA, to a category of less impairment based on the best-corrected VA. Another noteworthy finding is that, while this study included individuals with moderate to severe VI (VA between 6/18 and 6/120), the mean VA was in the range of moderate VI (6/38 to 6/48) which is similar to other studies (Wildsoet, Oswald & Clark 2000; Labib et al. 2009; Lee et al. 2010; Ganesh et al. 2013; Schwering et al. 2015). Furthermore, there was no significant gender difference as the VA of both male and female participants showed at least one logMAR line of improvement following refraction.

With regard to refractive error, only 16 participants were wearing spectacles however subjective refraction revealed that an additional 18 participants required spectacles. Although the mean best-corrected sphere was myopic, the large standard deviation showed that high degrees of myopia and hyperopia were present among the participants. This was further confirmed by the large range of refractive errors, and is similar to other studies that reported variation in refractive error among individuals with VI (Wildsoet, Oswald & Clark 2000; Sampath & Bedell 2002; Lee et al. 2010; Mokaya et al. 2014; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Less than half of the participants with refractive errors had astigmatism, and of those who did, with-the-rule (WTR) astigmatism was most common. Female participants had slightly higher mean cylindrical powers than the male participants although this was not statistically significant.

Contrast sensitivity ranged from profound loss to normal contrast sensitivity, thereby demonstrating the variability of contrast sensitivity among individuals with VI. This is comparable to another study that reported a similar range of contrast sensitivity in individuals with VI (Haymes et al. 1996). The mean binocular contrast sensitivity was not much better than the mean monocular contrast sensitivities which may be due to reduced binocular summation among individuals with VI. The mean monocular contrast sensitivity was similar among both genders however the mean binocular contrast sensitivity was significantly better in female than male participants. This is unlikely to be clinically significant as the mean binocular contrast sensitivities for both male and female participants were still categorised as moderate loss.

More than half of the participants passed the Panel 16 colour vision test indicating either a mild or no colour vision defect. Of the participants who failed, the majority had red-green colour vision defects followed by blue-yellow colour vision defects. There was no significant difference in the distribution of colour vision defects between both genders. The

majority of participants with retinitis pigmentosa (RP) and cataract followed Köllner's rule and presented with blue-yellow colour vision defects. The one study participant with Stargardt's disease was the exception to Köllner's rule and presented with a red-green colour vision defect.

The majority of participants had no central visual field defects in either the right or the left eyes. Similarly, another study also reported that the majority of participants did not have any central visual field defects (Mokaya et al. 2014). Of the participants in this study who did have central visual field defects, metamorphopsia and an absolute paracentral scotoma were most common. Furthermore, there was no significant difference in the distribution of central visual field defects according to gender.

With regard to objective five, which focused on QoL in adolescents with VI, the results showed that some adolescents with VI may not be able to judge the level of ease or difficulty associated with performing certain tasks. This may be more so in those adolescents who had VI since birth as they may not have any reference of ease and/or difficulty. The majority of participants reported the greatest difficulty with reading the smallest print in textbooks as well as reading the board in the classroom. For the 'getting around' domain, the most difficult task was walking in a crowded place, which may have been more evident among those with visual field defects. Swimming was preferred to ball games and athletics, which may be accounted for by swimming not relying as heavily on visual cues as the other two sports. Overall, the mean visual ability score indicated relatively good QoL which is in contrast to Tončić et al. (2016). Older participants (aged 14 years to 19 years) and males had significantly better QoL than younger participants (aged 10 years to 13 years) and females respectively.

The purpose of objective six was to compare visual function according to each of the main causes of VI. For each of the main causes of VI, the mean binocular VA was better than the mean monocular VA which may be accounted for by binocular summation. The mean refractive error in participants with OCA was myopic which is similar to previous studies (Sampath & Bedell 2002; Schwering et al. 2015; Khanal, Pokharel & Kandel 2016). Less than one-fifth of these participants had astigmatism, which is noteworthy as OCA is associated with high degrees of WTR astigmatism. Participants with OCA had significantly better contrast sensitivity than those with anterior segment disorders, posterior segment disorders and VI due to other causes. The most common colour vision defects among participants with anterior segment disorders and posterior segment disorders were tritan and deutan colour vision defects respectively. With regard to central visual field, an

absolute paracentral scotoma and metamorphopsia were most common among participants with posterior segment disorders and OCA respectively.

Objective seven sought to compare QoL according to each of the main causes of VI. Overall, participants with anterior segment disorders had the poorest QoL which is similar to another study that reported that individuals with anterior segment disorders have poorer QoL (Vashist et al. 2016). Participants with OCA had the best QoL which is in contrast to Maia et al. (2015) who reported that QoL is negatively affected in individuals with OCA. Individuals with OCA are expected to have poorer QoL because, in addition to VI, they also experience physiological and social difficulties.

6.3 Study limitations

There were a few limitations inherent in this study, including the unequal number of participants for each of the main causes of VI. The relatively smaller number of participants with anterior segment disorders limits the generalisation of the study results. Furthermore, the diagnosis of the cause of VI was not made in consultation with an ophthalmologist, but rather relied on the school records for each participant. This lack of a formal diagnosis for the cause of VI in some participants prompted the creation of the 'other' category. In addition, the case study design of this research study may also limit the generalisation of the findings as this study consisted only of students attending the Arthur Blaxall School. This did not account for those individuals with VI who may be attending mainstream schools or who are home-schooled. In addition, the lack of a control group of adolescents without VI prevents a comparison of QoL in adolescents with VI to those with normal vision.

6.4 Recommendations

Some recommendations that may enhance future studies, in addition to accounting for the limitations mentioned above, are mentioned below. A larger sample size may allow for a comparison of visual function and QoL between each specific condition, not just the main cause of VI. An assessment of the central and peripheral visual field with the use of the Humphrey visual field analyser may be more apt at quantifying the visual field defect. Furthermore, this may allow for a comparison of QoL among individuals with central visual field defects and those with peripheral visual field defects. An assessment of near VA as well as stereopsis may add to the assessment of visual function among individuals with VI. Another recommendation would be to include an analysis of the relationship between QoL and the severity of VI, as well as between the relationship between visual function and QoL.

One of the general recommendations in the treatment of adolescents with VI is to recognise that visual function and QoL varies among these individuals and that there should be no assumptions regarding how the cause of VI affects visual function and QoL. An example of this is the expectation of severely reduced contrast sensitivity in individuals with OCA, which was not the case in the findings of this study, as the participants with OCA had the best mean contrast sensitivity. Another recommendation is to consider that younger adolescents may have more difficulty coping with the VI than older adolescents. Consequently, the younger adolescents may require more specific care and attention in order for them to develop appropriate adaptation skills. In addition, the optimal environment for adolescents with VI would be one with adequate illumination and high contrast. Furthermore, it is recommended that adolescents with VI wear their best possible refractive correction.

6.5 Conclusion

The results of this study showed that visual function varied among adolescents with VI and that these individuals may have relatively poorer QoL. Furthermore, visual function and QoL also differed between each of the main causes of VI, whereby participants with anterior segment disorders had the poorest QoL and those with OCA had the best QoL. These findings suggest that a holistic approach to health care may improve the QoL of these adolescents with VI which may in turn reduce the global burden of VI.

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APPENDIX I: RECORD SHEET

Demographic Information

Study number	
Age	
Grade	
Gender	
Race	

Cause of visual impairment			
1. OCA		7. Cataract	
2. RP		8. Retinal detachment	
3. Amblyopia		9. Optic atrophy	
4. Corneal opacity		10. Stargardt's disease	
5. Glaucoma		11. High myopia	
6. ROP		12. Other:	

Observations

1. Head turn		2. Head tilt		3. Eye turn		4. Corneal opacity	
5. Nystagmus		6. Albinism		7. Ptosis		8. Other:	

Visual function PD: _____

	Current prescription	Refraction
OD		
OS		

Category of RX	RX		New RX		Category of cyl	RX		New RX	
	OD	OS	OD	OS		OD	OS	OD	OS
1. Simple myope					1. WTR				
2. Compound myope					2. ATR				
3. Simple hyperope					3. Oblique				
4. Compound hyperope									
5. Mixed astigmatism									

	OD			OS			OU		
		logMAR	Snellen		logMAR	Snellen		logMAR	Snellen
UVA									
AVA									

Category of AVA	OD	OS
0. Mild/ no VI (≥6/18)		
1. Moderate VI (<6/18, ≥6/60)		
2. Severe VI (<6/60, ≥3/60)		
3. Blindness (<3/60, ≥1/60)		
4. Blindness (<1/60, ≥LP)		
5. Blindness (NLP)		

Category of contrast sensitivity	OD	OS	OU
1. Normal (1.52 – 1.92)			
2. Moderate loss (1.04 – 1.48)			
3. Severe loss (0.52 – 1.00)			
4. Profound loss (≤ 0.48)			

Colour vision	OD	OS
1. No defect		
2. Deutan		
3. Protan		
4. Tritan		

Central visual field	OD	OS
1. No defect		
2. Central scotoma		
3. Scotoma		
4. Metamorphopsia		

Comments: _____

_____

Attached (tick):	
Amsler grid (x 2)	
D15 chart	
Mars chart	
CVAQC	

APPENDIX II: Cardiff Visual Ability Questionnaire for Children

1, very easy; 2, easy; 3, difficult; 4, very difficult; 5, don't do this for other reason/ not interested in doing this

Subscale: Education *Isikala: Okwezifundo*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani uma:*						
1	Your maths lessons? *wenza izifundo zezibalo?*	**1**	**2**	**3**	**4**	**5**
2	Your science lessons? *wenza izifundo ze-Science?*	**1**	**2**	**3**	**4**	**5**
3	Your geography lessons? *wenza izifundo ze-Geography?*	**1**	**2**	**3**	**4**	**5**
4	Your language lessons? *wenza izifundo zolimi?*	**1**	**2**	**3**	**4**	**5**
Subscale: Near vision *Isikalo: Ukubona eduze*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani uma:*						
5	Reading text books and work sheets you are given in your school? *ufunda izincwadi namaphepha owanikwa eskoleni?*	**1**	**2**	**3**	**4**	**5**
6	Reading the smallest print in your textbooks? *ufunda amagama amancane encwadini?*	**1**	**2**	**3**	**4**	**5**
7	Drawing, colouring or painting? *udweba, faka imibala nokupenda?*	**1**	**2**	**3**	**4**	**5**
8	Reading text messages on your mobile phone? *ufunda imiyalezo kumakhalekhukhwini?*	**1**	**2**	**3**	**4**	**5**
9	To read restaurant menus? *ufunda iphepha lokudla ezindaweni zokudla ngaphandle?*	**1**	**2**	**3**	**4**	**5**

Subscale: Distance *Isikalo: Ukubona Kude*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani uma:*						
10	Reading the board in your class room? *ubuka ibhodi eklasini?*	**1**	**2**	**3**	**4**	**5**
11	To watch television? *ubukela umabonakude?*	**1**	**2**	**3**	**4**	**5**
12	To watch a film at the cinema? *ubukela umdlalo e-bhayiskopo?*	**1**	**2**	**3**	**4**	**5**
Subscale: Getting around *Isikalo: Izinto ezisizungezile*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani:*						
13	Going out alone in the day light? *ukuhamba wedwa phandle kukhanya?*	**1**	**2**	**3**	**4**	**5**
14	To walk in a crowded place? *ukuhamba lapho kugcwele khona?*	**1**	**2**	**3**	**4**	**5**
15	Using public transport (bus/train)? *uma ukusebenzisa izinqola zomphakathi njengebhasi nesitimela?*	**1**	**2**	**3**	**4**	**5**
16	Reading bus or train time tables on a screen at a station? *ukubona izikhathi zezinqola zomphakathi njengebhasi nesitimela?*	**1**	**2**	**3**	**4**	**5**
Subscale: Social interaction *Isikalo: Ezokuxhumana nabantu*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani:*						
17	To chat with your friends? *ukuxoxa nabangani bakho?*	**1**	**2**	**3**	**4**	**5**
18	Recognizing faces or identifying your friends sitting close by or at your arm length? *ukubona nokukhomba ubuso babangani bakho abahleli eduze kwakho noma kangangengalo?*	**1**	**2**	**3**	**4**	**5**
19	Seeing your friends in a playground? *ukubona abangani bakho ensimini yokudlalela?*	**1**	**2**	**3**	**4**	**5**

Subscale: Entertainment *Isikalo: Ezobumnandi*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani:*						
20	To use a Playstation? *ukusebenzisa i-Playstation?*	**1**	**2**	**3**	**4**	**5**
21	To play computer games? *ukudla imidlalo kwi-Computer?*	**1**	**2**	**3**	**4**	**5**
22	Using your IPOD/MP3/MP4 players? *ukusebenzisa imishini yakho yomculo i-IPOD/MP3/MP4?*	**1**	**2**	**3**	**4**	**5**
Subscale: Sports *Isikalo: Ezemidlalo*						
Because of your eye sight and with your glasses and low vision aids if you use them, how difficult do you find: *Ngenxa yokubona kwakho, nezibuko zakho, nezinto ezikusiza ekungaboni kwakho, uma uzisebenzisa, uthola kunzima kangakanani:*						
23	Swimming? *ukubhukuda?*	**1**	**2**	**3**	**4**	**5**
24	To take part in athletics? *ukuzibandakanya kwezokugijima?*	**1**	**2**	**3**	**4**	**5**
25	To play ball games? *ukudlala imidlalo yebhola?*	**1**	**2**	**3**	**4**	**5**

Instruction: Scoring of the 25-item CVAQC

The reference scoring for the 25-item CVAQC is presented in table 1. These estimates can be used to approximate a person's visual ability by averaging the sum of item measure values that correspond to the person's responses across all the items. The response category 5 or no answer are considered as missing data which is scored “zero”.

The person visual ability = sum of item measure/ number of items answered (excluding items with missing data)

Table 1 : Scoring for 25-item CVAQC

Items	**Response category score (logits)**			
	1	**2**	**3**	**4**
	Very easy	**Easy**	**Difficult**	**Very difficult**
1. maths lessons	-2.64	-0.52	1.28	3.13
2. science lessons	-3.23	-1.11	0.69	2.54
3. geography lessons	-3.81	-1.69	0.11	1.96
4. language lessons	-2.91	-0.79	1.01	2.86
5. reading text books and work Sheets	-3.16	-1.04	0.76	2.61
6. reading smallest print in a text Book	-5.16	-3.04	-1.24	0.61
7. drawing, colouring or painting	-2.20	-.08	1.72	3.57
8. reading text messages	-2.87	-0.75	1.05	2.90
9. reading restaurant menus	-3.74	-1.62	0.18	2.03
10. reading the board in your Classroom	-3.75	1.63	0.17	2.02
11. watching television	-1.68	0.44	2.24	4.09
12. watching film at a cinema	-1.51	0.61	2.41	4.26
13. going out alone in day light	-2.55	0.43	1.37	3.22
14. walking in a crowded place	-3.75	-1.63	0.17	2.02
15. using public services (buses/trains)	-2.99	-0.87	0.93	2.78
16. reading bus or train time tables	-4.87	-3.82	-0.95	0.90
17. chatting with your friend	-1.27	0.85	2.65	4.50
18. recognizing faces	-2.19	-0.13	1.67	3.52
19. seeing friends in a playground	-4.04	-1.92	-0.12	1.73
20. playing video games	-1.93	0.19	1.99	3.84
21. playing computer games	-2.48	-0.36	1.44	3.29
22. listening to music	-2.32	-0.20	1.60	3.45
23. swimming	-2.21	-0.09	1.71	3.56
24. taking part in athletics	-3.11	-0.99	0.81	2.66
25. playing ball games	-3.78	-1.66	0.14	1.99

Alternatively, a ready-to-use excel spread sheet is available online at Welsh Eye Care website for scoring.

APPENDIX III: BREC APPROVAL

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

24 October 2016

Ms S Naipal (210501926)
Discipline of Optometry
School of Health Sciences
shiveninaipal@gmail.com

Title: Visual function and quality of life in adolescents with visual impairment: A case study of the Arthur Blaxall School in Pietermaritzburg.
Degree: M-Optom

BREC Ref No: BE457/16

EXPEDITED APPLICATION

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 28 July 2016.

The study was provisionally approved pending appropriate responses to queries raised. Your response received on 12 October 2016 to BREC correspondence dated 07 October 2016 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given **full ethics approval** and may begin as from 24 October 2016.

This approval is valid for one year from **24 October 2016.** To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2015), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be RATIFIED by a full Committee at its next meeting taking place on **08 November 2016.**

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor J Tsoka-Gwegweni
Chair: Biomedical Research Ethics Committee

cc supervisor:
cc postgraduate administrator: [illegible]

APPENDIX IV: PERMISSION FROM THE DEPARTMENT OF EDUCATION

education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Phindile Duma Tel: 033 392 1004 Ref.:2/4/8/867

Miss S Naipal
1 Surya Gardens
37 Stromia Road
Sea Cow Lake
Durban
4051

Dear Miss Naipal

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"VISUAL FUNCTION AND QUALITY OF LIFE IN ADOLESCENTS WITH VISUAL IMPAIRMENT: A CASE STUDY OF THE ARTHUR BLAXALL SCHOOL IN PIETERMARITZBURG"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 25 July 2016 to 01 December 2017.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Connie Kehologile at the contact numbers below
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report / dissertation / thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Arthur Blaxall School

Adv. MB Masuku
Acting Head of Department: Education
Date: 01 August 2016

KWAZULU-NATAL DEPARTMENT OF EDUCATION

POSTAL: Private Bag X 9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa ...dedicated to service and performance
PHYSICAL: 247 Burger Street, Anton Lembede House, Pietermaritzburg, 3201. Tel. 033 392 1004beyond the call of duty
EMAIL ADDRESS: kehologile.connie@kzndoe.gov.za / Phindile.Duma@kzndoe.gov.za
CALL CENTRE: 0860 596 363; Fax: 033 392 1203 WEBSITE: WWW.kzneducation.gov.za

APPENDIX V: PERMISSION FROM THE PRINCIPAL

CONSENT FORM

Principal of Arthur Blaxall School

Mrs Pillay

I, Shivani Naipal, humbly seek your permission to include the students of Arthur Blaxall School in my research study titled 'Visual function and quality of life in adolescents with visual impairment: a case study of the Arthur Blaxall School in Pietermaritzburg'.

Data collection will be conducted with the students living at the hostel over the weekends of the school term so as not to disrupt lessons or examinations. I estimate that data collection will occur in September 2016. A schedule will be implemented once approval from the Department of Education and UKZN Biomedical Research Ethics Committee has been received.

Confidentiality of all participants will be maintained at all times. The results of the study will be made accessible to you should you require it.

I, ANUSUYAH PILLAY, principal of Arthur Blaxall School, hereby grant permission to Shivani Naipal to conduct research at the school.

Pillay

Principal's signature

2016-09-30

Date

In the event of any concerns, you may contact the researcher on 084 556 5805 or email shivaninaipal@gmail.com, or the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
University of KwaZulu-Natal
Private Bag X 54001, Durban, 4000
KwaZulu-Natal, South Africa
Tel: +27 31 260 4769
Fax: +27 31 260 4609
Email: BREC@ukzn.ac.za

APPENDIX VI: PERMISSION FROM THE ACADEMIC LEADER

The Discipline of Optometry
University of KwaZulu-Natal
Westville
Durban
4000

26 August 2016

Dear Academic Leader of Optometry

I, Shivani Naipal, humbly seek your permission to use some of the Department of Optometry's equipment for a research study entitled 'Visual function and quality of life in adolescents with visual impairment: a case study of the Arthur Blaxall School in Pietermaritzburg'.

I request permission to use a single LogMAR chart, the Mars contrast sensitivity chart, the Panel D15, an Amsler grid, and a vertometer. I will take full responsibility for the equipment. I estimate that data collection for this research will occur in September 2016. In order to avoid comprising the normal clinic program, the equipment will be collected from the Department on a Friday afternoon and returned on Monday morning.

Please feel free to contact me if there are any queries. I humbly appeal to you to consider my request.

Yours sincerely,
Shivani Naipal
210 501 926

Supervisor: Miss N. Rampersad

I, Dr V R Moodley, Academic Leader of the Department of Optometry, hereby grant permission to Shivani Naipal to utilize equipment from the Department, namely a single LogMAR chart, Mars contrast sensitivity chart, Panel D15, an Amsler Grid, and a vertometer.

Academic Leader's signature

01/09/16

Date

APPENDIX VII: INFORMATION DOCUMENT – ENGLISH AND ISIZULU

Study title: Visual function and quality of life in adolescents with visual impairment: a case study of the Arthur Blaxall School in Pietermaritzburg

Dear parent/ guardian

My name is Shivani Naipal, from the Department of Optometry at the University of KwaZulu-Natal's Westville Campus. Your child is being invited to participate in a study that involves research on the impact of visual function on quality of life in adolescents with visual impairment.
Vision, as one of the five senses, plays a significant role in daily life. Vision is perceived when light enters the eye, passes through various structures, and focuses on a specific point at the back of the eye, thus providing the clearest image of an object. Visual function refers to the accuracy of this focusing ability of the eyes. Individuals with visual impairment have inadequate visual function, i.e. their vision cannot be corrected by spectacles or contact lenses and their vision is not enough for common daily activities. This, in turn, may affect the quality of their life. Therefore, the purpose of this study is to measure visual function in adolescents with visual impairment and compare it to their perceived quality of life. This will also include a comparison between the different causes of visual impairment.

What is involved in the study?
Initially there will be a screening procedure, in the form of a questionnaire, to record your child's details such as age, gender etc. This will be followed by refraction (determination of the type of spectacles that your child needs) and a measurement of your child's visual acuity, contrast sensitivity, colour vision, and visual field. Thereafter, he/she will be required to answer a few questions in an interview to assess their quality of life. Participation in this study will significantly aid our understanding of the effects of visual impairment and indicate the best possible methods to manage it. The study is expected to recruit 80 participants aged between 10 and 19 years from Arthur Blaxall School. The expected duration of the testing procedures is 40 minutes. A report on the visual status (such as, new spectacle lens prescription, ocular health, etc.) of your child/ ward will be made available to you. The results of the study will also be made available to you.

Participation is purely voluntary, and there are no additional costs or charges. Your child has the right to refuse participation or withdraw from the study at any time with no consequences. Refusal to participate will not affect your child's education at Arthur Blaxall School. There are no potential visual risks involved in this study, however there may be psychological distress associated with questions related to disability. If any signs of psychological distress are detected, a referral will be made to the psychologist on the school's medical team, and thereafter followed up by the researcher.

Confidentiality
Personal details of each participant will be known only to the researcher, but may be made available if required by law. Results obtained will be reported as group findings so as not to isolate any one participant. All data will be stored securely for a minimum of 5 years, after which it will be destroyed. This study has been ethically reviewed and approved by the UKZN Biomedical Research Ethics Committee (approval number BE457/16). In the event of any problems or concerns/questions, you may contact the researcher on 0845565805 or email shivaninaipal@gmail.com, or the UKZN Biomedical Research Ethics Committee, contact details as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
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IDOKODO LOLWAZI

Isihloko socwaningo: Ukusebenza kokubona nezinga lempilo kwintsha encane enenkinga yokungaboni kahle: isifundo sombhali u-Aurthur Blaxall School wase-Pietermaritzburg

Sawubona Mzali/Mgadi

Ukubona, kungokunye kwemizwa emihlanu, kudlala indima empilweni yansuku zonke.

Ukubona kwenzeka uma ukukhanya kungena ehlweni, kudlule ezindaweni eziningi, ebese kuqoqana endaweni eyodwa ngemumva kwehlo, ukuze isithombe sigqame. Ukubona kulele ekutheni amehlo ayakwazi yini ukusebenza ekuqoqeni lokhu ukukhanya. Abantu abangaboni kahle, amehlo abo akasebenzi kahle; kuwukuthi izibuko kanye nama-Contact Lenses akusabasebenzeli futhi ukubona kwabo akwanele ukuzwenza izinto zansuku zonke, lokhu kulimaza izinga lokuphila kwabo. Lolucwaningo lukala izinga lokusebenza kwamehlo kwintsha encane enenkinga enkulu yokungaboni kahle, iqhathaniswa nezinga lempilo yabo. Lokhu kuzohlanganisa nokuqhathanisa imibandela edala ukungaboni kahle.

Umntwana wakho uyamenywa ukuhlanganyela kulolu cwaningo ukunyusa ukuqonda kwethu izinto ezidala ukungaboni kahle kwimpilo yansuku zonke.

Yini eyingxenye yocwaningo?

Okokuqala kuzoba khona indlela yokubheka, kusebenziswa imibuzo, ukubhala imininingwane yomntwana njengeminyaka nobulili njalo njalo. Kuzolandela ukuhlola amehlo(bheka uhlobo lwezibuko umntwana azidingayo) nokuhlola indlela yokubona yomntwana, imibala, kanye nezinto ezisizungezile. Emva kwalokho umntwana uzocelwa ukuphendula imibuzo ngezinga le mpilo yakhe.

Ukuhlanganyela kulolu cwaningo angeke kube nezuzo kuwena noma umntwana kodwa kuzosiza thina ukuthi siqonde izinto ezibanga ukungaboni futhi sikwazi ukuthola indlela ypkuphatha kahle lesi simo. Ukuhlanganyela kulolu cwaningo kungokuzikhethela, futhi ayikho imali ekhokhwayo. Imiphumela yalolu cwaningo izotholakala uma uyidinga. Umntwana wakho unalo ilungelo lokuhoxa kulolu cwaningo noma ingasiphi isikhathi ngaphandle kokuba nezinkinga. Akukho ukuzifaka engcupheni ngokwempilo kulolu cwaningo.

Imfihlo

Yonke imiphumela izogcinwa iyimfihlo kuze kuyophela ucwaningo.

Imininingwane yomcwaningi Shivan Naipal, 0845565805, shivaninaipal@gmail.com

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APPENDIX VIII: CONSENT AND ASSENT FORM – ENGLISH AND ISIZULU

Study title: Visual function and quality of life in adolescents with visual impairment: a case study of the Arthur Blaxall School in Pietermaritzburg

I, parent/guardian of _____, confirm that I have read and understood the details of the abovementioned study and I consent to allow my child to participate in the study. I understand that participation is purely voluntary and all information will be kept confidential throughout the duration of the study. I am aware that my child may withdraw from the study at any time without any consequences.

_____ _____

Parent/Guardian's signature Date

I, _____, confirm that the details of the abovementioned study have been explained to my complete understanding. I consent to participate in this research study. I understand that participation is purely voluntary and all information will be kept confidential throughout the duration of the study. I am aware that I may withdraw from the study at any time without any consequences.

_____ _____

Participant's signature Date

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IFOMU LESIVUMELWANO

Isihloko socwaningo: Ukusebenza kokubona nezinga lempilo kwintsha encane enenkinga yokungaboni kahle: isifundo sombhali u-Aurthur Blaxall School wase-Pietermaritzburg

Mina, Mzali ka _____ ngiyavuma ukuthi ngifundile ngaqonda imininingwane yocwaningo lushiwo ngaphezulu futhi ngiyavuma ukuthi umntwana wami ahlanganyele kulolu cwaningo. Ngiyaqonda ukuthi ukuhlanganyela kungokozikhethela futhi lonke ulwazi kuzogcinwa luyimfihlo kuze kuphele ucwaningo. Ngiyaqonda ukuthi umntwana wami angahoxa kulolu cwaningo noma inini ngaphandle kokuba nezinkinga.

_____ _____

Ukusayini koMzali/Mgadi Usuku

Mina, _____, ngiyavuma ukuthi imininingwane yocwaningo olushiwo ngaphezulu luchazwe kahle ngokuqonda okuphelele. Ngiyavuma ukuhlanganyela kulesi sifundo socwaningo. Ngiyaqonda ngokuphelele ukuthi ukuhlanganyela kungokuzikhethela futhi lonkw ulwazi luzogcinwa luyimfihlo kuze phele ucwaningo. Ngiyazi ukuthi ngingahoxa kulolu cwaningo noma isiphi isikhathi ngaphandle kokuba nezinkinga.

_____ _____

Ukusayina komhlanganyeli Usuku

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APPENDIX IX: PUBLICATION - A REVIEW OF VISUAL IMPAIRMENT

African Vision and Eye Health
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AOSIS

Page 1 of 4 Review Article

A review of visual impairment

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Visual impairment (VI), a global concern that is likely to escalate with prolonged life expectancies, has gained increasing attention in the realm of eye care. The purpose of this article is to highlight the different aspects of VI, including its definition and characteristics, prevalence, causes and implications. The importance of rehabilitation in individuals with VI is also discussed.

Introduction

Definition and characteristics of visual impairment

Visual impairment (VI) is a condition of reduced visual performance that cannot be remedied by refractive correction (spectacles or contact lenses), surgery or medical methods.[1] Consequently, it results in functional limitations of the visual system that may be characterised by irreversible vision loss, restricted visual field and decreased contrast sensitivity, increased sensitivity to glare as well as decreased ability to perform activities of daily living, such as reading or writing.[2]

Corn and Lusk[3] affirm that individuals with VI have measurable vision, yet experience difficulties accomplishing visual tasks even with the use of refractive correction. Furthermore, these individuals are sometimes capable of enhancing their abilities to accomplish visual tasks with the use of compensatory low vision aids and/or environmental adjustments.[3] This description of VI is useful because it considers that individuals with VI may not always display predictable clinical changes in visual function and that changes in functional vision may not always correlate to measurable changes in clinical findings.[3]

In 1992, the World Health Organization (WHO) added a functional dimension to the definition of VI.[4] This definition is stated as:

> a person with low vision is one who has impairment of visual functioning even after treatment and/or standard refractive correction, and has VA of less than 6/18 to light perception, or a visual field of less than 10 degrees from the point of fixation, but who uses, or is potentially able to use, vision for the planning and/or execution of a task. (p. 18)[4,5]

This definition refers to the visual acuity (VA) of the better eye with the best possible refractive correction.

According to the International Classification of Diseases, 10th revision (ICD-10), VI may be classified into four levels, namely mild or no VI, moderate VI, severe VI and blindness.[6] Moderate and severe VI are collectively categorised as VA of less than 6/18, but equal to or better than 6/120 in the better eye with the best refractive correction (Table 1).[4,6] When the extent of the visual field is considered, an individual with a visual field radius of no greater than 10 degrees around the central point of fixation in the better eye is placed in the third category (blindness).[6]

Prevalence of visual impairment

Few studies have reported on the prevalence of VI.[7,8,9,10] More than 90% of individuals with VI live in developing countries. This geographical disparity may be attributed to a higher prevalence of conditions related to poverty or environmental conditions and poor access to health care services in developing countries.[4,7,11] In terms of gender, women are at a higher risk of VI because of longer life expectancies and lack of access to health care services especially in rural areas.[4] Furthermore, the global prevalence of blindness is greater in women than in men.[12] Interestingly, Stevens et al.[12] found that for blindness, this gender disparity is highest in high-income regions and lowest in Sub-Saharan Africa. The authors hypothesised that this low gender disparity in Sub-Saharan Africa may be because of onchocerciasis, which is more prevalent in men than women in endemic African regions.

The prevalence of VI varies depending on whether presenting vision or best-corrected vision is reported.[13] In 2002, it was estimated that with best-corrected vision there were 161 million individuals with VI globally.[9] However, when the prevalence of uncorrected refractive error was included, this value increased substantially to 314 million individuals with VI.[14] This implies that an additional 153 million individuals were visually impaired from uncorrected refractive error alone.[14]

The literature reports that there might be a decrease in the prevalence of VI (Table 2).[9,10,11,12,13,14,15,16] By 2010, there was an overall decline worldwide of approximately 10% in the total number of individuals with VI from 314 million to 285 million, of which an estimated 6.6% were children younger than 14 years.[8] In Africa, the total number of individuals with VI decreased slightly from 26.8 million in 2002 to 26.3 million in 2010.[8,9] The observed decrease in the prevalence of VI globally and in Africa may be attributed to the achievements of the VISION 2020: Right to Sight initiative by the WHO and the International Agency for the Prevention of Blindness (IAPB) that was implemented in 1999.[15] Some of these achievements include a fivefold increase in the number of cataract operations performed in India, decrease in blindness because of trachoma and onchocerciasis, and reduction in childhood blindness as a result of vitamin A supplementation, immunisation against measles, and increased focus on retinopathy of prematurity.[15] Furthermore, there has been profound advancement in providing spectacles to poor communities, thereby reducing VI caused by uncorrected refractive error.[15]

TABLE 1: The International Classification of Diseases, 10th revision classification of visual impairment.

Category	Presenting distance visual acuity	
	Worse than	Equal to or better than
0 Mild or no visual impairment	-	6/18
	-	3/10 (0.3)
	-	20/70
1 Moderate visual impairment	6/18	6/60
	3/10 (0.3)	1/10 (0.1)
	20/70	20/200
2 Severe visual impairment	6/60	3/60
	1/10 (0.1)	1/20 (0.05)
	20/200	20/400
3 Blindness	3/60	1/60*
	1/20 (0.05)	1/50 (0.02)
	20/400	5/300 (20/1200)
4 Blindness	1/60*	Light perception
	1/50 (0.02)	-
	5/300 (20/1200)	-
5 Blindness	No light perception	-
9	Undetermined or unspecified	-

Source: World Health Organization. International statistical classification of diseases and related health problems 10th revision (ICD-10) [homepage on the Internet]. 2016 [cited 2017 Jan 16]. Available from: http://apps.who.int/classifications/icd10/browse/2015/en#/H54

*, or counts fingers (CF) at 1 metre

In terms of the levels of VI, the number of individuals with moderate and severe VI worldwide decreased from 269 million in 2004 to 246 million in 2010.[8,9,14] In addition, globally it is estimated that there are 17.5 million children aged 0–14 years with moderate and severe VI.[8] Specifically in South Africa, the prevalence of individuals with moderate and severe VI decreased from 2.3% (660 405 of 47.8 million) in 2005 to 2.0% (662 472 of 50.1 million) in 2010.[16] However, there is a paucity of data available on VI in children and adolescents (aged 0–14 years) in South Africa. Of the global estimate of 1.4 million blind children, 1 million are found in Asia while 300 000 are found in Africa.[4]

Causes of visual impairment

The causes of VI differ significantly between regions, with the prevalence of cataract being lowest and macular degeneration being greatest in high-income regions.[17] Table 3 [7,8,9,10,17,18,19,20,21] summarises studies that have reported on the distribution of the major causes of VI. Globally, the leading causes of blindness and moderate and severe VI include uncorrected refractive error, cataract and macular degeneration.[4,8,9,17] Bourne et al.[17] further reported that the magnitude of individuals affected by blindness and moderate and severe VI caused by uncorrected refractive error increased from 6.3 million and 88.0 million in 1990 to 6.8 million and 101.2 million in 2010, respectively.

In Africa, the main causes of moderate and severe VI in adults are cataracts and diseases affecting the cornea and retina.[4,7] In Sub-Saharan Africa, the prevalence of cataracts causing VI

TABLE 2: Summary of studies reporting on the overall prevalence of visual impairment and its different levels.

Author	Year	Area	Number of visually impaired	Number of individuals with moderate and severe VI	Number of individuals blind
Resnikoff et al.[9]	2002	Global	161 million (19 million below age 15)	124 million (17.6 million below age 15)	37 million (1.4 million below age 15)
Resnikoff et al.[14]	2004	Global	314 million (incl. 153 million with uncorrected refractive error)	269 million (incl. 145 million with uncorrected refractive error)	45 million (incl. 8 million with uncorrected refractive error)
Pascolini and Mariotti[8]	2010	Global	285 million 18.9 million (aged 0–14)	246 million 17.5 million (aged 0–14)	39 million 1.4 million (aged 0–14)
Stevens et al.[12]	2010	Global	223.4 million	191 million (109 million women)	32.4 million (19.6 million women)
Resnikoff et al.[9]	2002	Africa	26.8 million	20 million	6.8 million
Pascolini and Mariotti[8]	2010	Africa	26.3 million	20.4 million	5.9 million
Sacharowitz[10]	2002	Sub-Sahara Africa	NR	16–18 million	5–6 million
Sacharowitz[10]	2002	South Africa	Approx. 600 000	NR	NR
The Vision Loss Expert Group[16]	2005	South Africa	872 780	660 405	212 375
The Vision Loss Expert Group[16]	2010	South Africa	869 084	662 472	206 612

NR, not reported; VI, visual impairment.

TABLE 3: Summary of studies reporting on the major causes of visual impairment.

Author	Area	Cause of moderate and severe VI	Cause of blindness
Resnikoff et al.[9]	Global	Cataract	Cataract, glaucoma, ARMD, trachoma, corneal opacity, childhood blindness, diabetic retinopathy
Pascolini and Mariotti[8]	Global	Uncorrected refractive error, cataract, glaucoma	Cataract, glaucoma, ARMD, childhood blindness, corneal opacity
Pizzarello et al.[20]	Africa	NR	Cataract, trachoma, onchocerciasis, childhood blindness, refractive error
Oduntan[7]	Africa	Cataract, corneal and retinal disease	NR
Bourne et al.[17]	Sub-Sahara Africa (southern)	Uncorrected refractive error, cataract, macular degeneration	Cataract, uncorrected refractive error, macular degeneration
Oduntan[7]	South Africa	Cataract, corneal opacity and glaucoma	NR
Sacharowitz[10]	South Africa	Cataract, glaucoma, refractive error, retinal diseases	Corneal scarring
Naidoo et al.[21]	South Africa	NR	Cataract, refractive error, glaucoma
Cockburn et al.[18]	Cape Town,	Cataract, posterior segment diseases, refractive error	Posterior segment diseases, cataract, glaucoma, ARMD
Maake and Oduntan[19]	Limpopo	Uncorrected refractive error, cataract, glaucoma	Cataract, glaucoma, corneal anomalies

ARMD, Age-Related Macular Degeneration; NR, not reported; VI, visual impairment.

declined from 24.2% in 1990 to 17.8% in 2010; however, the prevalence of macular degeneration and glaucoma increased from 2.8% and 1.5% in 1990 to 4.8% and 2.6% in 2010, respectively.[17] Specifically in South Africa, the main causes of moderate and severe VI include cataract, corneal opacity, glaucoma, refractive error and retinal diseases such as retinitis pigmentosa, Stargardt's disease, Usher's syndrome and Leber's Congenital Amaurosis.[7,10] Recent studies undertaken in South Africa confirmed that cataract, uncorrected refractive error, posterior segment diseases (optic atrophy, trauma and macular hole) and glaucoma were the main causes of moderate and severe VI.[18,19]

Even though 65% of individuals with VI are older than 50 years, childhood blindness and VI remain a major concern because of the expected number of years to be lived.[22] Of the 1.4 million children that are blind, a quarter is as a result of retinal diseases while 20% are because of corneal pathology.[23] Cataract and glaucoma account for 13% and 6% of blindness in children, respectively.[23] Globally, the main cause of moderate and severe VI in children aged 5–15 years is uncorrected refractive error.[4] Corneal scarring accounts for between 25% and 50% of the VI reported in rural parts of Africa and Asia.[23] In South Africa, the chief causes of childhood blindness include retinitis pigmentosa, albinism, cataract, glaucoma, nutritional causes, infections and inherited genetic disorders (other than retinitis pigmentosa and albinism).[7]

Implications of visual impairment

Visual impairment has severe consequences, more especially in developing countries. Its debilitating effects decrease the ability of affected individuals to function independently and may negatively impact daily living and quality of life.[24] Most of the information about the world is achieved through the sense of vision as it is fundamental to learning and integrating information from the other sensory organs.[25,26,27] Approximately 80% of learning occurs through vision. Thus, if VI is present at birth or develops shortly afterwards, it may negatively impact development. As a result, children with VI are developmentally delayed in gross and fine motor skills in addition to visual perception.[28] Furthermore, approximately 90% of children with VI are deprived of an education because of socioeconomic and physical barriers including discrimination and stigmatisation, limited accessible schools and the inability to cope with the impairment.[4,29]

The physical, social and psychological well-being of children and adolescents are also negatively affected.[30] It has been reported that children and adolescents with VI experienced reduced quality of life when compared to age-matched children and adolescents without VI.[31] VI also contributes to the socioeconomic burden on society as a result of a loss in education, career opportunities and economic gain for individuals with VI and their families.[14,32]

Rehabilitation in visual impairment

The functional ability of an individual with VI is not determined solely by the magnitude of vision loss. In addition to the physiology of the eye, other physical, psychological and social factors also influence daily living. Individuals with VI experience more symptoms of depression than those without VI.[33] The combination of social, functional and psychological disabilities related to VI result in an overall reduction in quality of life.[33] As a result, rehabilitation of an individual with VI requires a holistic approach that considers social, economic and psychological needs in addition to their visual needs.[34] An ideal interdisciplinary team of health care professionals that can provide such an approach would include, among others, an optometrist, ophthalmologist, psychologist, audiologist, occupational therapist, orientation and mobility instructor and physiotherapist.[34]

The rehabilitation of children and adolescents with VI aims to increase their functionality and independence, aid in their education and improve their social interaction. It has been reported that proper management of individuals with VI can provide the same quality of life as that of normally sighted individuals.[2] Rehabilitation services should be made available, accessible and affordable particularly in developing countries. Early intervention provides effective visual rehabilitation and is vital in reducing the incidence and impact of VI. The perspective of the child with VI is vital in their rehabilitation as their views do not always correspond with the views of their parents or even that of the health care professionals.[30] Significant gender differences exist regarding access to rehabilitation for individuals with VI. Even though more women are blind or have VI, only a minority seek

rehabilitation and/or low vision services.[35] This warrants the need for vision screening and awareness programmes targeting women, more especially in developing areas.

Conclusion

Visual impairment remains a global concern that is likely to escalate with prolonged life expectancies. Approximately 90% of individuals with VI live in developing countries because of poor access to health care services.[4,7] There has been an overall decline in the number of individuals with VI from 314 million to 285 million in 2010, which may be attributed to the achievements of the VISION 2020: Right to Sight initiative.[8,14,15] Women are at higher risk of VI than men; however, this gender disparity was lowest in Sub-Saharan Africa.[4,12] The implications of childhood blindness and VI may be more significant because of greater life expectancies,[22] thus contributing to the socioeconomic burden on society.[14] As a result, rehabilitation of individuals with VI requires a holistic approach that is readily available, accessible and affordable, particularly in developing countries.[34]

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

This article forms part of a Master of Optometry research study (BE 457/16) being undertaken by S.N. with N.R. as the supervisor.

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