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# Plusoptix photoscreener use for paediatric vision screening in Flanders and Iran

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## ABSTRACT.

**Purpose:** Photoscreening assesses risk factors for amblyopia, as an alternative to measurement of visual acuity (VA) to detect amblyopia, on the premise that its early correction could prevent development of amblyopia. We studied implementations of Plusoptix photoscreening in existing population-based screening in Flanders and Iran.

**Methods:** In Flanders, VA is measured at age 3, 4 and 6, photoscreening was added to existing screening at age 1 and 2.5 years in 2013. In Iran, VA is measured at ages 3–6 years, photoscreening was added at ages 3–6 years between 2011 and 2016. Plusoptix use was analysed in the literature for detection of risk factors for amblyopia and amblyopia itself, for ages 0–3 and for 4–6. A questionnaire, containing seven domains: existing vision screening, addition of photoscreening, implementation in screening program, training, attendance, diagnosis and treatment, and costs was distributed. In Iran, screening procedures were observed on site.

**Results:** Implementation of Plusoptix photoscreening was mainly analysed from questionnaires and interviews, its effectiveness from literature data. In Flanders, of 56 759 children photoscreened at age one (81% of children born in 2013), 9.2% had been referred, 13% of these were treated, mostly with glasses, resulting in an increase of 4-year-old children wearing glasses from 4.7% to 6.4%. In Iran, 90% of children aged 3–6 years participated in vision screening in 2016, but only those who failed the vision test were subjected to photoscreening.

**Conclusions:** In Flanders, the use of Plusoptix photoscreening at ages 1 and 2.5 resulted in an increase of children wearing glasses, but it remains unknown how many cases of amblyopia have been prevented. Studies are needed to determine the relation between size and sort of refractive error and strabismus, and the increased chance to develop amblyopia.

**Key words:** amblyopia – paediatric vision screening – Plusoptix photoscreener – strabismus

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## Introduction

Amblyopia is a decrease of visual acuity (VA) of an eye caused by not using that eye, for instance in case of strabismus or when the image of the eye is out of focus in case of high refractive error (particularly hypermetropia or astigmatism), and especially if it differs between the eyes (anisometropia). If a child with strabismus fixates predominantly with one eye, the perception of the other image of the other eye is suppressed. Amblyopia has a prevalence of approximately 3.25% (Groenewoud et al. 2010). Treatment is very effective if carried out in childhood, necessitating detection of amblyopia, for example by measurement of VA, at ages 4–5 (Atkinson et al. 1996). While strabismus may be noticed by parents, the amblyopia due to refractive error may remain unnoticed until much later (Sloot et al. 2015b). There is also evidence to suggest that early correction of hypermetropia can prevent the onset of some types of strabismus and that early correction of refractive error can prevent refractive amblyopia (Atkinson et al. 1996). Hence, a logical step seems measurement of refractive error (refraction) and, in case of large refractive error, prescription of glasses as early as possible, in childhood, to avoid development of amblyopia.

No studies have been carried out yet that determined the relation between

the size and sort of the refractive error or strabismus, and the increased odds to develop amblyopia. In 2003, the American Academy of Pediatric Ophthalmology and Strabismus (AAPOS) developed criteria for referral after photoscreening (Donahue et al. 2003, 2013). It was recommended that a child is referred by a screener to an orthoptist or ophthalmologist, in case of anisometropia  $> 1.5$  dioptres, hypermetropia  $> 3.5$  dioptres, astigmatism  $> 1.5$  dioptres or in case of astigmatism with oblique axis  $> 1.0$  dioptres, myopia  $< -3.0$  dioptres or manifest strabismus (Donahue et al. 2003). In 2013, the threshold of the AAPOS criteria was raised because too many children were being referred. The updated criteria for children aged 12–30 months were as follows: astigmatism  $> 2.0$  dioptres, hypermetropia  $> 4.5$  dioptres and anisometropia  $> 2.0$  dioptres, and for children aged 31–48 months: astigmatism  $> 2.0$  dioptres, hypermetropia  $> 4.0$  dioptres and anisometropia  $> 2.0$  dioptres (Donahue et al. 2013).

Photoscreener devices are widely used in several countries in the world to detect risk factors for development of amblyopia. All of these devices measure the refractive power of the eye, and, hence, can indicate if glasses are needed, and some photoscreeners can also detect strabismus in young children. These devices can be used before age 3. Measurement of VA in children at the age of 36 months as part of population-wide screening fails in 16.6% of children, in addition to 15.5% of children not reaching the threshold and, hence, cannot be done cost-effectively (Telleman et al. 2018). The rates of failed measurement of VA are lower when performed by experienced orthoptists (Becker et al. 2002). Visual acuity (VA) can be measured even in younger children by preferential-looking techniques, but only with highly trained personnel taking sufficient time (Atkinson et al. 1983).

Photoscreeners have gained popularity in the United States, where national vision screening programs and trained personnel have been scarce. In the United States, several photoscreener devices have been used, such as the MTI photoscreener, the West Palm Beach, the Visiscreen OSS-c, the iScreen system, the Welch Allyn Suresight vision screener and the

Plusoptix photoscreener (Arthur et al. 2009). All have been shown to be effective in detecting refractive errors in young children, to varying degree. The Plusoptix photoscreener, a German made, handheld video-refractor, also measures pupil size, interpupillary distance and eye alignment. The software algorithm derives the refractive strength of the eye of the light crescent, visible in the pupil when using off-axis, infrared illumination (Sanchez et al. 2016). Different versions of the basic software and equipment are marketed as screening devices, set up to report a pass/fail criterion based on predetermined settings (S04, S08, S09, S12 and S16) for community screening by minimally skilled personnel, as auto-refractors (A09, A12 and A16) which assess refractive error in ophthalmic practices, and also as specialist 'Power-Refractors' sold for laboratory use (Sanchez et al. 2016). The fundamental benefits of the Plusoptix photoscreener device over other photoscreeners are that it assesses both eyes simultaneously, thus, it can also detect strabismus in most cases and it is very quick to administer, but it also has some drawbacks such as limited operating range and a high 'untestable' rate (Arthur et al. 2009).

Many studies on photoscreening have been published, but none of these describe the implementation of photoscreening at a national scale. The Plusoptix photoscreener has only been incorporated into nationwide existing screening programs in Flanders and in Iran.

In vision screening in Flanders (Belgium), visual acuity (VA) is measured at age 3, 4 and 6 years. In 2013, the Plusoptix photoscreener was added at age 1 and 2.5 years for detection of amblyopia risk factors such as refractive error and strabismus. In vision screening in Iran, VA is measured 1–3 times between ages 3 and 6. In 2011, the Plusoptix photoscreener was first added. Currently, photoscreening is used in all of Iran at ages 3–6, but primarily in children in whom the measurement of VA has failed.

For this study, we performed a field orientation study including interviews and on site observations in Flanders and in Iran, to evaluate the experience in the first years of adding photoscreening to existing vision screening programs.

## Methods

A literature search on the effectiveness and possible role of the Plusoptix photoscreener in the detection of visual disorders was performed based on original papers and systematic reviews in addition to a literature search on the vision screening programs in Flanders, Iran and the Netherlands. We searched the PubMed database, Medline database and Cochrane Library data on 10 October 2017. A widespread electronic search was performed using several keywords both individually and in combination, such as photoscreener, Plusoptix, power refractor, preschool vision screening, vision screening, auto-refraction, paediatric vision screening and cycloplegic auto-refraction. Studies were selected by title and abstract analysis. Studies were eligible if they described primarily the effectiveness of the Plusoptix photoscreener in vision screening programs and compared it to a comparison group. Further inclusion criteria were as follows: English language, papers on handheld-devices specifically the Plusoptix photoscreener, on early detection of amblyopia with explanation of the referral criteria, and on photoscreening in healthy children only, original papers and systematic reviews. Exclusion criteria were as follows: papers on children older than 10 years old, on handheld-devices which did not mention the Plusoptix photoscreener and papers without a comparison group. If the studies seemed eligible, the full text was read.

### Literature data analysis

Data from the literature were analysed with the PICO procedure (Huang et al. 2006). The acronym PICO stands for: Patient, Population, Problem, Intervention, Comparison and Outcome. In principle, the PICO that was addressed was fourfold, as two age groups and two target conditions were evaluated.

The two **P**atient groups were as follows: children aged 0–3 years and 4–6 years. This distinction in age was made because VA can reliably be measured from age 4 onwards.

For the **I**nterventions, the distinction was made between the two target conditions: risk factors for amblyopia and amblyopia itself.

**Comparison 1: Retinoscopy under cycloplegia.** Cycloplegic retinoscopy, performed by orthoptists, ophthalmologists or optometrists, is the gold standard for measurement of refractive errors in young children. It is usually done after administration of eye drops that cause temporary paralysis of accommodation: cycloplegia. This procedure cannot be used for screening of all children in the population as it takes a long time, is unpleasant for the child, needs specific skills and safety measures and would, hence, be prohibitively expensive.

**Comparison 2: Measurement of VA.** Measurement of VA at age 4–6 is the gold standard for the diagnosis of amblyopia, especially if performed by trained personnel, and after exclusion of other causes of decreased VA. The difference between the VA in the amblyopic eye and the VA of the better eye should be at least two LogMAR lines for diagnosis of amblyopia to be made and other causes of decreased VA like structural abnormalities of the eyes are absent. In summary, we defined four **Outcomes** in the analysis, as two age groups 0–3 and 4–6 and two target conditions were evaluated.

#### Data collection

The literature search preceded the interviews. A field orientation study was performed using questionnaires. The questionnaires were distributed among local stakeholders in vision screening in Flanders and in Iran. Stakeholders were subsequently interviewed in person. In Iran, screening procedures were also observed on site. Questionnaires with seven domains (Appendices 1 & 2) were developed by a focus group (paediatric ophthalmologists, orthoptists and public healthcare researchers), and consists of the following domains: (1) pre-existing vision screening program, (2) age of addition of photoscreening, (3) implementation in the screening program, (4) training, (5) attendance, (6) diagnosis and treatment and (7) costs of vision screening. From these data and the literature, the current provision of childhood screening and the types of screening programs used were identified in both countries. The questionnaires were based on the questionnaires of the EUSCREEN Study. In this study, data are being collected about

paediatric vision and hearing screening programs from countries in Europe and compared for cost-effectiveness (Sloot et al. 2015a). Interviews were either recorded or notes were taken. Answers were collated and cannot be traced to named individuals. Data of vision screening in Flanders and Iran were collected from electronic screening records by the head of the department of the child healthcare centres. In Flanders, data collection was provided from interviews and electronic screening records by the Central advisory Doctor of the department of 'Kind en Gezin' which is a governmental agency in Brussels, coordinating screening programs in Flanders. In Iran, data collection was provided from interviews and unpublished electronic screening records from the national Welfare Organization in Tehran named 'Sazman Behzisti Keshvar'. In Iran, all screening programs are organized by Welfare Organizations, which are paid by the government.

## Results

Our literature search produced 38 papers on assessment of the effectiveness of the Plusoptix photoscreening in detecting risk factors for amblyopia: 20 papers met the inclusion criteria. We found seven studies with the specified sensitivity and specificity for detection of risk factors for amblyopia in comparison with cycloplegic retinoscopy and one study with specified sensitivity and specificity for detection of amblyopia in comparison with measurement of VA. A total of eight studies were included.

As for outcome of the PICO, the two age categories have been analysed together, as in the process of data analysis it turned out that several studies included children from both age groups (Table 1). Seven studies examined only the detection of risk factors for amblyopia and not the detection of amblyopia itself. One recent study (Van der Ploeg et al. 2017) compared screening with Plusoptix photoscreening with screening with measurement of VA, at the ages of 36, 45 and 60 months. The Plusoptix photoscreener does not measure VA and therefore cannot diagnose amblyopia per se but it does detect risk factors for amblyopia, like refractive errors and strabismus. Therefore, the PICO

primarily provided: outcome measures on the parameter: detection of amblyopia risk factors in children aged 0–3 and 4–6 years together.

#### Outcome one: Detection of amblyopia risk factors in children aged 0–3 and 4–6 years

Arnold et al. investigated the diagnostic accuracy of the Plusoptix S09 photoscreener for detection of refractive error or strabismus in 108 children with amblyopia between 9 and 146 months old, using the AAPOS 2003 criteria. Children were examined by the Plusoptix photoscreener, followed by an ophthalmic examination consisting of measurement of VA, eye examination and cycloplegic refraction. Sensitivity in children aged 4 and younger was 74%, specificity 92% and positive predictive value of 89%. In 21% of children, examination with the Plusoptix photoscreener failed (Arnold & Armitage 2014).

Ehrt et al. investigated screening for refractive errors by the Plusoptix S04 photoscreener in 161 children between 6 and 72 months old. The criteria for amblyogenic refractive errors were chosen according to German criteria defined by Arens & Bertram in 1998: hypermetropia  $\geq 3.0$  dioptres, myopia  $\leq -2.0$  dioptres, astigmatism  $\geq 1.0$  dioptres and anisometropia  $\geq 1.0$  dioptres. Sensitivity was 70% and specificity 80%. In 15% of children, no measurements were available (Ehrt et al. 2007).

Huang et al. studied the performance of the Plusoptix A12C photoscreener in 1766 children between 3 and 4 years old using the AAPOS 2013 criteria. The outcomes of measurement of refractive error were available in 359 children; sensitivity was 93%, specificity 94% and positive predictive value 41%. Sensitivity for strabismus was 25%, specificity 99.8% and positive predictive value 25% (Huang et al. 2017).

Paff et al. evaluated the diagnostic accuracy of the Plusoptix S08 photoscreener for detection of strabismus and refractive errors based on the AAPOS 2003 criteria. Therefore, Plusoptix photoscreening measurements were compared to the outcome of a cover test to detect manifest strabismus and cycloplegic refraction. In total, 200 children between 3 months and 11 years were included. Sensitivity for

**Table 1.** Sensitivity and specificity of detection of risk factors for amblyopia: refractive error and strabismus, and for detection of amblyopia itself with the Plusoptix photoscreener (Van der Ploeg et al. 2017).

References	Age child (months)	Plusoptix type	Target condition	Comparison	Sensitivity (%)	Specificity (%)		
Arnold et al. (2014)	9–48	S09	Amblyopia risk factors	Cycloplegic retinoscopy	Refractive error and strabismus	74	Refractive error and strabismus	94
Ehrt et al. (2007)	6–72	S04	Amblyopia risk factors	Cycloplegic retinoscopy	Refractive error and strabismus	70	Refractive error and strabismus	80
Huang et al. (2017)	36–48	A12C	Amblyopia risk factors	Cycloplegic retinoscopy	Refractive error	93	Refractive error	94
Matta et al. (2010)	36–60	S04	Amblyopia risk factors	Cycloplegic retinoscopy	Strabismus	25	Strabismus	99.8
Paff et al. (2010)	3–132	S08	Amblyopia risk factors	Cycloplegic retinoscopy	Refractive error	99	Refractive error	82
					Hypermetropia	33	Hypermetropia	98
					Myopia	74	Myopia	98
					Astigmatism	90	Astigmatism	78
					Strabismus	37		
Van der Ploeg et al. (2017)	36	S12C	Amblyopia risk factors & amblyopia	APK	-	-		
	45	S12C		Landolt-C	Landolt-C	67	Landolt-C	87
	60	S12C		Landolt-C	Plusoptix	63	Plusoptix	94
Sanchez et al. (2016)	-	S04, S08, S09, A09	Amblyopia risk factors	Cycloplegic retinoscopy	Hypermetropia	44	Hypermetropia	98
					Myopia	86	Myopia	95
					Astigmatism	-	-	
					Strabismus	41	Strabismus	98
Yan et al. (2015)	26–169	A09	Amblyopia risk factors	Cycloplegic retinoscopy	Refractive error	95	Refractive error	7.5
					Strabismus	41	Strabismus	8.3

In the study of Van der Ploeg et al. (2017), the sensitivity and the specificity of both the Landolt-C measurement of VA and that of the Plusoptix photoscreener were derived from the examinations at 45 and 60 months.

hypermetropia refractive error was 33.3%. for myopia 74% and for strabismus 37% (Paff et al. 2010).

Sanchez et al. investigated the diagnostic accuracy of the Plusoptix S04, S08, S09 and A09 in early detection of amblyopia in a review. Both manufacturer criteria and the AAPOS 2003 criteria were used to determine refractive error and strabismus. The Plusoptix photoscreener and most other photoscreeners were reported to have missed or underestimated the presence of strabismus (an important amblyogenic risk factor) with a sensitivity of 41% (Sanchez et al. 2016).

Yann et al. studied the performance of the Plusoptix A09 photoscreener in detecting amblyopia risk factors compared to cycloplegic retinoscopy in 178 children between 2.2 and 14.1 years old using the AAPOS 2003 criteria. Sensitivity was 94.9% and specificity 67.5% for detection of refractive error. Sensitivity for detection of strabismus was 40.7% and specificity 98.3% (Yan et al. 2015).

The effectiveness of the detection of risk factors for amblyopia at an age that VA can be measured has only been examined in the study of Matta et al. (2010). They studied the performance of the Plusoptix S04 photoscreener for detection of risk factors for amblyopia

in children aged 3–5 in a paediatric ophthalmology practice using the AAPOS 2003 criteria. In total, 153 children were included. After cycloplegia, 81 children were found to have risk factors for amblyopia after Plusoptix photoscreening, 93 children were found to have risk factors for amblyopia. Sensitivity after Plusoptix photoscreening was 99%, specificity 82%, the false-positive rate 18% and the false negative rate 1.2%. Compared to the general population, the children included in this study were from an orthoptic practice, were an enriched population with a higher prevalence of amblyopia (Matta et al. 2010).

**Outcome two: Detection of amblyopia in children aged 0-3 and 4-6 years**

Van der Ploeg et al. (2017) examined routine vision screening taking place at Youth Health Care Centers (YHCC) in the Netherlands. They compared current measurement of VA at ages 36, 45 and 60 months, the latter two, using Landolt-C optotypes, with the Plusoptix S12C photoscreener using referral based on the AAPOS 2013 criteria. In total, 2144 children were examined with both methods. Twenty-nine from 294 children were referred because of abnormal VA test, against 23 from 140

children who did not meet the AAPOS 2013 criteria with the Plusoptix test. Sensitivity for detection of amblyopia with the Plusoptix photoscreener was 63% and specificity was 94%. Sensitivity for detection of amblyopia with the Landolt-C was 67% and specificity was 87%. However, most children had had one or two VA measurements before, at 36 months or at 36 and 45 months, and children who were being treated by an orthoptist or wore glasses were excluded from the study: 3% at 36 months, 9.1% at 45 months and 11.7% at 60 months, respectively. Hence, amblyopia detection was studied in a population where most cases of amblyopia had already been detected and excluded from participation of the study.

**Field orientation in Flanders**

Vision screening in Flanders has been officially regulated by the government since 2000. In the vision screening program, most cases of amblyopia are detected by measurement of visual acuity at age 3, by the Kay Crowded Book at 3 metres, and at the ages 4 and 6 by the LogMAR Crowded Test, at school and at Child Health Care Centers (CHCC). The vision screening is

**Table 2.** Reason for referral, after photoscreening at age one in Flanders.

Reason for referral	Referrals (% , number) in 2013*	Referrals (%) in 2014†
Astigmatism	49.20% (4433)	36.0%
Anisometropia	19.20% (1729)	14.3%
Hypermetropia	10.10% (906)	6.8%
Myopia	1.90% (169)	1.4%
Pupil diameter deviation	1.20% (107)	0.8%
Unknown	18.4%	-
Other	-	40.7%

\* Reference: Report vision screening (Cijferrapport Oogscreening), Kind en Gezin, unpublished, 2015, Flanders, Belgium.

† Reference: Boelaert et al. (2017).

performed in the same way in all areas of Flanders.

The Plusoptix photoscreener was introduced on request by Kind en Gezin in 2006. Since 2013, examination with the Plusoptix photoscreener has been added at the age of 1 and 2.5 years carried out by a nurse in a CHCC in 330 health care centres of Kind en Gezin. The training of the nurses is organized internally by Kind en Gezin through online learning modules and practical training, which take around 1 week. Measurement of VA at age 3, 4 and 6 has a coverage between 95% and 100% (Guérin & Hoppenbrouwers 2003), while measurement of refractive error by the Plusoptix photoscreener in children between 0 and 3 years had a participation of 80.4% (59 595) in 2013. After detection of risk factors of amblyopia, children are referred to an ophthalmologist.

#### Outcomes of the vision screening at age one

For this analysis, all children born in 2013 in Flanders were eligible. Following screening by the Plusoptix, based on the original AAPOS 2003 referral criteria, in total 81% (56 759) children participated in the vision screening at age one, 90.8% (51 148) of these children passed the test, and 9.2% (5187) of the children were referred. In Table 2, the number of tests, the reasons for referral to an ophthalmologist and the percentage of referrals for a specific referral criterion are shown. Children were sometimes tested more than once and 5187 children were referred based on more than 1 reason for referral. Astigmatism was the most common reason for referral. Of the children with known follow-up results, 44.1% were diagnosed by the ophthalmologist as having a risk factor for amblyopia at

age one. Of these, 13% were treated (Cijferrapport Oogscreening, Kind en Gezin, unpublished, 2015).

In October 2013, the original AAPOS 2003 referral criteria were adjusted by CHCC Kind en Gezin, because of the high referral rates in 2013. In Table 2, screening results of children aged one born in 2014 in Flanders are presented, based on the adjusted referral criteria: astigmatism  $\geq 3$  dioptres, anisometropia  $\geq 1.5$  dioptres, hypermetropia  $\geq 4$  dioptres, myopia  $\geq 4$  dioptres, anisocoria  $> 1$  mm. In total, 50 955 children aged 1 participated in the vision screening in 2014. Following screening by the Plusoptix 7.9% (4025) of the children were referred, based on these revised criteria (Boelaert et al. 2017). Of all known follow-up results, 71% were diagnosed to be at risk for amblyopia at age one. In 50% of these children, treatment was started, 0.9% of children were treated with occlusion therapy, 3.7% with occlusion therapy and glasses and 56% with glasses only (Boelaert et al. 2017). Note that these criteria are slightly different from the revised AAPOS 2013 referral criteria.

To put the 7.9% referral rate following from the screening by the Plusoptix photoscreener into perspective, the regular vision screening at age 3 had 7.1% (11 771) referral and 2.3% (3813) repeat examination, whereas for vision screening between ages 4 and 6, 8.3% (19 345) was referred and 0.5% (1165) needed re-examination (Guérin 2014, data from 2005 to 2008).

#### Field orientation in Iran

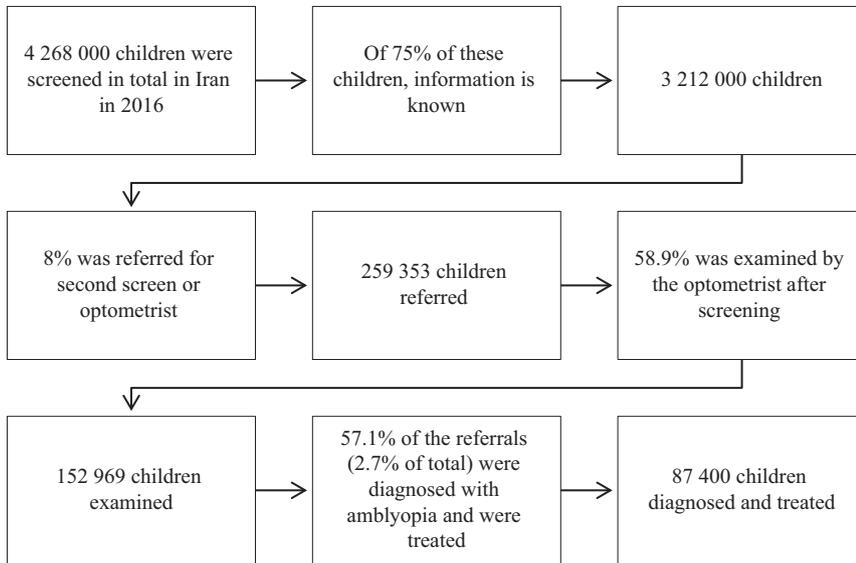
Since 1996, vision screening has been introduced in all 31 provinces in Iran. It started in the city of Bandar Abbas as a pilot screening program for

kindergarten children. As of 2000, all children in the cities and rural areas were included (Rafiei et al. 2017). All provinces have directors who organize yearly training sessions of 1–2 days for kindergarten teachers and nurses. The costs of training are supported by Welfare Organizations which are paid by the government. The standard screening procedure is measurement of visual acuity by the Snellen's illiterate E-chart at the ages of 3–6 years. Children aged 3–6 years are screened at least once (Rafiei et al. 2017). This is performed by certified kindergarten teachers, child health care nurses, primary school teachers and other trained professionals (Khandekar et al. 2009).

The Plusoptix photoscreener was first introduced in Iran in 2011 and was subsequently implemented in all 31 provinces. Measurements are carried out by optometrists and child health-care nurses. However, Plusoptix photoscreening is only used when measurement of VA by the E-chart fails, so photoscreening is not the primary screening test. It is mostly used for uncooperative children or children with mental disorders. So, while most children are screened for low vision and amblyopia itself, some children are screened for risk factors instead.

In case of suspected vision problems detected at the screening, children are first referred to optometrists. In case of uncertainty in diagnosis or unsuccessful treatment results, the child is referred to the ophthalmologist (Khandekar et al. 2009).

For this analysis, all children born in 2016 in Iran were included. Figure 1 gives an overview of the results of the vision screening for children aged 3–6 in 2016. Participation in the vision screening program was 90%, as at least one screening test before entering school is obligatory (Rafiei et al. 2017). In total, 4 268 000 children were screened in Iran in 2016, of which 1 622 939 (38%) children were screened with the Plusoptix photoscreener. It is unknown how many children were referred based on the Plusoptix photoscreener. Since there is a higher percentage of children who have been screened by the Plusoptix, than initially was intended, it is possible that a transition is taking place from using the Plusoptix when measurement of VA failed or when children



**Fig. 1.** Vision screening in Iran in 2016. Reference: Electronic screening records, Welfare Organization, unpublished, 2016, Tehran, Iran.

were uncooperative to the use of the Plusoptix as a primary screening tool. Data collected from electronic screening records were supplied by the national Welfare Organization in Tehran, Iran.

### Exploratory analysis of the costs

In Flanders, approximately 100 000 tests are carried out every year. Costs per test are between € 5.40 and 7.20 (the costs of the purchase and maintenance of the Plusoptix photoscreener device are not included). Each child can be tested twice. Costs per child were on average € 9.00. Between 2010 and 2013, 360 Plusoptix photoscreener devices were purchased. Current costs of the Plusoptix device are € 6.000-8000, with a life span of approximately 4–7 years, after which the device will be replaced (internal reporting Kind en Gezin, unpublished, 2015). In Flanders, in principle every device is replaced after 4 years. Total costs of the devices, covered by the government were €630 000 annually in a population of approximately 7.7 million. In the observation period 2011–2016 in Flanders, since the introduction of Plusoptix photoscreening, the number of 4-year-old children wearing glasses has risen from 4.7% to 6.4% (Guérin et al. 2017).

In Iran, the budget of the preventive vision screening program is about

6 500 000 000 Iranian Toman (€1 669 320) per year. The costs of the first screening were on average € 0.50 per child per screen. Costs of a consultation with an optometrist were ±€5.00. Costs of a consultation with the ophthalmologist were ±€10.00. In total, 260 Plusoptix devices were employed in a population of approximately 80.2 million. Each device costs ± €7400. Plusoptix costs are paid by Welfare organizations, which receive government funding. There were no maintenance costs of the Plusoptix photoscreeners for the Welfare organizations, as these are covered by the Company Binamed that represents the Plusoptix photoscreener in Iran.

### Discussion

Worldwide, many different screening program strategies have been installed to screen young children for amblyopia in order to start treatment of amblyopia when the children are young. If amblyopia is detected at age 7 or older, it takes more time and it is more difficult to treat (Fronius et al. 2014). This study shows two different approaches for the use of the Plusoptix in a screening setting. In Flanders, it is used primarily to prevent amblyopia by detecting amblyopia risk factors at age 1 and 2.5 years of age in the whole population, whereas in Iran it is used to detect refractive errors or strabismus if measurement of VA fails at age 3–6.

The way the Plusoptix photoscreener is employed in Flanders and Iran differs fundamentally, leads to different outcomes and makes comparison difficult. The use of the Plusoptix photoscreener between ages 3 and 6 in Iran, to measure refractive error and possible strabismus when VA measurement fails, is an interesting alternative option, to screen uncooperative, non-verbal children, or children with mental disorders who currently may not otherwise be tested at all.

The Plusoptix photoscreener is used exclusively without cycloplegia that is common for determining refractive errors by retinoscopy in young children and therefore may under-detect hypermetropia, with a reported sensitivity of 33% (Paff et al. 2010). Reports on its detection of strabismus vary, with a reported sensitivity of 25–41% (Sanchez et al. 2016). In the literature, reports about the deployment of the Plusoptix photoscreener and its effectiveness are difficult to compare. It is confusing that in some reports amblyopia and amblyopia risk factors are presented as a single outcome measure. As for children aged 4–6, it must be realized that there is little use for detecting risk factors for amblyopia at an age that amblyopia itself can be diagnosed by measurement of VA. The use of the Plusoptix photoscreener as a stand-alone screening test at ages 4–6 (Van der Ploeg et al. 2017) could be considered unethical without additional measurement of VA, as approximately one quarter of children with amblyopia at that age do not have a large refractive error or conspicuous strabismus (Groenewoud et al. 2010) and, hence, these children would not be detected a priori if measurement of VA would be replaced by photoscreening. It is also confusing that the sensitivity and specificity of photoscreeners for detecting risk factors are calculated on the basis of arbitrary thresholds for referral, like the AAPOS criteria, as children not fulfilling these criteria still can have amblyopia. When the relation between the size and type of the refractive error or strabismus, and the increased odds to develop amblyopia will have been established in a large study, the use of the AAPOS criteria will no longer be necessary.

Refractive errors and strabismus are known risk factors for amblyopia. Hence, it is reasonable to believe that

prescription of glasses at the age of one does prevent some cases of amblyopia, especially in children with strong refractive errors. However, it is unknown how many cases of amblyopia have been prevented by early prescription of glasses in Flanders. Data on benefits of early prescription of glasses have not been confirmed with published randomized controlled trials. The evidence that early glasses prevent the development of strabismus is still quite weak. This would require a study comparing two large cohorts, with retinoscopy in all children at age one, but prescription of glasses, in case of amblyopia risk factors, in only one of the two cohorts.

It is remarkable that in Flanders, a new vision screening device has been introduced in 2013 with considerable costs, without secure evidence on how many cases of amblyopia could be prevented by early prescription of glasses. The implementation of the Plusoptix photoscreener to screen for amblyopia risk factors in children aged 1 and 2.5 years costs €630 000 per year for the devices alone, assuming the 360 Plusoptix devices for as many health-care offices, are used during 4 years. The percentage of children wearing glasses at age four has risen from 4.7% to 6.4% between 2011 and 2016 (Guérin et al. 2017) leading to increased costs for parents.

In the VIP-HIP study by Group et al. (2016) additional usefulness of early prescription of glasses in preschoolers was demonstrated, however. It was shown that high uncorrected hypermetropia in children was associated with deficits in early literacy and essential skills. These deficits lead to problems in reading and writing development. Children who experienced reading problems in the first grade had an 88% chance of remaining poor readers after finishing the fourth grade and influencing later school performances (Group et al. 2016).

Therefore, early detection of refractive errors might be useful for future educational development of children. If detection of risk factors by Plusoptix photoscreener and prescription of early glasses improves efficiency of education, this would have a considerable impact on its cost-benefit analysis, but only if refractive error is *causal* to the educational disadvantage, not just associated with it.

As of September 2018, the vision screening program at Kind en Gezin in Flanders has changed. The Plusoptix devices have been replaced by a screening application on a smartphone with moderate sensitivity and specificity for the detection of amblyopia risk factors (Guérin 2018).

## Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

## Informed consent

Oral informed consent was obtained from the participants interviewed in this study.

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## Appendix 1

### Questionnaire on Vision Screening Program in Flanders.

- 1) Existing vision screening program
  - How often are the children screened in total and at what times?
  - Is the vision screening in Flanders performed in the same way in different regions? For example, always by an orthoptist?
- 2) Addition of photoscreening
  - At what age are the children screened with the Plusoptix photoscreener in Flanders?
  - How many children are referred by the Plusoptix photoscreener in Flanders?
  - What is the life expectancy of the Plusoptix screening device in Flanders?
- 3) Implementation in vision screening program
  - Where does the vision screening take place in Flanders?
  - How are the children examined?

- Has the content of the vision screening in Flanders changed over the years, if so, what has changed, and what have been the benefits of this?
- 4) Training
    - What was the training organized for screening professionals in Flanders?
    - Is a certificate required for training for screening professionals? (is there a periodic repetition of this training)
    - What are the costs of training for screening professionals paid by the government?
    - By whom is the vision screening performed?
    - What are the salary costs of professionals who perform vision screening?
  - 5) Attendance
    - What is the percentage of children invited for the vision screening in Flanders?
    - By whom are the children invited for the vision screening in Flanders?
    - How are the children invited for the vision screening in Flanders?
    - What is the percentage in the total population participating in the vision screening under the age of 7 years?
    - Has the percentage of children participating in the vision screening changed over the years, if so, is it increased or decreased?
  - 6) Diagnosis and treatment
    - How long does a screening test performed by the Plusoptix photoscreener take place?
    - How many children are referenced annually in Flanders for further diagnostics?
    - What are the costs of referral children after a positive test?
    - What are the differences in the cost of a consultation between an orthoptist or an ophthalmologist?
    - How many referred children are treated annually?
    - Has the number of prescription of glasses increased since the introduction of the Plusoptix?
  - 7) Costs of vision screening
    - How much money is spent per year on preventive vision screening in Flanders?

- What are the total screening costs per child, per screen in Flanders?
- Are there differences in costs in the different regions in Flanders, with regard to the vision screening?
- What are the purchase costs of the Plusoptix screening devices in Flanders?
- What are the maintenance costs of the Plusoptix screening devices in Flanders?
- Are there any other points that you consider relevant in mapping the cost-effectiveness of the Plusoptix?

## Appendix 2

### Questionnaire on Vision Screening Program in Iran

- 1) Existing vision screening program
  - How often are the children screened in total and at what times?
  - Is the vision screening in Iran performed in the same way in different regions? For example, always by an optometrist?
- 2) Addition of photoscreening
  - At what age are the children screened with the Plusoptix photoscreener in Iran?
  - How many children are referred by the Plusoptix photoscreener in Iran?
  - What is the life expectancy of the Plusoptix screening device in Iran?
- 3) Implementation in vision screening program
  - Where does the vision screening take place in Iran?
  - How are the children examined?
  - Has the content of the vision screening in Iran changed over the years, if so, what has changed, and what have been the benefits of this?
- 4) Training
  - What was the training organized for screening professionals in Iran?
  - Is a certificate required for training for screening professionals? (is there a periodic repetition of this training)

- What are the costs of training for screening professionals paid by the government?
  - By whom is the vision screening performed?
  - What are the salary costs of professionals who perform vision screening?
- 5) Attendance
- What is the percentage of children invited for the vision screening in Iran?
  - By whom are the children invited for the vision screening in Iran?
  - How are the children invited for the vision screening in Iran?
  - What is the percentage in the total population participating in the vision screening under the age of 7 years?
  - Has the percentage of children participating in the vision screening changed over the years, if so, is it increased or decreased?
- 6) Diagnosis and treatment
- How long does a screening test performed by the Plusoptix photoscreener take place?
  - How many children are referenced annually in Iran for further diagnostics?
  - What are the costs of referral children after a positive test?
  - What are the differences in the cost of a consultation between an optometrist or an ophthalmologist?
  - How many referred children are treated annually?
  - Has the number of prescription of glasses increased since the introduction of the Plusoptix?
- 7) Costs of vision screening
- How much money is spent per year on preventive vision screening in Iran?
  - What are the total screening costs per child, per screen in Iran?
  - Are there differences in costs in the different regions in Iran, with regard to the vision screening?
- What are the purchase costs of the Plusoptix screening devices in Iran?
  - What are the maintenance costs of the Plusoptix in Iran?
  - Are there any other points that you consider relevant in mapping the cost-effectiveness of the Plusoptix?

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