

VISION SCREENING

Stanley W. Hatch, OD, MPH, FAAO

Chapter Overview

The term screening may mean different things to different people, and screening is often confused with examination and diagnosis. A screening test has a known degree of error. A screening is not an examination, and a test result is not a diagnosis. Screening tests should not be done in isolation but as a part of screening programs. A screening program requires a structure based on the epidemiology of disease- that is, one based on the distribution and determinants of disease. A screening program includes defining the target population and disease condition(s), marketing the service, conducting the screening, making appropriate referrals, assisting with access to care, and measuring effectiveness. This chapter describes the public health principles behind screening and the process for organizing a screening program. A case study on preschool vision screening in the greater Los Angeles area will illustrate the principles by which the reader can then apply to other populations.

Objectives

On completion of this chapter, the reader should be able to:

1. Justify a screening program in terms of public health burden and benefit.
2. Use demographic information to define target populations for screening.
3. Identify through epidemiological data, conditions and tests which are appropriate candidates for screening.
4. Explain and calculate sensitivity, specificity, positive predictive value, negative predictive value, and yield.

Public Health Principles of Screening

“Screening is the presumptive identification of unrecognized disease or defects by means of tests, examinations, or other procedures that can be applied rapidly.” (1) This definition of screening elucidates three important criteria about disease screening: 1) identification, 2) previously unrecognized disease, and 3) quick and easy testing. Screening is not complete examination. Screening is not diagnosis or treatment. Screening is quick and easy detection of disease in someone who previously was unrecognized as having the disease.

When referring to screening, most people refer to having a screening test. Many do not understand the difference between examinations and screening. When parents

bring a child for an eye exam and the examiner asks if it is the child's first eye exam, a common answer is "no, they had an exam at school" or "at their pediatrician's office". Educating community members on the difference between screening and examination and care is a continual goal for public health professionals.

Appropriate screening should be a structured, organized, systematic program in a community. This system includes the following:

- A target population must be identified.
- The condition(s) to be screened for must be decided.
- A marketing program should be in effect.
- A uniform and valid screening protocol has to be used.
- Referral criteria which are widely accepted by health care providers must be agreed.
- A referral mechanism to insure access to examination and treatment needs to be available.
- Measurable variables such as cost effectiveness, improved quality of life and other public health benefits should be analyzed.

Who and What Are We Screening?

A target population is the first and most important part to decide in the planning of a screening program. There are several options for identifying target populations. Populations may be chosen based on geography: a city, county, state, or other region. It can be chosen by intrinsic biological characteristics such as age, genetics, or gender. Socioeconomic factors such as income level, cultural group, health insurance status, are other criteria for choosing the target population. In addition, environmental risk factors including occupation, school, medical treatment, travel patterns, food or water exposure, or consumer products use are often used to identify screening candidates.

Some health conditions are better to screen for than others. For a condition to be a good candidate for screening it should possess the following characteristics:

- High prevalence
- Public health burden
- A quick, accurate, painless, and reliable screening test is available
- Chronic
- Asymptomatic
- Treatable
- Prognosis is better when detected and treated early
- Treatment is more cost effective when detected early

It is not cost or time effective to screen for rare conditions. The incidence of ocular melanoma is 6-8 cases per million people per year (2). Clearly, population screening is not reasonable. Breast cancer affects as many as 1 in 8 women and is aggressively screened (3). The condition should have high morbidity. Unilateral amblyopia in adults is generally not burdensome. Patients adapted to the condition during childhood and it does not usually limit health quality. Uncorrected refractive error is burdensome since it may prevent driving, holding a job, and reading.

Only conditions with quick, painless, and inexpensive screening tests should be considered. Screening for hypertension requires just measuring blood pressure. Screening for glaucoma, however, requires intraocular pressure, pachymetry, optic nerve evaluation, and central visual field testing, so it is a poor screening candidate even though it is a leading cause of blindness. Chronic, asymptomatic diseases are more important to screen for then acute, symptomatic diseases. Prostate cancer is slow growing without early symptoms, so it is a good candidate for screening. In contrast, appendicitis is acute and painful. It could not be screened in a population because it would not be occurring at the time of the screening. Most patients who have it are already in the hospital from the symptoms. Amblyopia in children is asymptomatic and chronic. Conjunctivitis is acute and symptomatic. Children with amblyopia do not seek treatment on their own, but those with conjunctivitis are almost always referred by their parents, teachers, or school nurses to get treated. Treating amblyopia at an early age has better prognosis for visual acuity and binocular vision and is cost effective (4-6). Despite the high level of symptoms in conjunctivitis, most cases are self limiting. Treatment only aids in comfort and speed of recovery.

Type II diabetes is an excellent candidate for screening. The condition is common and it is estimated that many, if not most people with type II diabetes have not been detected. Type II diabetes has identifiable risk factors such as family history, age, race, and weight, so at risk individuals can be targeted. Type II diabetes can be screened by a rapid and easy to administer blood test (hemoglobin A1c). It is chronic with few, if any, symptoms, and the longer it is uncontrolled the greater the morbidity. It affects multiple organ systems and the later it is treated the more debilitating and costly it is to treat.

Before turning to how to develop a screening program, it is necessary to review the epidemiological principles, the basic science, behind valid screening.

The Science of Screening (some sections reprinted from reference 7 pages 197-200 out of print.)

In 1986, D. Hammond and P. Schmidt (8) published a study on using one test as an instrument for children's vision screening. Some experts had suggested that random dot stereopsis could serve as a proxy for the entire vision system. To pass a random dot stereopsis test, one needs bifoveal fixation, nearly equal visual acuity, and binocular

fusion. It is unlikely that a child possessing one or more of the most common childhood conditions (strabismus, amblyopia, anisometropia, high refractive errors, or a disease effecting visual acuity in one or both eyes) could pass a random dot stereopsis test. The test could be rapidly done without pain by an examiner with minimal training. Hammond and Schmidt tested 483 children with the Random Dot E stereogram and had comprehensive eye exams performed on all. They found the following results (table 1):

Table 1- 2 X 2 Table for the Random Dot E Stereogram

	Screening Test (+)	Screening Test (-)
Case	51	29
Noncase	39	364

To assess whether the Random E stereogram was a good screening instrument, an analysis is needed to find test's sensitivity, specificity, false positive rate, false negative rate, and predictive values. These values are probabilities (P) and are expressed as either decimals or percents. Prevalence is another example of probability. Prevalence is the proportion of persons with disease, that is cases, in the population at one point in time. If 0.13 or 13% of people in a group have cancer, then there is a 13% chance that a person picked randomly from the group has cancer.

Sensitivity is the proportion of diseased individuals that test positive by the screening test. From the data above, the random dot E stereogram test identified 51 out of 80 children with vision problems (64%); thus its sensitivity was 0.64.

Specificity is the proportion of disease-free individuals that test negative. The random dot E stereogram correctly classified 364 out of 403 children without vision problems (90%); thus its specificity was 0.90.

The false-positive rate is not a rate but a proportion. It is the proportion of individuals who test positive even though they are free of disease. The false-positive rate equals one minus the specificity. The false-positive rate for the random dot E stereogram equaled 1-0.90= 0.10, or 10%.

The false-negative rate is not a rate but a proportion. It is the proportion of individuals who test negative even though they have the disease. The false negative rate equals one minus the sensitivity. The false-negative rate for the random dot E stereogram equaled 1 – 0.64 = 0.36, or 36%.

Conditional probability represents the probability of an event given that another event has occurred. It is designated with a $|$. For example, $P\ (D_1 \mid T^+)$ equals the probability

of disease given that one test's positive on test *T.* In this chapter, D_1 represents having the disease and D_2 represents being free of the disease.

Positive predictive value is the probability of having the disease, given that one tests positive. This equals $P(D_1 / T^+)$.

Negative predictive value is the probability of not having the disease, given that one tests negative. This equals $P(D_2 / T^-)$.

Constructing a two by two table is an efficient means for calculating the above values. Table 2 illustrates the process generally and for the data on the Random E Stereogram.

Table 2- Two-by-two tables for calculating sensitivity and specificity.

Classic 2 X 2 Table	Screening Test (+)	Screening Test (-)
Case	A	C
Noncase	B	D

2 X 2 *Table for the Random Dot E Stereogram*	Screening Test (+)	Screening Test (-)
Case	51	29
Noncase	39	364

Sensitivity = the proportion of cases identified by a positive test result = a / (a + b), so sensitivity = (51) / (51+ 29) = 0.64 or 64%.
Specificity = the proportion of noncases identified by a negative test result = d/ (c+d), so specificity = (364)/ (39 + 364) = 0.90 or 90%. Source: (8)

To evaluate sensitivity and specificity, controlled experiments are performed in which each subject's disease status is known with a high degree of certainty.

Predictive values depend on prevalence. Screening for glaucoma in elementary school children will lead to some positive test results but few cases of glaucoma. Because predictive values depend on prevalence, they can only be assessed for screening programs in populations and not on a case-by-case basis. This relationship is derived from Bayes' theorem-a probability distribution. The relationship is defined mathematically:

$$P(D_1 \mid T^+) = \frac{P(D_1)\,P(T^+ \mid D_1)}{[P(D_1)\,P(T^+ \mid D_1) + P(D_2)\,P(T^+ \mid D_2)]}$$

Where $P(D_1 | T^+)$ = positive predictive value, D_1 = presence of disease, D_2 = absence of the disease, T^+ = positive test result, and $P(D_1)$ = prevalence.

The following two examples further illustrate the dependence of prevalence on predictive values, and how, as with much in epidemiology, a screening test can be evaluated through a two-by-two table.

In the first case, suppose visual acuity has a sensitivity of 0.70; that is, 70 % of clinically significant refractive errors and ocular diseases will be detected by visual acuity. Let us assume a specificity of 80 %- that is, a 20 % over referral rate. Assuming that 30 % of elementary school children have clinically significant refractive errors or ocular disease: $P(D_1)$ = prevalence =0.30; $P(D_2)$ = 1 – prevalence = 0.70; and $P(T^+ | D_2)$ = 1 – specificity = 0.20.

$$\text{Positive predictive value} = P(D_1 | T^{+}) = \frac{(0.30)(0.70)}{[(0.30)(0.70) + (0.70)(0.20)]}$$

$$= 0.60 \text{ or } 60\%.$$

Therefore, each positive test has a 60% chance of being correct.

In the second case, suppose the prevalence of clinically significant refractive errors and ocular diseases in preschool children is 5%. Given the same sensitivity and specificity: $P(D_1)$ = prevalence =0.05; $P(D_2)$ = 1 – prevalence = 0.95; and $P(T^+ | D_2)$ = 1 – specificity = 0.20.

$$\text{Positive predictive value} = P(D_1 | T^{+}) = \frac{(0.05)(0.70)}{[(0.05)(0.70) + (0.95)(0.20)]}$$

$$= 0.15 \text{ or } 15\%$$

Thus, each positive test has only a 15% chance of being correct or an 85% chance of being wrong.

In the first case, the positive predictive value is 60% meaning that for every 100 children who test positive and are referred, 60 will need treatment and 40 will not. In the second case, only 15 of the 100 children who test positive will need treatment and 85 will not *even when the test has the same sensitivity and specificity*. One can further extrapolate to very rare conditions that even when tested with very high sensitivity and specificity procedures, a positive finding is still more likely to be a false positive then a true case. Thus, it is always dangerous to screen for very rare conditions.

On the other hand, when prevalence is high, short cut formulas can be used which do not include prevalence. Predictive values can be estimated quickly from two-by-two tables like those in Table 2.

Positive predictive value $P(D_1 | T^+) = a / (a + c)$

Negative predictive value $P(D_2 | T^-) = d / (b + d)$

The above formulas are not appropriate when prevalence is low.

KEY CONCEPT: ***Predictive value depends on prevalence. Screening efficiency and validity are only high in populations with high prevalence of disease.***

The phi coefficient (Φ) is a test statistic similar to the chi-squared. It ranges from –1.00 to +1.00. It gives overall efficacy of the screening test. A phi coefficient of +1.00 indicates the screening test is a perfect predictor of disease. A –1.00 means the test always predicts wrong (in such a situation one could just change the screening result from positive to negative and get the right answer every time!). A phi coefficient of zero indicates the test has no better prediction that a coin toss. In general, a phi coefficient of +0.75 or higher is necessary for a screening test to be used for population screening. The phi coefficient can be calculated from the two-by-two table:

$$\Phi = \frac{ad-bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}$$

For the random dot E stereogram example,

$$\Phi = \frac{(51)(364)-(29)(39)}{\sqrt{(51+29)(39+364)(51+39)(29+364)}} = +0.52$$

Yield is the number of new cases identified by the screening. Other measures of screening effectiveness are market penetration, the number or percent of persons screened previously not screened or under care, number or percent of persons referred and confirmed to have received care, and quality of life impact by the screening program on community members, especially those receiving treatment for previously unrecognized conditions.

Now that the reader understands how to evaluate the effectiveness of screening tests and the difference between a screening program and a screening test, a case study will be presented to show the application in a community and to illustrate the other program parts like marketing, referral, access to care, and follow up.

CASE STUDY

A University affiliated eye clinic desires an outreach program for economically distressed children in the greater Los Angeles area. The administration decides that population screening is the most efficient method to identify cases. Because school age children are screened in school but preschoolers are often not screened, it is decided to target children under age five years. Our task is to design the screening program.

Public Health Questions for the Case Study

1. Is there a need for identification and treatment of eye conditions in this population?
2. What conditions should be screened and referred for treatment?
3. How will the program be financed?
4. What improvements in health will result from implementing the program?

In this case study, the target population is children under age five years in the greater Los Angeles area. Is there a need for identification and treatment of eye conditions in this group? To answer this question, one needs to assess if there are common unrecognized conditions that are treatable and have significant public health burden.

Epidemiology

In the United States and Canada, 2-20% of children under age five years have clinically significant eye conditions (table 3).

Table 3- Epidemiology of eye conditions in preschool children. Data reported in percent are prevalence; data presented in number/100,000/year are incidence.

Condition	US Data
Refractive error	0.05-21%
Hyperopia >3.25 D	0.01-7.5%
Astigmatism >1.50 D	0.03-5.5%
Myopia >2.0 D	0-3%
Anisometropia	0.02-4.2%
Hyperopia >1 D	Subclasses of anisometropia not reported
Astigmatism >1.5 D	
Myopia >3 D	
Strabismus	0.6-6.7%
Amblyopia	0.3-4.5%
Nystagmus	0.1-0.2%

Congenital organic disorders total	0.13% and 57/100,000/year
Inflammatory including conjunctivis	1510/100,000/year
Ocular cancer	4/100,000/year

[From references (7,9-16). The lowest values for refractive error, strabismus, and amblyopia are derived from Donahue et al (15) by dividing the raw data in their table 5 by 15,059 the reported total sample size. Because these data are from screenings by the MTI Photoscreener versus full eye exams, the prevalence is underestimated by 27-63% due to the MTI's sensitivity of 37-73% (13,14,17,18).]

Some differences exist between ethnicities. Japanese preschoolers have less hyperopia, less strabismus, and less amblyopia (19). In grade school children, Native Americans show more astigmatism (20), and Asians have more myopia (21,22). Hispanic grade children in one study had similar refractive errors to whites and blacks (21), but in a larger study Hispanic children had higher proportions of myopia (22). Children born prematurely with low birth weight have higher proportions of refractive error especially myopia. They also have high percentages of strabismus and amblyopia (9).

Certain vision conditions are associated with and may contribute to deficits in gross motor development, fine motor development, cognitive development, perceptual skills, reading readiness, and learning disability. Any severe or profound visual impairment during infancy interferes with gross motor development. Without adequate vision, the infant has little motivation to lift the head when she is lying on the tummy. Therefore, she also does not push up with the arms to raise the torso. Neck, shoulder, abdominal, and back muscle tone fail to thrive. Similar delays occur for crawling, pulling up, standing, and walking. Physical therapy at an early age is very important for these infants. Even if vision cannot be treated, the muscle tone and coordination can be treated.

Children with high hyperopia or astigmatism tend to have lower intelligence (23) and greater risk of learning disability (24,25). Children whose hyperopia is corrected prior to age four, perform better on standardized reading tests in elementary school (26). Final visual acuities were reported better in children with early hyperopic correction in one study (27) but not another (28). A prospective study of primarily low income Latino preschool children found that visual motor integration and performance IQ scales were reduced in those with high refractive errors. These scores improved after six weeks of spectacle wear to equal an emmetropic control group (29). While participants and examiners were not masked, the use of widely accepted standardized tests and active control groups supports a biological effect.

From U.S. Census data (30) about 14 million people live in the greater Los Angeles area. About 1.05 million are under age 5. Latino (33-47%) and white (30-47%)

persons are the largest ethnic groups followed by Asian Americans (6-16%) and African Americans (2-10%). Other groups compose 2-29% of the population. The poverty rate runs from 10.2-16.4%. The percent of uninsured for all ages ranges from 17.7- 22.6%. For individuals under age 18 it is 15.0-18.7%. There are large undocumented populations in the area and accurate estimates are not available. Many, if not most, live in poverty and do not have health insurance. It is safe to suggest that at least 250,000 preschool children in the greater Los Angeles area have vision conditions in need of identification and treatment.

How many children receive vision screening currently? Many pediatricians screen infants and toddlers with a light reflex, but this is not adequate for identifying intermittent strabismus, small angle strabismus, anisometropia, and refractive errors. A significant set of pediatricians do not perform screenings or only use a visual acuity test when the patients are old enough to read an eye chart (31). Further, not all preschoolers see a pediatrician or family practitioner as recommended. Population wide screenings are not practiced, so screenings are available only in those areas where individual groups such as health departments, Lions Clubs, medical or optometry schools, or independent providers give screenings.

For our case study, we have a target population with a demonstrated need. The next step is deciding on the condition(s) to be screened, determine the screening tests, and set referral criteria.

After reviewing the epidemiology of preschool vision conditions and their associations with developmental issues, the candidate conditions for screening are significant refractive errors, amblyopia, and strabismus. Other conditions are too rare or do not meet other criteria for screening.

Since the early 1990s, a tremendous amount of research has been conducted on vision screening in preschool children. A consensus has developed for the following referral criteria (table 4):

Table 4- Target conditions for preschool vision screening.

Hyperopia >3.25 D Astigmatism >1.50 D Myopia >2.0 D Anisometropia Hyperopia >1 D Astigmatism >1.5 D Myopia >3 D	Strabismus any	Amblyopia >2 lines difference in acuity between eyes

The Vision in Preschoolers Study Group is a multicenter inter-professional coalition which sought to quantify and analyze screening methods, propose guidelines for valid and reliable testing, and test screening protocols (13,14,32-34). While a uniform

protocol has yet to be agreed by the major players in children's care (American Academy of Pediatrics, American Association of Pediatric Ophthalmology and Strabismus, American Optometric Association, American Public Health Association, Centers for Disease Control and Prevention, Prevent Blindness America) several strategies are finding wide usage.

Visual acuity testing with Lea Symbols can be completed for nearly all 3-5 year old children (34-36). Visual acuity by itself detects most high refractive errors and amblyopia. It may miss significant hyperopia and strabismus. Visual acuity could not be used for infant and toddler screening.

Random dot stereopsis has been proposed as good screening test for strabismus and amblyopia. It performs similar to visual acuity. Children older than age 3 can usually complete a two choice matching test (33). In the example above for calculating sensitivity, specificity, and predictive values, Random Dot E by itself performed modestly. A study from Nova Scotia, Canada, combining visual acuity and the Frisby Stereo test improved sensitivity to 75%, but lowered specificity to 68%, and negative predictive value was 90% (36).

To justify screening for the conditions in table 4, a valid, reliable, efficient, and cost effective test for refractive error and strabismus in infants and toddlers must be available. Photoscreening and hand held autorefraction have this potential. Since its introduction nearly 20 years ago, photoscreening validity and reliability continues to be refined and improved. Photoscreening is done with a camera, originally one which used instant film but is now largely digital. The child has to fixate briefly on a camera mounted target, usually flashing red lights, and a screener takes a picture. The picture is then analyzed by computer, lay screener, or sent to a trained examiner to determine the screening result. The camera records corneal and retinal light reflexes. Obscured images suggest cataract or other intraocular disease. Deviated corneal reflex infers strabismus. Differences in brightness between retinal reflexes are associated with strabismus or anisometropia. Certain size crescents in the retinal reflexes are correlated with refractive error. Because amblyopia can only be caused by strabismus, anisometropia, or high refractive error, photoscreening should theoretically detect all the target conditions listed in table 4. Autorefractors and photoscreening have shown a convergent evolution such that hand held autorefractors look and perform similar to photoscreening cameras and photoscreening cameras now use software to analyze images.

As manufacturers have produced photoscreening devices and hand held autorefractors, researchers have done many good field studies to assess validity and reliability. Most studies on photoscreening find the magnitude of hyperopia to be underestimated (37-41). Sensitivity ranges from 37 to 90% and specificity ranges from 20 to 94%. Inter and intra rater reliability for photoscreening appears to be less than great (41-43) though there are proposals for improvement (44). The most

comprehensive study, reported by the Vision in Preschoolers Study Group (14), assessed validity for 5 photoscreeners or autorefractors in at least 2588 children age 3-5 years (table 5).

Table 5- Validity of photoscreening and autorefraction devices in children enrolled in Head Start.

	Power refractor II	iScreen Photoscreener	MTI Photoscreener	SureSight Vision Screener	Retinomax Autorefractor
Sensitivity	0.54	0.37	0.37-0.95ψ	0.79-0.85*ψ	0.64
Specificity	0.90	0.94	0.94	0.62	0.90

*Manufacturer's criteria. When specificity was set at 0.90, sensitivity fell to 0.63.
ψ The most recent study (45) compared the MTI Photoscreener with the SureSight autorefractor on 100 consecutive patients in a tertiary care center age 1-6 years. Using the VIP referral criteria (table 4), sensitivity and specificity for the SureSight was 79.3% and 64.3% respectively while the MTI was 94.8% and 88.1%.

The variation in results between and within studies remains concerning. No screening instrument has been shown to be more specific than noncycloplegic retinoscopy by a licensed eye care professional (14) for detecting refractive error (sensitivity 81%; specificity 90%), but little data are available for children younger than age 2.5.

Based on the best currently available data, the university affiliated eye clinic for the case study should use the following screening protocols (table 6).

Table 6- Suggested vision screening protocol for preschool children.

Age 0-3	Photoscreener by trained screeners	History of: premature birth, parent or sibling with strabismus		
Age >3-5	Retinoscopy or Photoscreener	Lea symbols (VA)	Random Dot Stereopsis	

Marketing

A marketing program would need to be developed to attract parents and caregivers. A network of people and agencies from pediatrician offices to WIC (women, infants, and children) programs to early intervention centers to independent day care providers to individual parents could be accessed or developed. Planned advertising, appropriate lead time, English and Spanish communications are all important. Screening locations

and scheduling should be easy to access by stay at home parents, working parents, care givers, etc. There should be public transportation available, parking, and walking access. Screening sites need diaper changing areas, private areas for breast feeding, stroller accessibility, and if possible play areas and volunteers to supervise siblings.

For referral and follow up, a system of written and verbal communication should be in place. Before the screening, eye care professionals in the area need to be contacted to find out if they accept referrals and if they regularly provide the type of care the population requires. In this case, experience with infant and preschool eye care is necessary. Inquiries must also be made regarding what insurance potential providers accept, especially the state Medicaid plan and Children's Health Insurance Plan (SCHIP). A plan needs to be in place for persons who do not have insurance. The program director should have a written screening plan for volunteers. Training could include basic counseling on health insurance such as persons who may qualify for Medicaid or SCHIP. If possible, applications in both English and Spanish or other languages, should be available on site with persons to assist writing for those unable to read or write. Additional resources can be given for exam and glasses coverage through organizations which may include: Lions Club, Volunteer Optometric Services to Humanity, United Way, American Red Cross, religious missions with focus on health or education, public health clinics, community health centers, or university affiliated clinics that provide free or discounted care. Networking with a coalition of likeminded groups also can lead to grant opportunities. Most large screening programs need grant funding to operate on an annual basis.

Once screening participants have signed in, been screened and are given verbal and written results of their screening and potential provider information, a follow up contact schedule is set up. A few weeks after the screening, patients with positive screening results need a phone call, post card, or email to see if they secured appointments. Phone calls are preferred as appointment and results can be confirmed immediately. For severe conditions where no phone or mail contact is possible, it may be necessary to send a caseworker to the patient's home to insure examination and treatment has been done. Patients who did not obtain follow up can be assisted in setting up their appointment. For follow through data, participants could be asked to have providers fill out a brief form with a self addressed stamped envelope to be mailed back to the screening program director for data gathering on diagnosis and treatment.

Public Health Burden Addressed

It is agreed then that the public health burden for undetected vision conditions in children under age five is sufficient to warrant population screening. The data presented suggest that:

1. Many of these conditions are associated with decreased reading readiness and poorer school performance as well as other developmental deficits.
2. Most of the conditions do not have symptoms, so patients do not self refer. Although some screening is done by some pediatricians in well child visits only a minority of the important conditions can be detected in the pediatric office.
3. Prognosis and cost effectiveness of treatment are improved with early detection and quality adjusted life years improved.
4. The conditions are common enough, perhaps 1 in 10 children, to justify screening.
5. A screening program including marketing, communication, financing, referral, and follow up can be accomplished.

Vision Screening in Other Populations

The chapter thus far has illustrated principles of public health and epidemiology in developing a vision screening program for preschool children in the greater Los Angeles area. The need for screening through population data, health care access data, current screening practices, and justifying a public health burden and prognosis for improvement was completed. The same methodology should be used to assess the need for and design of screening programs for other conditions or populations.

School vision screenings have been studied extensively. The Modified Clinic Technique (table 7) remains the gold standard, but many schools prefer not to employ eye doctors to perform cover test and retinoscopy as required for the MCT. The advancement in autorefraction technology allows for a properly trained nurse or lay screener to now perform the MCT in the school setting. Schools have systems in place for access to the population, permission to screen, and referral via parents.

Table 7- The Modified Clinic Technique for school screenings (46).

TEST	REFERRAL CRITERIA
Visual acuity	20/40 either eye
Retinoscopy	-0.50 D myopia, +1.50 D hyperopia, 1.0 D astigmatism, or 1.0 D anisometropia
Cover test	5 p.d. eso or exophoria at distance, 6 p.d. esophoria or 10 p.d. exophoria at near, any strabismus, 2 p.d. hyperphoria
External exam	Any external disease
Ophthalmoscopy	Any internal disease

CLINICAL PEARL: *Retinoscopy remains the most accurate screening test for refractive error even with the advancements in autorefraction.*

Population screenings for healthy young adults has not been widely advocated. Sight threatening conditions below age 50 are rare, so the risk of false positives is high. Degenerative myopia and diabetic retinopathy are the most likely causes of preventable vision impairment in this group. The patients with high myopia are likely under care, and persons with diabetes should be targeted for annual comprehensive eye exams through primary care, diabetes screenings, and public health education . Refractive and binocular conditions, while common, are symptomatic, and healthy adults should self refer.

Vision screening for older adults prompts many interesting questions. Should screenings target specific conditions or patients? Should we have glaucoma screenings or elder vision screenings? Should screenings be tailored to at risk groups or should these groups be under continuous eye care?

Glaucoma is a condition which draws great attention for health screening in the aged. The disease has no symptoms early on, it is chronic, and sight threatening. If treated early, the disease is controllable in almost all cases. The disease meets all the criteria for an ideal disease for screening except one: there is no one quick, easy test to detect early stage glaucoma. The diagnosis of glaucoma is often subtle. Experts assess risk factors including family history, age, and race. Clinical tests include intraocular pressure, anterior segment exam, corneal thickness, optic nerve evaluation, and visual fields. The final assessment is usually how likely the patient is to develop glaucoma rather than they definitely do or do not have it. While many patients and providers look to intraocular pressure as a quick screening for glaucoma, its predictive value is poor. Given that half of open angle glaucoma patients have normal intraocular pressure, sensitivity is also low. These problems lead eye care public health experts to recommendations like the National Eye Institute's statement (47) below:

> Detection of glaucoma in higher-risk individuals is best done through a comprehensive eye examination. Those at an increased risk for glaucoma are Blacks over age 40, everyone over age 60, and individuals with a family history of glaucoma. The eye examination should include an appropriate family history, measurement of visual acuity and intraocular pressure, examination of the retina and optic nerve through dilated pupils, and, where indicated, evaluation of the visual field. People thought to have glaucoma should receive appropriate follow-up and management. People at higher risk of glaucoma who do not have the disease should be examined at least every two years. Eye care professionals may recommend more frequent examinations for those considered at sufficient risk for imminent optic nerve damage.
>
> A traditional method of detecting glaucoma is tonometry, which measures intraocular pressure. However, because of individual variations in what constitutes normal intraocular pressure, tonometry by itself is not sufficient for

an accurate diagnosis of glaucoma. Data collected at several public glaucoma screenings suggest that many people without glaucoma will screen positive with tonometry alone, while many individuals with glaucoma will screen negative. An eye care professional can detect glaucoma during a comprehensive eye examination through dilated pupils and may also identify other ocular conditions requiring attention. The examination also provides an opportunity for educating individuals about appropriate eye care.

CLINICAL PEARL: *No single screening test has adequate sensitivity and specificity to detect glaucoma.*

Thus, the consensus for glaucoma is individuals at higher risk should be under comprehensive eye care. Screening people at low risk is not helpful, so no consensus exists for lower risk populations. The same conclusions have been made for other diseases of adulthood. Persons with diabetes should see an eye doctor at least annually. People over age 75 have a 27% chance of macular degeneration (7 pg 272) and should see an eye doctor at least annually. Diabetes, cardiovascular diseases, and cancer increase with age and all adults should see a primary care provider for screening tests such as fasting blood sugar, hemoglobin A1C, lipid screening, for women, breast exam, mammography, and pap smear, for men prostate exam, and for all individuals over age 50 colon cancer screenings at recommended intervals. In 2004, cardiovascular disease, cancer, and diabetes accounted for 60% of all deaths in the United States (48). If all Americans received the recommended screenings, most of those would be detected and treated earlier for substantial public health benefit.

Many conditions or populations may be targeted for vision screening. It is difficult to anticipate all situations, so the reader must be able to apply the principles discussed in this chapter. Table 8 lists some common situations in addition to those described previously.

Table 8- Situations where vision screening is and is not indicated.

Condition or population	**Prevalence**	**Chronic, asymptomatic, treatable**	**Quick, easy, painless screening test**	**Screening appropriate**
Community health fair	Moderate Low Low Low	Hyperopia Glaucoma Amblyopia Strabismus	No No Yes Yes	No No Yes No
Mexican immigrants	Moderate	Hyperopia Glaucoma Amblyopia	No No Yes	No No Yes

		Strabismus	Yes	No
Native American Indian tribe	Moderate	Hyperopia Astigmatism Diabetes Amblyopia Strabismus	No Yes Yes Yes Yes	No Yes Yes Yes Yes
African-American	Moderate	Glaucoma Diabetes Hyperopia Amblyopia Strabismus	No Yes No Yes Yes	No Yes No Yes Yes
Cataract	High	No	Yes	No
Macular degeneration	Moderate	No	Yes	No
Binocular and accommodative conditions	Low	No	No	No
Other anterior segment conditions	Low	No	No	No
Other retinal or neurologic conditions	Low	No	No	No

The principles of screening described in this chapter are as important in the clinic as they are for public health. Every test ordered from visual acuity to lab tests have predictive values, sensitivities, and specificities. Assuming test measures are normally distributed, which most physiologic functions are, abnormal is defined as two standard deviations from the mean. Therefore, 5%, one in 20, of clinical tests will be positive by chance. The question the clinician must answer for every test is: does this result mean a disease exists or is it just the high or low end of the normal curve. Men over 180 cm in height are two standard deviations taller than average, so they are not "normal". Are they ill? Usually not. A person with intraocular pressure above 22 mmHg has by definition ocular hypertension, but they have only a 50% chance of having glaucoma. *It is this process of clinical decision making which is the heart of all health care practice. As much as we wish diagnosis to be black and white most conditions are shades of gray. Clinicians deal in probabilities just as much as statisticians, epidemiologists, and public health professionals.*

Study Questions

1. List the characteristics of what screening is and what it is not.
2. A nursing home contracts with an eye care professional to provide services for its patients. It is desired that most services be provided on site to avoid costly and difficult transportation. All patients are enrolled in Medicare. It is not feasible to do complete eye exams on every resident, but some type of screening needs to be done in addition to patients who request full exams. Describe a screening program for this population.
3. In a nursing home population, visual acuity is equally sensitive for detecting cataract and optic atrophy. Should there be a difference in positive predictive value and how will it differ or why will it not?
4. What testing protocol would be valid and reliable for screening a high school sports team?
5. A senior citizens council asks for a glaucoma screening to be performed at a monthly event. What are the options?
6. Which of the following effect predictive value?
    a. Sensitivity
    b. Specificity
    c. False positive rate
    d. False negative rate
    e. Prevalence

Take Home Conclusions

- A screening program includes defining the population, identifying conditions to screen, determining a test protocol, marketing and recruitment, follow through, and efficacy measures.
- Conditions which are appropriate to screen are chronic, asymptomatic, vision threatening, have high morbidity, are easily identified by a low cost, quick, and painless test protocol, and have better prognosis for treatment when detected earlier.
- Sensitivity is the proportion of cases detected by the test; specificity is the proportion of non cases identified by the test; positive predictive value is the probability that given a positive test result a person will actually have the condition; yield is the number of new cases identified and referred from the screening.
- Clinical tests done in the office follow the same laws of probability as applied to screening tests.

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