VALIDATED PORTABLE PEDIATRIC VISION SCREENING IN THE ALASKA BUSH

A VIPS-LIKE STUDY IN THE KOYUKON

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KEYWORDS: vision screening, autorefraction, photorefraction, amblyopia, anisometropia, pediatric, epidemiology, refraction

Abstract

Background

Photoscreening and remote autorefraction showed promise in the urban "Vision in Preschoolers Study." We transported a comparative screening with confirmation program to a remote part of interior Alaska.

Methods

80 children from villages in the Koyukon region received on-site three-pronged vision screening followed by gold-standard confirmatory exams. Each had patched HOTV acuity, photoscreening and Suresight remote autorefraction.

Results

There was a high prevalence of amblyopia and vision disorders in these villages. Acuity testing was moderately valid but not useful for children less than 4 years old. Suresight has specificity over 90% with sensitivity of 60%. Photoscreening had specificity over 95% and sensitivity of 70% and was better than Suresight for children under age 4.

Conclusion

The Welch Allyn Suresight had similar high validity in the Koyukon as in VIPS and provides immediate, on-site results. Photoscreening, particularly with commercial digital flash cameras and specific interpretation, is a cost effective screening tool particularly for younger children.

Introduction

Amblyopia is the most common etiology of vision loss in children and young adults[1, 2]. Screening for vision defects in young children combined with thorough therapy can dramatically reduce the prevalence of amblyopia in developed countries[3-5]. Considering the potential adverse economic impacts of urban life with uncorrected acuity in one eye[6], pediatric vision screening is a highly cost-effective societal intervention with less than $6000 per QALY (quality adjusted life years; 2004 US dollars)[7]. Due to the lack of municipal services for the visually impaired, and high rates of traumatic vision loss in the sound eye[8, 9], the value of amblyopia reduction in the Alaska Bush may be even higher. The success of amblyopia therapy is directly linked to compliance[10, 11], a factor that may be improved through the use of atropine penalization[12, 13] or adherent protective occlusion[14].

Acuity testing directly measures the sensory defect in amblyopia in children of sufficient age and development to participate[5, 15]. Photoscreening[16] and remote autorefraction[17] have the potential to detect ocular conditions (strabismus and refractive errors) which directly lead to amblyopia. The Polaroid MYI photoscreener used by lay screeners has worked well in urban and rural Alaska[18-21]. Photoscreeners have been developed to allow onsite computer interpretation[22]. Light weight, battery-operated commercial digital flash cameras with a short flash-to-lens distance provides an inexpensive, portable alternative for photoscreening[23, 24].

The Alaska Blind Child Discovery is a cooperative, charitable research project to vision screen all preschool Alaskans that has received institutional review from Providence Alaska Medical Center. Lay screeners take photoscreen images and send them to the coordinating center for highly specific physician interpretation[19], data collection and mailed parental notification[18, 20]. Much of the screening within Alaska's limited road system has been done by volunteers from the District 49 Lions Clubs while remote villages are often screened by public health nurses. Regions of the North Slope and rural Interior Alaska had not yet been screened by ABCD[21].

The National Institutes of health is currently funding the Vision in Pre-Schoolers study affectionately called VIPS[17]. It the first of three phases, several commercially available objective and subjective tools were employed by pediatric optometrists and ophthalmologists on 2588 Head Start preschool children aged 3-5 years before comprehensive confirmatory exams. For a given level of specificity (90%) tests were compared by their sensitivity to detect mild, moderate and severe vision defects in children. Two photoscreeners (MTI interpreted at Vanderbilt[25] and the iScreen[26]) only achieved a sensitivity of 37% and were therefore dropped from further VIPS study. Two remote autorefractors including the Welch Allyn Suresight achieved higher sensitivity over 80% for more severe conditions.

We report our experience utilizing portable flip-card acuity testing, photoscreening, and Suresight remote autorefraction followed by gold-standard comprehensive exams in some remote areas of interior Alaska.

Methods

During two extended weekends in the spring of 2003 and 2004, missionary aviator Roger Huntington flew ABCD screeners and the pediatric ophthalmologist to villages in the Koyukon region. Information regarding the screening was mailed to educators in advance. Screening clinics were held in the schools, in the health clinics, or in a private home. Parents reviewed ABCD paperwork and consented to the screening and the associated comprehensive eye exam. Children with significant refractive error were sent sturdy spectacles made by Dr. Lynn Coon's optical shop in Wasilla. The screenings, eye exams and spectacles were provided at no charge.

Three types of vision screening were employed: patched acuity, photoscreening and remote autorefraction. On the first year, screening was done by a first year WAMI medical student and on the second year by a sixth grader. In each screening clinic, acuity was tested with good light, and the photoscreening was performed with ambient light reduced in a dim room, or a modified tent.

Acuity was tested using a 10-foot flip card surround HOTV with logMAR presentation ranging from 20/100 to 20/20 (Precision Vision, LaSalle Illinois, Catalogue # 2006). The non-tested eye was occluded with an adhesive patch. A matching card was place in the child's lap to assist non-literate identification. 20/40 level was presented first, and smaller or larger optotypes sequentially presented depending on pass or fail of the preceding. The acuity level was defined as the smallest optotypes for which the child passed at least 3 of 4. We employed AAP pass levels of 20/40 for children age 3, and 20/32 for those older than 4 years[27].

Photoscreening for 2003 was done with an MTI photoscreener (MTI, Lancaster PA). After careful MTI comparison[24], the more portable Gateway DV-

S20 digital flash camera (www.gateway.com) exposed from 1.6 meters was used in 2004. Non-mydriatic pupil enlargement was sought with a dim environment, and distracting bystanders were kept away from the screener to reduce stray off-fixation during flash exposure. The cameras were held directly in front of the screener's face to improve target fixation. Photoscreens were interpreted using the "delta center crescent" criteria referring all cases with refractive light crescents extending to within 1 mm of the central Hirshberg reflex, or beyond[23]. Photoscreens were labeled by immediate writing on the MTI Polaroid images, or by affixing a nametag to the clothing before flash exposure with the Gateway DV-S20.

The Suresight remote autorefractor (Welch Allyn, Schenectady, NY) is a battery operated, hand held device that employs Hartmann-Shack wavefront analysis. It is aimed at one eye at a time and focused according to an auditory pitch. Both eyes are screened in sequence after which an estimate of sphere and cylinder for each eye is presented on an LCD screen, or available for infrared transmission to a thermal printer. A reliability factor, particularly low in wiggly infants, is also generated for each eye. We employed the rapid pediatric screening mode that calculates a difference in spherical equivalent. The manufacturer has predefined failure criteria identified by an asterix on the readout. The VIPS study also published more stringent referral criteria aimed at reducing false positive referrals[17].

After screening, pupil reflexes were checked using the Enhance Brückner Test[28] and motility determined using a Spielman occluder and cardinal fields of gaze. Then a cycloplegic mixture of cyclopentolate 1% plus neosynephrine 2.5% was instilled in each eye. Thirty minutes later, the children were refracted using the phoropter trapeze[29]. The anterior segment was examined by slit lamp, and the retina examined by indirect ophthalmoscopy. Targeted ocular disorders were defined by AAPOS criteria[30].

Results

During two extended weekend screening expeditions to the villages of Hughes, Allakaket and Allatna, Galena, Koyukuk and Nulato, 80 children, aged 7.2±4.4 years received a battery of screening tests followed by the Alaska Blind Child Discovery [gold-standard comprehensive] Exams (ABCD-E). Of these 21(26%) had already had eye exams and 7 (9%) already had previously been prescribed spectacles. According to AAPOS guidelines[30], 21 (26%) had amblyopia or ocular conditions for which screening is intended. One had a small central cataract and one had high anisometropic myopia due to staphyloma. Five had strabismus (4 exotropia and 1 accommodative esotropia). Thirteen had high refractive error (8 astigmatism, two hyperopia and three myopia). Two had pupil defects (1 Horner's Syndrome and one iris coloboma) and one had congenital ptosis. One child had tearing due to a mixed mechanism of nasolacrimal obstruction and lower lid trichiasis. One girl had hysterical denial of vision; she gave poor initial screening acuities but inconsistent confrontation fields with otherwise normal exam. Distributions of refractive errors for these children are given in Figure 2. The regression trend for mean refractive error by age is given in Figure 3.

Most children were easily able to complete the acuity testing and seemed to enjoy using the decorated adhesive patches that assured monocular measurements, however 17 were either too young or developmentally challenged to give reliable acuities. The Welch Allyn Suresight gave reasonably reliable readings, or the "frustrated" unable beep (we interpreted as fail) for all but three children. The Gateway DV-S20 gave sufficiently clear digital images in 33 children, however one child tipped her head forward such that her eyebrows essentially obscured the papillary images making interpretation unreliable. The MTI photoscreener produced reliable images in the other 47 children.

Table 2 gives validation statistics on all screenings whereas Table 3 shows validation statistics for all children less than 4.0 years of age. Table 4 shows validation statistics for all children 4.0 years and older. Alaska Blind child Discovery has developed screen statistics to emphasize the adverse impact of un-screenable, and un-interpretable screenings, the "ABCD-sensitivity" and the "ABCD-specificity[19]." Conventional measurement of Prescreening Probability varies by screening test due to these cases. Acuity testing was very poor for children less than 4 years of age, but had an ABCD sensitivity of 60% and specificity of 79% in older children. Both objective tests performed well on all children with ABCD sensitivity/specificity of 57% / 92% for Suresight with VIPS criteria and 68% / 97% for photoscreening. Photoscreening outperformed Suresight for children younger than 4.0 years yielding an ABCD sensitivity / specificity of 50% / 89% compared to 29% / 82% for Suresight.

Children in these Koyukon villages had the following refraction statistics: sphere right 0.31± 1.9 and left 0.34± 2.1 diopters with cylinder right 0.53± 0.68 and left 0.50 ± 0.67 and anisometropia (spherical equivalents) 0.30±0.29 only 10% over 0.75 diopters. Age regression : sphere R = 2.26 - 0.27 (age) and sphere L = 1.99 – 0.27 (age). The actual cycloplegic refraction was regressed against the readings on the screening mode of the Welch Allyn Suresight (Figure 4).

Conclusion

In five days of remote screening clinics in five villages, 21 children with significant eye disorders were detected, and seven amblyopic children were started on spectacles and or therapy. Young lay screeners were able to accurately identify the majority of severe cases with valid, portable screening devices. The prevalence of severe eye disorders in this region was high although, unlike the VIPS study, we did not intentionally inflate the prescreening probability. Not all children in the larger villages were able to be screened, and therefore parents with heightened concern for their children, perhaps due to symptoms and signs of vision problems or positive family histories, may have been over-represented in our cohort.

The older children performed well on the patched flip-card acuity testing with only one girl giving false positive results due to hysterical denial of vision. Amblyopic children who had already received spectacles may have achieved adequate passing acuities despite amblyogenic conditions leading to more false negative validation on this test. Children seemed to enjoy the patches and we are confident no child "cheated" by peaking, an otherwise common and devastating defect for some acuity screening protocols.

Both photoscreening and Welch Allyn Suresight had very good validation. When initially introduced, many pediatric vision investigators were not impressed by this remote autorefractor since it did not seem to agree with direct refractive data[31]. Our findings confirmed this "hunch" (figure 4), however the Suresight reliably identified or target conditions by either manufacturer's, and the VIPS criteria[17]. One striking advantage of the Suresight for lay screening is the onsite, immediate interpretation.

The Suresight currently costs over $4500 (USD) and was not as easy as the photoscreeners to focus on wiggly or developmentally delayed children. Both the $4500 MTI Polaroid-based photoscreener, and the inexpensive ($89) Gateway DV-S20 photoscreener gave very valid results and were particularly applicable to the younger children. Photoscreening set-up and interpretation DVDs are available form the www.ABCD-vision.org website. We hope onsite, immediate computer interpretation for photoscreening[22] becomes commercially available, portable, and financially competitive.

If the devices from our Koyukon project were only used on the 80 children reported, then average cost per screening would be $0.38 for the chart plus $0.18 for the pre-printed patches or $0.56, the Gateway DV-S20 at $1.12 per child, the Suresight at $56 per child and the MTI at $58 per child due to Polaroid film costs. We expect that these tools will continue to function for several years and actually screen hundreds of children bringing the average screening cost down. The incremental costs of screening over ignoring these children is actually the screening cost plus confirmatory exam costs plus treatment costs and long-term follow-up costs[20]. The goal to screening is to detect treatable eye disease early enough to allow effective, consistent treatment. Citizens with best corrected acuities better than 20/40 have significant societal benefit over those with non-treated amblyopia[6]. We hope that early detection of amblyogenic factors with rapid delivery of durable, consistent spectacles will decrease amblyopia severity and allow better long-term reduction in the prevalence of residual amblyopia blindness in remote parts of Alaska.

Table

Criteria	AAPOS[30]	VIPS[17]	VIPS (group1)	VIPS (group2)	VIPS(group3)
Anisometropia	≥1.50 D	>1.00 D	>2.00 D	"not severe"	
Strabismus	Any manifest	Heterotropias 1°	Constant	Intermittent	
Hyperopia	≥3.50 D	>3.25 D	>3.25 D	3.25D-5.0D	3.25D-5.0D
Myopia	>3.00 d	>2.00 D	≥6.00 D	4.0D – 6.0D	2.0D – 4.0D
Media opacity	> 1 mm				
Astigmatism	≥1.50 D	>1.50 D	≥2.50 D	1.5D-2.5D	
Astigmatism oblique	≥1.00 D				
Myopic anisometropia		>3.0 D	>6.0 D		
Ptosis	≥ 1mm marginal reflex distance				
Visual acuity	AAP age	≤.5 (age 3), ≤.7 (age >4)			
Amblyopia unilateral		≥3 line difference	≥3 line Δ, ≤.3, suspected	2 lines Δ presumed	
Amblyopia bilateral		≤.5 (age 3), ≤.7 (age >4)	≤.5 (age 3), ≤.7 (age >4)		
Reduced VA with no amblyogenic factor		.4 & .5 (age 3), .5 & .67 (age >4)			.4 & .5 (age 3), .5 & .67 (age >4)
Acuity sensitivity		54%	72%	41%	44%
Acuity specificity		89%	89%	89%	89%
Photoscreen sensitivity		37%	56%	26%	20%
Photoscreen specificity		94%	94%	94%	94%
Suresight sensitivity		63%	81%	68%	29%
Suresight specificity		90%	90%	90%	90%

Table 2: Validation table for all Koyukon children screened. A 2x3 validation table[19] shows screening test positive, negative and inconclusive versus gold-standard, ABCD-E confirmatory exam positive and negative based on AAPOS guidelines[30]. ACUITY was 10-foot, flip card surround HOTV with patching of the untested eye. Photoscreen was either MTI or Gateway DV-S20 utilizing the delta-center-crescent interpretation[23, 24]. The Welch Allyn Suresight was interpreted using manufacturer's guidelines, and the more stringent criteria afforded by the VIPS study[17]. ABCD sensitivity and specificity reward screening with low "unscreenable /inconclusive" rates.

Koyukon Vision Screen		2003-4		ACUITY	Photoscreen	Suresight	VIPS Suresight
			A	9	15	15	12
	exam +	exam -	B	9	1	9	2
screen +	A	B	C	5	6	3	6
screen-	C	D	D	42	57	50	57
screen I	E	F	E	6	0	3	3
	N=(A+B+C+D)		F	8	1	0	0
prescreen Probability		(A+C)/N		22%	27%	23%	23%
sensitivity		A/(A+C)		64%	71%	83%	67%
specificity		D/(B+D)		82%	98%	85%	97%
PPV		A/(A+B)		50%	94%	63%	86%
NPV		D/(C+D)		89%	90%	94%	90%
ABCD sensitivity		A/(A+C+E+F)		32%	68%	71%	57%
ABCD specificity		D/(B+D+E+F)		65%	97%	81%	92%

Table 3: Validation for screening all children less than 4 years old.

Age zero to 3.9		Validation		ACUITY	Photoscreen	Suresight	VIPS Suresight
			A	0	3	3	2
	exam +	exam -	B	1	0	3	1
screen +	A	B	C	0	2	1	4
screen-	C	D	D	0	8	6	9
screen I	E	F	E	5	0	1	1
	N=(A+B+C+D)		F	8	1	0	0
prescreen Probability		(A+C)/N		0%	38%	31%	38%
sensitivity		A/(A+C)		n/a	60%	75%	33%
specificity		D/(B+D)		0%	100%	67%	90%
PPV		A/(A+B)		0%	100%	50%	67%
NPV		D/(C+D)		n/a	80%	86%	69%
ABCD sensitivity		A/(A+C+E+F)		0%	50%	60%	29%
ABCD specificity		D/(B+D+E+F)		0%	89%	60%	82%

Table 4: Validation for screening Koyukon children 4 years and older.

Older than 3		Validation		ACUITY	Photoscreen	Suresight	VIPS Suresight
			A	9	12	12	11
	exam +	exam -	B	9	1	6	1
screen +	A	B	C	5	4	2	3
screen-	C	D	D	38	47	42	47
screen I	E	F	E	1	0	2	2
	N=(A+B+C+D)		F	0	0	0	0
prescreen Probability		(A+C)/N		23%	25%	23%	23%
sensitivity		A/(A+C)		64%	75%	86%	79%
specificity		D/(B+D)		81%	98%	88%	98%
PPV		A/(A+B)		50%	92%	67%	92%
NPV		D/(C+D)		88%	92%	95%	94%
ABCD sensitivity		A/(A+C+E+F)		60%	75%	75%	69%
ABCD specificity		D/(B+D+E+F)		79%	98%	84%	94%

Figures

Figure 1. Medical Student Dustin Lang holds a MTI photoscreener as Missionary Aviator Roger Huntington readies his Piper Pacer in the Village of Allakaket, April 2003.

Figure 2. Distributions of ABCD-E refractions for children in the Koyukon. These are derived from cycloplegic refractions showing sphere right and left eye, cylinder power right and left eye, and the difference in spherical equivalent (anisometropia) in diopters. The box plot for each can be interpreted as a median line enclosed by a box encompassing the 25th and 75th percentiles with a diamond demonstrating the mean and standard deviation of the mean. The bar encompasses 10th and 90th percentiles with outlier dots.

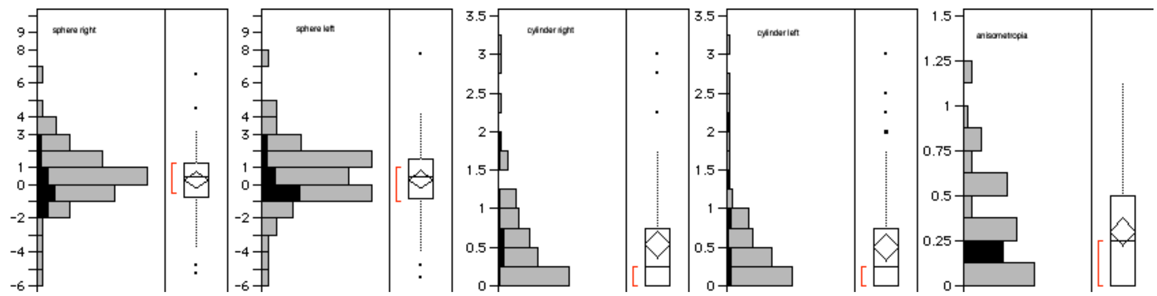


Figure 3. The effect of age on spherical equivalent (right eye) for children in the Koyukon region. (spherical equivalent right = 2.26 – 0.28 (age), Rsquare = 0.23.

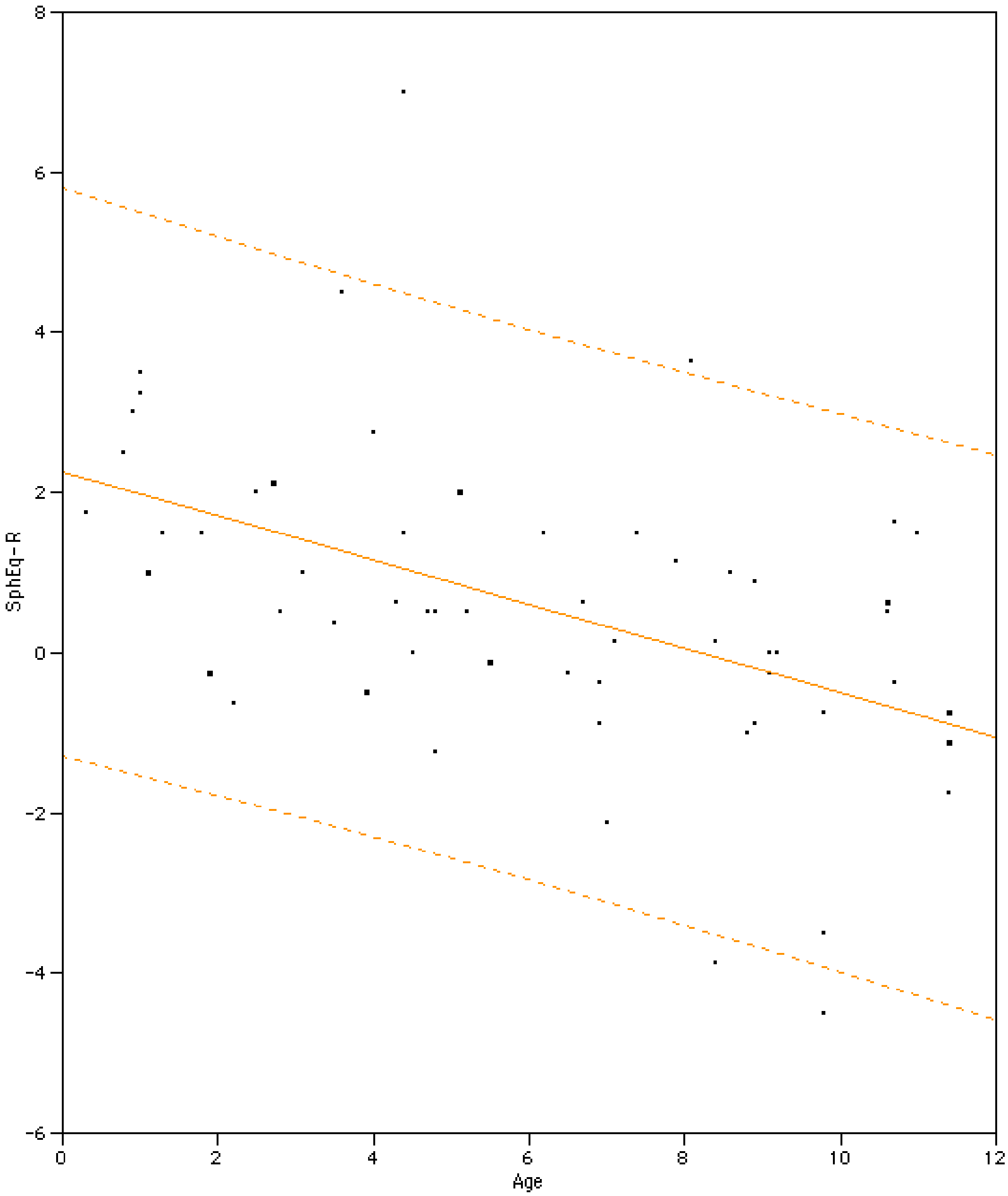
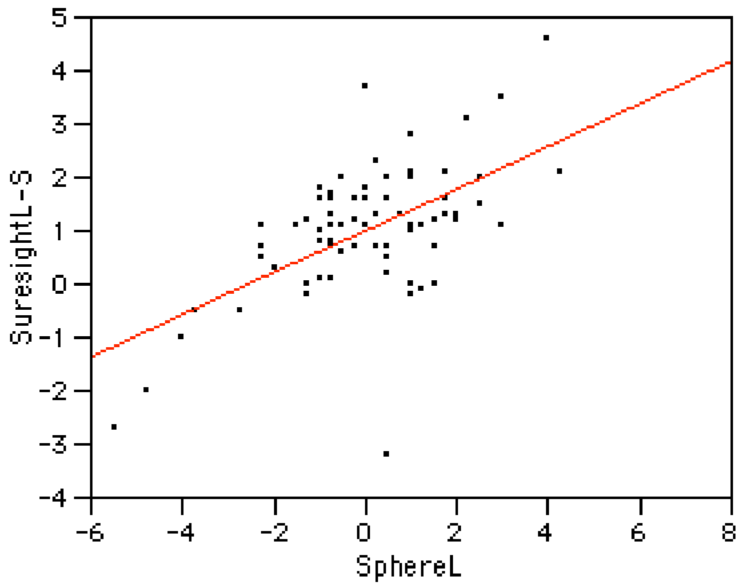


Figure 4. The regression of actual refraction (sphere left) versus the Suresight screen reading for children in the Koyukon. Suresight R_S = 0.6842213 + 0.3496205 Sphere-R (Rsquare = 0.30), Suresight L-S = 0.9672692 + 0.412365 Sphere-L (Rsquare = 0.35), Suresight R-C = 0.1235774 + 1.3648161 Cyl-R (Rsquare = 0.46), and Suresight R-C = 0.1235774 + 1.3648161 Cyl-R (Rsquare = 0.35), Suresight R-C = 0.1235774 + 1.3648161 Cyl-R (Rsquare = 0.02).



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