Report article

Vision examination for 3-year-old children in Tsubame city: Transition of the health checkup program and accuracy of the screening tests

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Abstract

The accuracy of screening tests with revision of the Vision Examination Program for 3-Year-Old Children in Tsubame City was determined. The study included 910 children, who underwent examinations at the Tsubame public health center over 20 months from April 2017 to October 2018.

Target periods were: Period A, when secondary visual acuity tests were conducted at the health center for children who did not undergo the primary visual acuity test at home and for whom the test could not be conducted; Period B, when secondary visual acuity tests were conducted at the health center for all children irrespective of the results of the primary visual acuity test conducted at home; and Period C, when objective refraction examinations were conducted.

We studied the issuance of slips for complete examinations, number of children who underwent medical examination at medical institutions, and the results of medical examinations and positive rates.

Slips for complete examinations were issued to three children (1.33%) in Period A, 38 children (10.92%) in Period B, and 37 children (11.01%) in Period C; two children underwent medical examinations (66.67%) in Period A, 28 children (73.68%) in Period B, and 31 children (83.78 %) in Period C.

True positives were 100.00% for Period A, 92.86% for Period B, and 87.10% for Period C. False positives were 0% for Period A, 7.14% for Period B, and 12.90% for Period C. For Period C, the issuance of slips for complete examinations and percentage of children who underwent medical examination at medical institutions increased.

It was unclear about the accuracy of the screening test by the introduction of objective refraction test, but the rate of visits to medical institutions increased.

Introduction

Health checkups for 3-year-old children consists of an infant medical examination based on the Maternal and Child Health Act [1]. Vision examinations for early detection of amblyopia was

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introduced in 1990. The Maternal and Child Health Act was revised in 1997, and the entity for implementing the health checkup program was transferred from prefectures to municipalities.

The objective of the Vision Examination Program for 3-Year-Old Children is early detection of amblyopia at an early stage for providing treatment. Presently, amblyopia is detected in many children during pre-school health checkups and health checkups at schools [2, 3]. It has also been reported that regional disparities exist in the content of visual examinations [4].

Visual sensitivity increases rapidly after birth, with a period of high sensitivity continuing up to the age of about 1.5 years, after which visual sensitivity gradually decreases and the development of vision almost stops at the age of around 8 years [5]. Therefore, it is necessary to detect amblyopia before children begin school. Visual development could be delayed if vision problems such as strabismus and refractive errors are present during the immature period in the progress of visual development [6]. Children with normal intellectual development are able to understand the visual acuity test using the Landolt ring, when they become 3 years of age, and it is therefore easy to detect strabismus and refractive errors that may cause amblyopia [7].

In recent years, numerous objective refractometers with excellent portability and operability have become available in medical clinics, and they are being widely introduced because the objective refraction examination has been recognized as important throughout Japan as part of the Vision Examination for 3-Year-Old Children [8-10].

To increase the rate of detection of amblyopia during the Vision Examination for 3-Year-Old Children, physicians, public health nurses, nurses, and orthoptists in Tsubame City, Niigata Prefecture have worked together since FY 2017, and have revised the Vision Examination Program, first by introducing the visual acuity test for all children at health centers, and then by introducing objective refraction examinations.

In this study, we report the transition of the Vision Examination Program for 3-Year-Old Children in Tsubame City and its accuracy in vision screening tests.

Materials and Methods

Tsubame City sought a better 3-year-old child's visual checkup. They reviewed the health checkup program in stages and examined the accuracy of the screening test.

In this study, 910 children, with an average age of 39.56 ± 0.65 (mean ± SD) months, who underwent the Vision Examination for 3-Year-Old Children at the Tsubame Public Health Center over 20 months from April 2017 to October 2018, were included.

The research period was divided into three parts according to the contents of the health checkup program. Period A was 5 months from April 2017 to August 2017, during which the secondary visual acuity test was conducted at the health center for children who did not undergo the primary visual acuity test at home or did not test successfully. Period B was 7 months from September 2017 to March 2018, during which secondary visual acuity tests were conducted at the health center for all children irrespective of the results of the primary visual acuity test conducted at home. Period C was 7 months from April 2018 to October 2018, during which the primary visual acuity test at home, secondary visual acuity test, and objective refraction examination using Spot™ Vision Screener [11] (Figure 1) (hereinafter referred to as SVS) were implemented at the health center for all children. The subjects were 226 in period A, 348 in period B, and 336 in period C. (Table 1).

The details for undergoing the 3-Year-Old Health Check-up were sent by post to households, along with the medical questionnaire form (Figure 2) and primary visual acuity test set for home use. The families were requested to conduct the visual acuity test at home before the day of the health

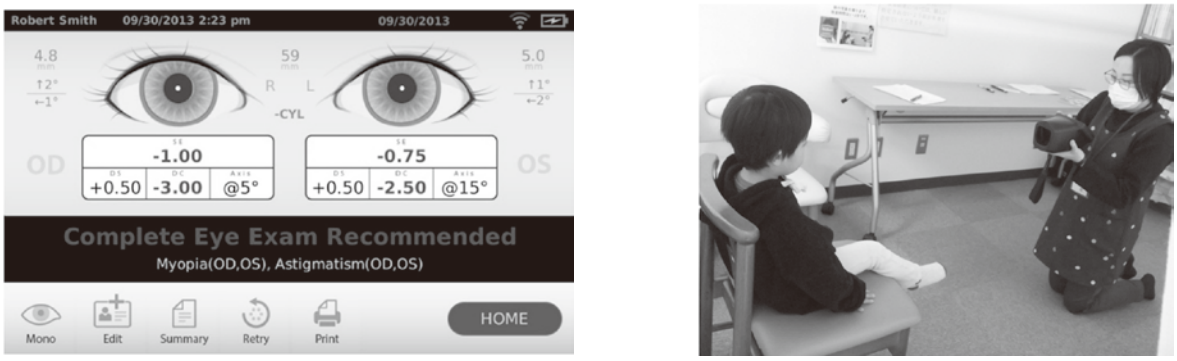


Figure 1. SVS display screen and state of measurement.
When refraction abnormality and ocular misalignment that can lead to amblyopia are measured, the characters on the screen are displayed in red. Even in the case of young children, screening is possible in 1 second.

Table 1. Classification of research period.

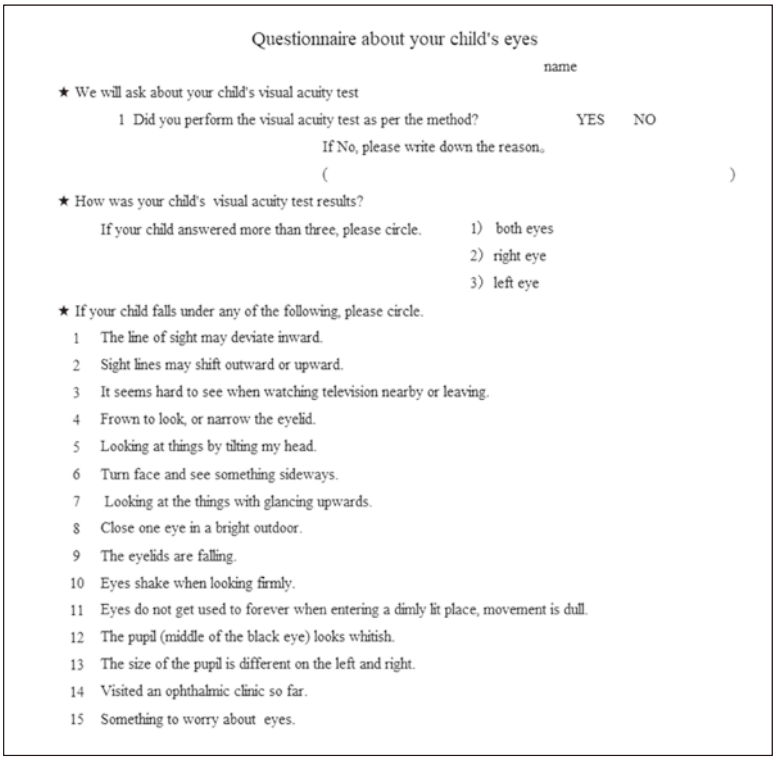
	A period	B period	C period
Research period	April 2017 - August 2017 5 months	September 2017 - March 2018 7 months	April 2018 - October 2018 7 months
Visual checkup contents	・Medical questionnaire form ・Primary visual acuity test at home ・Secondary visual acuity test at public health center (Children who did not undergo the primary visual acuity test at home or did not test successfully.)	・Medical questionnaire form ・Primary visual acuity test at home ・Secondary visual acuity test at public health center (all children)	・Medical questionnaire form ・Primary visual acuity test at home ・Secondary visual acuity test at public health center ・objective refraction examination using Spot™ Vision Screener (all children)
Number of children	226	348	336

check-up, and to list the test results using the medical questionnaire form.

Children turning 40-month-old underwent the 3-Year-Old Health Check-up during that same month. The objective refraction examination using SVS was conducted by an orthoptist. A measurement distance of approximately 1 m was maintained in front of the eyes of the children being examined with SVS, and both eyes were measured simultaneously (Figure 1).

Referring to the amblyopia risk factor criteria of the United States for SVS [12,13] (Figure 3), children who did not meet the criteria for amblyopia risk factors were marked as a pass, while those who met the criteria were marked as a fail.

Two nurses were in charge of the secondary visual acuity test conducted at the health center. The testing distance was set at 2.5 m, and a Landolt ring chart with angular vision of 1.0 visual acuity was used (Figure 4).



Questionnaire about your child's eyes

name

★ We will ask about your child's visual acuity test

1 Did you perform the visual acuity test as per the method? YES NO

If No, please write down the reason。

( )

★ How was your child's visual acuity test results?

If your child answered more than three, please circle. 1) both eyes
2) right eye
3) left eye

★ If your child falls under any of the following, please circle.

1 The line of sight may deviate inward.
2 Sight lines may shift outward or upward.
3 It seems hard to see when watching television nearby or leaving.
4 Frown to look, or narrow the eyelid.
5 Looking at things by tilting my head.
6 Turn face and see something sideways.
7 Looking at the things with glancing upwards.
8 Close one eye in a bright outdoor.
9 The eyelids are falling.
10 Eyes shake when looking firmly.
11 Eyes do not get used to forever when entering a dimly lit place, movement is dull.
12 The pupil (middle of the black eye) looks whitish.
13 The size of the pupil is different on the left and right.
14 Visited an ophthalmic clinic so far.
15 Something to worry about eyes.

Figure 2. Medical questionnaire form (Recommended by Niigata Prefecture).
Parents of the child fill in and bring it on the day of the 3-year-old health checkup.

Abnormal refractive error that can be a risk factor for amblyopia

Age (month)	Anisometropia	Astigmatism	Myopic (equivalent spherical value)	Hyperopic (equivalent spherical value)
6～12	1.5	2.25	2	3.5
12～36	1	2	2	3
36～72	1	1.75	1.25	2.5

Risk factors other than refraction abnormal value

All ages	constant strabismusstrabismus at Primaryposition	8 ⊿ or more
	opaque media	1mm or more

Figure 3. Risk factors for amblyopia (ARF) using the SVS.
ARF using SVS determined by American Academy of Pediatrics [10,11] . In this reference value, since there are many false positives, a recommended reference value (cutoff) is currently considered.
Reference value for eye refraction SVS refractive error determination ≦ (D:Diopter)

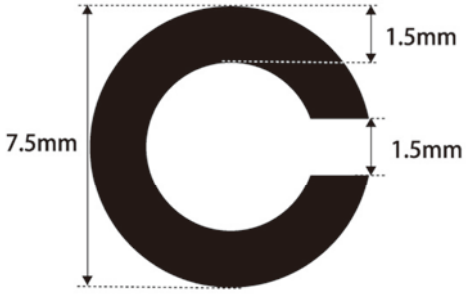


Figure 4. The 1.0 Landolt ring chart with an angular vision of 1.0.
When breaks in the Landolt ring of visual acuity 1.0 with a standard testing distance of 5 m could be confirmed from the distance of 2.5 m, the visual angle is 2 minutes = 2/60th of 1 degree.

The decimal visual acuity value was set at 0.5. In normal visual development, assuming that the visual acuity of a 3-year-old child is about 0.5.

Visual acuity 0.5 is a standard value set by the Niigata Prefecture Health and Welfare Department as an indicator of normal visual development of 3-year-old children.

When a child identified three out of the four positions (left, right, top, and bottom) of the breaks in the visual acuity chart, the child was marked as a pass, and if less than three positions were identified, the child was marked as a fail.

For children who were not able to understand the visual acuity test, the test was conducted again at the public health center after 2 months. The visual acuity results used for screening are those of the secondary examination at the Tsubame Public Health Center.

The slips for complete examinations were issued to the children when considered necessary by the public health nurse based on the relevant items in the medical questionnaire form and screening test results, and on an interview with the parents.

The criteria for screening tests based on the slip for complete examination were issued, and these were obtained in advance from an ophthalmologist.

The items to consider in this study are as follows. The number and ratio of slips for a complete examination, the number and ratio of children who underwent a medical examination at a medical institution after being issued the slip, and that diagnostic results. These were compared in three periods.

Data were calculated using Excel Statistics Ver.7.0. Statistical differences were analyzed by Fisher's exact test. P values less than 0.05 were considered to indicate statistical significance.

This study was approved by Tsubame City and the Ethics Committee of Niigata University of Health and Welfare (Approval No:18010-180629).

Results

Children who had a check on the questionnaire did not understand the visual acuity test or had failed with visual acuity.

The number of slips for a complete examination was issued to three children (1.33%) in the Period A group, 38 children (10.92%) in Period B, and 37 children (11.01%) in Period C (Table 2). It was significantly higher than in A period that ratio of the slips for a complete examination in B and C periods ($p < 0.05$).

Three children in the Period A group and 38 children in Period B who were issued slips for complete examinations did not have visual acuity of 0.5 in the secondary visual acuity test. In 37 children of the Period C group, 13 children (35.14%) did not have visual acuity of 0.5 in the secondary visual acuity test and three children (8.11%) had amblyopia risk factors using the SVS. Twenty-one children did not have visual acuity of 0.5 in the secondary visual acuity test and had amblyopia risk factors as determined with the SVS (56.76%) (Figure 6).

The number of children who underwent a medical examination at a medical institution after being issued the slip for complete examination was two children (66.67%) in the Period A group, 28 children (73.68%) in Period B, and 31 children

(83.78%) in Period C (Table 2). It was significantly improved C period that percentage of children who consulted a medical institution ($p < 0.05$).

Among the children who underwent medical examinations at a medical institution, those who required treatment or follow-up observation involved two children in the Period A group, 26 children in Period B group, and 27 children in the Period C group.

Children who underwent medical examination at medical institutions, who did not have any abnormality were 0 in the Period A group, two in Period B group, and four in Period C group (Table 3).

Classification		Screening test results		Total
		Positive （+）	negative （−）	
Presence of disease	Yes （+）	True Positive (TP)	False Negative (FN)	Prevalence (TP + FN)
	No （−）	False Positive (FP)	True Negative (TN)	Non-prevalence (FP + TN)
Total		Screening positive (TP + FP)	Screening negative (FN + TN)	Total number of screening (T)

Figure 5. Indicators for the accuracy of the health checkup.
Because only children who test positive during the screening are recommended for medical examination at a medical institution in the Vision Examination Program for 3-Year-Old Children, the number of false negatives and true negatives cannot be determined.

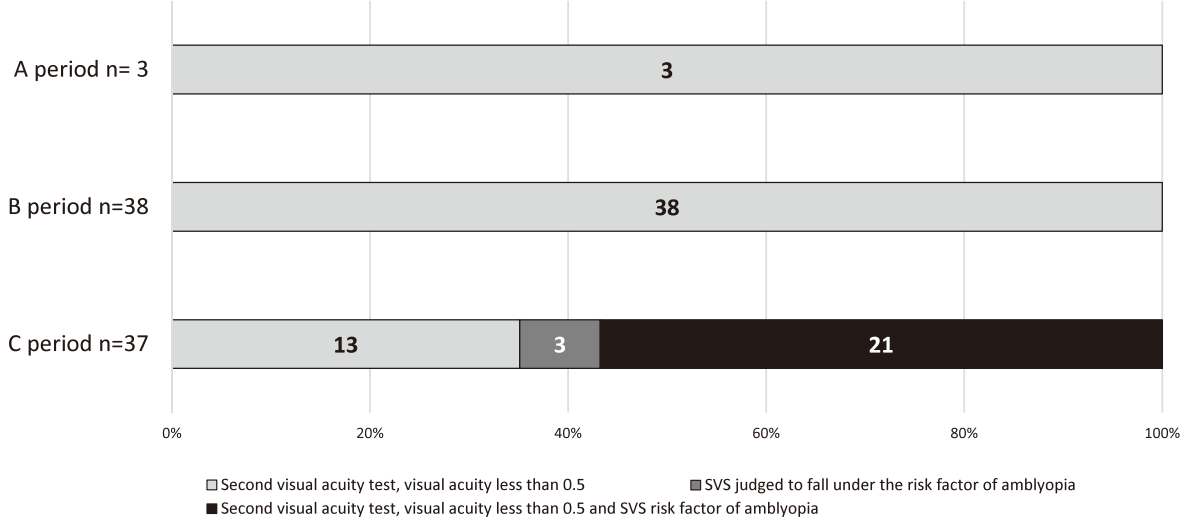


Figure 6. Issuance of slips for complete examination.
In period C, 24 out of 37 (64.86%) of whom the consultation recommendation slip was issued were the criteria for ARF in SVS.

Table 2. Summary of visual checkup.

	A period	B period	C period
a Number of health checkup	226	348	336
b Number of complete examination slips issued (b/a)	3 (1.33%)	38 (10.92%)	37 (11.01%)
c Number of children who received medical consultation in ophthalmology (c/b)	2 (66.67%)	28 (73.68%)	31 (83.78%)
d Number of children who did not receive medical consultation in ophthalmology (d/b)	1 (33.33%)	10 (26.32%)	6 (16.22%)

Table 3. Summary of consultation at ophthalmic medical institutions.

			A period	B period	C period
a	Number of children who received medical consultation in ophthalmology		2	28	31
Diagnosis results of ophthalmic medical institutions	b	Required treatment / follow-up	2	26	27
	c	No abnormality	0	2	4
Screening accuracy indicator		True positive rate (b/a × 100)	100.00%	92.86%	87.10%
		False positive rate (c/a × 100)	0.00%	7.14%	12.90%

For screening test validity, true positives were 100.00% for the Period A group, 92.86% for the Period B group, and 87.10% for the Period C group. False positives were 0.00% for the Period A group, 7.14% for the Period B group, and 12.90% for the Period C group (Table 3). There was no significant difference in any of the three periods ($p > 0.05$).

Discussion

Most importantly, the change in the health checkup program has increased the rate of visits to medical institutions.

In Niigata Prefecture, the Vision Examination Program for 3-Year-Old Children in most of the municipalities consists of screening with a medical questionnaire form and a primary visual acuity test conducted at home.

After 2017, Tsubame City introduced a secondary visual acuity test and an objective refraction examination at the health center, in the health checkup program. As a result, the number of slips indicating a complete examination has increased. The increase in the number of children who need treatment or follow-up is associated with it, and it can be inferred that amblyopia is reduced. According to the national survey of the Japan Ophthalmologists Association in fiscal 2012, the number of the slips for a complete examination issued is 6.96% [14]. In Shizuoka City, it was 0.63% in 2013, but has increased to 22.20% in 2015-2016 by introducing objective refraction test [15]. This rate is higher than our this research. The cause is that medical checkup programs and consultation recommendation criteria differ among municipalities. In Tsubame city, 11.31% of consultation vote issuance rate to medical institutions during C period, it is necessary to consider this number of future trends.

Because follow-up is not always possible during the visual sensitivity period, it cannot not be determined if the child who is negative in the screening test is a true negative or false negative.

In recent years, children's play tends to decrease outdoor physical activity, while play with indoor video games etc. is increasing [16]. It is suggested

that this change in environment may have some impact on children's visual function [17]. Therefore, visual checkup within the sensitive period is important.

Objective refraction examination is recommended as it is useful to identify amblyopia in one eye, and the results can be used to test the visual acuity of children lacking intellectual development [18,19].

The SVS system used in this program reduces the measurement time, as it measures both eyes simultaneously; whereas, conventional objective refracting instruments measure each eye by using an internal fixation target.

Because measurements can be performed by using an external fixation target from a distance of about 1 m, the success rate of examination is high even for young children [20]. In this study, the SVS test could be conducted for all children, and even children with developmental delays, such as those with Down's syndrome could also be examined.

With these advantages, introduction of the SVS (after its introduction in 2015) has seen a rapid increase in early childhood health examinations, including the Vision Examination Program for 3-Year-Old Children, in pediatric ophthalmology, and even for pediatric medical care [21].

It has been reported that the accuracy of SVS screening tests increases the false positives [22]. The results of this study also showed that the highest false positive rates were in the Period C group, when the SVS was introduced. In a previous study [23], we reported that astigmatism was overestimated by the SVS when it was tilted during measurement, because the SVS was not provided with tilt sensors like the Retinomax autorefractor, which was conventionally used in pediatric medical care.

Overestimation of astigmatism also leads to false positives. Although the SVS is operated such that it does not tilt by paying attention to this point, astigmatism exceeding the criteria corresponding to the risk factors of amblyopia are the highest as measured with the SVS [24].

Because screening at the health center is a measurement of natural pupils, it is not possible for a 3-year-old child with strong lens control to intervene in the examination by adjusting the lens, even if the SVS test distance is about 1 m. It is also necessary to pay attention to changes in pupil diameter during measurements.

However, in the vision checkup, because the slip for complete examination is issued only when marked as a fail with the screening test, it is not possible to determine whether it is a true negative or false negative.

Although in 3-year-old is an age where children can understand the visual examination based on their intellectual development, the results of a single screening test cannot be relied upon because of differences in individual development and variations in visual acuity [25], which is also characteristic of childhood vision.

Even if a child is marked as a fail when visual acuity of 0.5 is not obtained, it may be a false positive. While, even if a child is marked as a pass with visual acuity of 0.5, it may be a false negative. In the Period A group, screening was complete when the child was marked as a pass with the primary visual acuity test at home. The visual acuity value of 0.5 in the screening test, It is considered to be a reasonable value also from past papers [26,27].

It is very likely that the number of slips issued for complete examination in the Period A group was low because the method used for visual acuity tests at home was not correctly given. Therefore, we are planning to change visual acuity tests manual for home distribution.

There was a significant increase in the numbers of slips issued for complete examinations in the Period B group because the visual acuity test was not limited to the home, and nurses who were skilled in visual acuity testing measured visual acuity at the health center. As a result, it is impor-

tant not to rely excessively on the results of the visual acuity test at home, and improvements should be made to the current primary visual acuity test for home use.

Among children who did not have visual acuity 0.5 in the secondary visual acuity tests at the health center, it can be expected that they have intellectual problems. In such cases, it is useful to determine the risk factor for amblyopia with SVS. For 3-year-old child visual checkup, combined use of visual acuity test and SVS at the health checkup site is recommended.

In visual checkup for 3-year-old children, we think, it is important to carry out objective refraction tests in addition to visual acuity tests. However, its usefulness could not be clarified in this study.

The accuracy of screening tests, which add objective refraction tests to visual acuity tests, requires a long-term survey. we are planning to follow up the results of elementary school health checkup for children.

The revision of the health checkup program reduced the number of children who did not undergo the medical examination at a medical institution after the issuance of slips for a complete examination, and was useful for the early detection of amblyopia.

Acknowledgments

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Conflicts of Interest

None of the authors has any conflicts of interest or any financial ties to disclose.

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