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Original Article

Detection of Strabismus and Amblyopia in 1.5- and 3-year-old Children by a Preschool Vision-screening Program in Japan

Toshihiko Matsuo[a]*, Chie Matsuo[b], Hiroaki Matsuoka[c], and Keiko Kio[c]

[a]*Department of Ophthalmology, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama 700–8558, Japan,*
[b]*Kyoyama Dental Clinic, Okayama 700–0016, Japan, and*
[c]*Okayama Municipal Government Health Care Office, Okayama 700–8546, Japan*

All children at the age of 1.5 and 3 years in Japan undergo physical, mental, and developmental checkups including dental, eye, and hearing examinations. The vision-screening program consists of 3 steps: questionnaires and home visual acuity testing as the first step (only for 3-year-old children), visual acuity testing by nurses and inspection by medical officers at regional Health Centers as the second step, and detailed examinations by ophthalmologists as the third step. This study aims to reveal the prevalence of strabismus and amblyopia as obtained from data in the vision-screening program. The final diagnoses made by ophthalmologists and sent back to the Health Centers in Okayama City were reviewed to elucidate the prevalence of strabismus, amblyopia, refractive errors, and other diseases in 1.5- and 3-year-old children in Okayama City in 5 years from 2000 to 2004. Of approximately 6,500–6,900 total children, 83.7–86.8% at 1.5 years old and 77.8–81.9% at 3 years old were brought to the Health Centers. The rates of strabismus were 0.01–0.12% at 1.5 years old and 0.20–0.34% at 3 years old, while the rates of amblyopia were 0% at 1.5 years old and 0.13–0.18 % at 3 years old. The higher rates of strabismus at 3 years old were attributed mainly to the increase of exotropia and intermittent exotropia. In conclusions, the prevalence of strabismus was different between 1.5- and 3-year-old children. The vision-screening program in Japan functions to detect strabismus and amblyopia.

Key words: strabismus, amblyopia, esotropia, exotropia, preschool vision screening program

According to Maternal and Childhood Health Law in Japan, all children at the age of 1.5 and 3 years must undergo physical and developmental checkups, including urinalysis, dental, eye, and hearing examinations. The 3-year-old children examination was started as a prefecture project in 1961 and became a municipality project in 1997. The 1.5-year-old children exanimation was started as a municipality project in 1978. Vision and hearing examinations have been included as part of the checkups since 1991. At present, therefore, the examinations for 1.5-year-old and 3-year-old children are conducted by municipalities and function as part of preschool vision screening programs in Japan. Children between 1.5 and 2 years are involved in the 1.5-year-old examinations, while children between 3.5 and 4

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*Corresponding author. Phone: +81–86–235–7297; Fax: +81–86–222–5059
E-mail: matsuot@cc.okayama-u.ac.jp (T. Matsuo)

years are involved in the 3-year-old examinations.

The eye examinations in the vision-screening programs consist of 3 steps. At the first step of the examination (this is only for 3-year-old children), questionnaires asking about specific problems such as squint as well as printed Landolt rings in 2 different sizes for visual acuity testing at home are sent to families. Families then bring children to the regional Health Centers. At the second step, nurses at the Health Centers measure uncorrected visual acuity (this is only for 3-year-old children), while pediatricians or medical officers inspect eye alignment. Orthoptists' involvement in this second screening process is not standard in the system. At the third step, children with suspected diseases are sent to ophthalmologists for detailed eye examinations. The final diagnoses are sent back to the Health Centers.

Detecting strabismus and amblyopia in the early stage of life is particularly important so that treatment can be started as early as possible; children can then gain better visual acuity, and hence, better binocular function. As a first step to obtaining basic data for evaluating the current vision-screening programs in Japan, we have previously revealed the prevalence of strabismus and amblyopia in elementary school children aged 6 to 12 years in Okayama Prefecture [1]. Okayama Prefecture, with a population of approximately 2 million, is located in the western part of Honshu, the main island of Japan, and the demographics are representative of the Japanese population. This study aims to reveal the prevalence of strabismus, amblyopia, refractive errors, and other diseases as determined from data obtained from the system of 1.5- and 3-year-old children examinations in Okayama City, the capital of Okayama Prefecture, with a population of approximately 700 thousand.

Subjects and Methods

The printed Landolt rings sent to families of children were in 2 sizes: the large and small rings were equivalent to visual acuity of 0.1 and 0.5, respectively, when tested at a distance of 2.5 m. The families were told to test the visual acuity of children first with both eyes open using the 0.1-equivalent Landolt ring at 1 m. The visual acuity for both eyes open and then for each eye with the other eye occluded was tested with the 0.5-equivalent Landolt ring at a distance of 2.5 m. Four different directions of the Landolt ring (top, bottom, right, and left) were tested by rotating the printed ring, and children were said to pass the test when they correctly recognized at least 3 different directions.

The questionnaire sent to families asked whether visual acuity testing was done at home and whether children understood the test and passed the 0.5-equivalent visual acuity testing for both eyes and for each eye. Questions regarding the presence or absence of eye-related conditions were also asked: convergent or divergent or vertical deviations, watching television at a near distance, abnormal head postures (chin up or down, face turn, and head tilt), winking at light, lid fissure narrowing, blepharoptosis, nystagmus, leukocoria, pupils in different sizes, and slower mobility at dark. It was also asked whether any eye diseases had been diagnosed by ophthalmologists.

At Health Centers, all children, except for those who had passed the 0.5-equivalent visual acuity testing for each eye at home, underwent visual acuity testing for each eye using the 0.5-equivalent Landolt ring at a distance of 5 m. The children were determined to pass the test when they correctly recognized at least 3 different directions of the ring. The children who had problems raised by the questionnaire or who failed the visual acuity testing or who were pointed out to have problems by pediatricians or medical officers were sent to ophthalmologists.

The final diagnoses made by ophthalmologists in documents and sent back to the Health Centers in Okayama City were summarized to elucidate the prevalence of strabismus, amblyopia, refractive errors, and other eye diseases in 1.5- and 3-year-old children in Okayama City in the 5-year period from 2000 to 2004. Orthoptists were not involved in the screening process at the Health Centers in Okayama City. Three major reasons for the referral to ophthalmologists, suspicion of visual disturbance, strabismus, or other eye diseases, were also correlated with the final diagnoses made by ophthalmologists.

Results

In the 1.5-year-old examinations, 5,792 (83.7%) of 6,923 children in 2000, 5,645 (84.8%) of 6,659 in

2001, 5,683 (84.4%) of 6,734 in 2002, 6,004 (86.8%) of 6,919 in 2003, and 5,734 (85.7%) of 6,694 in 2004 were brought to the Health Centers (Table 1). Of these children, 22 (0.3%), 23 (0.3%), 20 (0.3%), 16 (0.2%), and 19 (0.3%) children were examined by ophthalmologists, respectively. In the 3-year-old examinations, 5,186 (77.8%) of 6,666 children in 2000, 5,372 (79.7%) of 6,739 in 2001, 5,341 (80.0%) of 6,676 in 2002, 5,320 (81.8%) of 6,504 in 2003, and 5,411 (81.9%) of 6,608 in 2004 were brought to the Health Centers (Table 2). Of these children, 212 (3.2%), 242 (3.6%), 204 (3.1%), 207 (3.2%), and 181 (2.7%) children were examined by ophthalmologists, respectively. The rates of strabismus, including congenital nystagmus and superior oblique muscle palsy, were 0.01–0.12% at 1.5 years old and 0.20–0.34% at 3 years old, while the rates of amblyopia were 0% at 1.5 years old and 0.13–0.18% at 3 years old. The higher rates of strabismus at 3 years old were attributed primarily to the increase in exotropia and intermittent exotropia (Table 1, 2).

The rates of refractive errors were 0–0.03% at 1.5 years old and 1.06–1.75% at 3 years old. The rates of other diseases were 0.03–0.07% at 1.5 years old and 0.12–0.16% at 3 years old. Serious conditions such as congenital cataract and optic disc atrophy were rare in this survey.

Three major reasons for the referral to ophthalmologists, suspicion of visual disturbance, strabismus, or other eye diseases, and the final diagnoses at 1.5 years old and at 3 years old are shown in Tables 3 and 4, respectively. At 1.5 years old, strabismus was detected based on suspicion in the second screening process at the Health Center. At 3 years old, strabismus was mainly detected based on the same suspicion, but also, to a very small extent, based on suspicion of visual disturbance. The other eye diseases were detected based on suspicion at both 1.5 and 3 years of age. Other reasons for the referral were conjunctival diseases such as conjunctivitis and pigmentation, abnormal head posture, ptosis, and children's habit such as rubbing the eyes, winking frequently, and narrowing lid fissures.

Table 1 The prevalence of strabismus, amblyopia, refractive errors, and other diseases at 1.5 years old in Okayama City, Japan

Year	2000	2001	2002	2003	2004
Total number of children	6,923	6,659	6,734	6,919	6,694
Number of children examined at health centers	5,792 (83.7%)	5,645 (84.8%)	5,683 (84.4%)	6,004 (86.8%)	5,734 (85.7%)
Number of children examined by eye doctors	22 (0.3%)	23 (0.3%)	20 (0.3%)	16 (0.2%)	19 (0.3%)
Number of children with the final diagnoses					
Exophoria	1	1	2	1	3
Strabismus	6 (0.09%)	8 (0.12%)	4 (0.06%)	3 (0.04%)	1 (0.01%)
Exotropia	3	2	1	0	0
Intermittent exotropia	2	2	1	0	1
Esotropia	1	1	1	2	0
Superior oblique muscle palsy	0	0	1	0	0
Congenital nystagmus	0	2	0	1	0
Unclassified strabismus	0	1	0	0	0
Amblyopia	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Refractive errors	0 (0%)	0 (0%)	2 (0.03%)	1 (0.01%)	0 (0%)
Myopia/myopic astigmatism	0	0	1	0	0
Hyperopia/hyperopic astigmatism	0	0	1	1	0
Others	3 (0.04%)	2 (0.03%)	5 (0.07%)	2 (0.03%)	2 (0.03%)
Entropion	1	0	3	0	2
Blepharoptosis	1	1	1	1	0
(Allergic) Conjunctivitis	0	0	1	1	0
Conjunctival pigmentation	1	0	0	0	0
Iris atrophy	0	1	0	0	0
No abnormality	12 (0.17%)	12 (0.18%)	7 (0.10%)	9 (0.13%)	13 (0.19%)

Discussion

Preschool vision screening has been conducted in many countries, and the results of detailed analysis have been reported based on the systems [2–22]. In Japan, children have at least 3 chances for eye checkups before they enter elementary schools at the age of 6 years: 1.5-year-old and 3-year-old checkups, and pre-entry checkups at 5 years old. This study revealed that approximately 85% of children at 1.5 years old and 80% at 3 years old are routinely brought to the Health Centers in Okayama City every year from 2000 to 2004. Further effort is required to search for the reasons why 15–20% of children were not brought to the Health Centers for the checkups.

The vision-screening program conducted as part of the 1.5-year-old and 3-year-old children examination has detected refractive errors, strabismus, amblyopia, and other eye diseases. This survey is the first to show the prevalence of refractive errors, strabismus, and amblyopia in 1.5- and 3-year-old children in Japan, based on such preschool vision-screening programs. The final diagnoses in this system were made by ophthalmologists, and thus, the definitions or criteria of these diagnoses are the current standards at textbook levels shared by ophthalmologists.

The prevalence rates of strabismus and amblyopia revealed in this study, varied significantly from year to year over the period of 5 years: the rates of strabismus were 0.01–0.12% at 1.5 years old and 0.20–0.34% at 3 years old, while the rates of amblyopia were 0% at 1.5 years old and 0.13–0.18% at 3 years

Table 2 The prevalence of strabismus, amblyopia, refractive errors, and other diseases at 3 years old in Okayama City, Japan

Year	2000	2001	2002	2003	2004
Total number of children	6,666	6,739	6,676	6,504	6,608
Number of children examined at health centers	5,186 (77.8%)	5,372 (79.7%)	5,341 (80.0%)	5,320 (81.8%)	5,411 (81.9%)
Number of children examined by eye doctors	212 (3.2%)	242 (3.6%)	204 (3.1%)	207 (3.2%)	181 (2.7%)
Number of children with the final diagnoses					
Exophoria	6	8	9	7	10
Strabismus	13 (0.20%)	23 (0.34%)	21 (0.31%)	14 (0.22%)	17 (0.26%)
Exotropia	4	6	4	3	3
Intermittent exotropia	6	13	8	9	10
Esotropia	2	2	7	1	3
Superior oblique muscle palsy	0	0	2	1	0
Congenital nystagmus	1	2	0	0	1
Unclassified strabismus	0	0	0	0	0
Amblyopia	12 (0.18%)	9 (0.13%)	11 (0.16%)	9 (0.14%)	12 (0.18%)
Unclassified amblyopia	0	2	5	2	0
Anisometropic amblyopia	7	5	3	4	11
Ametropic amblyopia	5	2	3	3	1
Refractive errors	112 (1.68%)	118 (1.75%)	88 (1.32%)	103 (1.58%)	70 (1.06%)
Myopia/myopic astigmatism	53	56	51	44	31
Hyperopia/hyperopic astigmatism	40	52	25	46	27
Mixed astigmatism	19	10	12	13	12
Others	10 (0.15%)	11 (0.16%)	8 (0.12%)	10 (0.15%)	8 (0.12%)
Entropion	4	6	4	4	3
Blepharoptosis	1	1	0	0	0
(Allergic) Conjunctivitis	3	1	2	0	3
Conjunctival pigmentation	2	2	2	1	2
Corneal opacity	0	1	0	0	0
Nevus Ota	0	0	0	1	0
Marcus-Gunn syndrome	0	0	0	1	0
Congenital cataract	0	0	0	2	0
Optic disc atrophy	0	0	0	1	0
No abnormality	59 (0.89%)	73 (1.08%)	67 (1.00%)	64 (0.98%)	64 (0.97%)

Table 3 The reasons for referral to ophthalmologists and the final diagnoses at 1.5 years old in Okayama City, Japan

The reasons for referral	Suspected visual disturbance					Suspected strabismus					Suspected other diseases				
Years	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Number of children with the final diagnoses															
Exophoria	0	0	0	0	0	1	1	2	1	3	0	0	0	0	0
Strabismus															
Exotropia	0	0	0	0	0	3	1	1	0	0	0	1	0	0	0
Intermittent exotropia	0	0	0	0	0	2	2	1	0	1	0	0	0	0	0
Esotropia	0	0	0	0	0	1	1	1	2	0	0	0	0	0	0
Superior oblique muscle palsy	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Congenital nystagmus	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
Unclassified strabismus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Refractive errors															
Myopia/myopic astigmatism	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hyperopia/hyperopic astigmatism	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Others															
Entropion	0	0	0	0	0	0	0	0	0	2	1	0	3	0	0
Blepharoptosis	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0
(Allergic) Conjunctivitis	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Conjunctival pigmentation	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Iris atrophy	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
No abnormality	1	1	0	2	3	11	10	7	7	7	0	1	0	0	3

Table 4 The reasons for referral to ophthalmologists and the final diagnoses at 3 years old in Okayama City, Japan

The reasons for referral	Suspected visual disturbance					Suspected strabismus					Suspected other diseases				
Years	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Number of children with the final diagnoses															
Exophoria	3	3	2	5	6	3	5	7	2	4	0	0	0	0	0
Strabismus															
Exotropia	1	0	0	2	0	3	6	4	1	3	0	0	0	0	0
Intermittent exotropia	1	0	1	2	1	5	13	7	7	9	0	0	0	0	0
Esotropia	0	0	1	1	1	2	2	6	0	2	0	0	0	0	0
Superior oblique muscle palsy	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0
Congenital nystagmus	1	0	0	0	0	0	2	0	0	1	0	0	0	0	0
Unclassified strabismus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amblyopia															
Unclassified amblyopia	0	2	5	2	0	0	0	0	0	0	0	0	0	0	0
Anisometropic amblyopia	7	5	3	4	10	0	0	0	0	1	0	0	0	0	0
Ametropic amblyopia	5	2	3	3	1	0	0	0	0	0	0	0	0	0	0
Refractive errors															
Myopia/myopic astigmatism	49	51	50	39	28	4	2	1	3	3	0	3	0	2	0
Hyperopia/hyperopic astigmatism	36	46	25	43	24	4	5	0	2	2	0	1	0	1	1
Mixed astigmatism	18	10	11	12	12	1	0	1	0	0	0	0	0	1	0
Others															
Entropion	4	3	4	4	2	0	0	0	0	0	0	3	0	0	1
Blepharoptosis	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
(Allergic) Conjunctivitis	1	1	2	0	1	0	0	0	0	0	2	0	0	0	2
Conjunctival pigmentation	0	0	0	0	0	0	0	0	0	0	2	2	2	1	2
Corneal opacity	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Nevus Ota	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Marcus-Gunn syndrome	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Congenital cataract	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Optic disc atrophy	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
No abnormality	48	56	45	53	49	10	15	21	11	12	1	2	1	0	3

old. That the rates of amblyopia at 1.5 years old were zero is understandable since visual acuity testing was not carried out at this age in the program.

The large ranges of variation of the prevalence rates could be attributed to several limitations in this study from the perspective of epidemiological methods. A first limitation is that this study involved children in Okayama City with a population of approximately 700 thousand, and that therefore the cohort of children is possibly too small to obtain the prevalence of rare diseases such as strabismus and amblyopia. As such, a survey covering children in Okayama Prefecture with a population of approximately 2 million or a nation wide survey is necessary to obtain a cohort large enough to reveal accurate prevalence rates of strabismus and amblyopia. A second limitation is that this study covered only approximately 85% of children at 1.5 years old and about 80 % of children at 3 years old in each year in Okayama City. Such levels of the recruitment might cause a bias and underestimate the prevalence rates of strabismus and amblyopia.

The prevalence of strabismus, including congenital nystagmus and superior oblique muscle palsy, was found to be higher at 3 than at 1.5 years old. This increase in the incidence of strabismus according to age is attributed primarily to the increase in exotropia and intermittent exotropia. In contrast, the prevalence of esotropia was found to be stable, although slightly increased, between 1.5-year-old children and 3-year-old children.

In our previous study [1], we revealed that the prevalence of strabismus and amblyopia in 6–12-year-old children enrolled in elementary schools in Okayama Prefecture, Japan, was 1.28% and 0.14%. The prevalence of strabismus, both esotropia and exotropia including intermittent exotropia, increased according to age from 3 years old to 6–12 years old, indicating that esotropia and exotropia develop newly after 3 years old. In contrast, it should be noted that the prevalence of amblyopia is the same between children at 3 years old and those at 6–12 years old. Since amblyopia is caused by any form of visual deprivation during the critical period of visual cortex development until 3 years of age, the prevalence of amblyopia at age 3 and the prevalence of amblyopia, including its past history, at 6–12 years should be theoretically the same.

From another perspective, the same prevalence rates of amblyopia between children at 3 years old and elementary school children at 6–12 years old suggests that this preschool vision screening program functions well for detecting amblyopia. In Okayama City, nurses, pediatricians, and clinical medical officers play a major role in the checkups including eye examinations, and orthoptists are not involved in this screening process. Questionnaires, uncorrected visual acuity testing, and inspection are the main means of screening, while orthoptic tests such as refraction and stereoacuity testing are not done at all.

Until now, orthoptist involvement in preschool vision screening programs has commonly been advocated [6, 7, 11]. In addition, caution is required in evaluating the benefits of introducing a new technology such as photorefraction [23–27]. Cost-effectiveness analysis has also been proposed for preschool vision screening programs [19]. As far as amblyopia is concerned, the present preschool vision screening at 3 years old in Okayama City is doing well as part of general checkups with trained nurses, clinical medical officers, and pediatricians, even without the help of orthoptists or new technology.

As a matter of course, the 1.5-year-old and 3-year-old children examinations must continue to be reevaluated from the perspective of the specificity and the sensitivity of the detection of strabismus and amblyopia. The orthoptists' involvement or new technology such as photorefraction should be tested to develop a better system for detecting strabismus and amblyopia. Furthermore, the introduction of refraction testing would be meaningful from the perspective of evaluating risk factors for strabismus and amblyopia such as ametropia and anisometropia. The follow-up of children with strabismus and amblyopia who were detected in the vision-screening program is also important to assessing the quality of the program. Under these circumstances, early treatment of strabismus and amblyopia, following early detection, would show to what extent these children merit from the preschool vision-screening program as an intervention of preventive medicine.

The present study and our previous results [1] demonstrate that the prevalence of strabismus differs largely according to age, even in the same population. The prevalence of strabismus in different age

groups in recent years provides basic information in terms of understanding the genetic background for strabismus in the Japanese population [28–30]. In addition, the prevalence is a key to estimating the power of statistics for genetic analysis of strabismus such as sib-pair analysis and multiple pedigree analysis [31].

In conclusion, this study has revealed the prevalence of strabismus and amblyopia in Japanese children at 1.5 and 3 years old. The prevalence of strabismus was found to increase with age, primarily as a result of the increase in exotropia and intermittent exotropia. The prevalence of amblyopia in children at 3 years old in this study was the same as that determined in elementary school children at 6–12 years old in our previous study, suggesting that the preschool vision screening program functions well in terms of detecting amblyopia. In future, follow-up studies of these children with strabismus and amblyopia detected in the preschool vision-screening program will be necessary to reveal how they benefit from the early detection in terms of visual acuity and binocular function.

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