Economic Evaluation of Orthoptic Screening: Results of a Field Study in 121 German Kindergartens

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PURPOSE. The purpose of this study was to analyze the cost-effectiveness of an orthoptic screening program in kindergarten children.

METHODS. An empiric cost-effectiveness analysis was conducted as part of a field study of orthoptic screening. Three-year-old children (n = 1180) in 121 German kindergartens were screened by orthoptists. The number of newly diagnosed cases of amblyopia and amblyogenic factors (target conditions) was used as the measure of effectiveness. The direct costs of orthoptic screening were calculated from a third-party-payer perspective based on comprehensive measurement of working hours and material costs.

RESULTS. The average cost of a single orthoptic screening examination was 12.58 Euro. This amount consisted of labor costs (10.99 Euro) and costs of materials and traveling (1.60 Euro). With 9.9 children screened on average per kindergarten, average labor time was 279 minutes per kindergarten, or 28 minutes per child. It consisted of time for organization (46%), traveling (16%), preparing the examination site (10%), and the orthoptic examination itself (28%). The total cost of the screening program in all 121 kindergartens (including ophthalmic examination, if required) was 21,253 Euro. Twenty-three new cases of the target conditions were detected. The cost-effectiveness ratio was 924 Euro per detected case. Sensitivity analysis showed that the prevalence and the specificity of orthoptic screening had substantial influence on the cost-effectiveness ratio.

CONCLUSIONS. The data on the cost-effectiveness of orthoptic screening in kindergarten may be used by such third-party payers as health insurance or public health services when deciding about organizing and financing preschool vision-screening programs. (Invest Ophthalmol Vis Sci. 2002;43:3209–3215)

The main purpose of preschool vision screening is the prevention of amblyopia. Although repeated cross-sectional studies, in particular from Scandinavian countries, suggest that preschool vision screening may reduce the prevalence of amblyopia, there has been a debate on the appropriateness of preschool vision-screening programs. In particular, there has been concern about the lack of scientific data on the effectiveness of such programs, and, consequently, rigorous evaluation has been called for.

Because resources for health care are limited, there is a growing interest among decision makers in the cost-effectiveness of health care interventions. For a service to be covered by social health insurance or public health service programs it may become a prerequisite that its cost-effectiveness be demonstrated. Yet, little is known about the cost-effectiveness of preschool vision-screening programs. To our knowledge, no empiric economic evaluations have been conducted to date.

Clinical experience holds that treatment of amblyopia and amblyogenic factors, such as strabismus and certain refractive errors, is most effective when started as early as possible during the sensitive period of visual maturation. However, because such visual deficits mostly occur in children with healthy-looking eyes, detection requires examination methods for which the patient’s cooperation is needed. In most children, sufficient cooperation for reliable assessment of monocular visual acuity can be expected from age 3 onward. Therefore, the fourth year of life is considered best for vision screening.

In Germany, there is no nationwide specific preschool vision-screening program. Few local public health authorities conduct vision assessment, mainly in school children and of their own accord. Vision assessment is performed by general practitioners (GPs) and pediatricians as part of general preventive care examinations. However, the effectiveness of this assessment in detecting amblyopia and amblyogenic factors is considered to be poor, because GPs and pediatricians lack the necessary experience for ophthalmic testing in this age group. Therefore, only a proportion of affected children have eye disorders detected and treated by age 3, especially those with obvious symptoms (e.g., obvious strabismus) or those who consulted an ophthalmologist for other reasons (e.g., for a “red eye”).

Preschool vision screening conducted by orthoptists has been discussed as an option to improve the prevention of amblyopia. Because of easy access to children, it has been proposed that orthoptic screening be conducted in kindergarten. Screening in kindergarten avoids fundamental changes in the health care system that are often difficult to bring about. A dental screening and awareness program conducted in children 6 years of age in German kindergartens has been in place for years and could be used as a model for preschool vision screening.

The cost-effectiveness of screening programs strongly depends on the prevalence of the target conditions, which again depends on exactly how they are defined. To date, there is no consensus on how the most frequent visual developmental deficits due to strabismus and refractive errors should be treated, and at what age, to prevent irreversible damage effectively and efficiently, and to avoid an impairment of health-related quality of life. In a recent review, the prevalence of amblyopia and amblyogenic factors (estimated from the yield of screening programs) was found to range between 2.7% and
Therefore, cost-effectiveness data should be available that take into account varying levels of prevalence.

The purpose of this study was to analyze empirically the cost-effectiveness of an orthoptic preschool vision-screening program performed on 3-year-old children in German kindergartens to detect untreated cases of amblyopia or amblyogenic factors that, without early treatment, are likely to cause a lasting visual deficit. For comparison, the current situation without an orthoptic preschool vision-screening program was used. Because the prevalence of untreated target conditions may differ in other populations, the impact of changes in the prevalence on the cost-effectiveness was analyzed in detail.

**METHODS**

An empiric cost-effectiveness analysis was conducted as part of a field study of orthoptic screening.

**Study Population**

One hundred twenty-one (121) kindergartens in two counties of Southern Germany participated in the field study. All 3-year-old children attending these kindergartens were eligible for the study. Parents were asked for informed consent in writing. To our best knowledge, only one parent whose child was already in treatment for strabismus refused participation. On the scheduled day of the orthoptic screening examination, 1180 children were present in kindergarten and were enrolled in the study.

**Target Conditions**

Target conditions were defined as any untreated visual deficits with a corrected monocular visual acuity of less than 0.5 (10/20) in either eye, or with a corrected monocular visual acuity of less than 0.8 (10/12.5) in both eyes and a logarithmic line difference between eyes of more than two lines on ophthalmologic examination. The number of newly detected cases of target conditions was used as the measure of effectiveness. Cases of visual deficits that had already been treated were not considered when measuring effects.

**Components of the Evaluated Screening Program**

Because the field study was also designed to evaluate the accuracy of screening, more examinations were conducted than would be components of a screening program. This was taken into account in the cost-effectiveness analysis, which was restricted to the costs and effects generated by the screening program.

A flowchart of the screening program of which the cost-effectiveness was evaluated is shown in Figure 1. All 3-year-old children were to be examined once by an orthoptist in kindergarten. The orthoptic screening examination consisted of cover tests, examination of eye motility and head posture, and uncorrected monocular visual acuity testing with Lea symbols (Precision Vision, Villa Park, IL). The Lea single optotype test was used at 10 ft (3 m) to test visual acuity, because it combined high testability, reduced test time, and showed similar sensitivity for amblyopia as did line tests. The uncorrected visual acuity threshold to pass the examination was set at 0.8 (10/12.5) monocular visual acuity in both eyes, or at least 0.5 (10/20) in both eyes and less than two lines’ difference between visual acuity of the right and left eyes (L. Hyvärinen; Lea-Test Ltd., Helsinki, Finland, personal communication, 1998). Children with a positive screening result would be referred to an ophthalmologist for diagnosis, those with a negative screening result would be rated healthy and those with an inconclusive screening result would be rescreened in kindergarten at a later time when cooperation would be likely to have improved. If the rescreening result was positive, inconclusive, or missing (no participation), children would also be referred to an ophthalmologist for diagnosis.

In the field study, all children underwent an orthoptic screening examination while in kindergarten between July and December 1999 (phase I). All children were reexamined in their kindergartens by a different orthoptist between January and March 2000 (phase II). For the cost-effectiveness analysis, empiric cost and effect data for all children from phase I of the field study, and, for those children with an
inconclusive result, respective data from phase II were used. In addi-
tion, data were used from the ophthalmologic examinations of those
children who were referred because of positive, inconclusive, or miss-
ing screening results, as required by the screening program.

Measurement of Costs

Direct costs of the screening program were measured from the per-
spective of a third-party payer such as the German social health insur-
ance or public health service that may finance such a program. This
means that only those costs were included that would be incurred by
a third-party payer, assuming no copayment for medical services by
the participants. Nonmedical cost incurred by the parents (e.g., for travel
to the ophthalmologist) were not considered.

Labor and material costs of orthoptic screening examinations as
well as costs of diagnostic ophthalmologic examinations were consid-
ered and calculated in Euro at prices current in 2000. In that year, the
average Euro-to-U.S. dollar (U.S.$) exchange rate was 0.92 U.S.$ per 1
Euro, and the average purchasing power adjusted conversion rate was
0.99 U.S.$ per 1 Euro (i.e., close to parity).24

Labor Costs. Working time of orthoptists and administrative
personnel was measured comprehensively in phase I and phase II of
the field study. Working time was divided into office time for organi-
sing the screening program and time for visiting the kindergartens. The
latter was subdivided into travel time, time for preparing the exami-
nation site in kindergarten and examination time. Time measurement
was conducted by self-administered working-time registration forms.
Orthoptists were asked to fill in the respective form for each visit to a
kindergarten. Personnel in charge of organizing the screening program
were asked to complete the respective forms once a day.

To obtain labor costs, working time was valued at 25.31 Euro per
hour (0.39 Euro per minute), which corresponds to the tariff class Vb
of the German Federal Employee Tariff (Bundesangestelltentarif; BAT),
which applies to salaried orthoptists working in the public health
sector and includes all ancillary wage costs.

Material and Travel Costs. Material costs comprised costs of
orthoptic material, phone, stamps, parent information leaflets and
consent forms. Travel costs were valued at 0.27 Euro per kilometer in
accordance with German tax regulations.

Costs of Ophthalmologic Examination. Costs of a stan-
dard ophthalmologic examination of children referred from preschool
vision screening were calculated at 36-40 Euro, based on the German
social health insurance’s relative value scale for outpatient physician
services (Einheitlicher Bewertungsmasstab für Ärzte; EBM25), which
defines individual physician services and states point volumes for
them. An average conversion factor (point value) of 0.041 Euro was
used. For those covered by the social health insurance (approximately
90% of the German population), there is no copayment for physician
services. Analogous calculation of costs based on the uniform fee
schedule of German private health insurance26 (which is much more
detailed) resulted in 40.03 Euro. This value is close and well within the
range of costs used in sensitivity analyses.

Sensitivity Analysis

To analyze the stability of results, the influence of 11 parameters on the
cost-effectiveness ratio (CER) was evaluated in various sensitivity anal-
yses.

Univariate Sensitivity Analysis. To evaluate the effect of
variations in costs of the single orthoptic examination and of the single
ophthalmologic examination, univariate sensitivity analyses were per-
formed by varying these costs upward and downward by 25% each
when calculating the costs of the screening program.

Multivariate Sensitivity Analysis Based on a Decision
Analysis Model. To evaluate the influence of other parameters, a
decision analysis model of the screening program was developed. The
model is based on a spreadsheet (Excel; Microsoft, Redmond, WA),
which is provided as freeware by the authors.27 It allows calculation of
the CER from model parameters for which the values may be varied.

The results calculated by the decision analysis model are shown in
gray cells.

Figure 2. Form for input and output of data for decision analysis
model developed in a spreadsheet computer program. Data for model
parameters are inserted in the cells. The results calculated by the deci-
sion analysis model are shown in gray cells.
calculated to range between 81.4% and 90.8% and specificity between 96.9% and 98.7%. In a review from 1995, for various screening programs of 4-year-old children in Sweden, sensitivity was calculated to range between 86.7% and 95.5% and specificity between 97.1% and 99.6%. Although screening performed by orthoptists may tend to be more accurate than that performed by nurses, orthoptic screening in children 3 years of age may be less accurate, especially less specific, than screening performed by nurses in children 4 years of age. To fully take into account this uncertainty, parameter values for sensitivity and specificity were varied widely in the sensitivity analysis, namely from 80.0% to 100.0% each.

Analysis 2. Worst-case and best-case scenarios were analyzed by using least-favorable and most-favorable values for all 11 parameters in the decision analysis model, as shown in Table 1. For this purpose, values of parameters measured empirically in the study were varied according to their 95% confidence intervals (except for cost data, for which the values obtained in the field study were increased and decreased by 25% each).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analysis 1 (Influence of Prevalence, Sensitivity, and Specificity)</th>
<th>Analysis 2 (Best-Case and Worst-Case Scenarios)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of target conditions (%)</td>
<td>1.0–5.0</td>
<td>Worst Case: 1.0</td>
</tr>
<tr>
<td>Sensitivity of orthoptic examination (%)</td>
<td>80.0–100.0</td>
<td>Best Case: 5.0</td>
</tr>
<tr>
<td>Specificity of orthoptic examination (%)</td>
<td>80.0–100.0</td>
<td></td>
</tr>
<tr>
<td>Inconclusive screening results (%)*</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>Inconclusive rescreening results (%)*</td>
<td>16.3</td>
<td></td>
</tr>
<tr>
<td>Participation rescreening (%)*</td>
<td>78.2</td>
<td></td>
</tr>
<tr>
<td>Compliance visit to ophthalmologist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After positive screening (%)*</td>
<td>97.2</td>
<td></td>
</tr>
<tr>
<td>After lacking rescreening (%)*</td>
<td>79.3</td>
<td></td>
</tr>
<tr>
<td>After inconclusive rescreening (%)*</td>
<td>64.7</td>
<td></td>
</tr>
<tr>
<td>Costs per screening examination (Euro)*</td>
<td>12.58</td>
<td></td>
</tr>
<tr>
<td>Costs per ophthalmologic examination (Euro)*</td>
<td>36.40</td>
<td></td>
</tr>
</tbody>
</table>

* For these parameters, values measured empirically in field study were used in analysis 1. In analysis 2, values for these parameters reflect the limits of their 95% confidence intervals (except for cost data, for which the values obtained in the field study were increased and decreased by 25% each).

**Ethics**

The institutional review board approved the study design, which adhered to the tenets of the Declaration of Helsinki.

**RESULTS**

**Costs of Orthoptic Screening Examination**

In phase I, working-time observation forms were filled in completely by orthoptists at 109 (90.1%) of 121 visits to kindergartens. In these 109 kindergartens, the average number of examined children was 9.88. The mean total working time per kindergarten was 279 minutes or 28.3 minutes per examined child (Table 2). Almost half of the total working time (46%) was used for organization. For the orthoptic examination itself, only 28% of the total working time was used, which corresponded to 8.0 minutes per child.

In phase II, the total working time per kindergarten was 187 minutes or 21.6 minutes per examined child and hence almost one quarter less than in phase I. This was mainly because organization time was reduced to 69 minutes per kindergarten (the same children were reexamined and organization was more efficient because of increased experience).

<table>
<thead>
<tr>
<th>Resource</th>
<th>Quantity per Kindergarten (min)</th>
<th>Valuation per Unit (Euro)</th>
<th>Costs per Kindergarten (Euro)</th>
<th>Costs per Child* (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examination</td>
<td>78.97 min</td>
<td>0.39</td>
<td>30.69</td>
<td>3.11</td>
</tr>
<tr>
<td>Preparation of examination room</td>
<td>27.98 min</td>
<td>0.39</td>
<td>10.87</td>
<td>1.10</td>
</tr>
<tr>
<td>Travel</td>
<td>45.16 min</td>
<td>0.39</td>
<td>17.55</td>
<td>1.78</td>
</tr>
<tr>
<td>Organization</td>
<td>127.23 min</td>
<td>0.39</td>
<td>49.44</td>
<td>5.00</td>
</tr>
<tr>
<td>Sum of labor time</td>
<td>279.34 min</td>
<td>0.39</td>
<td>108.55</td>
<td>10.99</td>
</tr>
<tr>
<td>Materials and travel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>Lump sum</td>
<td></td>
<td>10.47</td>
<td>1.06</td>
</tr>
<tr>
<td>Travel</td>
<td>20 km</td>
<td>0.27</td>
<td>5.32</td>
<td>0.54</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>124.33</td>
<td>12.58</td>
</tr>
</tbody>
</table>

* Average number of children screened per kindergarten: 9.88.
Table 3. Cost-Effectiveness of the Orthoptic Screening Program and Its Variation

<table>
<thead>
<tr>
<th></th>
<th>Baseline Program</th>
<th>Variation of Program*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs of all orthoptic screening examinations (Euro)</td>
<td>16,156</td>
<td>15,775</td>
</tr>
<tr>
<td>Costs of all ophthalmologic examinations (Euro)</td>
<td>5,097</td>
<td>3,822</td>
</tr>
<tr>
<td>Total costs (Euro)</td>
<td>21,253</td>
<td>19,595</td>
</tr>
<tr>
<td>Detected cases (x)</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Costs per detected case (Euro)</td>
<td>924</td>
<td>933</td>
</tr>
<tr>
<td>Incremental cost-effectiveness ratio of baseline program vs. variation of program (Euro)†</td>
<td>829</td>
<td></td>
</tr>
</tbody>
</table>

* Variation of orthoptic screening program in which only those 1067 children were screened whose parents indicated no current ophthalmologic treatment of the child on the consent form.
† Additional total costs per additional case detected when baseline program is compared with variation of program: (21,253 Euro − 19,595 Euro)/(23 − 21)

For a conservative estimate, the cost calculations for the screening program were based on working time measurement from phase I only. However, the reduced working time in phase II was taken into account by the sensitivity analysis, in which the costs of the orthoptic screening examination were varied downward by 25%.

Orthoptists traveled an average of 20 km per kindergarten (round trip). The sum of travel and material costs averaged 15.78 Euro per kindergarten or 1.60 Euro per examined child. The average total costs of orthoptic screening examinations were 124.33 Euro per kindergarten or 12.58 Euro per examination.

Cost-Effectiveness of the Screening Program

Figure 1 shows the number of children who passed through the different steps of the screening program. It also shows the number of nonparticipating and noncompliant children.

A total of 1180 children were screened, of whom 135 (11.3%) had inconclusive results due to insufficient cooperation. Insufficiently cooperative children were significantly younger than cooperative children (mean age, 40.9 vs. 42.9 months, P < 0.0001, t-test), with 64.7% being younger than 42 months (3.5 years). Of the 135 children with inconclusive screening results, 104 participated in rescreening. Therefore, a total of 1284 (1180 + 104) orthoptic examinations were performed at a total cost of 16,156 Euro (1284 × 12.58 Euro). In addition, 140 ophthalmologic examinations were performed in those children with positive, inconclusive, or missing screening results at a total cost of 5097 Euro (140 × 36.40 Euro). The total cost of the screening program was 21,253 Euro (Table 3).

Twenty-three cases of untreated target conditions were detected by this screening program. These comprised 3 children with a unilateral small-angle strabismus, and 20 children with anisometropia and high refractive errors. The cost per detected case (CER) was 924 Euro (21,253 Euro/23).

In 12 of the 1180 children, no conclusive result could be obtained in the screening program, because they did not comply with the referral to an ophthalmologist after positive or inconclusive screening.

The cost of the screening program per child for whom a result could be obtained was 18.20 Euro (21,253 Euro/1,108).

Sensitivity Analysis

Influence of Examination Costs. If, in univariate analysis, the costs per single orthoptic examination were increased (or decreased) by 25% to 15.73 Euro (or 9.44 Euro), the CER would increase (or decrease) by 19% to 1100 Euro (or 749 Euro) per detected case. If the costs per single ophthalmologic examination were increased (or decreased) by 25% to 45.50 Euro (or 27.30 Euro), the CER would increase (or decrease) by 6% to 979 Euro (or 869 Euro) per detected case.

Influence of Prevalence, Sensitivity, and Specificity. The CER of 924 Euro per detected case found empirically in the study may result from various combinations of prevalence, sensitivity, and specificity. Figure 3 shows the influence of the prevalence of target conditions for various combinations of sensitivity and specificity of orthoptic examination found by multivariate analysis. It can be seen that prevalence has a strong influence on the CER. For example, if specificity and sensitivity were both set at 80%, the CER ranged from 581 Euro (5.0% prevalence) to 2801 Euro (1.0% prevalence) per detected case. Furthermore, it shows that specificity has a stronger impact on the CER than sensitivity. For example, at a prevalence of 2.0%, the CER would be 800 Euro per detected case if sensitivity and specificity were both 100%. If specificity decreased to 80% (with other parameter values staying constant), the CER would increase to 1146 Euro per detected case. If, instead, sensitivity decreased to 80%, the CER would increase less strongly to 984 Euro per detected case.

Worst-Case—Best-Case Scenarios. If for all parameters the least-favorable values were used in the decision analysis model as shown in Table 1, the CER was 3641 Euro per detected case. If, on the other hand, the most-favorable parameter values were used, the CER was 242 Euro per detected case. Most of
the prevalence of untreated target conditions among those children whose parents indicated current ophthalmologic treatment was almost equal to the prevalence among all other children. Two untreated children with a severe visual deficit had been examined by ophthalmologists before the screening, but the ophthalmologists’ recommendations for a follow-up had been neglected by the parents. Thus, the screening may serve to reinforce the need for intervention and increase compliance with follow-up protocols.

**Choice of End Point and Methodology**

As in many published economic evaluation studies of screening programs and diagnostic tests in other areas of medicine, in this cost-effectiveness analysis only the costs and effects were considered that occurred up to the clinical end point diagnosis. For a more comprehensive evaluation of orthoptic vision screening, further studies should analyze the costs and effectiveness of treatment and the disability caused by visual deficits. The definition of visual deficits could be linked to meaningful reductions of health-related quality of life for that purpose. The generic term amblyopia, which summarizes visual deficits of very distinct pathophysiologic origins, could be omitted in this perspective, as in this study. To make different studies comparable, dedicated software modules could be used to standardize results. The spreadsheet software developed for this study could be refined and used as a reference procedure for this purpose.

In this cost-effectiveness analysis, the alternative course of action with which orthoptic screening was compared was no orthoptic screening, which was associated with no costs and no effects until the chosen end point. In current practice, some of the cases detected by the screening program might have been detected by other means (and at other costs) at a later time had there been no orthoptic screening in kindergarten. To include this in an empiric study would require a far more extensive study design covering several years of individual follow-up. However, the chosen study design is very likely to yield a conservative estimate of the cost-effectiveness of orthoptic screening compared with study designs with a longer follow-up. Most other means of vision assessment tend to be less sensitive, less specific, and more costly than orthoptic screening, which would cause incremental CERs of orthoptic screening to be more favorable than the CER found in this study. In a recent evaluation of various methods of vision assessment performed by pediatricians in Germany, the most favorable values found for sensitivity, specificity, and the proportion of inconclusive results were 54%, 78%, and 3%, respectively. By feeding these parameter values into the decision-analytic model introduced earlier, the following can be shown: If all children in this study received pediatric vision assessment instead of orthoptic screening, the additional costs of orthoptic screening per additional case detected (incremental CER) compared with pediatric vision assessment would be less than the 924 Euro found in this study as soon as pediatric vision assessment cost more than only 4 Euro per child, assuming a prevalence of 2.5% as an example. This is mainly due to the low specificity of pediatric vision assessment causing many costly false-positive results. Thus, extending the empiric analysis to a time frame that includes a longer period of follow-up would be likely to yield an even more favorable incremental CER than found in this study.

In conclusion, this study provided data on the cost-effectiveness and its determinants of orthoptic vision screening in kindergarten. This information may be used by third-party payers such as health insurance or public health services when deciding about organizing and financing preschool vision-
screening programs. Although we did not analyze the cost-effectiveness of treatment in this study, decision makers should take into account that treatment after early detection through screening potentially avoids a visual deficit that may last for almost a lifetime.

**References**


**Economic Evaluation of Orthoptic Screening**