The Usefulness of the Denver Developmental Screening Test to Predict Kindergarten Problems in a General Community Population

DAVID CADMAN, MD, MSc, FRCP(C), LARRY W. CHAMBERS, PhD, STEPHEN D. WALTER, PhD, WILLIAM FELDMAN, MD, FRCP(C), KIM SMITH, BSc, AND RUTH FERGUSON, BScN

Abstract: The Denver Developmental Screening Test (DDST) was administered to 2,569 children five to seven months prior to starting kindergarten in September 1980 in a geographically well-defined community. The test was administered by trained public health nurses. At the end of the 1980–1981 school year, all 163 kindergarten teachers in the area completed a rating form for each child in their class. The rating form determined global ratings of: 1) learning abilities; 2) classroom behavior; 3) amount of special attention required; and 4) referrals to special education services outside the classroom. The specificity of the DDST in predicting kindergarten teacher ratings was 99 per cent for all areas. Test sensitivity varied from 5 per cent to 10 per cent in detecting problems in the four areas. The predictive values of an positive test varied from 31 per cent for behavior problems to 62 per cent for extra attention required in the classroom. Negative test predictive values varied from 79 per cent to 93 per cent. These results based on kindergarten teacher ratings suggest that, because of the low sensitivity and modest predictive value, the DDST may be relatively inefficient to use in a school entry screening program in a general community population of children. (*Am J Public Health* 1984; 74:1093–1097.)

Introduction

This paper reports the relation between the Denver Developmental Screening Test (DDST) results of 4- to 5-year old preschool children in a general community population and teacher reports of the performance of these children during kindergarten. This investigation was undertaken as one of a series of studies we are conducting to determine the effectiveness of community preschool screening programs to detect developmental disabilities.

The DDST, developed by Frankenburg and his colleagues,[1,2] has become the best known and most widely used developmental screening test.[3–5] The test items are arranged in categories of gross motor, language, fine motor—adaptive and personal—social development. Although conceptual and methodological criticisms of the DDST have been raised occasionally in the literature,[6,7] its ease of administration and feasibility to use in screening situations have led to widespread acceptance and use of this test in community screening programs.

One type of screening program in which the DDST has been employed frequently is the testing of children prior to school entry to detect those thought to be at risk of subsequent school problems.[8,9] In a 1980 survey, we found that 18 of the 43 local public health departments in Ontario—Canada's most populous province—screened 75 per cent or more of all children in their communities prior to school entry, and 20 of the remaining units used the screening test, but with less complete community coverage. Despite the popularity of the DDST, we are unaware of any previous investigation of the sensitivity, specificity, or predictive value of the test for community preschool screening.

Address reprint requests to Dr. David Cadman, McMaster University, Faculty of Health Sciences, Departments of Pediatrics and Clinical Epidemiology and Biostatistics, Box 2000, Station A, Hamilton, Ontario L8N 3Z5, Canada. Authors Chambers, Walter, and Smith are also with the Department of Clinical Epidemiology/Biostatistics; Feldman is with the University of Ottawa, Department of Pediatrics; Ferguson is with the Niagara Regional Health Unit, Ontario. This paper, submitted to the Journal September 12, 1983, was revised and accepted for publication February 1, 1984.
Editor's Note: See also related letters to the editor, pp 1171 this issue.

The essential properties of tests used for school entry developmental screening are: 1) high *sensitivity* (yielding a positive result in a high proportion of individuals who actually have subsequent school problems); 2) a high *specificity* (yielding a negative result in a high proportion of those who do not have subsequent school problems); and, most importantly, 3) a high *predictive value* resulting in a high proportion of children with and without subsequent school problems among those with positive and negative test results, respectively.

Methods

The study was conducted in a 750 square mile area in Southern Ontario bordering New York State. The area is served by four school districts administered by separate school boards and by one regional local public health department. The area has a population of 375,000 living in several urban and rural centers,[10] and is well served by health, social, and preschool developmental services.

During February to April 1980, 4,292 children were brought by their parents or guardian to a mandatory school registration interview held in the school which the child was due to attend in September 1980. Children known to have developmental retardation severe enough to preclude enrollment in either regular or special education streams were not brought to regular kindergarten registration in the area schools. Nineteen parents (<1 per cent) declined to have their children enrolled in the study. A total of 1,704 children (40 per cent) were randomly selected using sealed envelopes with computer generated random numbers, to be enrolled in other studies. These children did not receive the DDST and/or follow-up described below and are not reported upon in this paper. All remaining 2,569 children registering for kindergarten in the region in 1980 received the DDST and, when a positive test result was obtained, were followed by a public health nurse. Informed consent to participate in this study was obtained by a public health nurse at the school registration interview.

The DDST was administered and scored according to the Instruction Manual[11] by one of the 60 public health nurses. The nurses had an average of five years experience using the test and all had undergone annual training sessions.

The test was administered to each child individually in a quiet area of the school at the time of the Spring 1980 school registration interview. All 146 children who received an abnormal, questionable, or untestable result had a second DDST administered (as is recommended in the Test Manual) in their home by one of two nurses who conducted all home retests. Children who received an abnormal, questionable, or untestable result on both test occasions were classified as having a positive screening test result.

A simple random sample of 36 children was drawn from all who had an in-home test. These children were given a second in-home retest, on average, eight days later. Excellent in-home intratester agreement by public health nurses using the DDST was found (kappa = 0.72).[12]

When a child obtained a positive DDST result, the health department protocol recommended that: a public health nurse discuss the test results with the parent and recommend to the parent that the child be seen by the family physician; the DDST results and comments of the nurse be sent to the child's physician along with a request that the physician send his/her findings and recommendations to the Health Unit; the DDST results, nurse's comments, and physician's recommendations (if available) be sent to the school health nurse (a different individual than the nurse who administered the DDST); and the school nurse discuss this information with the child's teacher and/or school principal at the beginning of the 1980–1981 school year.

At the end of the 1980–1981 school year (an average of 14 months after DDST testing), all 163 kindergarten teachers in the region completed a rating form for each child in their class. The rating form determined teachers' global ratings of each child's academic and learning abilities, classroom behavior, and amount of special attention required in the classroom. Any referrals to special education services beyond those available from the classroom teacher were also documented.

Results

The age and sex distribution of the study children at the time of DDST administration is shown in Figure 1. The comparison of DDST results and teacher reported school performance is shown in Tables 1 and 2. A 100 per cent teacher response rate was obtained. There were 126 children (5 per cent) lost to follow-up because they had moved from the community. Of these children, 125 had negative screening test results, while only one had a positive DDST. Five teacher ratings forms were incomplete, hence the small differences in total number of children reported in Table 1. The prevalence of teacher-reported learning/academic problems was 17 per cent, and of behavior problems 11 per cent. Twenty-one per cent of children required extra teacher attention in the classroom, and 8 per cent of the children were referred to special education services within the school system.

The specificity of DDST results in identifying children felt by their teachers to have no kindergarten problems was uniformly high (99 per cent). Estimates of the predictive value of a normal DDST result range from 79 per cent to 93 per cent. The preschool DDST is extremely insensitive when compared to kindergarten teacher reports of problems in the target areas. Test sensitivity for academic and learning problems was found to be 6 per cent, for behavior problems 5 per cent, for special attention in the classroom 5 per cent. Sensitivity for referrals to special education services for more severe problems was 10 per cent. Estimates of the predictive value of a positive screening test range from 31 per cent to 62 per cent.

Discussion

Several events must take place after the administration of a preschool developmental screening test if a program is to be effective and efficient. Diagnostic evaluation must be undertaken, efficacious therapeutic and preventive interventions must be made available, and compliance by parents and professionals with these interventions must be promoted. Moreover, this chain of events must begin with a developmental screening test that has good measurement properties in the general population.

The determinants of predictive value are the sensitivity and the specificity of the developmental screening test and the prevalence of school problems in the community. A general expression of this relationship can be derived using Bayes' Theorem[13]:

$$\text{Positive Predictive Value} = \frac{(\text{Sensitivity})(\text{Prevalence})}{(\text{Sensitivity})(\text{Prevalence}) - (\text{1-Specificity})(\text{1-Prevalence})}$$

$$\text{Similarly, Negative Predictive Value} = \frac{\text{Specificity (1-Prevalence)}}{(\text{1-Sensitivity})(\text{Prevalence}) + \text{Specificity (1-Prevalence)}}$$

The predictive value of a positive test result will decline dramatically if the true prevalence of school problems in the community is lower than that found, for example, in a clinic-derived sample of children with a high prevalence of school problems.[14]

In community screening situations, small declines in test specificity produce huge declines in the predictive value of a positive test. Moreover, the sensitivity and specificity of a developmental screening test may also change as one moves from high prevalence situations (for example, in a clinic population) of possibly more severe developmental problems to the general population situation of lower prevalence and milder problems. It may therefore be inappropriate to extrapolate how well a screening test will perform in the latter situation.[15,16]

Camp, *et al,* have reported on the value of the preschool DDST in predicting subsequent school problems in a clinic-derived sample of 65 children and found the predictive values of positive and negative screening test results to be 73 per cent and 68 per cent, respectively.[17] In that study, however, 57 per cent of the children had school problems. As we have indicated, there are serious methodologic pitfalls in extrapolating this type of data about a developmental screening test to the general population of children in a community.

The study reported here is the first of which we are aware that investigates the sensitivity, specificity, and predictive value of the widely used DDST in a general population of preschool children. The study population is a representative and unbiased sample of all children registering for school and outcomes of almost all children are reported.

Two potential sources of bias in this study require comment. First, if children who had a positive DDST result received efficacious interventions in the few months be-

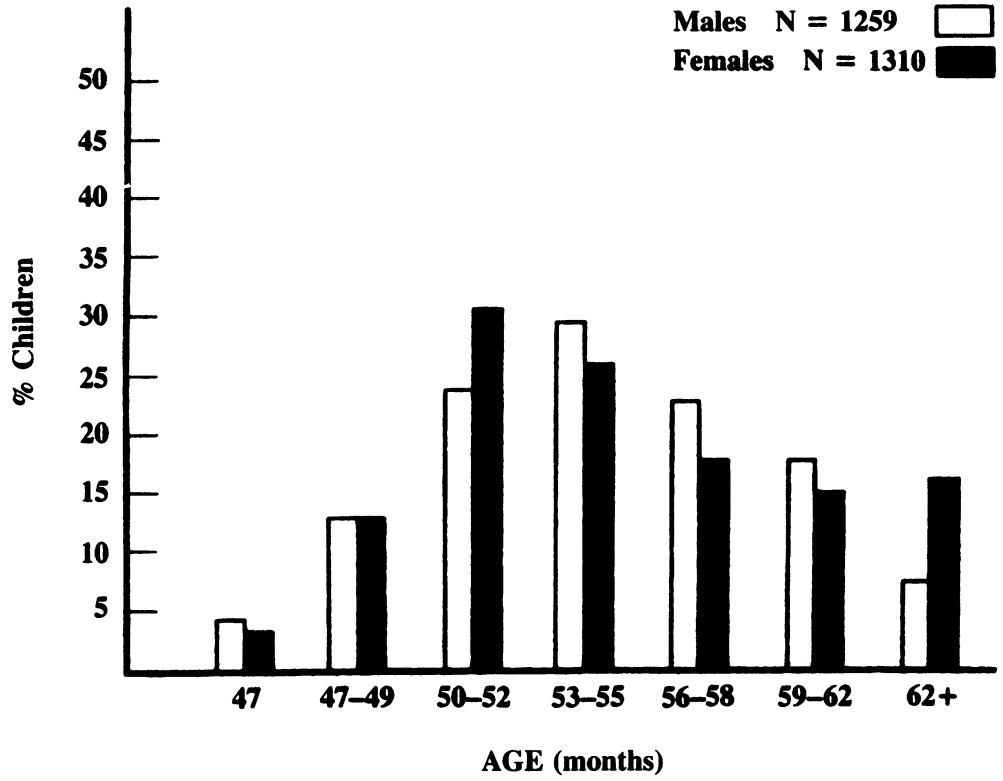

FIGURE 1—Age and Sex Distribution of the Study Group

tween the time of screening and starting school, the reported prevalence of problems, test sensitivity, and specificity as well as positive predictive values of the test would all be decreased. We think that this is an unlikely possibility. We are unaware of any such rapid interventions of proven efficacy for developmental problems of the sort detected at preschool screening. Second, kindergarten teachers who were informed of children having positive screening test at the beginning of the school year may have had an expectation bias. Children with positive test results could have been incorrectly labeled as "problem" children. This phenomenon would have falsely elevated test sensitivity, specificity, the prevalence of school problems, and the positive predictive value of the DDST. However, even if this bias were introduced, it would not account for the important test deficiencies (low sensitivity and positive predictive value) which we have found.

Kindergarten teacher's ratings of children's learning, behavior, and special needs are a very important measure of early school performance. We used this measure for several reasons. Firstly, such ratings have high credibility among educators in the Province of Ontario. Under provincial legislation, schools must undertake "early identification" of children at risk for school problems. In most instances, this task is completed by kindergarten teachers judgments.[18] As well, teachers' perceptions of their pupils may influence childrens' school adjustment, self-esteem, peer acceptance, and even academic achievement.[19,20] Barnes has recently reported that primary grade teacher ratings are as least as predictive of subsequent learning problems as a measure comprised of standardized cognitive tests.[21] Finally, the 100 per cent response rate to the rating form attests to its acceptance by teachers and feasibility of use in large community studies.

Other criteria of early school performance have been used. For example, Camp, *et al,* have reported the agreement between the preschool DDST results (abnormal, questionable, or normal) and the results of "IQ tests" (IQ < 80 or ≥ 80) during the child's early school years.[17] A moderate level of concordance was found (kappa = 0.57). However, as these authors point out, the DDST measures a broader range of function than intelligence tests. Thus, we judged teacher reports, which are also broader in scope than intelligence tests, to be a more appropriate assessment of kindergarten performance than IQ tests. However, because kindergarten is a time of considerable adjustment and maturation, this measure should not be viewed as a definitive assessment of primary grade school performance.

In this study, the DDST was administered by well-trained public health nurses. Most community screening programs, if they are to be feasible, must deploy this type of health professional rather than, for example, using pediatricians or psychologists to administer the test. Our results confirm reports[3] that trained public health nurses can reliably administer and score the DDST.

Effectiveness and cost-effectiveness of a preschool developmental screening program are ultimately the most important issues for communities already using, or considering implementing, such a program: First, does the program benefit those children to whom it is offered and are any harmful effects minimal? The screening test result can be wrong. As we have demonstrated, the risk of having a false

TABLE 1—Comparison of DDST Results and Teacher-Reported School Performance

	Teacher-Reported Learning Difficulties		
	Yes	No	Total
DDST Positive	23	19	42
Result Negative	381	2020	2401
TOTAL	404	2039	2443

	Teacher-Reported Special Attention for Learning/Behavior Problem		
	Yes	No	Total
DDST Positive	26	16	42
Result Negative	507	1889	2396
TOTAL	522	1905	2438

	Teacher-Reported Behavior Problems		
	Yes	No	Total
DDST Positive	13	29	42
Result Negative	260	2141	2401
TOTAL	273	2170	2443

	Teacher-Reported Referrals to Special Education		
	Yes	No	Total
DDST Positive	19	23	42
Result Negative	178	2220	2398
TOTAL	197	2243	2440

TABLE 2—Percentage of Sensitivity, Specificity, and Predictive Value of Preschool DDST Results

Type of Problem	Prevalence*	Sensitivity*	Specificity*	Positive Predictive Value*	Negative Predictive Value*
	%	%	%	%	%
Learning Difficulties	17 (16–17)	6 (4–8)	99 (99–99)	55 (39–70)	84 (83–86)
Behavior Problems	11 (11–12)	5 (3–8)	99 (98–99)	31 (18–47)	89 (89–90)
Special Attention in Classroom	21 (21–22)	5 (3–7)	99 (99–99)	62 (46–76)	79 (77–80)
Referral to Special Education Services	8 (8–9)	10 (6–14)	99 (99–99)	45 (30–61)	93 (92–94)

*95% Confidence Interval appears in parentheses.

positive test result becomes quite large when looking for relatively low prevalence problems in children who had been previously presumed to be developmentally normal. Incorrectly labeling children as suspected of having a problem may produce substantial social and emotional harm.[22]

Secondly, the community and its policy makers must judge if the magnitude of benefit achieved justifies the expenditure of limited community resources for this screening program. The authors of this paper are conducting a randomized controlled trial of a community preschool developmental screening program, and answers to these questions will begin to emerge by 1985.

The extremely low sensitivity and modest predictive values of the preschool DDST found in the current study lead us to conclude that this screening test is unlikely to initiate an effective or efficient school entry screening program in a community with a relatively low prevalence of school problems.

REFERENCES

1. Frankenburg WK, Dodds JB: The Denver Development Screening Test. J Pediatr 1967; 71:181.
2. Frankenburg WK, Goldstein AD, Camp BW: The revised Denver Development Screening Test: its accuracy as a screening instrument. J Pediatr 1971; 79:998.
3. Bryant GM, Davies KJ, Richards RM, *et al*: A preliminary study of the use of the Denver Developmental Screening Test in a health department. Dev Med Child Neurol 1973; 15:33.
4. Health and Welfare Canada: Periodic Health Examination Task Force Report. Hull, Quebec: Canadian Government Publishing Centre, 1980.
5. Frankenburg WK, Fandal A (eds): Proceedings of the Third International Conference on the Early Identification of At Risk Children. Denver: J.F.K. Child Development Center, 1981.
6. Thorpe HS, Werner EE: Developmental screening of preschool children: a critical review of inventories used in health and education programs. Pediatrics 1974; 53:362.
7. MacIntyre RK, Keeton A, Agard R: Identification of Learning Disabilities in Ontario. Toronto, Ontario: Ontario Ministry of Education, Ontario Institute for Studies in Education Publications, 1980.
8. Law G, Howell JM: Planning a multiphasic screening program for preschoolers. Can J Public Health 1969; 60:423.
9. Thores A, Philon J: A preschool screening on Vancouver Island: a two-year follow-up. Can J Public Health 1974; 65:385.
10. 1981 Census of Canada, Ottawa, Ontario: Statistics Canada Publication Sales, Statistics Canada, 1982.
11. Frankenburg WK, Dodds JB, Fandal AW: Denver Developmental Screening Test Reference Manual (Rev. Ed.). Denver: Ladoca Publishing Foundation, 1975.
12. Cohen J: A coefficient of agreement for nominal scales. Educ Psychol Meas 1960; 20:37.
13. Fletcher RH, Fletcher S, Wagner EH: Clinical Epidemiology—the Essentials. Baltimore: Williams and Wilkins, 1982.
14. Clinical epidemiology rounds: how to read clinical journals: II to learn about a diagnostic test. Can Med Assoc J 1981; 124:703.
15. Feinstein A, Kramer M: Clinical biostatistics: the architecture of observer/method variability and other types of process research. Clin Pharmacol Therap 1980; 28:551.

16. Goddard MJ: On allowing for diagnostic imperfections in assessing effectiveness of treatment for schistosomiasis. Int J Epidmiol 1977; 6:381.
17. Camp BW, Van Doornick WJ, Frankenburg WK: Pre-school developmental testing in prediction of school problems. Clin Pediatr 1977; 16:257.
18. Government of the Province of Ontario, Bill 82, 1981.
19. Rosenthal R, Jacobsen L: Pygmalion in the Classroom: Teachers Expectation and Pupil's Intellectual Development. New York: Holt, Rhinehart and Winston, 1968.
20. Sutherland J, Algozzine B: The learning disabled label as a biasing factor in the visual motor performance of normal children. J Learn Disabil 1979; 12:17.
21. Barnes KE: The Janksy Screening Index: A Seven Year Predictive Evaluation and Comparative Study (abstract). Fourth International Conference: Early Identification of the At-Risk Child, Rocky Mountain Child Development Center Publication, 1983.
22. Bergman R, Stamm D: The morbidity of cardiac non-disease in school children. N Engl J Med 1967; 276:1008.

ACKNOWLEDGMENTS

This research was supported by the Ontario Ministry of Education Contract MA-5512-01-356. Drs. Cadman and Chambers are supported by Health Scientist Awards of the Ontario Ministry of Health; Dr. Walter is supported by a National Health Scientist Award from Health and Welfare Canada. We wish to thank the following: Mrs. J. Browning for assistance in developing the teacher assessment forms; the Niagara Region School Health Coordinating Committee; the staffs on the Lincoln County Board of Education, the Lincoln County Separate Schools, the Niagara South Board of Education, the Welland County Roman Catholic School Board, and the Niagara Regional Health Unit. Assistance in data coding was provided by Ms. M. L. Shmuck and typing by Ms. L. Holmes.

National Conference on Research and Medical Education in Alcohol and Drug Abuse

November 8 and 9, 1984 the Association for Medical Education and Research in Substance Abuse will hold its Eighth Annual Conference on Research and Medical Education in Alcohol and Drug Abuse at the Dupont Plaza Hotel, Washington, DC. It will be targeted to professional educators in medicine, nursing, social work and other health fields. For more information, contact AMERSA President, David C. Lewis, MD or Conference Coordinator, Carol N. Williams, PhD, at Brown University Center for Alcohol Studies, Box G, Providence, RI 02912. Phone: (401) 863-1102.