Technical Reports

Cost Analysis of Wisconsin's Program of Multiphasic Health Screening

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MULTIPHASIC HEALTH screening, as one component of the nation's total system of medical care delivery, has undergone a period of unprecedented growth in the past decade. The key element in this growth has been the introduction of multi-element chemical testing (*1*), which in turn has sired programs providing large-scale screening at a minimum cost per person. The concepts of such multiple test chemical screening have been extensively discussed in a monograph edited by Benson and Strandjord (*2*) which defined some of the basic types of tests and problems associated with multiphasic health screening. Among the various prepaid medical care plans in the United States, the Kaiser-Permanente program (*3*) is the best known example of routine use of multiphasic health screening as a part of health maintenance. Recently, a detailed cost analysis in the Kaiser program (*4,5*) strongly emphasized the value of health screening in a profit-oriented prepaid medical care plan.

Mackintosh has provided a cost analysis (*6*) for the Automated Multiphasic Health Testing Facility of the Tulane Project (New Orleans, La.). A more general article (*7*) by Gelman has defined some of the "cost benefit" concepts we used in the current study, while an earlier paper by Yedidia and associates (*8*) related costs and population mobility in health screening facilities. Arguments for and against multiphasic screening from the aspect of costs and benefits have been crystalized in two published and widely circulated papers, one by Garfield (*9*) and the other by Ahlvin (*10*). These authors consider the basic argument about multi-element testing—that, while the costs per test are extremely low, these costs are associated with low yields and that the overall program costs are high.

The most detailed survey to date (*11*) has placed the number of chemical tests performed in the United States for screening purposes, exclusive of tests done for outpatients or patients being admitted to hospitals, at more than 6 million annually. Likewise,

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for 1970, the same monograph lists more than 88 district programs that fall in the health screening category.

A recent innovation in health screening has been the multiphasic health screening program of the Wisconsin Division of Health (*12*). A State-sponsored program which is similar in terms of equipment and tests, although on a smaller scale, is underway in West Virginia (*13*). To our knowledge, these programs represent the first direct involvement of State governmental agencies in providing the general public with multiphasic health screening over a large number of parameters and using the large multi-channel chemical analyzer.

Of critical interest to any public health agency considering, or already engaged in, multiphasic health screening are the actual costs of such State-sponsored programs, as well as the breakdown and distribution of these costs within specific areas of the screening program. We have summarized the results of an intensive 2-year study of the actual costs in the Wisconsin program.

Tests and Testing Procedures

The basic multiphasic screening program of the Wisconsin Division of Health has been described previously (*12*) and has been reviewed in a general descriptive article (*14*). In this program, all laboratory services are provided at the State Laboratory of Hygiene, which is located on the University of Wisconsin campus in Madison. The program is an outgrowth of a former chest X-ray and tuberculosis screening project, which grew to include diabetes screening and which, since October 1969, has included chest X-rays, blood pressure screening, collection of medical histories, and collection of blood samples for biochemical analysis of 12 parameters. The program is based in three buses (soon to be escalated to five), which cover the entire State every 4 years.

All services, including the profiling of blood chemistry, are provided without cost to any interested citizen of the State. The following list shows the equipment used by the various components of the program and the services they provide for it:

Field operations

Equipment: 3 mobile units

Services:
- Collection of medical histories
- Collection and processing of blood samples
- Blood pressure readings
- Chest X-rays
- Papanicolaou smears

Central laboratory

Equipment:
- 1 SMA 12/60 12-channel multi-element chemical analyzer
- 1 single-channel glucose Auto-Analyzer
- 1 LINC—8 computer

Services:
- Coding
- Inventorying stores and supplies
- Collation of data

Central office—services

Reviewing reports

Disseminating data

Central data processing and storage

Studies of data

Noncentral office—services

Physicians' followup on referrals

Public health nurses' followup

At the central laboratory, the blood samples are analyzed by the SMA 12/60 and by single-channel analyzers. The data are coded onto optical scanner forms for processing by the computer of the Wisconsin State bureau of administration (IBM 360–50). At the central office of the division of health, all these data are reviewed. When abnormal results are encountered, they are passed to a medical reviewer (a physician), who makes final decisions about referral. Patients are notified, by postcard, of the general results. When the results are abnormal, the patient's own physician receives a complete report of all the screening data. Under the administration of the division of health, public health nurses follow up on abnormalities. All data are put into long-term storage on IBM computer tapes for epidemiologic and other studies.

The onset of the third year of the program and an increasing workload emphasized the need for an accurate definition of costs that would permit us to determine their distribution within the program. Since there is no standard method of cost accounting for multiphasic screening, a preliminary definition of categories was formulated. Following are the items included in and excluded from our cost analysis of the laboratory-related activities of the screening program.

Costs included—all laboratory expenses

Reagents

Standards and controls

Expendable supplies

Supplies for machines

Cost of instruments

Salaries of laboratory and collection personnel

Data processing within the laboratory

Costs not included—all nonlaboratory expenses

Central staff (secretarial)

Administrative staff

Consultant physicians

Maintenance of mobile units

Laboratory space

Table 1. Cost in cents of reagents for one channel (inorganic phosphorus)

Reagent	Flow rate (ml. per minute)	Cost per milliliter	Cost per sample
H_2SO_4 (Brij)	0.60	0.0011	0.00066
H_2SO_4 (ultra wet)	.80	.0011	.00088
Ammonium molybdate	.60	.0013	.00078
Hydrazine sulfate	.23	.0015	.00034
Total cost of reagents for this channel			0.00266

By carefully documenting costs in each of the seven categories included in our analysis, we were able to assign the various costs accurately within the laboratory portions of the program. Such documentation of the costs associated with laboratory operations was our objective since, in actual programs, these costs often remain the great unknowns.

Costs of Reagents

The means used to compute the cost of reagents for one of the 12 tests in the panel (inorganic phosphorus) is shown in table 1. The calculation is based on the amount of reagent that is required to operate the machine for 1 minute, that is, to analyze one sample (at the rate of 60 samples per hour). The total cost of reagents for the instrument for this one test was found to be 0.0027 cents. For the entire panel of 12 tests used in the system, the total cost of reagents was only 7.462 cents. If the cost of reagents is expanded to include the running of standards and controls, as well as the warmup of the SMA/12 instrument, and prorated over the entire year, the cost is still only 9.7 cents per test panel. On the basis of approximately 47,000 specimens per year in 1970, the annual cost for reagents was $4,559. In the following list, the 12 tests are ranked in descending order according to the cost of reagents.

Test	*Cost in cents*
Uric acid	1.855
Cholesterol	1.260
Alkaline phosphatase	.763
Total bilirubin	.670
Glucose	.614
Total protein	.480
Albumin	.468
Calcium	.388
SGOT (serum glutamic oxalacetic transaminase)	.309
Inorganic phosphorus	.266
Blood urea nitrogen	.238
Creatinine	.151
Total cost of reagents for panel	7.462

Standards and Controls

Lyophilized human serum was used as a standard for the SMA 12/60 analyzer; other types of lyophilized material were used as controls. For the single-channel glucose analyzer, commercially purchased aqueous standards were also used. The cost of standards and controls during 1 year's operation of the program was $8,930. During that year 47,000 specimens were analyzed. The cost of controls per sample analyzed was approximately 10 cents greater than that of reagents. Following is a summary of the costs for 1 year of the standards and controls used with each analyzer.

Standard or control	*Cost*
For SMA-1260 analyzer:	
Reference serum	$1,925
Normal unassayed control	1,391
Abnormal high control	2,229
Abnormal low control	2,229
For single-channel analyzer:	
Aqueous standards	36
Normal serum control	560
Abnormal serum control	560
Standards	1,961
Controls	6,969
Total	$8,930

Expendable Supplies

A number of expendable items were used in processing screenees from the time they entered the mobile unit until their results were completed at the laboratory. Included in our analysis were the

Table 2. Major expendables for program for 1 year

Item	Cost
Blood-drawing supplies	$9,250.07
Vacutainer supplies	3,588.00
Vacutainer-grey top	1,974.92
Vacutainer-red top	3,687.15
Chart paper	2,050.00
Single-channel	150.00
SMA 12/60	1,900.00
Shipping containers	1,982.00
Boxes	375.00
Glass vials (SMA)	807.00
Glass tubes (glucose)	800.00
Miscellaneous expendables	3,120.00
Tubing for pump	631.00
Xerox supplies	323.00
Report forms	1,974.00
Computer supplies	192.00
All other expendables	3,148.28
Total, all expendables	$19,550.35

costs of such expendables as data-processing supplies used within the laboratory but not the cost of X-ray film. The major expendables used in 1 year of operation of the program are summarized in table 2. The expenses related to collection of blood samples accounted for 57.4 percent of the total costs for expendables during the year. The total cost for expendables per specimen analyzed was 41 cents.

Maintenance

Table 3 provides a summary of the maintenance performed on one SMA 12/60 during 1 month. Table 4 provides a summary of maintenance for one SMA and one single-channel analyzer for 1 year, showing both the cost of the replacement parts and the length of time required to perform this maintenance. The abnormally large expenditures for August reflect the replacement of 16 flow cells in the instrument, and the abnormally large ones for October, the addition of a new chemistry to the 12/60. Based on 47,000 specimens analyzed per year, the maintenance costs for the instrument came to $6,110, or 13 cents per specimen. The monthly expenditure in time of approximately 20½ hours for maintenance for a 12/60 and a single-channel analyzer does not seem unreasonable.

Cost of Instrumentation

The cost of instrumentation in the laboratory, amortized over a 5-year period, came to approximately 29 cents per specimen analyzed.

To this point, the costs included in our analysis have been essentially those related to manipulation of samples (for example, the collection and analysis of blood specimens). The net cost of these elements of the program was $1.12 per specimen. Certain peripheral expenditures, for example, salaries of field and laboratory personnel and expense of data processing in the laboratory (see next two sections) added significantly to program costs.

Salaries

Salaries included in the cost analysis were those for personnel aiding in the collection of specimens and those for persons working in the laboratory phases of the operation. For the current program, they numbered 12—eight in the field collecting specimens and four working in the laboratory operation. For these 12 persons, wages, fringe benefits, and expenses totaled $118,272—$70,472 for collection and $47,800 for laboratory functions. The cost of personnel is by far the largest item in the program, amounting to $2.51 per specimen analyzed, or $1.50 per sample for specimen collection and $1.01 per sample for processing within the laboratory.

Data Processing in Laboratory

The cost of data processing activities in the laboratory (primarily the hand coding of data and the processing of related laboratory records) was approximately 22 cents per specimen. This figure is based on the actual expenditure for the time required by the optical scan coders

Table 3. Cost and time required for maintenance performed in January 1970

Date	Maintenance performed	Cost	Time required
15th	Replacement of uric acid flowcell.	$84.75	20 minutes
21st	Changing pump tubing	39.20	5 hours
22d	Phasing	.....	8 hours
23d	Phasing	.....	8 hours
24th	Lubrication and cleaning of 4 pumps	.....	30 minutes per pump
24th	Lubrication of recorder slide wire.	.....	10 minutes
Total		$123.95	23 hours, 30 minutes

Table 4. Cost and time required for maintenance performed during 1970, by month

Month	Cost	Time required
January	$123.95	23 hours, 30 minutes
February	90.76	8 hours, 35 minutes
March	300.00	1 hour, 40 minutes
April	66.70	5 hours, 30 minutes
May	118.25	51 hours, 30 minutes
June	57.60	5 hours, 30 minutes
July	260.00	10 hours, 0 minutes
August	1,750.00	50 hours, 5 minutes
September	364.82	12 hours, 10 minutes
October	2,820.64	43 hours, 10 minutes
November	78.88	15 hours, 10 minutes
December	78.40	18 hours, 0 minutes
Total	$6,110.00	244 hours, 50 minutes
Monthly mean	509.16	20 hours, 50 minutes

Table 5. Summary of costs of laboratory phases of the multiphasic screening program

Category	Field collection and laboratory operations[1]		Laboratory operations only	
	Cost	Percent of total	Cost	Percent of total
Salaries	$118,272.00	65.2	$ 47,800.00	43.2
Expendables	19,550.35	10.8	19,550.35	17.6
Amortization of instrument	13,600.00	7.5	13,600.00	12.2
Coding standards and controls	10,340.00	5.7	10,340.00	9.3
Controls	8,930.00	4.9	8,930.00	8.1
Maintenance	6,110.00	3.4	6,110.00	5.5
Reagents	4,559.00	2.5	4,559.00	4.1
Total	$181,361.35	100.0	$110,889.35	100.0

[1] Including field collection of specimens.

(IBM 1230) to analyze 47,000 specimens. The costs are computed on an hourly basis.

Summary of Costs

The net cost of the laboratory phases of the multiphasic screening program was $3.85 per specimen. This figure represents all phases of the processing of a specimen, from its collection in the field to the reporting of laboratory results to the division of health for review. Based on strictly laboratory expenses, the cost per specimen was $2.35. The costs of phases of the program by category, including field collection and laboratory operations, and the costs for strictly laboratory operations are compared in table 5.

In considering field collection and laboratory operations, salaries accounted for the largest part of the program costs 65.2 percent, followed by expendables 10.8 percent, instruments 7.5 percent, coding 5.7 percent, standards and controls 4.9 percent, machine maintenance 3.4 percent, and finally, reagents 2.5 percent.

On the basis of actual laboratory operations, that is, excluding salaries of the field personnel collecting specimens, but including salaries for laboratory personnel, salaries continued to be the largest item in the survey, at 43.2 percent. The next largest category was expendables 17.6 percent, followed, in order, by instrumentation 12.2 percent, coding 9.3 percent, standards and controls 8.1 percent, maintenance 5.5 percent, and finally, reagents 4.1 percent. Based on strictly laboratory operations, the cost per specimen was $2.35.

Cost Effectiveness

The actual cost of analysis of the samples was less than one-third of the total program costs in both the Wisconsin and Kaiser-Permanente programs. Our

Table 6. Incidence and cost of positive results on blood tests in Wisconsin multiphasic health screening program

Test (by sex of screenees for some tests)	Referral range	Rate per 100 tests performed	Cost
Glucose:			
Males	>180 mg. per 100 cc.[1]	2.6	$12.33
Females	>180 mg. per 100 cc.[1]	2.4	13.36
Cholesterol:			
Males	150–300 mg. per 100 cc	5.8	5.53
Females	150–300 mg. per 100 cc	7.4	4.33
Uric acid:			
Males	>8.5 mg. per 100 cc	2.9	11.06
Females	>7.5 mg. per 100 cc	1.2	26.73
Albumin	3.5–5.0 gm. per 100 cc	1.8	17.82
Total protein	6.0–8.0 gm. per 100 cc	2.0	16.04
Calcium	>11.5 mg. per 100 cc	.16	200.50
SGOT (serum glutamic oxalacetic transaminase)	10–50 international units	3.4	9.43
Inorganic phosphorous	5.0 mg. per 100 cc	2.0	16.04
Alkaline phosphatase:			
Males	>125 international units	1.1	29.16
Females	>125 international units	1.0	32.08
Total bilirubin	>1.0 mg. per 100 cc	.4	80.20
Blood urea nitrogen:			
Males	25 mg. per 100 cc	4.4	7.29
Females	25 mg. per 100 cc	2.0	16.04

[1] Depending on intake.

study brings the cost per sample of screening data into closer perspective. Since the cost of an individual test (for example, glucose or cholesterol) varies only slightly in terms of the different chemical reagents required, one may simply divide the cost per sample ($3.85) by 12 (the number of tests in the panel) to obtain the approximate cost per test of 32.08 cents. This figure represents the cost of all elements of the multiphasic screening program from the time that a person presents himself at the screening station until his test results are supplied to a medical reviewer.

Table 6 shows the different rates (that is, the incidence) of abnormal results found in testing the Wisconsin population for each chemical determination. The cost column represents the calculated cost of finding a single abnormal result, based on 32.08 cents per test performed. The figures, in general, compare fairly closely with those reported (direct costs only) for the Kaiser program. (*5*).

The cost of discovering an abnormal test result, such as for glucose or cholesterol, is relatively low. Preoccupation with abnormal results, however, can lead to gross underemphasis of the importance of nonreferral test results produced by a health screening program of this kind. The medical profession is becoming acutely aware of the significance in the practice of medicine of a person's normal biochemical parameters (*15*). Consequently, the accumulation of baseline data in a person's medical records (to serve as an indicator of health status) must remain a major objective of such screening programs.

The Wisconsin program has shown that it is not economically feasible to operate at low volumes unless optimum use of personnel and equipment is achieved. Items such as maintenance, inventory, scheduling, and organization have to be integrated into the program. The study of laboratory costs in the Wisconsin multiphasic health screening program should be of value to other agencies planning such programs, since in such projects the actual distribution of costs remains the biggest unknown.

Conclusions

Based on a cost analysis of laboratory operations in the multiphasic screening program, our conclusions are:

1. The cost of instrumental analysis of specimens is negligible in comparison with the cost of collection. Such analysis accounted for only 18 percent of the total program costs, while personnel and supplies used in collecting specimens accounted for about 76 percent.

2. Data processing within the laboratory is a major expense. (We are seeking other approaches based on the use of a small laboratory computer to speed the initial data processing by on-line data acquisition to eliminate hand coding.)

3. The costs per sample analyzed are optimized at approximately 40 to 50 thousand specimens per year—a conclusion based on optimum use of instruments and personnel. This sample load, we believe, represents the maximum for a single SMA 12/60.

4. Maintenance and inventories are the key factors in optimizing the operation of the program. At 40 to 50 thousand specimens per year, a regular program of maintenance and a stock of machine parts are essential. Our standard inventory of parts, valued at approximately $16,200, represents only 8.9 percent of the yearly cost of the program. The rate at which the program acquires samples precludes a shift to backup techniques so that preventive maintenance and a system of emergency stocks are essential.

REFERENCES

(*1*) Laessig, R. H.: The analytical chemist and multielement chemical testing in preventive medicine. Anal Chem 43: 18a–41a, July 1971.

(*2*) Benson, E. S., and Strandjord, P. E., editors: Multiple laboratory screening. Academic Press, New York, 1969.

(*3*) Collen, M. F.: Periodic health examinations using an automated multitest laboratory. JAMA 195: 380–383, Mar. 7, 1966.

(*4*) Collen, M. F., Kidd, P. H., Feldman, R., and Butler, J. L.: Cost analysis of a multiphasic screening program. New Engl J Med 280: 1043–1045, May 8, 1969.

(*5*) Collen, M. F., Feldman, R., Siegelaub, A. B., and Crawford, D.: Dollar cost per positive test for automatic multiphasic screening. New Engl J Med 283: 685–690, Aug. 27, 1970.

(*6*) Mackintosh, D. R., and Kraus, G. P.: Cost analysis of the developmental phase of an automated multiphasic health testing facility. Public Health Rep 85: 685–690, August 1970.

(*7*) Gelman, A. C.: Automated multiphasic health testing. Public Health Rep 85: 361–365, April 1970.

(*8*) Yedidia, A., Bunow, M. A., and Muldairn, M.: Mobile multiphasic screening in an industrial setting. XIII. Cost requirements of mobile health screening. J Occup Med 11: 653–658 (1969).

(*9*) Garfield, S. R.: Multiphasic health testing and medical care as a right. New Engl J Med 283: 1087–1089, Nov. 12, 1970.

(*10*) Ahlvin, R. C.: Biochemical screening—a critique. New Engl

J Med 283: 1084–1086, Nov. 12, 1970.

(*11*) Multiphasic screening and automated health evaluation programs directory, 1970–71 ed. (supp.). Multiphasic Health Screening Newsletter, Burbank, Calif., 1970.

(*12*) Laessig, R. H., Schwartz, T. H., and Preizler, J.: State of Wisconsin multiphasic health screening program. *In* Advances in automated analysis, 1970, edited by E. C. Burton, et al. Thurman and Associates, Miami, Fla., 1971, vol. 1., pp. 261–269.

(*13*) Statewide multiphasic health screening. Lab Management 9: 26–30, May 1971.

(*14*) Traveling laboratories will administer battery of tests. Lab World 19: 48 (1968).

(*15*) Keys, A.: Serum cholesterol and the question of "normal." *In* Multiple laboratory screening, edited by E. S. Benson and P. E. Strandjord. Academic Press, New York, 1969, p. 147.

SCHWARTZ, THOMAS H. (Wisconsin Division of Health), LAESSIG, RONALD H., and PREIZLER, JOSEF: *Cost analysis of Wisconsin's program of multiphasic health screening. Health Services Reports, Vol. 87, June–July 1972, pp. 523–529.*

The laboratory costs of a State-sponsored, statewide multiphasic health screening program in Wisconsin were analyzed. Included in the analysis were the costs of processing a person from the time he entered the blood sampling station until the results of his screening were presented to a medical reviewer. The overall cost per person was $3.85. In addition to analysis of blood samples with an SMA 12/60 12-channel multi-element chemical analyzer and a single-channel glucose AutoAnalyzer, the screening included an evaluation of blood pressure, the taking of a personal medical history, and a chest X-ray. The actual cost of processing a blood sample (excluding the cost for personnel who collected the specimens in the field) was $2.35.