The Time-Skill-Frequency (TSF) Unit for Reporting Laboratory Work-Load

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The concept that the number of tests performed is an accurate measure of the laboratory work-load may be misleading. On the premise that a system based on technician-time would be superior, the time-skill-frequency (TSF) unit was devised. The TSF unit is the length of time necessary for an average analyst to perform a single determination, multiplied by factors based on the length of time necessary to do duplicate determinations, the skill involved, and the frequency with which the test is performed in the laboratory. Ideally such units should be calculated for the methods and conditions of each individual laboratory.

The most widely used system of reporting laboratory work-load—as the number of tests performed in a specific period—is not an accurate measurement of the work-load and may even be misleading. For example, clinic and hospital administrators may regard tests such as those for protein-bound iodine and urine reducing sugar as of equal weight.

In recent years little has been published concerning ways of evaluating work-load in the laboratory (1). Owen and Finch (2) have calculated a standard laboratory man-hour. Their system does not differentiate between types of tests but gives information as to how the man-hour is spent. In Canada, work units (3) have been calculated on the basis of 10 min. of the technician’s time. This system, although superior to the “total number of tests” system, apparently has not taken into consideration important factors and gives little or no leeway in regard to the variety of methods that may be used in different labora-

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tories. The College of American Pathologists (4) have published a list of relative values for various determinations for the purpose of determining fees for laboratory service. This list of values might be roughly adaptable to evaluating the laboratory work-load.

Therefore, it was believed that a unit was needed that was a more accurate reflection of the work-load than the total number of tests. In the development of this unit the most important factor taken into consideration was the amount of technician-time required to perform an analysis. This amount of time was different for each type of determination. Without modification, this time, expressed in units of fractions of an hour, would have been more accurate than reporting each test as a single unit; however, further improvement was made. This unit (fraction of an hour) was modified in terms of the time required to perform multiple determinations. Some tests are so complex that despite the number of analyses to be done, little or no time can be saved by doing them together—they must be done singly. Such tests add much more to the work-load than do those determinations in which multiple tests can be done simultaneously.

Since technician-time is required to prepare solutions (this time will vary with various tests), the average preparation-time determination was added to the basic time. As some tests require considerably more time for calculation than do others, the calculation-time should be added.

Consideration should be given to the skill required to perform each test. Tests that are difficult and must be performed by highly skilled technicians should be weighted to differentiate them further from routine determinations that require little training or background. Extra weight should be given where expensive equipment is required, particularly if the cost of the equipment is so high that the income from its use does not pay for it in a short time.

Determinations that are done only rarely throw a greater load on personnel than those done frequently. Often special equipment is required, and storage space must be provided for this equipment and the necessary reagents. Moreover, reagents may not be stable and some must be made fresh each time. The technician's work schedule may be upset by rare tests, their appearance at irregular intervals interfering with the planning of clear-cut schedules. The extra time required for these rarely ordered procedures crowds the schedule for other analyses that are regularly done. On the other hand, determinations that
must be done in large numbers each day are given special treatment in order that these tests may be turned out rapidly and efficiently. Thus, the unit must be weighted according to the daily frequency of each determination.

**Time-Skill-Frequency Unit**

With these factors in mind, the time-skill-frequency (TSF) unit was developed. The various laboratory tests were timed to 1/100 of one hour as done singly by an average laboratory technician; this was represented by $t_1$. (Waiting periods of 15 min. or longer, when the technician was not actually performing some function of the analysis, were not included.) The time to do two tests ($t_2$) was chosen as a measure of the time required to do a multiple number of tests. Larger multiples than 2 gave units that were obviously out of proportion for the difficult determinations that required long periods. The daily time to prepare reagents for a particular determination, to wash special glassware, or to make special adjustments of instruments was divided by the daily average of the number of tests. This gave the average preparation time ($t_p$) for each analysis. This time plus the calculation time ($t_r$) was added to the time to do one test ($t_1$), which gave the technician time ($T$) per test. Thus:

$$t_1 + t_p + t_r = T$$

$T$ was multiplied by the ratio of $t_2:t_1$, which modified $T$ in terms of the ease with which the test could be done in multiples.

Arbitrary factors were selected for skill and frequency. For simple procedures that required no previous training, and which could be learned with a minimum of instruction, the skill factor of 0.6 was assigned. The tests requiring intermediate skill were assigned factors between 0.6 and 1.0—the latter, the factor for requiring the greatest skill. A factor of 1.0 was used for the most infrequent test (<1 per day). For determinations done more frequently than the rate of 25 per day the factor was 0.6. Factors chosen for other frequencies, were: 0.9 for 1–2 tests, 0.8 for 3–10 tests, and 0.7 for 11–25 tests.

Thus:

$$t_1 + t_p + t_r = T$$

$$\frac{t_2}{t_1} (S)(F) = Tu$$

$$10 Tu = Ur$$

where $t_1 =$ time to do one determination in hours; $t_2$ is the time to do
two; $t_p$ the preparation time (see text); $t_c$ the calculation time; $T$ the total working analyst time; $S$ the skill factor (see text); $F$ the frequency factor (see text); and $Tu$ the modified analyst time in hours.

In order that the final units not be fractional numbers, $Tu$ is multiplied by 10 to give $Ur$, which is expressed in rough (approximate) units rounded off to the nearest whole number to become TSF units in tenths of an hour.

**Sample Calculation**

Calculation of units for a test is illustrated by the following for the determination of hemoglobin (as oxyhemoglobin). The average time of performing the determination was 3 min. (0.05 hour). There is no saving in time when hemoglobin determinations are done in multiples; two determinations required 6 min. (0.10 hour). Technician-time required to wash the test tube cuvets and the pipets was 0.01 hour. Reagent preparation-time was considered negligible, as sufficient reagent was prepared at one time for several thousand determinations. About 0.5 min. (0.01 hour) was required to translate the colorimeter reading into grams of hemoglobin, and to write the value on the report form. An intermediate skill factor of 0.8 was assigned. The frequency of the hemoglobin determinations exceeds 25 tests per day; thus the frequency factor of 0.6 was used. The steps in the final calculation of the TSF units for hemoglobin are:

$$0.05 + 0.01 + 0.01 = 0.07$$

$$\frac{0.1}{0.05} (0.07)(0.8)(0.6) = 0.07$$

$$0.07 (10) = 0.7$$

Rough units ($Ur$) were rounded off to the nearest whole number to obtain the TSF unit ($U$). Thus for the hemoglobin determination, $U$ became 1.

Table 1 lists the stages in the calculations of TSF units for several determinations done in the clinical laboratory.

Table 2 gives the times, factors, and units for the Clinical Chemistry Laboratory of the Cleveland Clinic. Ideally a work unit should enable one to compare the load per technician in various clinical pathology laboratories. However, it is not likely that the use of such a unit as the TSF unit would be adequate for an accurate comparison between laboratories. Different laboratories may not be compared because of differences in emphasis. For example, one laboratory may spend a
Table 1. Representative Data Used in Calculating the TSF Unit

<table>
<thead>
<tr>
<th>Test</th>
<th>ti</th>
<th>to</th>
<th>ts</th>
<th>St</th>
<th>F</th>
<th>T</th>
<th>T+</th>
<th>U+</th>
<th>U</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>1.00</td>
<td>1.20</td>
<td>0.10</td>
<td>0.01</td>
<td>0.9</td>
<td>15</td>
<td>0.7</td>
<td>1.11</td>
<td>0.84</td>
<td>8.4</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.20</td>
<td>0.22</td>
<td>0.05</td>
<td>0.01</td>
<td>0.7</td>
<td>175</td>
<td>0.6</td>
<td>0.26</td>
<td>0.11</td>
<td>1.1</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>0.05</td>
<td>0.10</td>
<td>0.01</td>
<td>0.01</td>
<td>0.8</td>
<td>150</td>
<td>0.6</td>
<td>0.07</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>P.B.I.</td>
<td>1.50</td>
<td>1.75</td>
<td>0.25</td>
<td>0.05</td>
<td>1.0</td>
<td>10</td>
<td>0.8</td>
<td>1.80</td>
<td>1.68</td>
<td>16.8</td>
</tr>
<tr>
<td>Transaminase</td>
<td>0.40</td>
<td>0.50</td>
<td>0.10</td>
<td>0.01</td>
<td>0.8</td>
<td>11</td>
<td>0.7</td>
<td>0.51</td>
<td>0.36</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Table 2. Time-Skill-Frequency Units for the Clinical Chemistry Laboratory of the Cleveland Clinic

<table>
<thead>
<tr>
<th>Test (Reference No.)</th>
<th>TSF units</th>
<th>Test (Reference No.)</th>
<th>TSF units</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;-Aminolevulinic acid (5)</td>
<td>17 Kjeldahl</td>
<td>Aminopeptidase (6)</td>
<td>7 Lactic dehydrogenase (29)</td>
</tr>
<tr>
<td>Asparagine (7)</td>
<td>8 Lipase (50)</td>
<td>Arsenic (8)</td>
<td>17 Lipid (total) (31)</td>
</tr>
<tr>
<td>Ascorbic acid (9)</td>
<td>20 Methemoglobin (52)</td>
<td>Barbiturates (10)</td>
<td>12 Phosphatase (55)</td>
</tr>
<tr>
<td>Bence Jones (11)</td>
<td>2 Phosphorus (55)</td>
<td>Bilirubin (12)</td>
<td>6 Porphyrins (screening) (54)</td>
</tr>
<tr>
<td>Bromide (13)</td>
<td>5 Porphyrins (24-hr. study) (54)</td>
<td>Bromide (18)</td>
<td>5 Porphyrins (34)</td>
</tr>
<tr>
<td>Sulphobromophthalein (14)</td>
<td>3 Porphobilinogen (55)</td>
<td>Calcium (15)</td>
<td>8 Protein (total) (56)</td>
</tr>
<tr>
<td>Carbon monoxide (16)</td>
<td>8 A/G (56)</td>
<td>Carotene (17)</td>
<td>6 FBI (57)</td>
</tr>
<tr>
<td>Cefoperazone (18)</td>
<td>3 Quinidine (58)</td>
<td>Chloride (19)</td>
<td>2 Renal calculi (6)</td>
</tr>
<tr>
<td>Cholesterol*</td>
<td>3 Reducing sugar (urine) (qual.) (6)</td>
<td>Cholesterol (60)†</td>
<td>3 Reducing sugar (urine) (quant.) (6)</td>
</tr>
<tr>
<td>Cholesterol esters (60)</td>
<td>5 Sulfonamide (59)</td>
<td>Copper oxidase (61)</td>
<td>5 Thiocyanate (40)</td>
</tr>
<tr>
<td>Creatine (62)</td>
<td>10 Thymol (41)</td>
<td>Creatinine (63)</td>
<td>5 Transaminase (42)</td>
</tr>
<tr>
<td>Fat, fecal (65)</td>
<td>14 Urea (43)</td>
<td>Glucose*</td>
<td>1 Urea clearance</td>
</tr>
<tr>
<td>Glucose (64)†</td>
<td>2 Uric acid (44)</td>
<td>Glucose tolerance</td>
<td>8 Urobilinogen (46)</td>
</tr>
<tr>
<td>Glycoprotein (65)</td>
<td>13 Water (body) (46)</td>
<td>Insulin tolerance (66)</td>
<td>9 Xylose tolerance (47)</td>
</tr>
<tr>
<td>Iron and IBC (67)</td>
<td>16 Zinc sulfate (48)</td>
<td>Kepler A (68)</td>
<td>3</td>
</tr>
<tr>
<td>Kepler B (68)</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*AutoAnalyzer.†Manual.
sizable portion of time in research projects, another in the development of new tests, and another in teaching. It may not be possible to evaluate objectively these types of activity, and thus it might not be wise to compare closely one laboratory with another.

Table 3 demonstrates one of the uses of the TSF unit. Laboratory work for 4 years was tabulated according to the total number of tests done, representative tests, and the total TSF units. The number of tests performed increased 38% in 3 years—from 68,950 tests in 1957, to 94,959 in 1960. However the increase in the work-load is even more striking when expressed as TSF units: 205,507 units in 1957 as compared to 338,586 units in 1960, which is an increase of 65%. Examination of the distribution of the work showed that, whereas the number of blood glucose determinations (a low-unit test) increased slightly, the increases in numbers of high-unit procedures such as serum cholesterol and serum transaminase determinations (a relatively new test) were responsible for the great increase in the work-load.

This new representation of the work-load has been used to justify additions of personnel and automatic equipment to the laboratory. On Jan. 1, 1957, the laboratory staff comprised eight technicians; since then, personnel has been increased by one technician, and three automatic systems have been added to the laboratory equipment.

**Comments**

I wish to emphasize that calculations were made on the basis of an individual concept of an "average" analyst. This concept will probably vary with each individual laboratory director. In addition, the units might possibly be further improved by consideration of other parameters, although the rewards would probably not be worth the effort. However, it is believed that this study is a good foundation for

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Glucose (1 TSF)</th>
<th>Cholesterol (5 TSF)</th>
<th>Transaminase (4 TSF)</th>
<th>TSF units, total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>68,950</td>
<td>35,321</td>
<td>4,162</td>
<td>300</td>
<td>205,507</td>
</tr>
<tr>
<td>1958</td>
<td>76,716 (11*)</td>
<td>35,777</td>
<td>5,604</td>
<td>973</td>
<td>253,802 (24*)</td>
</tr>
<tr>
<td>1959</td>
<td>83,838 (22*)</td>
<td>35,709</td>
<td>7,649</td>
<td>2,394</td>
<td>293,139 (43*)</td>
</tr>
<tr>
<td>1960</td>
<td>94,959 (38*)</td>
<td>37,723</td>
<td>9,194</td>
<td>2,987</td>
<td>338,586 (65*)</td>
</tr>
</tbody>
</table>

*Percentage of increase over 1957.*
the development of an adequate means to report the work-load of a laboratory. In addition, these units should serve as an excellent basis for the calculation of laboratory fees. It should be emphasized that the use of this type of unit has its greatest value in comparing the work performed by a particular laboratory during one period with that performed during another period. The TSF units should best be calculated for the condition existing in each particular laboratory for the methods used by that laboratory.

References