# The insertion tape: a new circumference tape for use in nutritional assessment

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ABSTRACT Certain body circumferences, such as the mid-upper arm circumference, are regarded as useful indicators of the nutritional status of children. The insertion tape is designed to reduce errors of measurement, prone to occur with the present tapes. At the widened origin of the new tape is a narrow slot perpendicular to the tape's long axis. The measurer threads the distal end of the tape through this slot, tightens to the required tension around the circumference and reads from an open window near the slot. Modifications of the basic tape for specific uses of measurement, screening and survey, are described. *Am. J. Clin. Nutr.* 28: 782–787, 1975.

Since its first use in community surveys in 1958 (1), the mid-upper arm circumference (MUAC) has become increasingly used as an indicator of the nutritional status of children, particularly those aged 1–5 years (2–7). Standards for this age group are "precise age independent" (8, 9). Children's weight according to age, is widely accepted in showing the nutritional profile of a community, although not differentiating "nutritional dwarfing" from more recent protein—calorie malnutrition (PCM) (10, 11). A weight—for—age graph which flattens or falters is the earliest recognized sign of PCM, but this approach requires regular surveillance by trained staff (12). Cost, maintenance, testing and transport of scales limit widespread field use, especially in those areas where PCM is common. Scales pose important measurement errors even when used by trained staff (13) and errors related to clothing and to variable food, fluid, fecal and urinary content also occur.

Mid-upper arm circumference is cheaper and more practical to obtain than other soft tissue indices. It measures fat and muscle combined and since only a tape measure is required, MUAC is universally applicable. Apart from calf circumference (14), perhaps no other method can be used so widely. However, the design of tapes presently in use predisposes to measurement errors, in that two widths of the same tape must be aligned for the required scale orientation (Fig. 1). This may result in poor control, angulating of the tape around the circumference to be measured and incorrect alignment of scale markings. The reading requires precise orientation of the zero point. Commercial tapes, furthermore, vary in diameter, thickness, graduations and placement of numerals.

What errors may be expected with some of the conventional tapes? Certain tapes, such as those recommended by Jelliffe (2) for circumference measurements, have the printed numeral across the tape's long axis and not precisely aligned with the corresponding graduation. A trial conducted by the author using a similar tape (Korbond fiberglass), resulted in a systematic error of +0.5 cm in over 30% of 266 recordings. Sites were copied on sheets as expected viewing areas for circumference readings, to 15 nurses and 15 medical students, after a preliminary explanation. As shown in Fig. 1, it is not clear to which major graduation the 26 belongs. Thus a likely reading is 26.3 − 10 = 16.3 cm. Substituting the 10 for zero involves a subtraction which produces further reading errors. This substitution often results when a long fiberglass tape is cut into shorter segments for reasons of economy, so that the middle parts no longer have a zero point. In

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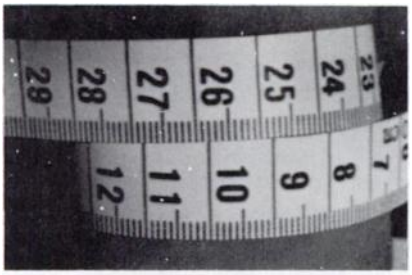


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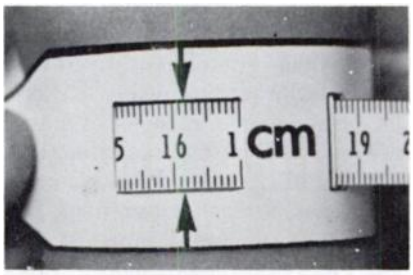
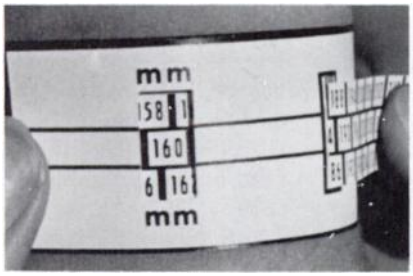
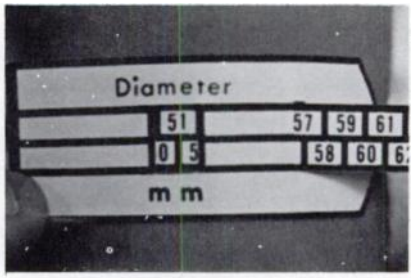



2. INSERTION




3. NUMERAL

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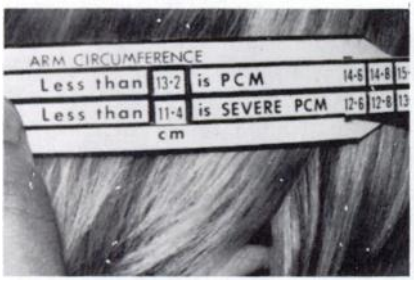


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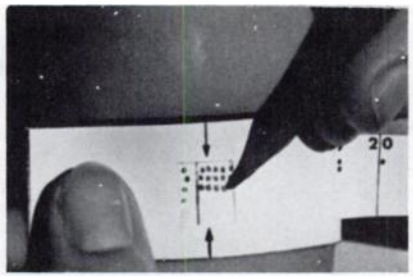
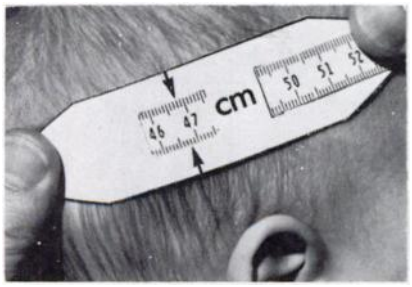



6. SURVEY




7. INSERTION head

8. Mid-point upper arm

FIGURES 1–8. READING AREAS

the same trial, other tapes with the numeral along the long axis and precisely aligned with the corresponding graduations, were used. The subtraction procedure using 10 as the zero point resulted in an error of at least 1.0 cm in 13.3% of 540 reading-recording tests.[3]

A further trial conducted by the author compared measurements between an insertion and a standard metal tape ("Lufkin" white clad tape rule). Five measurers used these two tapes to measure the head circumferences of nine young children. For each subject, the standard deviation of the readings obtained by the five measurers using each type of tape was computed to indicate the extent of agreement among the examiners. The mean of the standard deviations for the insertion tape was smaller than that of the metal tape. Using the paired *t*-test, the difference of these two means was statistically significant at the 0.10 level. Two gross outliers due to reasons unrelated to the instrument used, were excluded from the calculations.

## The insertion tape

The insertion tape (Fig. 2) was constructed to overcome many of the measurement problems. The tape inserts into itself to allow: *1*) good control around the upper arm or other circumference; *2*) correct alignment around the arm and of the reading scale; and *3*) a clear, direct, window reading.

Two arrows, one next to the narrow slot and the other at the distal end of the tape, guide the insertion. The measurer threads the end of the tape through the slot from behind, either before or after the mid-upper arm is encircled. The free part of the tape is drawn through the slot to the required tension around the arm. The window reading is made at the point of the two arrows perpendicular to the long axis of the tape.

## Tape modifications

An open window at the reading area allows useful variations of the basic insertion tape (Figs. 3—7, Plate 1). The numeral tape presents a complete reading to be simply copied; the diameter tape allows a direct arm diameter estimate for use with triceps' skinfold thickness for muscle evaluation; a third uses the arm—to—head circumference ratio as an immediate screening method for PCM; finally the tape itself can be the complete record sheet, the measurements marked at the window site, so that no individual readings, recordings or copies are required. The diameter and ratio tapes employ simplifications of methods already detailed.

### *The numeral tape*

In certain situations a numeral insertion tape may be more appropriate than one with standard markings. This is particularly suitable for use by nonmedical people at community level. A complete numeral is read in the window and recorded. The reading speed and errors are minimized because no counting of graduations is required. The measurer is instructed to read only the complete number flanked on each side by a vertical bar. Prototypes for testing have the block outlines in red and the numerals in black. This separates more clearly the adjacent figures. For technical reasons, the readings are graded in 2-mm increments. This does not seriously detract from the required precision and has advantages in speed and reliability of reading. The numbers may be presented as centimeters. The decimal point increases numeral crowding within the block but may be preferred by convention.

### *The diameter tape*

The numeral principle described can be used for direct readings of total mid-upper arm diameter. An approximate estimate of muscle diameter is derived by simply subtracting the triceps skinfold thickness value from this arm diameter, each in millimeters. The production of an inexpensive, reliable skinfold caliper for children would greatly increase the field use of this method.

With this procedure it is important to determine the mid-point of the upper arm. A double scale as shown in Fig. 8 may be used.

[3] Full details of trials are available on request from the author. During the same reading trials, of 1,187 measurements with the insertion tape, only 1.8% had an error of at least 0.2 cm and 0.1% an error of at least 1.0 cm. Tapes with similar graduations and numerals but no window had corresponding results. Recordings were more rapid with the insertion tape presentations.

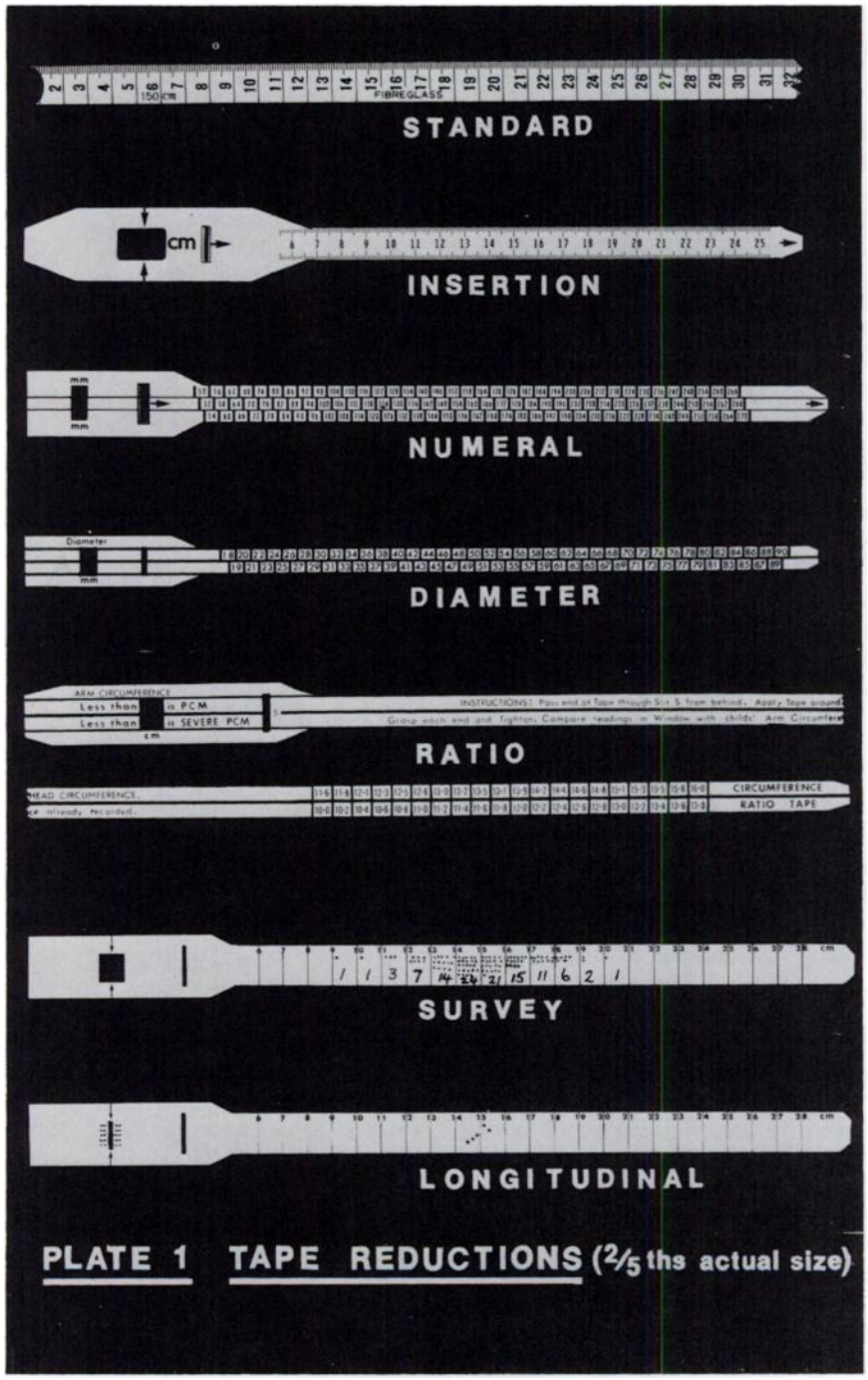



PLATE 1 TAPE REDUCTIONS (2/5ths actual size)

Note the origin of the scale is aligned with the tip of the acromial process and the modified "ruler" placed along the lateral aspect of the upper arm. The number at the scale on the left side of the ruler is read at the olecranon and the mid-point marked on the arm at the same number on the opposite scale.

*Ratio tape*

The estimate of arm—to—head circumference ratio to screen children aged 3 to 48 months for PCM has been recommended (15). With an insertion tape in position around the head, the known arm circumference is compared with that shown in the window reading and the category determined immediately. In the example, a child with MUAC of 12.0 cm would be screened as PCM but not severe PCM.

*Survey tape*

The tape itself can be used as a final record "sheet" in surveys, the measurement defined at the window site as a mark. The figure shows a pencil mark being made by an assistant. This is done on the area of the tape on that side of the vertical line where the arrows point. When some 25 marks complete a category, the other side of the tape or a new tape may be used. On completion of the survey, there will be a series of marks or dots to be totalled for each centimeter range. The full process of reading, recording and categorizing, with compounding of errors, is bypassed.

*Longitudinal tape*

The principle is similar to the survey tape. A paper tape is selected for an "at risk" child. According to the time interval, each recording is marked in the narrow window at a slightly lower level down the tape's vertical axis. After five recordings, the resulting graph section is cut out and pasted on a progress sheet in line with the same centimeter graduations. The child has a new tape and the procedure repeated for the next time span. Progress at any time may be shown to a family member, by means of the graph. For children aged 1–5 years, where MUAC is expected to be fairly constant, a marked deviation may be interpreted as a soft tissue nutrition or hydration change rather than a growth change; or as an error.

Both the survey and longitudinal tape still require a proper measuring technique, but have probable widespread applications.

*Other circumference measurements*

All insertion tapes can be elongated for larger circumferences such as head, chest, abdomen and thigh. This longer tape can then be used for any body circumference.

## Materials and cost

PVC-coated fiberglass is the most suitable, but its expense of production, especially for a limited number, warrants consideration of other materials. Plastics such as "polyart" and "mylar," PVC-coated linen and plasticized or laminated materials are being investigated. "Tyvac," a paper with a plastic interior, is durable and resistant to the effects of water. Tyvac may be suitable for the survey tape, where pencil recordings can be erased without disturbing the surface and the tape reused. However, it stretches 1 to 2 mm for every 30 cm. Laminating prevents stretching but predisposes to permanent creases. It is possible for the insertion piece alone to be of a more durable material, which would allow reduction in its width and act as a template for convenient handling and storage.

*Availability of insertion tapes*

A limited number of most of the tapes described are available on request. Further information, including a protocol for simple trials, would be supplied with the tapes.

## Discussion

Unlike other anthropometric tools, the tape measure may be conveniently used within the community—family setting. Health workers must have simple ways to assess nutritional state, particularly PCM. The more inaccessible the target groups, the greater the need to simplify, especially where PCM is common and professional workers are few. If one measurement for nutritional assessment works at the field level, it must be considered for national and regional evaluation also. For this purpose MUAC may serve. Its critical limitation is the correct technique of measuring.

The insertion tape compared with conventional tapes, improves control, alignment and reading of body circumferences. This new device provides a rapid, simple and reliable method for screening, survey and longitudinal

assessment. Field testing is needed to determine its full value.

To members of relief teams during and after the Nigerian Civil War and the countless children from and for whom the idea was formed. To Prof. T. Stapleton and Dr. B. Dowd, Institute of Child Health, Sydney, and Dr. D. Miller, Center for Disease Control, Atlanta, U.S.A., for encouragement and advice; to Prof. J. Tanner and Dr. D. Morley, Institute of Child Health, London, for advice on the numeral tape design; to Prof. A. Shakir, Baghdad Medical College, Iraq, for the idea of the ratio tape; to Mr. V. C. N. Blight, Government Printer, Sydney and Buck Printing Co., Boston, for producing some of the tapes; to the Department for the Readability of Print, Royal College of Art, London, for permission to use a unique numeral type; to Mr. J. Galvin, Beckenham, U.K., for assistance with numeral placement; and to students and faculty members of the Harvard School of Public Health, Boston and Prof. D. Jelliffe, UCLA, California. for reviewing the paper. Photographs were taken by Dr. J. Kolins and the author. The insertion tape has been patented by the Department of Health, Commonwealth of Australia.

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