評估身體組成的廉價和適當的技術: 研究者的展望

Low-cost appropriate technologies for body composition assessment: a field researcher's view

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The field setting, as distinct from the clinical and laboratory settings, relates to the study of populations and subpopulations. It can involve either free-living or institutionalized individuals. The concept of 'body composition' goes beyond the traditional assumptions of screening anthropometrics, although it includes many of the same measures. The principal practical considerations for the selection of measurement techniques are ethics and cost. The quantitative considerations are the precision and accuracy of the measures. The biological considerations relate to the interpretation of the measure in terms of underlying body constituents; do the values mean what we hope them to mean?

Introduction

The definition of field studies and field research should be apparent. In contrast to clinical studies, which deal with individuals in the context of disease and pathological diagnoses, field research relates to populations as a whole and to subsegments of the groups. Field applications are in the domains of epidemiology and public health. The goals are various: (1) to describe the distributions and prevalences of abnormalities of specific variables; (2) to monitor spontaneous changes over time (surveillance); (3) to determine the response to (changes with) interventions; and/or (4) to determine associations between and among variables.

With respect to any variables, there are a series of practical considerations and a series of quantitative considerations in field research, as well as the most fundamental of considerations, biological meaning.

Practical considerations

The practical considerations in field measurements relate to ethical considerations and cost considerations.

Ethical considerations. On 4 May 1993, a curious new story broke over the worldwide CNN network about a scandal related to the dosing of 'radio-active pills' to Alaskan Indians and Eskimos during US Air Force inspired research into the adaptation to severe cold during the heart of the Cold War in the 1950s. 'Were the Eskimos used as guinea-pigs?' is what the 1990s Alaskan Senator wants to know. Well, we have the issue of hazard and risk, joining the issue of informed consent, joining the issue of healthy subjects' research. As the story — embellished for the lay viewer — was reported, anyone with medical training realized that what they were talking about was radioiodine thyroid uptake, possibly with thyroid imaging scans. The Eskimo subjects in the 1950s were still hunter-gatherers in lifestyle, and generally were not English-speakers. How 'informed' was any consent they might have provided, given the linguistic and conceptual barrier? In a clinical context, one would hardly hesitate to recommend a thyroid-uptake test and radioscintographic thyroid scan; it is of low risk, and of enormous diagnostic benefit in clarifying a diagnostic situation. It is of some risk from long-lasting radiation exposure; of what benefit is it to the individual healthy Aleutian or Inuit to have the test? In this particular case, the knowledge gained was to benefit a population, and since the US Military — not the native Alaskans — was the favored population, the 40-year-old experience was sufficient to represent a news headline and a political football.

The exposure to any risk or discomfort in the field setting can be questioned at any time. All research procedures must be duly reviewed and assessed by the institutional review board in the research approval process, but decades from now, a lawyer or news reporter may reopen the issue. In healthy persons, with no benefits to gain from a test, an intensive scrutinity must be given and exhaustive assurance that assent and consent were truly informed must be established.

Related to the ethical considerations are those of feasibility of application related to the cultural acceptability of the technique. Populations may accept techniques that are hazardous to their health, but reject some which have no health implications because they offend norms of the culture. In anthropometry, the removal of certain garments of clothing by an observer, even of the same sex, may impede the obtaining of certain measurements[1].

Cost considerations. The cost of a test is the result of the expenses for the instrument (initial outlay, maintenance) and the operational costs per measurement (subject cost, labor, disposables). The investment for the instrument can be huge or trivial, but the more measurements that are made the lower becomes the average cost of each test, eventually approaching the ongoing operational expenses. The simplest paradigm of cost considerations would be to choose the techniques for measurement that have the absolutely lowest cost; in theory one could maximize the test performed for a given ceiling of resources. Generally, however, one discards this paradigm in favor of one that looks at the cost-effectiveness of learning what one wants to learn from the exercise. This begins with one's factoring in the minimal population sample-size needed for statistical confidence limits, and the exact biological questions that need to be addressed. The final cost paradigm thus becomes a complex interplay of judgements and considerations. If a test with a higher validity and precision — but higher cost — obligates a lower number of measurements, one has a favorable trade-off. Finally, if a low-cost procedure fails to reliably address the biological issues of interest, its application is no bargain at any price!

Quantitative considerations

The prime considerations in the quantitative domain are the accuracy and precision of a measurement, per se, and its reliability when used in screening to classify individuals diagnostically.

Accuracy. Accuracy is the ability of a measurement system to achieve the 'right answer' (correct value), as arbitrated by a 'gold standard' method. It may be necessary to take the average of multiple measurements to achieve maximal accuracy.

Precision. Precision is the ability of a measurement technique to produce a consistent, stable value. It is the reproducibility or repeatability of a measure. This can be effected by the inherent biological oscillation of the variable measured, by intrinsic variability of the measuring instrument, by the stability of technique within an observer, and/or by the degree of standardization and calibration between or among multiple measures and or instruments.

Sensitivity and specificity. A measurement, per se, is descriptive, but diagnostically neutral. However, one gives it diagnostic meaning by establishing a cut-off criterion, above or below which 'abnormality' is defined. When it comes to a screening test, one can determine how frequently the measure correctly detects the abnormal-status condition when it truly exists, as determined by a gold standard; this is known as the 'sensitivity' of the measure. One is also interested in how frequently the measure correctly detects the *normal*-status ;situation, when the person is truly free of the abnormal condition. This is known as the 'specificity' of the measure.

It is also usual to define another quantitative diagnostic quality, which is the predictive value of a positive test, meaning how often is abnormal deviance of the measurement truly reflective of the condition in question. The converse is the predictive value of a negative test, meaning how often is the failure to detect the condition truly an assurance of normalcy.

Biological considerations

Suppose we have a measure that is ethical to measure, inexpensive to measure, precisely and accurately measured. The proof of the pudding becomes the *meaning*, that is, the biological interpretation. Does the measure or the index faithfully address the question one is proposing to ask? One concern is 'overweight'. This operationally would be an inappropriate body mass in relation to height. From normative curves, one could determine the outliers on the heavy side of the distribution and classify excess weight. However, overweight may have different classificatory and health implications if the excess is muscle tissue or fat mass. A more refined concern is overweight due to *excessive fattiness* or *adiposity.*

What are the low-cost anthropometric options in field assessment of body composition?

In Table 1 are listed the tools and techniques that could conceivably be used to assess body composition; not all of them, of course, are appropriate for the field. Recently, Deurenberg reviewed an even more extensive list of methods with comments on utility and cost. The reader is referred to that paper[2].

With respect to weight, both accuracy and precision are important. The intrinsic discrimination of the instrument need not be greater than 0.5 kg, but in the field context it must be portable, durable and maintain its calibration. If *multiple* instruments are used to gather data for a common data-pool, they must be inter-calibrated frequently to eliminate systematic bias from site to site. If an 'extravagance' has to be made, investing in balances that maximize portability, durability and measurement stability, despite a higher purchase price, is a wise decision for the field setting.

The instruments for measuring height and surface dimensions are relatively trivial in price. The professional, manufactured knee-height caliper is available (Medical Express, Beaverton, Oregon, USA) but a home-made variety can be made for a lower cost. The measurement of skinfold thicknesses are generally made with spring calipers, either with the North American variety, Lange calipers (Lange, Cambridge, Maryland, USA) or with the European brand, Holtain calipers (Holtain, UK). Infrared (IR) (refractometry) spectrophotometry has been advanced as a method for assessing subcutaneous fat[3]. It has been called an 'expensive skinfolds caliper'. Nothing convinces us the IR refractometry has any advantage over calipers in assessing subcutaneous fat layers.

Table 1. Classification by categories of techniques available for the assessment of human body composition.

ANTHROPOMETRY		
	Surface Measurements	
		Standing height (stature)
		Armspan
		Knee-height
		Circumferences (diverse sites)
	Thickness measurements	
		Skinfold thicknesses (diverse sites)
DILUTION METHODS		
	Deuterium dilution	
	Tritium dilution	
	Bromide dilution	
	Sulfate dilution	
ELECTROMAGNETIC		
	Bioelectrical impedance analysis (monofrequency)	
	Bioelectrical impedance analysis (multifrequency)	
	Total body electroconductivity (TOBEC)	
IMAGING		
	Single-photon	
	Dual-photon	
	Dual-X-ray	
	Computerized tomography (CT)	
	Infrared refractometry	
	Magnetic resonance imaging (MRI)	
ENDOGENOUS RADIATION		
	Potassium 40 content	
	Whole body neutron activation analysis	

Dilution techniques for water spaces — total body water; extracellular water; intracellular water — exist. If only total body water is of interest, the test can be very non-invasive with collection of urine, saliva or even tears. For the differentiated water spaces, however, in most laboratories a sample of blood must be obtained. Bioelectrical impedance analysis, especially the emerging multifrequency BIA, is inexpensive after the initial equipment is purchased.

Applying low-cost anthropometric measures in field studies: some experiences from Guatemala

In Guatemala, as in other developing countries, the first approach has been standard measurements of mass, surface dimensions and thicknessess. These require only a balance, metric tape and skinfold calipers, all non-invasive and eminently portable. Over the past eight years, CeSSIAM has obtained the basic measures in over 1000 elderly and perhaps 5000 children. In Guatemala, we generate the Quetelet body mass index (BMI) as the index of comparison for adults and elderly, given the cut-off criteria for undernutrition[4,5] and for overweight and obesity[4]. In children, we have generally related the height and weight data to the internationally accepted reference standards for the US National Centre for Health Statistics (NCHS), in terms of weight-for-age, height-for-age and weight-for-height.

We have, however, had to temper our acceptance of the interpretive standards with critical skepticism. Do the same criteria for critical underweight (chronic energy deficiency) apply all the way up to the third age? Until functional and/or mortality correlations are made with BMI in a longitudinal fashion in Guatemala and elsewhere in the very elderly, we remain skeptical of the <20 kg/m[4] or <18.5 kg/m[5] cut-off criterion for undernutrition in the older population.

Armspan is the distance from fingertip to fingertip with the arms extended laterally, parallel to the ground, to the maximal extent. As long bones do not change in length with aging, and since the height/armspan ratio is approximately 1.0 in early adult life, Dequeker et al.[6] recommend this index for determining the loss of height with advancing age. In two rural Guatemalan communities, Vasquez et al.[7] of CeSSIAM measured this index in 1475 persons across the spectrum of age.

Bioelectrical impedance analysis (BIA) has been advanced as a method for assessing total body water, and hence the size of lean body mass[8]. In preschool children of a poor, peri-urban community in Guatemala, CeSSIAM staff members measured basic anthropometry and conducted BIA determinations in over 2700 individuals[9]. Of interest was the close correlation of the BIA index (height squared/resistance) with other anthropometric measures. More recently, Manolo Mazariegos and Micheal McCormick have begun to explore the use of *multifrequency* BIA in young children. This is a technique that portends the possibility of distinguishing intra- and extracellular water and the integrity of cell membranes with the same, simple non-invasive approach.

Conclusion

Arguably, the diversity of applications and volume of measurements would be much greater in the field setting, ie for epidemiological and public health purposes, than in the clinical context in the interaction of patient and practitioner. Even if it were not for the differentially greater risk of undernutrition in less developed and underprivileged nations, the fact that the third world population represents three-quarters of the earth's inhabitants would incline the opportunities to the developing and transitional nations. The cost constraints are dual in the third world field setting. First, it is more difficult to justify the use of scarce resources on diagnosis — as opposed to intervention and action — in confronting public health problems. Secondly, when a course of study is elected, the resources are unlikely to be abundant, and the less expensive the technology the more justifiable is the investigation. It can honestly be said that, were it not for low-cost, acceptable body composition techniques, there would be little opportunity for work in the field in developing countries.

In planning the field application of techniques for body composition assessment, the virtues of precision and accuracy must be weighed. If the purpose is descriptive and comparative, then the accuracy of a method has primacy. If the study, is longitudinal with serial measurements, standardization and precision are at a premium. Many low-cost techniques arise in their biological interpretation. We attempt to use the measures both to define body composition and to classify nutritional status. However, as we see emerging through inter-method comparative calibration exercises, such as the 'Rosetta Stone' project at Columbia University in New York[10], the interpretations given to the measures and indices may not represent their true biological reality. Take the following examples: short stature is not prima facie evidence for 'chronic undernutrition;' waist/hip circumference ratios may not reflect the intra-abdominal distribution of fat; body mass index cut-off criteria may not be generalizable across ethnic groups. Thus, a field worker sees an urgent need to co-correlate low-cost techniques with their more direct and probing 'gold standards.'

Field workers have long been wedded to anthropometric techniques. The 'brave new world' before us is to move the paradigm from nutritional status classification, to an assessment of the composition of the body at all of the five levels suggested recently by Wang[10], and to do it within budgetary constraints. We must link biology and engineering and harness their effort to permitting maximum 'resolution' of body composition with minimum invasiveness and cost.

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