3D optical scanning for clinical body shape assessment comes of age

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Simple measurements of body shape have long been used to assess nutritional status. Even body mass index (BMI), which adjusts weight for height, represents a very crude index of relative volume, but provides no information on where body weight is anatomically distributed. Measuring body girths represents a first step to address this.

Many girths have been applied to specialised clinical tasks. The mortality risk associated with child undernutrition is indexed by thresholds for mid-upper arm girth,[1] while waist girth or the waist-hip ratio is used to assess central adiposity in relation to cardiovascular risk. For example, a study of 27,000 adults in 52 countries showed that waist girth was a more sensitive predictor than BMI of myocardial infarction.[2]

Nevertheless, girths remain very crude measurements of shape. A girth is simply a linear distance around the surface of a body component, and offers no information on the shape contained by that perimeter, nor the composition of the underlying tissues.

Over the last decade, a technique known as 3-dimensional photonic or optical scanning (3DOS) has emerged, capable of assessing shape in much greater detail.[3] Although the technology varies, all 3DOS methods project light onto the body and record the surface topography. Initial data capture provides a 'point-cloud', which is processed using computer algorithms. Automatic landmark identification allows an 'e-tape measure' to be applied, extracting multiple girths, distances, diameters and cross-sectional areas.

Early national surveys of clothing size demonstrated that 3DOS is simple to apply in large populations and is well accepted, including in children.[4] These surveys showed profound shape variability within a given BMI level in women, less so in women.[5] Ethnic groups also differed in shape, again adjusting for BMI,[6] which may reflect varying cardiovascular risk in association with weight gain.

However, these early studies also had limitations. First, 3DOS was not originally designed for biomedical application, rather for updating clothing sizes. The manufacturers' software was somewhat primitive, and inaccurate reconstruction of the body surface and incorrect landmark identification could introduce significant error. Overall, early use of 3DOS increased the speed of measuring large numbers of humans, but did not transform our understanding of the relationship between shape and health.

Given that complete assessment of body topography quantifies body volume, one possible application of 3DOS would be in densitometry, where body composition is estimated using Archimedes' principle. However, densitometry is highly sensitive to errors in the assessment of volume, and imperfect surface-fitting algorithms, and difficulty in accounting for air in the lungs, resulted in very wide limits of agreement with other methods of volume assessment.[7]

These limitations were quickly recognised, and alternative approaches were proposed to index shape variability and its health correlates. In the UK Sizing survey, Independent Components Analysis was used to identify different aspects of shape variability, including overall size, the centrality of weight distribution, and torso posture (**Figure 1**).[5] These new outputs more genuinely describe shape variability, and moreover are statistically independent of each other, and so might perform better cumulatively in predicting clinical outcomes. However, the problem at this stage was that the large sizing surveys had no data on health outcomes.

The challenge of using simple markers of shape, such as girths as highlighted above, is that they may not relate well to body fat distribution, in which case they may also be poor predictors of cardiovascular risk. The clinical potential offered by 3DOS is illustrated in **Figure 2**. Composite shape outputs could potentially correlate better both with body fat distribution measured by gold standard methods such as magnetic resonance imaging (MRI), and with biomarkers of cardiovascular risk.

The report in this issue by Bennett Ng and colleagues therefore takes a key step forward, by demonstrating the validity of this conceptual approach for the first time.[8] They generated new composite 3DOS shape outputs in over 400 adults, using principal components analysis. They then tested the associations of these shape outputs with markers of adiposity obtained by dual X-ray absorptiometry, and with biochemical markers of cardiovascular risk. As anticipated, the new composite shape outputs correlated substantially better with both adiposity and cardiovascular risk than did conventional anthropometric measurements.

To achieve the full benefits of this approach, further work is still required. The authors have so far studied healthy subjects, and need to repeat the approach in people characterised by a range of diseases. Ethnic groups differ in subtle but important ways in all of these traits – body size, regional tissue distribution, and cardiovascular risk markers.[9] Obtaining gold standard measurements of adiposity using MRI might help address these differences, improving the capacity to predict metabolic risk on an ethnic-specific basis. Finally, computer scientists need to improve the algorithms for reconstructing the body surface topography and key landmark identification.

Nevertheless, the potential of this approach is exciting. Compared to many medical technologies, 3DOS is relatively cheap, easy to operate, and well tolerated by most individuals. Beyond clinical use, the technology is now found in health clubs, allowing regular monitoring of shape. Personalised dynamic models could be generated to predict the impact of shape change on adiposity.[10] On the plus side, people are inherently more interested in how they look to the human eye than in the details of their adipose tissue depots. 3DOS is a technology that could connect patient and clinician in new and valuable ways. But a word of caution: both men and women, particularly in adolescence and early adulthood, may become obsessed by their body shape, and this may lead to problems such as eating disorders and steroid use in the pursuit of distorted norms. The measurement and interpretation of body shape must therefore be addressed with sensitivity.

Legends for illustrations

Figure 1. Front and side views of women from SizeUK, with each image displaying the body shape characteristic of women at ±2 standard deviations. From left to right, the pairs of images illustrate different dimensions of body shape variability, using independent component analysis (ICA): (a) overall torso size, (b) shape attributable to height and chest

girth, (c) upper torso posture, (d) lower torso posture. Reproduced with permission from Wells et al.[5] Copyright A Ruto 2007.

Figure 2. Schematic diagram showing how 3DOS may play a new role in clinical practice. 3DOS may be better than BMI at indexing fat distribution as measured by gold standard methods such as MRI, and improve the ability to monitor cardiovascular risk.

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Figure 1

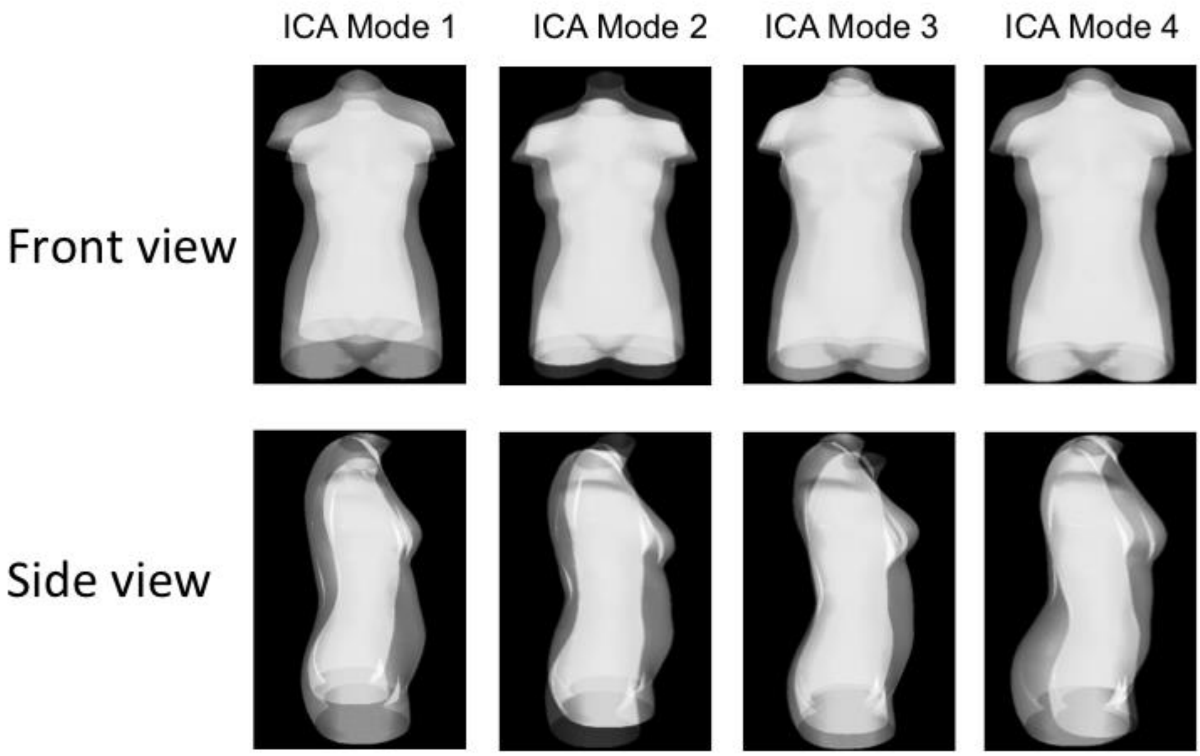
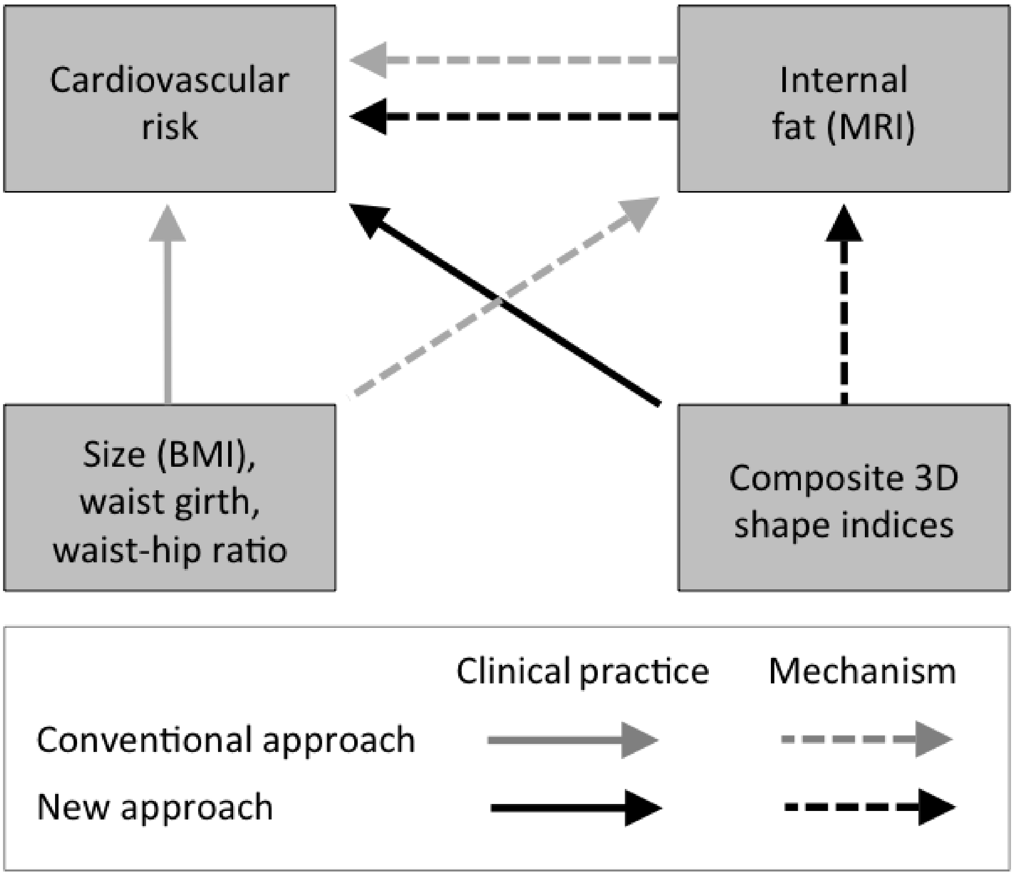


Figure 2


Cardiovascular risk
Internal fat (MRI)
Size (BMI), waist girth, waist-hip ratio
Composite 3D shape indices
Clinical practice
Mechanism
Conventional approach
New approach