FROM 3D SCANNERS TO SMARTPHONE-BASED DIGITAL ANTHROPOMETRY: A PRELIMINARY METHODOLOGICAL STUDY FOR PHYSICAL EDUCATION AND SPORTS PEDAGOGY

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Abstract
The study presents the SOMATON digital anthropometry framework and preliminary results from 363 anonymized 3D body scans. It examines whether smartphone-based image data could become a scalable complement to 3D scanning for estimating body dimensions, joint positions and morphological typology in physical education and sports pedagogy.

Key words
digital anthropometry, photogrammetry, body typology, physical education, 3D scanning, smartphone imaging, machine learning

1 Introduction

Educational and sports practice often works with simplified indicators of the human body, such as height, body mass, body mass index or general somatotype categories. These indicators are useful for basic orientation, but they do not capture the complexity of body proportions, segment lengths, joint positions, lever relationships or the position of the centre of gravity. In physical education and sports pedagogy, this limitation is important because children, adolescents and athletes are frequently compared through identical performance tasks despite having different morphological preconditions.

Classical somatotype models, especially the Sheldon and Heath-Carter approaches, played an important role in the development of human body classification (Sheldon, 1940; Heath & Carter, 1967). However, they were developed in a period when current technologies such as 3D body scanning, computer vision, parametric modelling and machine learning were not available. Current digital technologies make it possible to describe human morphology in greater detail and to examine how body proportions may be related to movement performance, training adaptation, injury risk and pedagogical individualization.

The SOMATON project was developed as a digital anthropometry framework focused on a more detailed description of body morphology. The project does not aim to label individuals in a deterministic way. Its purpose is to build a data-based model of body variability that can be validated, criticized and further developed. In the educational context, such a model may support a more sensitive interpretation of movement differences among pupils and athletes. It may also help reduce inappropriate comparison of individuals whose physical performance is influenced not only by motivation and training history but also by body structure.

The present study transforms a previous conference contribution into a preliminary scientific study. It reports selected results from an anonymized 3D scan dataset and proposes a validation pathway for the next research phase: estimating selected anthropometric parameters from smartphone-based image data. The central issue is not whether a smartphone can replace a 3D scanner in all situations, but which parameters can be estimated with sufficient accuracy for educational, sports and preventive use.

2 Aim and research questions

The aim of this study is to present the SOMATON framework as a preliminary methodological model of digital anthropometry for physical education, sports pedagogy and interdisciplinary educational research. The study has two specific objectives: first,

to summarize selected preliminary results obtained from 3D scans and algorithmic body typology; second, to define a future validation design for estimating body dimensions and joint positions from two-dimensional image data.
The study addresses the following research questions:
RQ1: What preliminary distribution of morphological body types can be observed in an anonymized dataset of 363 3D-scanned adults?
RQ2: Which categories of anthropometric parameters form the core of the current SOMATON digital anthropometry framework?
RQ3: What methodological steps are required to validate smartphone-based image estimation against 3D scanning and manually annotated anthropometric data?
RQ4: How can digital anthropometry contribute to physical education and sports pedagogy without becoming a stigmatizing or deterministic classification tool?

3 Theoretical background

Anthropometry provides a methodological basis for describing the structure and proportions of the human body. Traditional field methods often include height, body mass, circumferences, skinfolds and selected breadths. These variables remain useful, but their isolated interpretation can be insufficient when the objective is to understand movement predispositions or pedagogical differences in motor tasks. Body structure is relational: the meaning of a body segment depends on its proportion to total body height, neighbouring segments, pelvis and shoulder breadths, and the functional task being performed.
Somatotype models historically attempted to capture stable patterns of body constitution. The Sheldon system used three broad categories, while the Heath-Carter method introduced a more quantitative evaluation of endomorphy, mesomorphy and ectomorphy (Heath & Carter, 1967). The limitation of these approaches is not that they are useless, but that they may be too general for present-day digital analysis. They may insufficiently describe segmental ratios, joint positions, morphological asymmetry and multidimensional body patterns.
Three-dimensional scanning and computer vision create new possibilities for educational and sports research. A 3D body scan can be used to identify anthropometric landmarks, calculate distances, circumferences, volumes and proportional indices, and compare individuals with reference models. In the next stage, image-based methods may reduce technological barriers. Smartphone imaging, if validated against 3D scans and manually annotated data, could make repeated body assessment more accessible in schools, clubs and community prevention programmes.
A key methodological distinction must be made between conceptual visualization and scientific measurement. A visually attractive digital model is not sufficient for research use. Each output, such as shoulder width, limb length, waist circumference, centre-of-gravity-related approximation or joint position, must be validated separately against a reference method. This is consistent with the logic of method-comparison research, where correlation alone is not sufficient to demonstrate agreement between methods (Bland & Altman, 1986; Atkinson & Nevill, 1998).

4 Materials and methods

This study uses a preliminary methodological design based on an anonymized SOMATON dataset. The dataset includes 363 adult participants selected from a larger archive of more than 500 digitally scanned individuals. The dataset contains both men and women with varied body morphology and physical activity background. The aim of the present article is not to provide a final population norm, but to report preliminary distributions and formulate a research pathway for further validation.
The initial data layer was obtained using a proprietary 3D body scanning system. The system enables the capture of a full-body surface representation in a standardized standing position. The analytical software allows the marking of key anthropometric

landmarks and the calculation of selected length, width, circumference and volume variables. In the present framework, more than 50 morphological indicators can be considered for body pattern analysis.

The current SOMATON typology works with five preliminary morphological tendencies labelled A-E. These tendencies are not intended as fixed personality or performance categories. They are algorithmic body-pattern models that express the degree of similarity between a scanned subject and each reference pattern. The output is therefore a percentage similarity profile rather than a rigid binary assignment.

Anthropometric variables are grouped into four main categories: length parameters, width parameters, circumference parameters and volume/proportional parameters. Examples include trunk length, lower limb segment length, arm span to body height ratio, shoulder width, pelvis width, waist circumference, chest circumference, relative pelvis volume and relative trunk volume. In further work, joint localization is treated as a separate but related computational task because it may support both anthropometry and movement analysis.

The planned smartphone-based validation pathway consists of four steps. First, the image is preprocessed by removing the background, correcting perspective and aligning the body posture. Second, key body points and joint positions are estimated. Third, a parametric body representation is generated from the image input. Fourth, regression models estimate selected body dimensions and classification models estimate the morphological profile. Each module must then be compared with reference data from 3D scans and manual annotation.

5. Preliminary results

The preliminary typology analysis of 363 scanned subjects showed that all five morphological tendencies were represented in the dataset. The distribution was not uniform, but no type was absent. This supports the assumption that the proposed model captures several distinct morphological directions rather than one dominant body pattern.

Table 1: Preliminary distribution of body types in the full anonymized dataset (n = 363)

Body type	Number of subjects	Percentage
Type A	85	23.4%
Type B	74	20.4%
Type C	63	17.4%
Type D	92	25.3%
Type E	49	13.5%

Source: anonymized preliminary SOMATON dataset; compiled by the authors.

Type D had the highest representation in the full dataset, followed by Type A and Type B. Type E had the lowest representation. These results should be interpreted cautiously because the dataset is preliminary and not yet a representative population sample. However, the distribution is useful for the development of validation studies because it shows that the model must be tested across several morphological profiles, not only in an average body shape.

Table 2: Examples of variables included in the SOMATON framework

Variable category	Examples	Relevance for education and sport
Length parameters	trunk length, limb segments, arm span	lever relationships, movement technique
Width parameters	shoulders, pelvis, hips, joints	body proportions, stability, sport specificity
Circumference parameters	chest, waist, hips, thigh, calf	morphology, body composition context
Volume/proportions	trunk, pelvis, head ratios	morphological profile, longitudinal monitoring
Joint positions	neck, shoulders, elbows, wrists, hips, knees, ankles	movement analysis, posture and motor evaluation

Source: anonymized preliminary SOMATON dataset; compiled by the authors.

Gender-specific preliminary observations suggest that male and female distributions may differ. In the previous analytical phase, Type A and Type D were more frequent among men, while the female distribution appeared more balanced across the five tendencies. Such findings are consistent with the need to evaluate male and female morphology separately in further research. They also support the requirement for larger, more diverse datasets before any pedagogical or sports recommendation can be made. The current results are therefore best understood as methodological and exploratory. They confirm that 3D scanning and algorithmic typology can generate structured outputs that are suitable for further validation. At the same time, they show that a smartphone-based approach cannot be introduced as a universal replacement without parameter-specific error analysis. Length and width variables are expected to be more stable in image-based estimation, while circumferences and volumes will likely require stronger modelling assumptions.

6. Discussion

The preliminary findings support the usefulness of digital anthropometry as a research tool for physical education and sports pedagogy. The main contribution is not the creation of a final body classification, but the formulation of a framework that connects body morphology, educational interpretation and computational modelling. This is important because pedagogical practice often evaluates motor performance without sufficient information about body structure. A child with a different trunk-to-leg ratio, shoulder-to-pelvis ratio or centre-of-gravity-related body pattern may experience the same movement task differently from peers.

For sports pedagogy, the proposed framework may help coaches and teachers interpret individual differences more precisely. In jumping, sprinting, gymnastics, combat sports or swimming, segment lengths and leverage conditions can influence technique and adaptation. This does not mean that body type should determine sport participation. Instead, it can provide an additional layer of information for individualization. The ethical challenge is to prevent morphological data from being used as a selection label that limits participation.

For education, the concept of anthropometric empathy is central. Teachers may benefit from understanding that differences in motor performance are not explained only by effort, discipline or motivation. Some differences are also related to body morphology, motor history and maturation. Digital anthropometry could therefore contribute to a more individualized and less stigmatizing approach in physical education, provided that data are interpreted carefully and with appropriate ethical safeguards.

From a technological perspective, the most important next step is validation. Smartphone-based photogrammetry and image analysis are promising because they

may reduce cost and logistical barriers. Nevertheless, the scientific value of the approach depends on agreement with reference measurements. The planned validation should therefore compare estimated values with 3D scan outputs and manually annotated landmarks. Bland-Altman analysis, mean absolute error, root mean square error and regression-based error modelling should be used for method comparison (Bland & Altman, 1986; Atkinson & Nevill, 1998).

The article also contributes to the educational research field by proposing a research infrastructure, not only a single technical application. The SOMATON framework can generate research questions for doctoral students and interdisciplinary teams: Which body variables are stable enough for school use? Which variables require laboratory-level accuracy? How should results be presented to teachers, pupils and parents? Which outputs are useful for pedagogy, and which should remain in the research domain?

Limitations

This study has several limitations. First, the dataset is preliminary and was not designed as a representative national sample. Second, the current article reports selected exploratory results rather than a completed validation of smartphone-based measurement. Third, the typological model is still under development and requires replication in larger, sex-specific and age-specific samples. Fourth, some body dimensions, especially circumferences and volumes, may be difficult to estimate accurately from two-dimensional images without parametric modelling.

Another limitation concerns educational interpretation. Even if future measurement accuracy is sufficient, body typology must not be used as a deterministic label. The goal is not to decide what a child can or cannot do. The goal is to understand how body structure may influence movement tasks and how teaching or training can be adapted. Future research must therefore combine statistical validation with ethical guidelines and pedagogical training.

Ethical considerations

The use of photographs, 3D scans and body measurements raises important ethical questions. Digital anthropometric data are sensitive personal data and require informed consent, anonymization, secure storage and data minimization. In school-based research, additional safeguards are necessary because children and adolescents represent a vulnerable population. Any future application must comply with data protection rules and should avoid visual or verbal outputs that could stigmatize participants.

The authors recommend that digital body typology should be used only as an interpretative and educational support tool. It should not be used as an exclusion criterion for sport participation or as a simplified prediction of talent. The educational value of the system depends on how responsibly results are explained and applied.

7. Conclusion

The SOMATON project represents a preliminary methodological framework for digital anthropometry in physical education, sports pedagogy and interdisciplinary educational research. The current 3D scan-based system provides structured data on body dimensions, proportions and morphological tendencies. Preliminary results from 363 anonymized subjects show that several body-pattern tendencies can be identified and compared.

The next research phase will test whether smartphone-based image data can estimate selected body parameters with sufficient accuracy. The scientific condition for this transition is careful validation against 3D scans and manually annotated data. If such validation is successful, digital anthropometry may become more accessible for schools, sports clubs and preventive programmes. Its main value should not be rapid classification, but a more precise and ethically responsible understanding of human body variability.

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Bibliographic references
Ackland, T. R., Lohman, T. G., Sundgot-Borgen, J., Maughan, R. J., Meyer, N. L., Stewart, A. D., & Müller, W. (2012). Current status of body composition assessment in sport. Sports Medicine, 42(3), 227-249.
Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error reliability in variables relevant to sports medicine. Sports Medicine, 26(4), 217-238.
Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, 327(8476), 307-310.
Carter, J. E. L., & Heath, B. H. (1990). Somatotyping: Development and Applications. Cambridge: Cambridge University Press.
Durnin, J. V. G. A., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness. British Journal of Nutrition, 32, 77-97.
Heath, B. H., & Carter, J. E. L. (1967). A modified somatotype method. American Journal of Physical Anthropology, 27(1), 57-74.
Heyward, V. H., & Wagner, D. R. (2014). Applied Body Composition Assessment. 2nd ed. Champaign: Human Kinetics.
Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. British Journal of Nutrition, 40(3), 497-504.
Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Gómez, J. M., et al. (2004). Bioelectrical impedance analysis, Part I: Review of principles and methods. Clinical Nutrition, 23(5),. 1226-1243.
Ling, C. H. Y., de Craen, A. J. M., Slagboom, P. E., Gunn, D. A., Stokkel, M. P. M., Westendorp, R. G. J., & Maier, A. B. (2011). Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition. Clinical Nutrition, 30(5), 610-615.
Nana, A., Slater, G. J., Stewart, A. D., & Burke, L. M. (2015). Methodology review: Using dual-energy X-ray absorptiometry for the assessment of body composition in athletes and active people. International Journal of Sport Nutrition and Exercise Metabolism, 25(2), 198-215.
Sheldon, W. H. (1940). The Varieties of Human Physique: An Introduction to Constitutional Psychology. New York: Harper & Brothers.
Zlatos, V., Simonek, J., Vadura, J., & Krcmar, M. (2026). Comparison of methods for estimating body fat percentage using skinfolds, InBody, and DXA: A pilot study. Journal of Physical Education and Sport, 26(4), 826-834. https://doi.org/10.7752/jpes.2026.04083

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