BEAM 2026

Enhancing PassFit:

Anthropometric Outputs with User-Defined Dimensions

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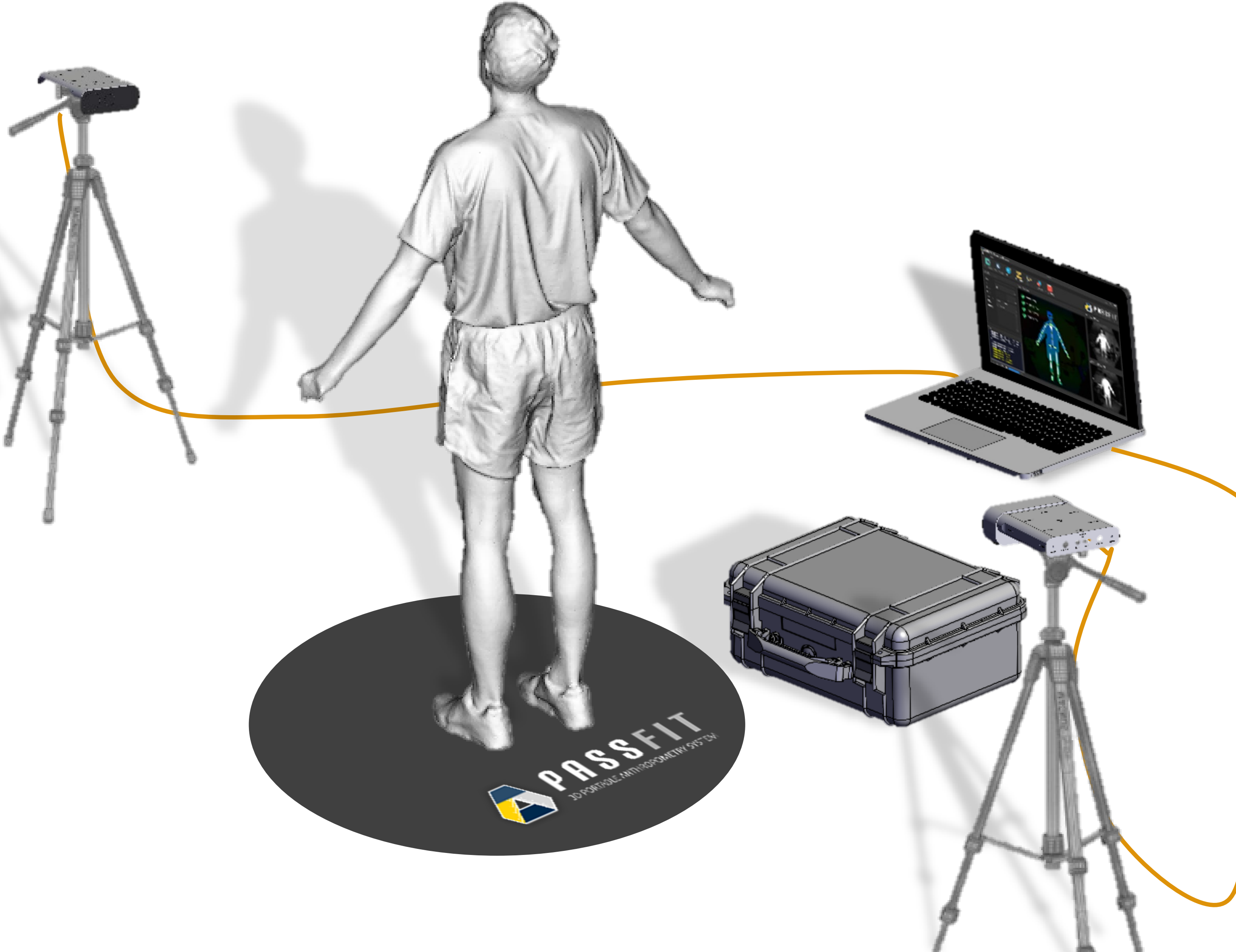
PassFit Overview

Portable, privacy-safe body measurement without scanning suits or fixed studio infrastructure.

- **Portable field kit**
  Two depth sensors, a laptop, an alignment panel, and a foot mat travel as a compact deployable system.
- **Fast survey workflow**
  Quick capture and processing support high-throughput anthropometric data collection in operational settings.
- **Clothed-body scanning**
  PassFit estimates body shape and dimensions from lightly clothed participants rather than minimally clad protocols.
- **Secure local processing**
  No personally identifying scan data is transmitted to a remote server during routine use.



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Current PassFit Pipeline

A statistical body shape models convert clothed point cloud scans into standard anthropometric outputs and sizing-ready data.

1

Body Shape Scanning

Capture clothed-participant point clouds from two synchronized depth sensors.

2

Statistical Shape Model Fitting

Fit the statistical body model and estimate low-dimensional body-shape PC scores.

3

Standard Output Estimation

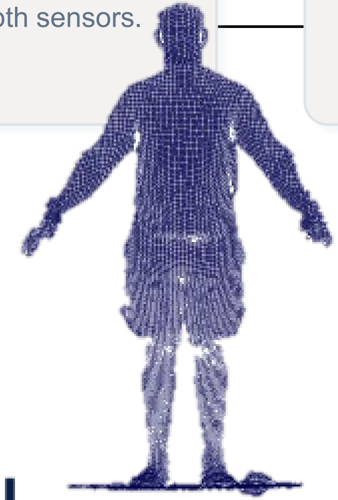
Predict 136 standard anthropometric dimensions from shape descriptors and related inputs.

4

Operational Applications

Deliver outputs for anthropometric survey, anthropometric qualification, and garment or PPE sizing.

- Anthro. survey
- Anthropometric qualification
- Garment / PPE sizing



Why extend PassFit beyond standard outputs?

PassFit already reports ANSUR-equivalent body dimensions, but many deployments need outputs beyond the standard set.

1. **Measurement definitions/protocols vary**
   Landmark choice, tape path, posture, and soft-tissue compression can change the value.
2. **Measurement vary from measurer to measurer**
   Inter-measurer variability, Certain measuring style and knowledge
3. **Programs often need additional targets**
   Some applications need body fat %, garment ease, fit indicators, or best-fit size.

What users need in practice

PassFit standard outputs
136 standard anthropometric dimensions

+ Calibration of standard dimensions
Adjust outputs to match local definitions or manual measurement protocols.

+ User-defined body dimensions
Add custom body measures that are outside the standard set.

+ Application-specific targets
Estimate outputs used for sizing, body composition, fit, or readiness analysis.

Modeling Method for Calibration/User-defined Outputs

PassFit provides an automatic modeling method selection for calibrating and predicting general data

User Inputs

- Stature
- Weight
- Sex

PC Scores

- 60 scores from fitted avatar, describing the individual's body shape

Predicted Standard Dimensions

- ANSUR-equivalent 136 PassFit standard outputs

Automatic Model Selection

Elastic Net

*SFS

*GAM

XGBoost

- **Evaluates multiple algorithms**
- **Selects the best performer** based on validation

*SFS: sequential forward selection
*GAM: generalized additive models

Use-provided Target Data

Calibrated dimensions

Adjust to match user definitions or protocols

User-defined dimensions

Custom body measures outside the standard body dimensions

Application-specific targets

Examples: body fat %, garment ease, fit indicators, etc.

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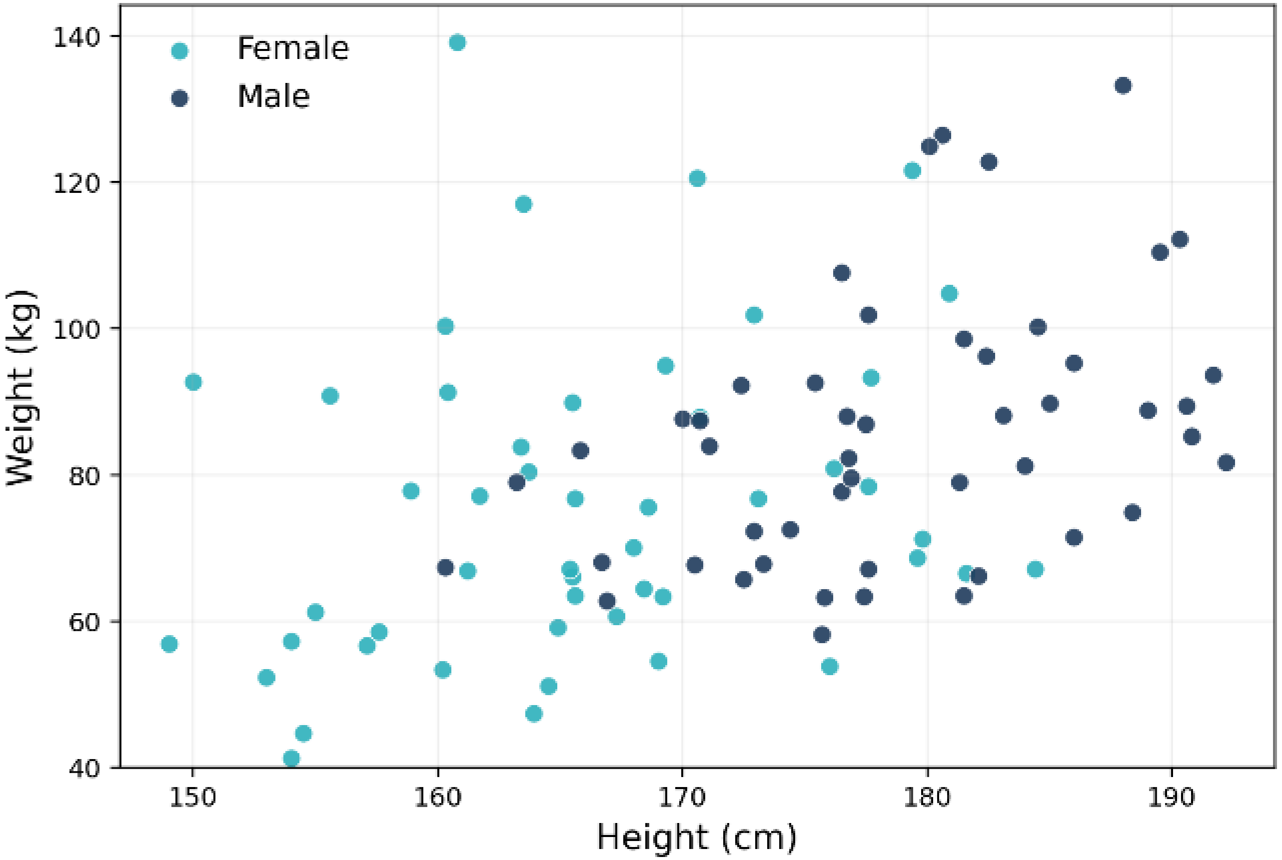
Study dataset used for PassFit development

Study context

- STI-TEC funded a targeted dataset for PassFit development and calibration.
- 50 female and 50 male subjects ages 19 to 45 YO were recruited and measured
- Difficult outputs such as waist, chest, and sitting height were manually reviewed and measured.
- Tanita SC-331S bioimpedance was added for body-fat-related endpoints.

Sample coverage in height and weight



50 / 50
female / male
in target file

27.1
mean BMI
kg/m^2

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Calibration Example: Waist Circumference (Omph.)

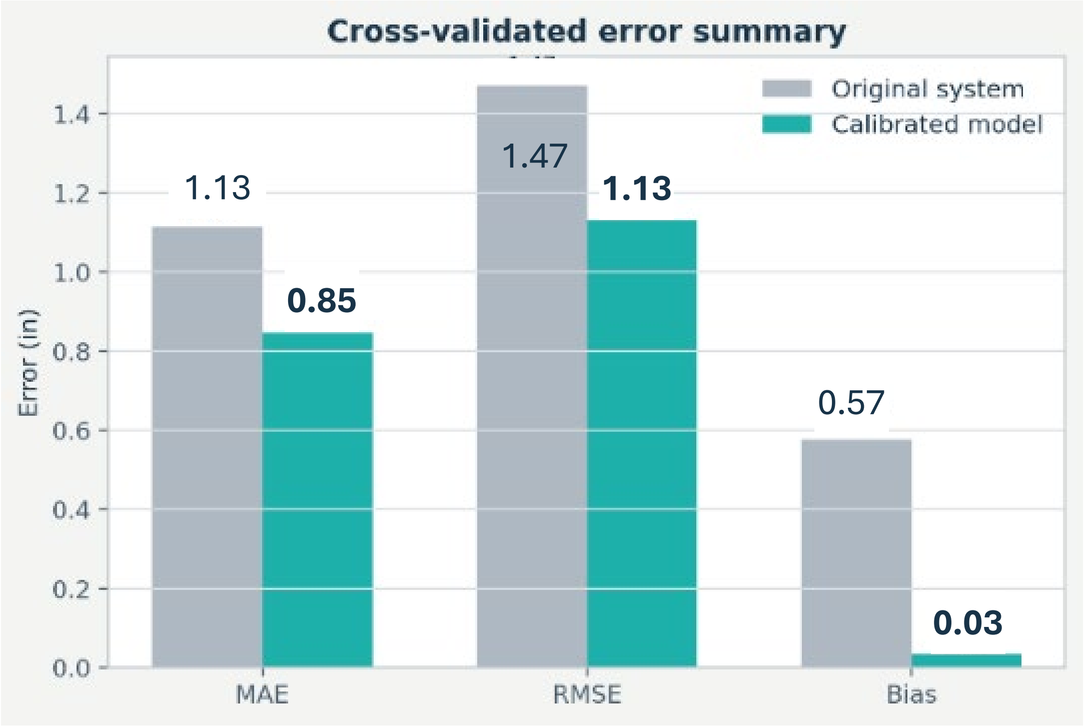
Calibration (SFS + linear regression) cut MAE by 24% and removed most of the systematic positive bias.

0.85 in	**1.13 in**	**0.969**	**0.03 in**
MAE	RMSE	R^2	Bias (orig. 0.57 in)

***MAE** = mean absolute error, i.e., the average absolute difference between predicted and measured waist circumference.

Key signals: WC_pred, Gender, Stature, Weight, PC39, PC28, PC22
Validation: 5-fold CV on the filtered sample

Conclusion: calibration reduced MAE from 1.12 to 0.85 in and centered the bias near zero.



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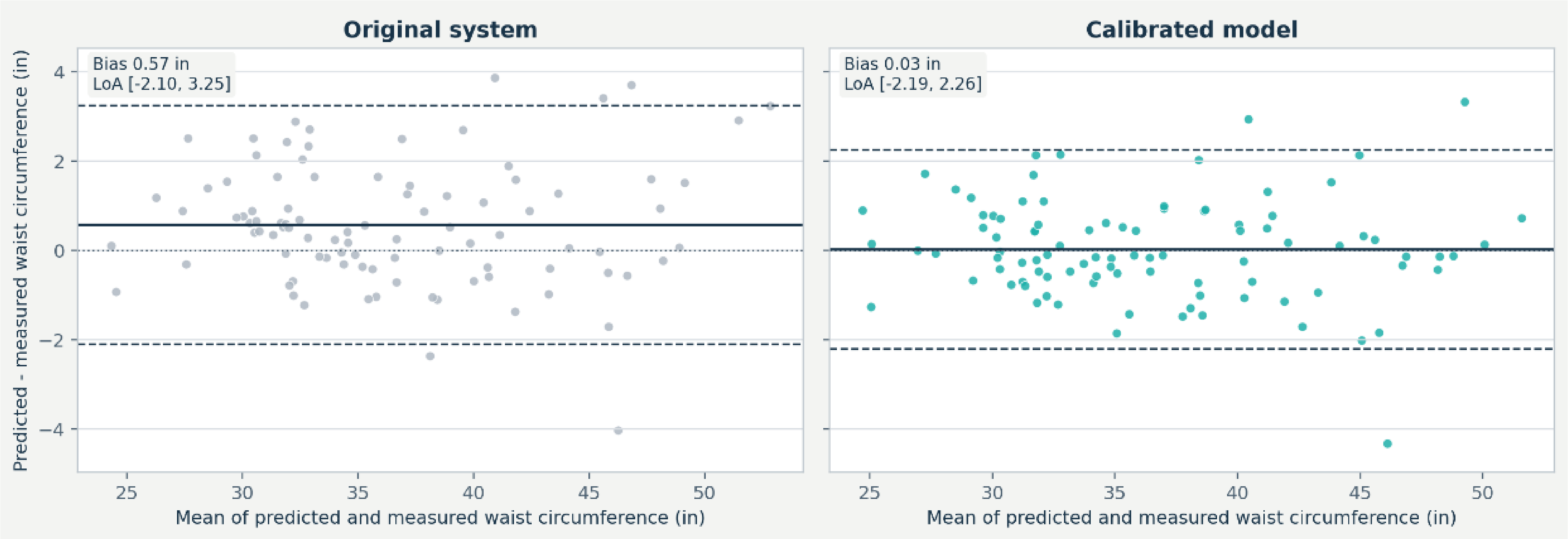
Calibration Example: Waist Circumference (Omph.)

x-axis = mean of predicted and measured waist circumference (in)
y-axis = predicted − measured waist circumference (in).
Solid line = mean bias; dashed lines = limits of agreement.



Interpretation: after calibration, the point cloud is centered much closer to zero bias (0.03 in vs 0.57 in) while the limits of agreement remain tighter.

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Natural Waist Circumference Prediction

98 subjects · 63 predictors (Gender, Stature, Weight, PC1–PC60) · 3-fold cross-validation

SFS(8) + linear regression delivered the best waist circumference prediction at the natural waist.

0.72 in
MAE

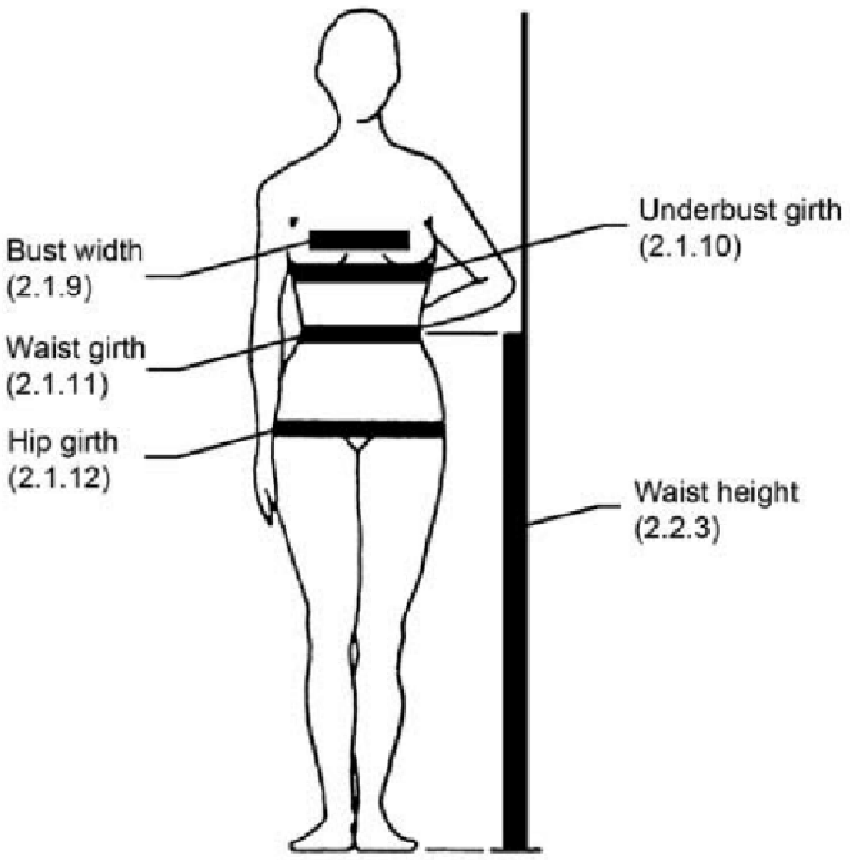
0.91 in
RMSE

0.925
R^2

Key signal Weight plus a small subset of shape PCs (PC12, PC15, PC24, PC46, PC48, PC55) and Gender explained most of the variation.

Cross-validated MAE comparison

$$Waist_{Natural} = \beta_0 + \beta_1 \cdot Gender + \beta_2 \cdot Weight + \beta_{12} \cdot PC12 + \beta_{15} \cdot PC15 + \beta_{24} \cdot PC24 + \beta_{46} \cdot PC46 + \beta_{48} \cdot PC48 + \beta_{55} \cdot PC55$$



Conclusion For this dataset, a sparse linear model outperformed more flexible alternatives. SFS + LM was the most defensible choice for natural-waist circumference prediction.

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Body Fat % Prediction

97 subjects · 63 predictors (Gender, Stature, Weight, PC1-PC60) · 5-fold cross-validation

Elastic Net delivered the most stable and accurate Body fat % prediction.

1.83%
MAE

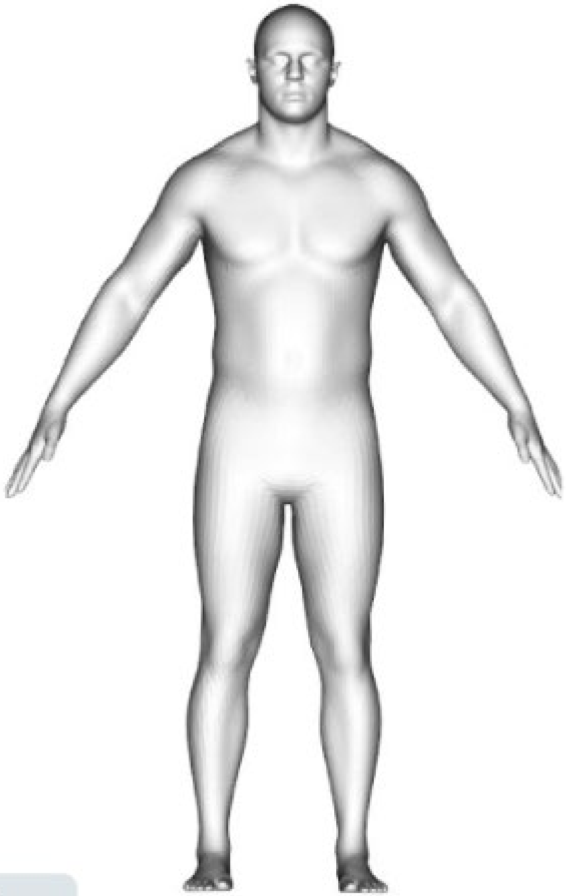
2.39%
RMSE

0.947
R^2

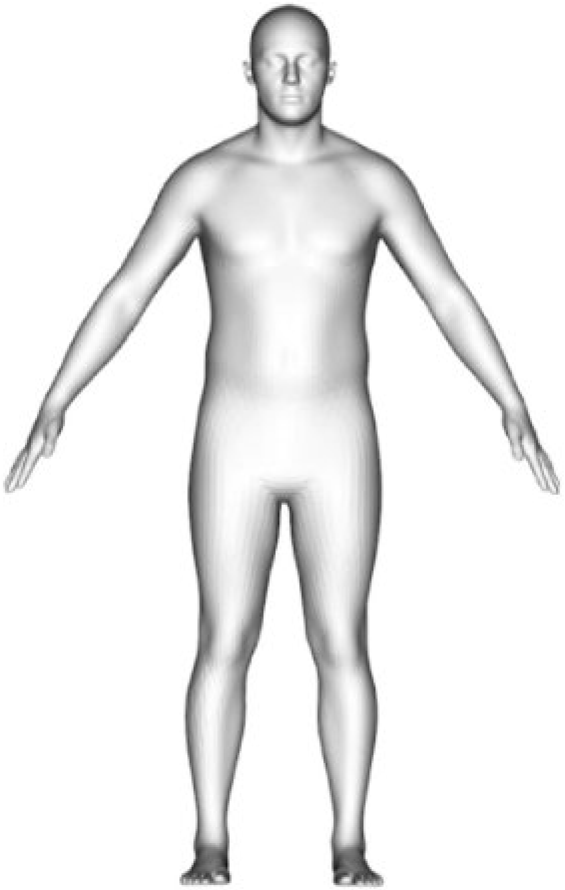
Key signal Weight (+), Stature (-), Gender, PC11, PC45, and PC53 were the main predictors.

Cross-validated MAE comparison

Conclusion For this dataset, a regularized linear model outperformed the more flexible alternatives, and Elastic Net was the most defensible choice for Body fat % prediction.



PC45



PC53

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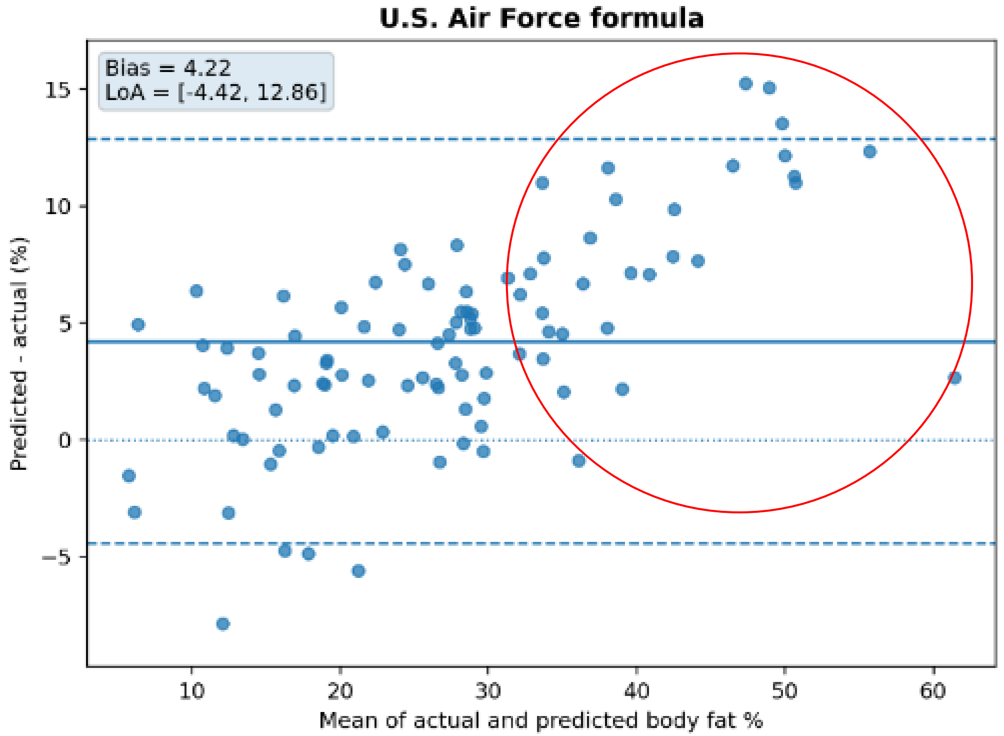
Body Fat % Prediction: AF formula vs. Elastic Net

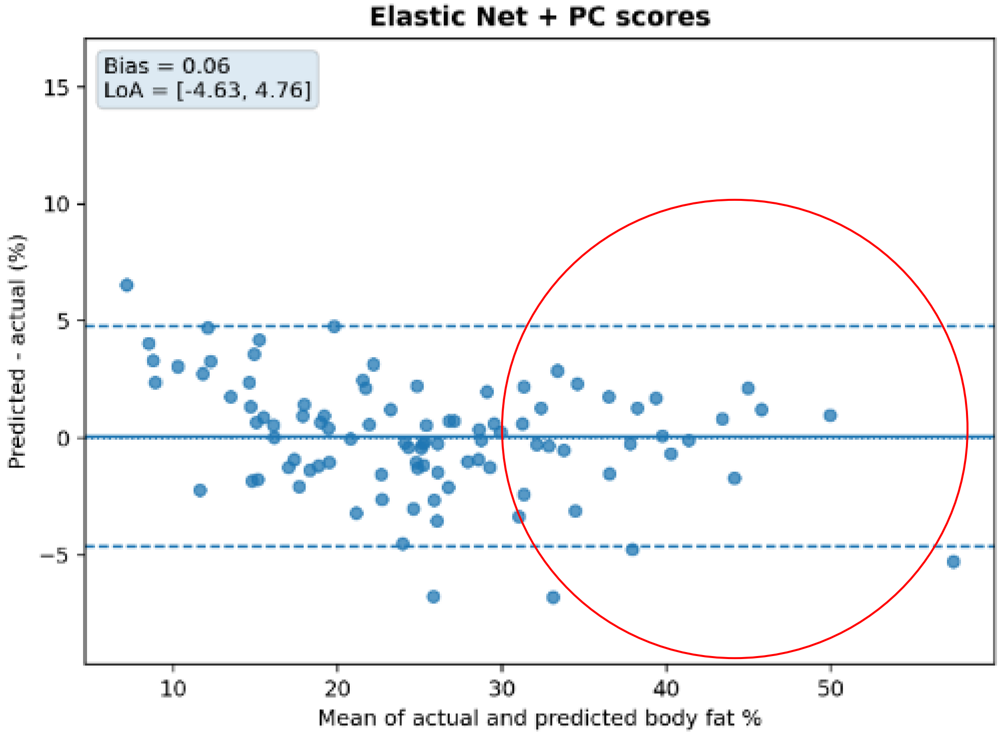
Same 96 subjects · Elastic Net evaluated with 5-fold nested CV · Navy formula evaluated from circumference inputs

AF: Height + waist + neck (+ hip in females)



MAE **4.95%** R^2 **0.67** Bias **4.22**

Elastic Net: Gender + stature + weight + PCs



MAE **1.83%** R^2 **0.95** Bias **0.06**

Takeaway The current model cut MAE by 43% and nearly eliminated the positive bias seen in the AF formula.

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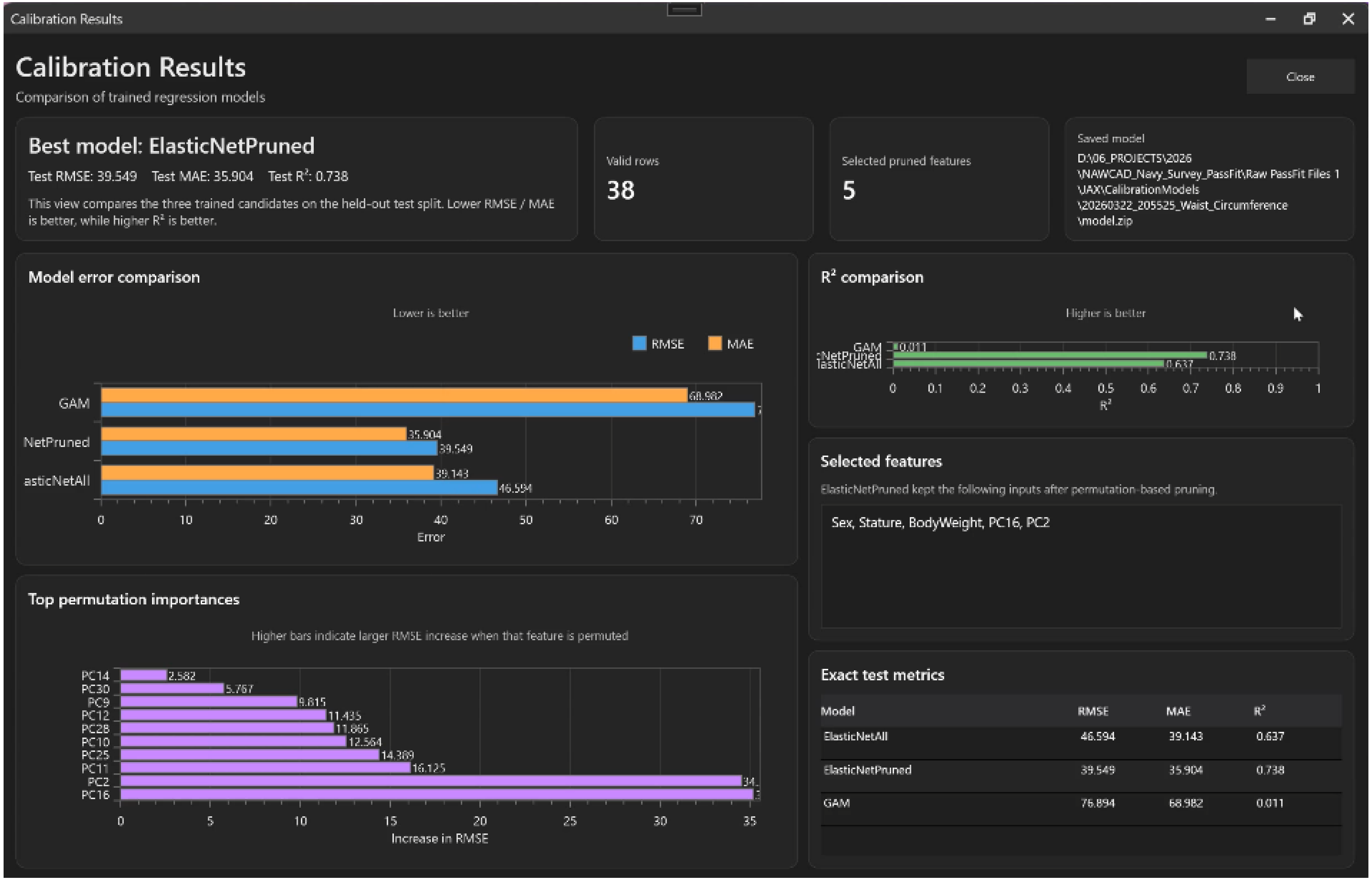
System Demo: Calibration/ User-defined Data Prediction



Key Takeaways

Users can enhance PassFit to meet their needs.

1 PassFit can go beyond standard outputs

PassFit is not limited to its built-in standard dimensions. This study showed that the same framework can be extended to predict calibrated dimensions and a wide range of user-defined outputs.

2 3D body shapes improve custom prediction

Using 3D body-shape information through PC scores, together with basic anthropometrics and standard outputs, led to more stable and useful prediction of user-provided data.

3 Customization can be fully automated

Model comparison and variable selection across LM, SFS, GAM, Elastic Net, and XGBoost were automated in a user module, making customization practical without a complex manual workflow.

Example evidence

Waist circ. calibration

MAE 1.12 → **0.85 in**
Bias 0.57 → 0.03 in

Natural-waist prediction

MAE **0.72 in**
R^2 0.925

Body fat % prediction

Elastic Net MAE **1.83%**
AF formula MAE 4.95%

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Thank you

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The 2nd Biomechanical Engineering and Anthropometry Meeting (BEAM)
March 24-26th, 2026

Mobile 4D Body Scanning and Dynamic Anthropometry for Large-Scale Campaigns

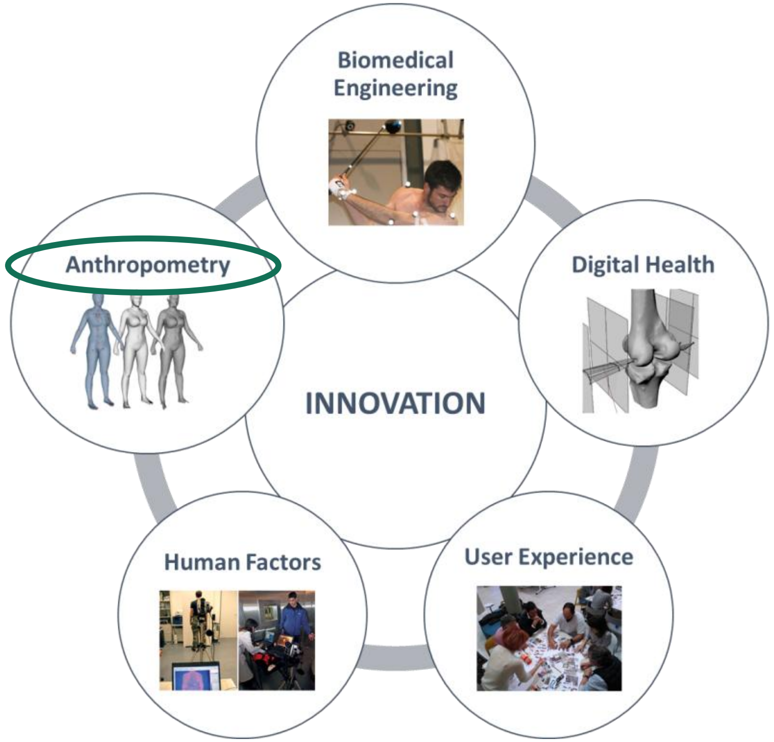
Iranzo, S. Ballester, A., Parrilla E., Gómez, D. Remón. A., Alemany, S.

IBV

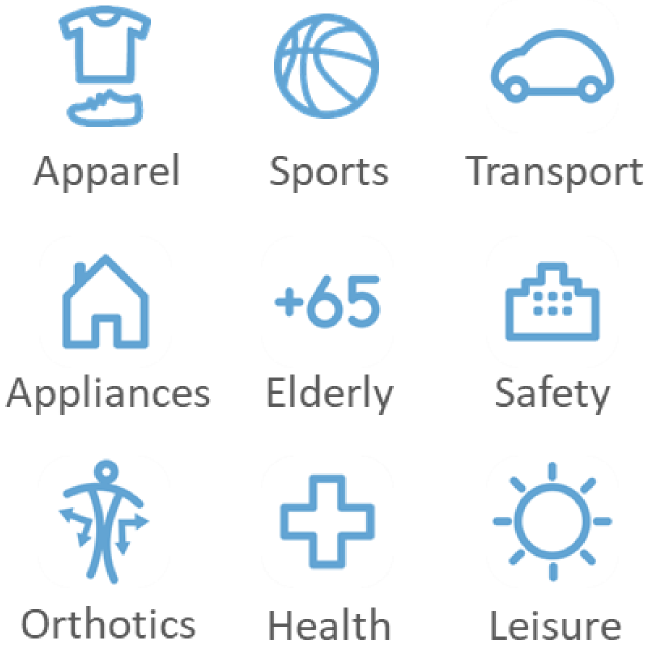
IBV is a private not-for-profit R&D organisation

IBV is a R+D+i centre of 170 professionals, where we study the behaviour of the human body and its relationship with the products and environments.

R&D Areas of the IBV



Knowledge & Technology transference



MOVE 4D

IBV

Digital Anthropometry at IBV

2004 Start gathering 3D foot scans

2007 Start gathering 3D body scans

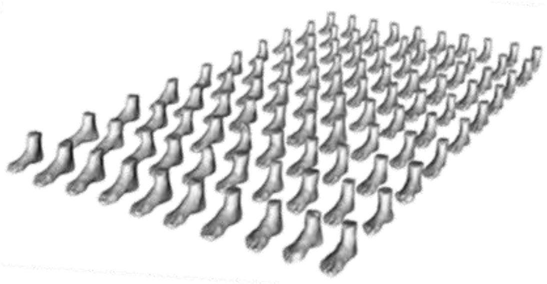
2012 Start developing own 3D processing software for research

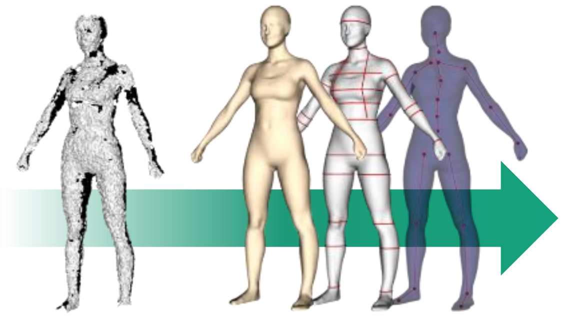
2015 Launch of **3D FOOT reconstruction** with smartphone photographs

2018 Launch of **3D BODY reconstruction** with smartphone photographs

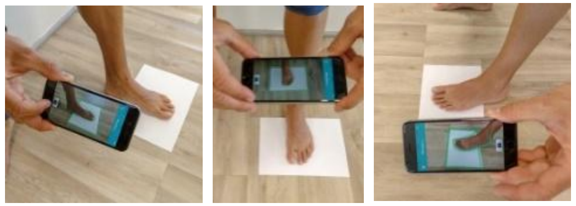
2019 Launch of **MOVE4D scanner**

2025 **15 MOVE4D Labs** Worldwide

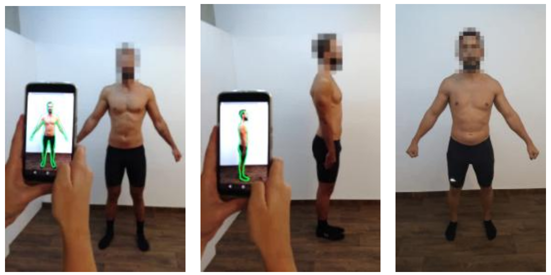


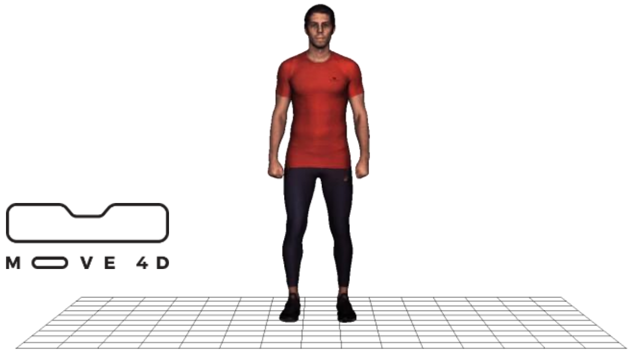


3D avatar feet



3D avatar body





IBV

Towards scalable functional anthropometry

1. Mobile 4D body scanner

- Modular sensors
- Set up 2-3 hours
- Large campaigns

2. Customized pipeline configuration

- Capture protocols
- Personalized digital tape: landmarks and measurements
- Re-use of measurement lists.

3. Functional anthropometry

- Body behaviour in motion
- Fit /Reach /Ergonomics

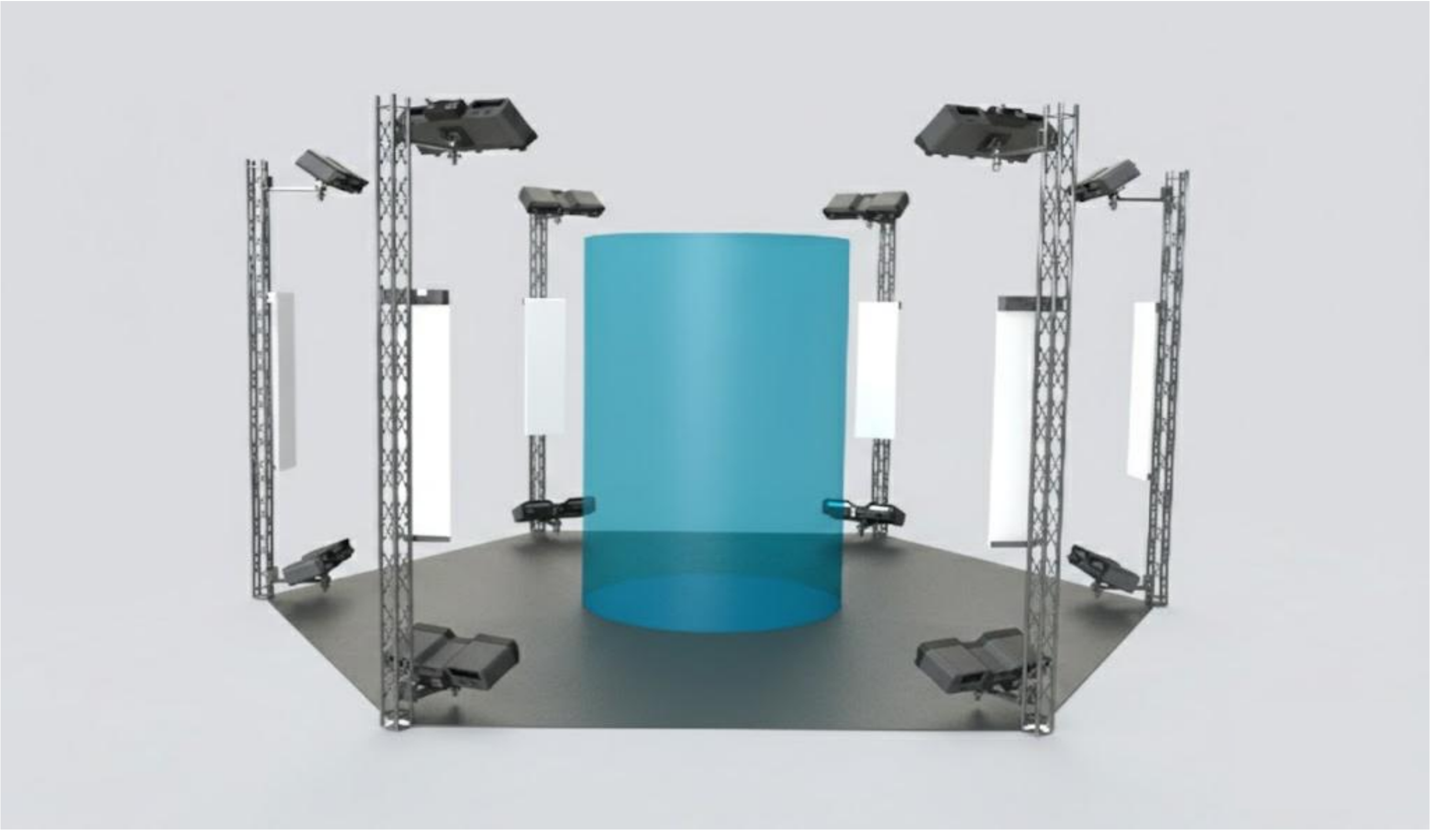
MOVE 4D

IBV

Mobile Move4D

1. Mobile 4D body scanner

- ✓ Modular sensors → 12 units
- ✓ Set up 2-3 hours
- ✓ Large campaigns

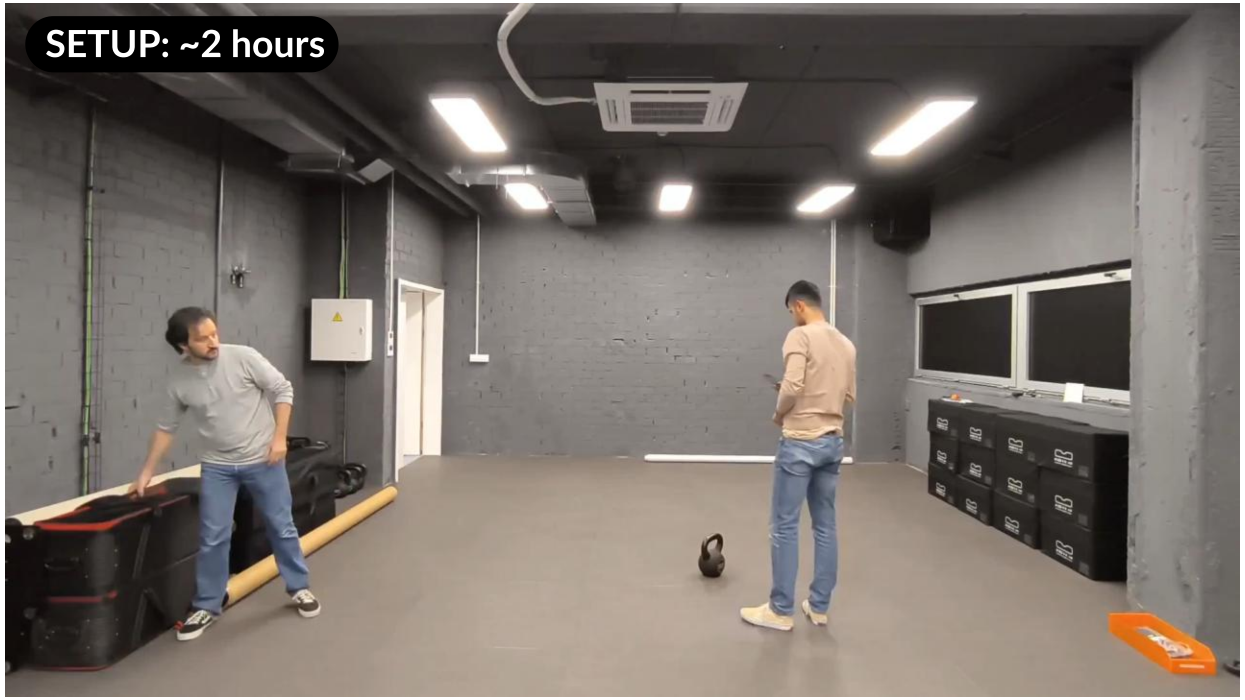


ROOM DIMENSIONS	RECOMMENDED
Footprint	6 x 5.5 m
Room Height	2.7 m
Scanning Volume	∅ 2.5m x 1.5m

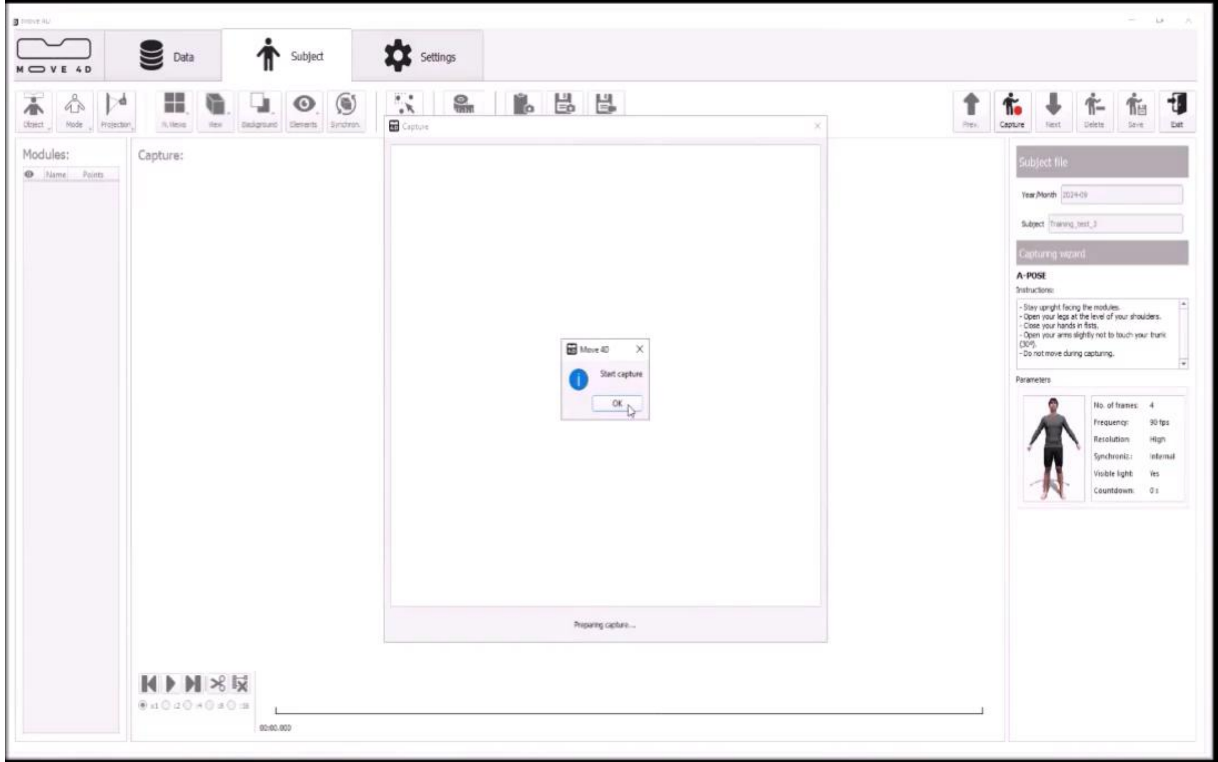
Mobile Move4D

Suitable for large-scale anthropometric surveys

- ✓ **High 3D accuracy** in different postures (< 1 mm).
- ✓ **Texture** for anatomical annotations.
- ✓ **Mobile** and easy to deploy.
- ✓ Easy and **fast to calibrate** (wand calibration).
- ✓ **Automatic processing** of 3D/4D data, body landmarks & measurements.
- ✓ Easy to **anonymize** datasets.
- ✓ **Local processing** preventing personal data share with 3rd parties.
- ✓ Potential use in future **dynamic studies**. Fast raw data processing.



Mobile Move4D



Accuracy of a 3D Temporal Scanning System for Gait Analysis: Comparative with a Marker-Based Photogrammetry System

—— MBSP ◦◦◦ 3DTS

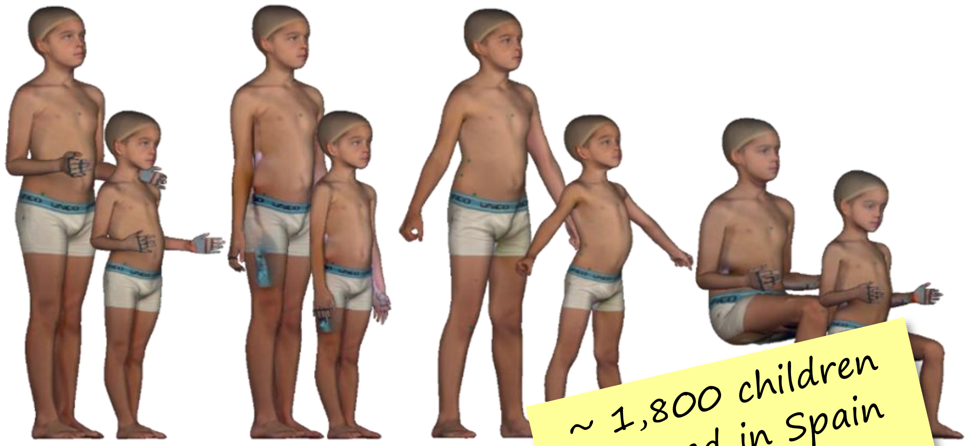
Nicolau, A. V. R., et al.. (2022). Accuracy of a 3D temporal scanning system for gait analysis: Comparative with a marker-based photogrammetry system. *Gait & Posture*, *97*, 28-34.

2 gait repetitions each subject

Mobile Move4D

Success cases: Mobile laboratories for anthropometric studies

"Anthropometric and strength data of children for use in standardization"



~ 1,800 children scanned in Spain with Mobile Move4D

Canadian Institute for Safety, Wellness & Performance (CISWP)

"Driving the Next Generation of Workplace Safety"

~ 4,000 workers different sectors, workstation design and interfaces

Full Automated Processing

Efficient and **automated** end-to-end **integrated** pipeline from a **real** human in motion to its digital twin in action

Point cloud acquisition system → Homologous Mesh processing → Rigged homologous meshes → Measurement extraction

Automatic processing without manual intervention

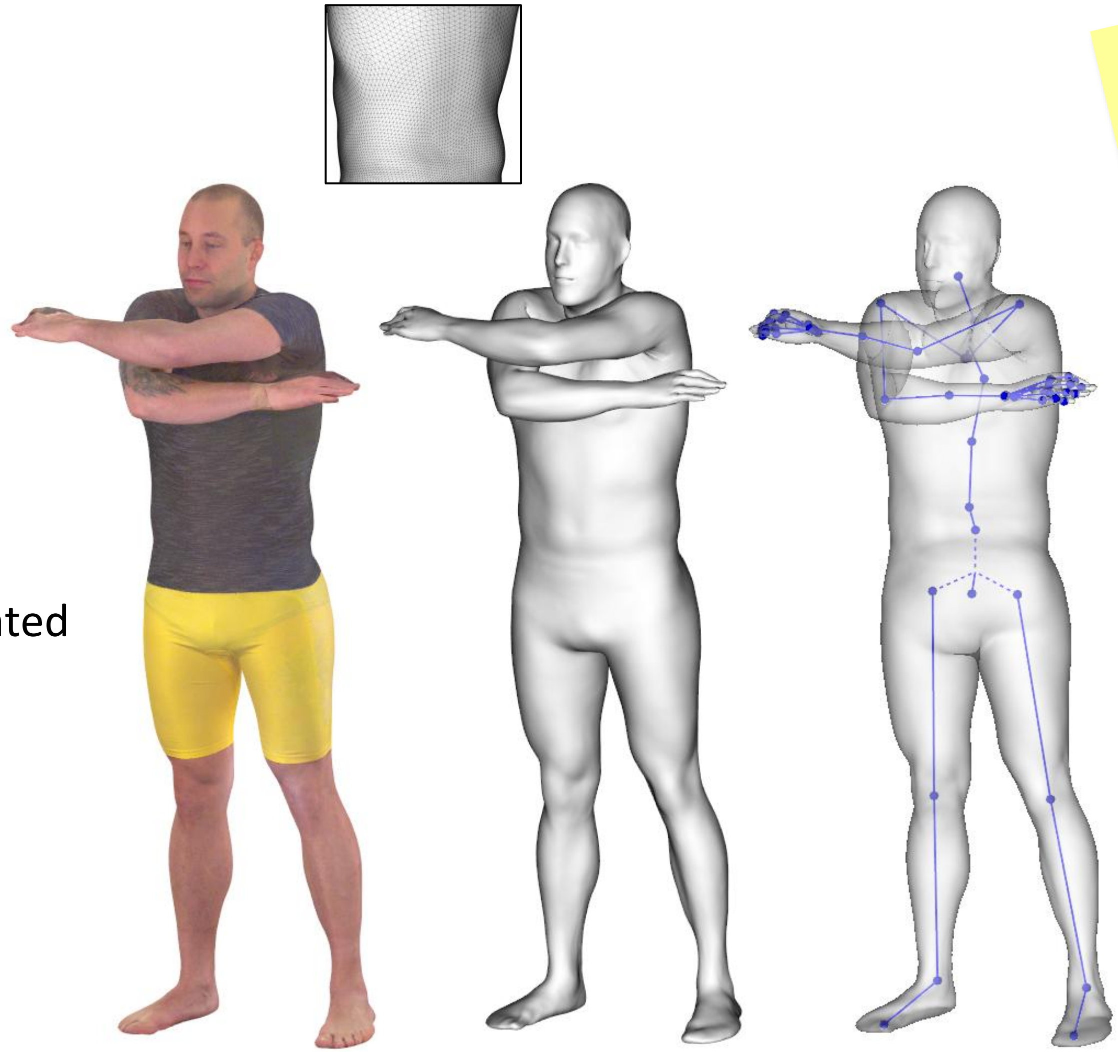
Automated Processing

3D Body Sequences Processing

From a **raw point cloud**

- ✗ super dense
- ✗ noisy
- ✗ unstructured
- ✗ incomplete

Fully automated



Anatomic homology along the sequence and between subjects

To an homologous **mesh**

- ✓ Lightweight
- ✓ single-surface
- ✓ watertight
- ✓ complete
- ✓ structured

Mesh processing – Data Models

#1 Body shape (β) and pose (θ)

12K subjects
24K poses / 11 subjects

$$M(\beta,\theta) = W\left(T_B\ (\beta,\theta),\ J(T(\beta)),\theta,\Omega\right)$$
$$T_B(\beta,\theta) = T(\beta) + B(\beta,\theta)$$
$$T(\beta) = \bar{T} + S\beta$$

#2 Hand shape (β_H) and pose (θ_H)

2K hands (MANO)

Similar to body model (and merged to it)

#3 Predominant body (φ_B) and hand pose (φ_{HR}, φ_{HL})

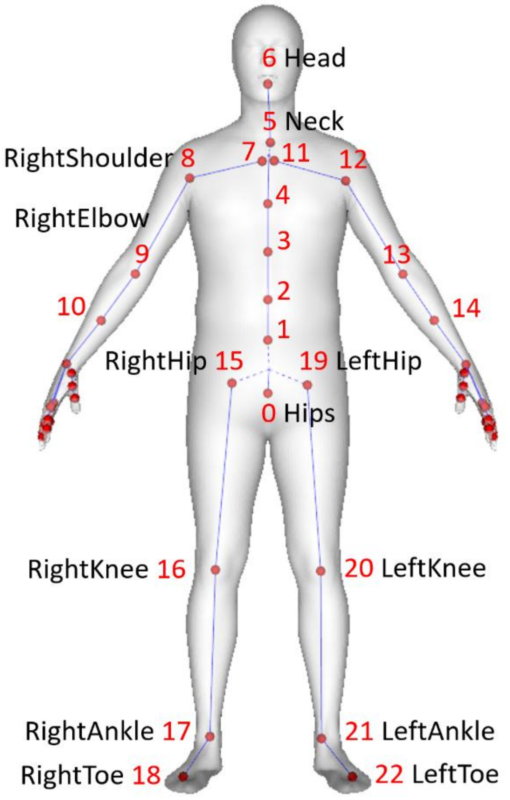
20K poses / 113 subjects
2K hand poses

$$\theta_B(\varphi_B) = \overline{\theta}_B + P_B\varphi_B$$
$$\theta_{HR}(\varphi_{HR}) = \overline{\theta}_{HR} + P_{HR}\varphi_{HR}$$
$$\theta_{HL}(\varphi_{HL}) = \overline{\theta}_{HL} + P_{HL}\varphi_{HL}$$

#4 Face shape (α_S) and expression (α_E)

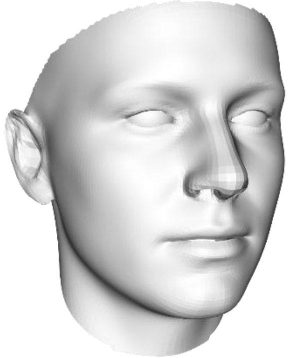
Basel Face Model

$$F(\alpha_S,\alpha_E) = \bar{F} + F_S\alpha_S + F_E\alpha_E$$



1,2,3,4 Chest, Chest2, Chest3, Chest4
7,11 RightCollar, LeftCollar
12,13 LeftShoulder, LeftElbow
23,24 RightWrist, LeftWrist

50K verts
99K faces



Parrilla, E., et al. (2024). Capture and automatic production of digital humans in real motion with a temporal 3D scanner. In *Eurographics Conference*.

Configurable measurement framework

Personalized measurement definition

2. Customized pipeline configuration

- Capture protocols
- Personalized digital tape: landmarks and measurements
- Re-use of measurement lists.

Personalized measurement sets

↓

Store

↓

Apply to:

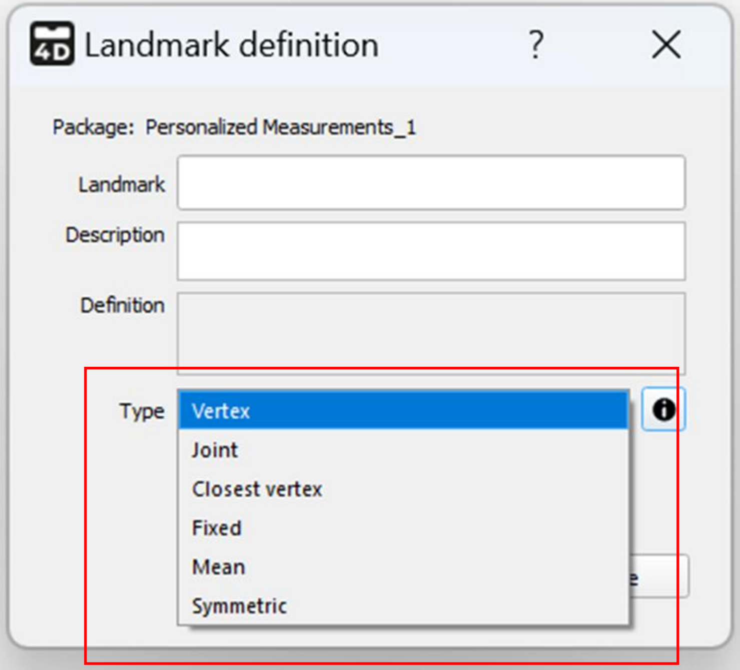
Postures & Sequences

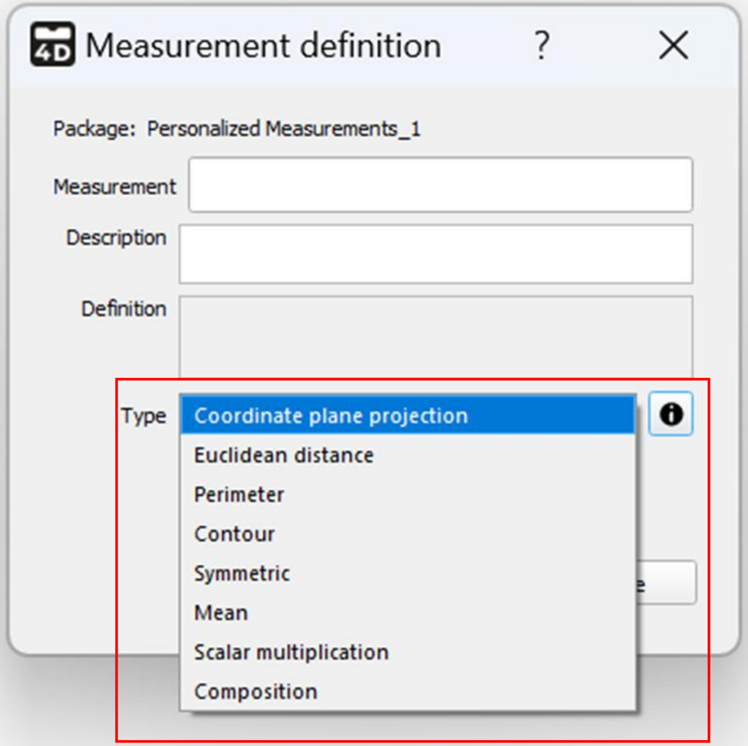
Subjects & Population

Configurable measurement framework

Personalized measurement templates

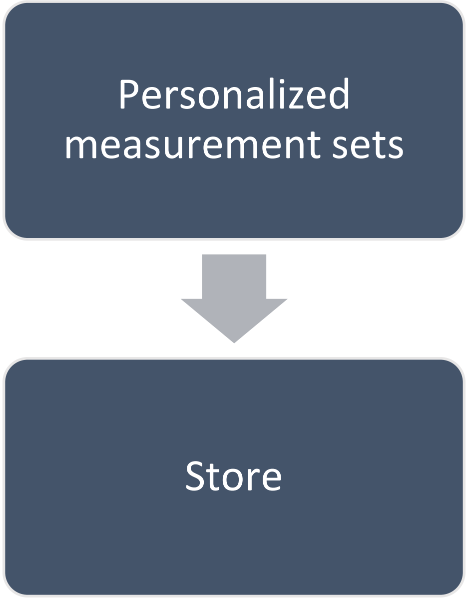
Personalized measurement sets



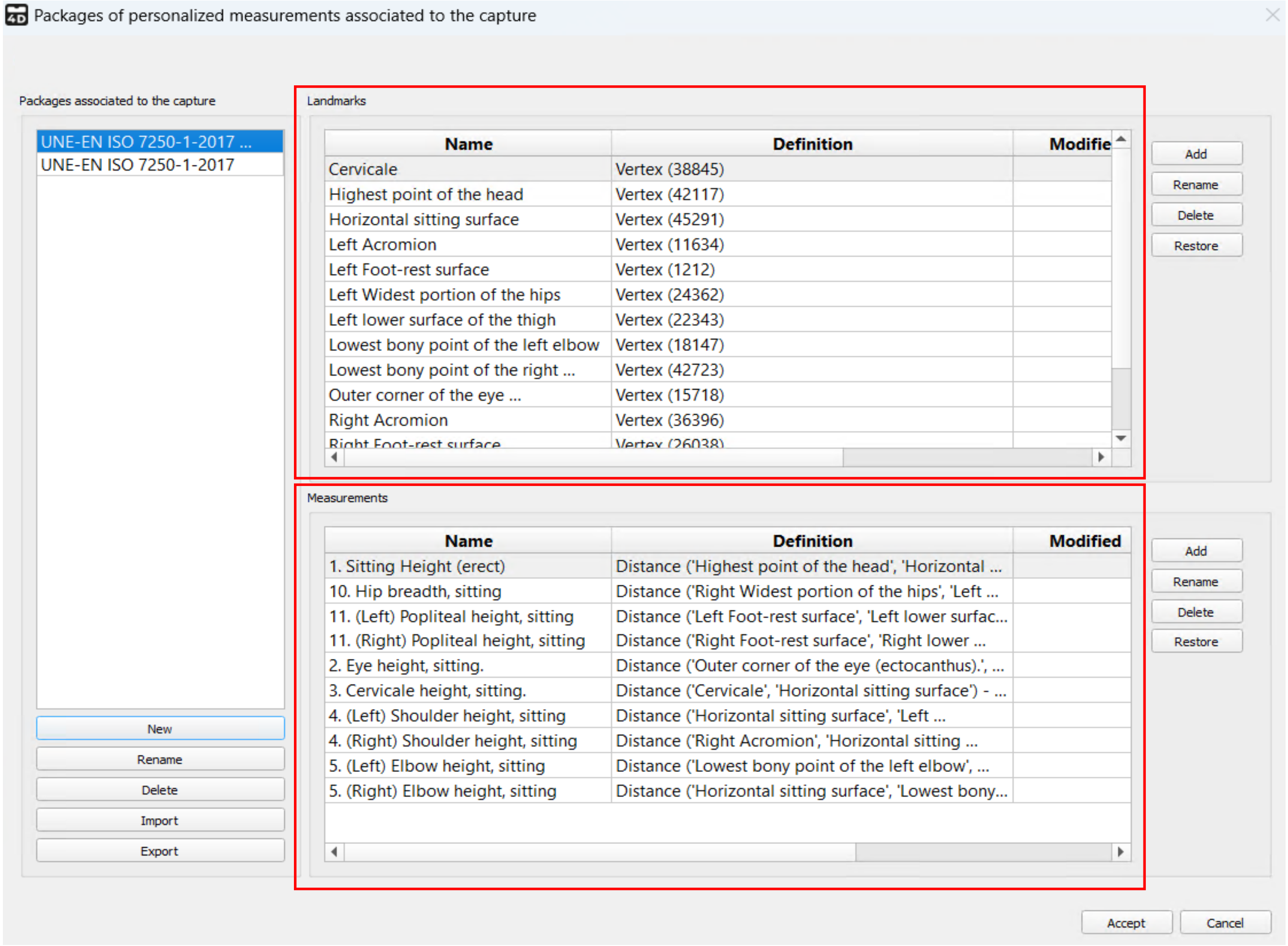


Configurable measurement framework

Personalized measurement templates



Example: Sitting Measurements ISO 7250



Configurable measurement framework

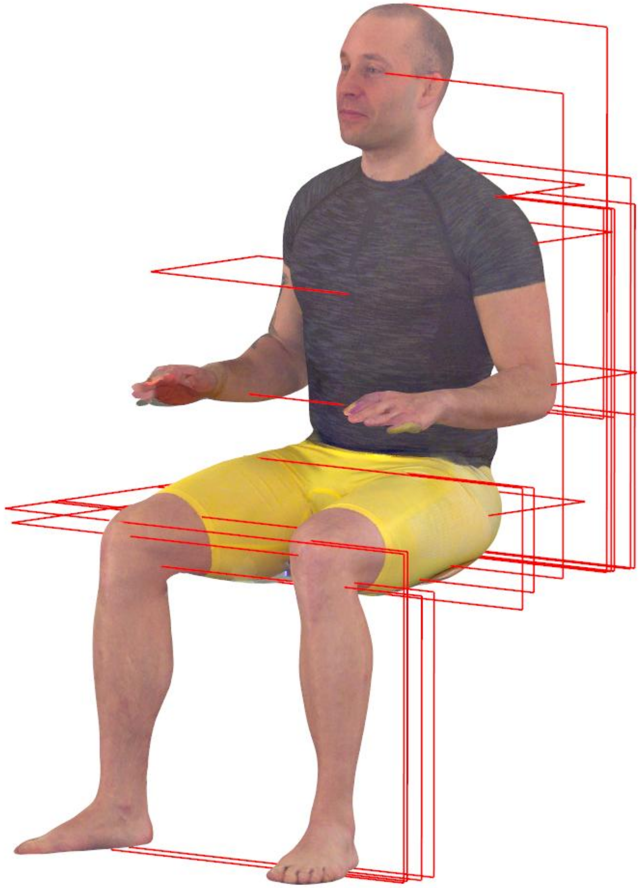
Personalized measurement templates

Personalized measurement sets

Store

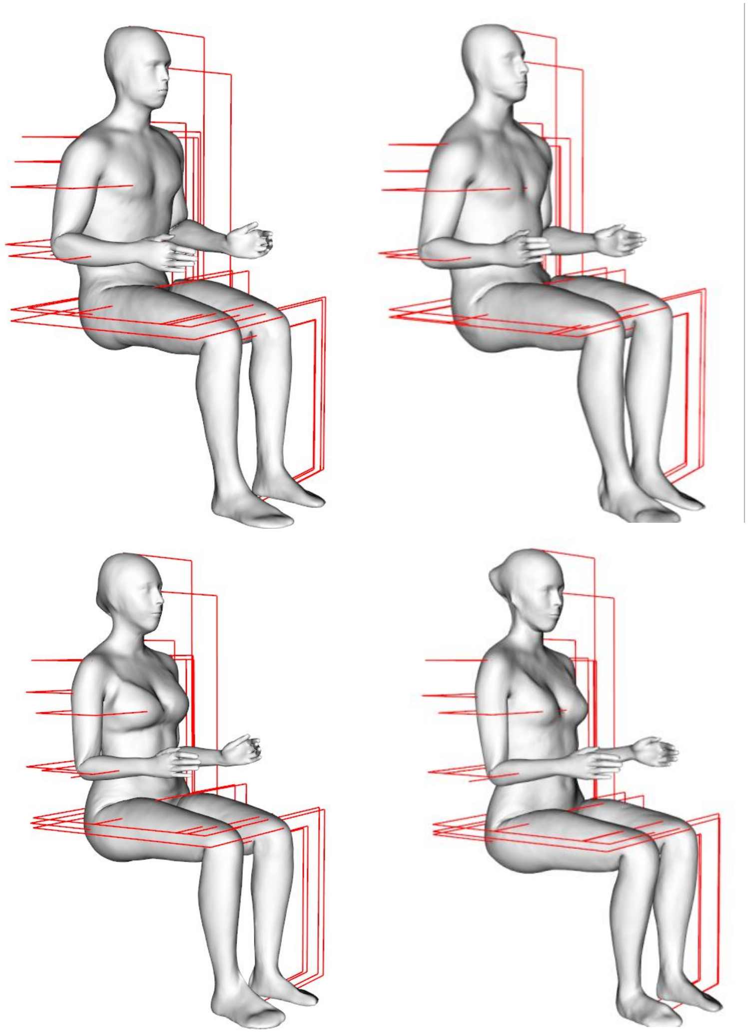
Apply to:
Postures & Sequences
Subjects & Population

✓ Definitions over static postures



Example: Sitting Measurements ISO 7250

✓ Computed across datasets



Configurable measurement framework

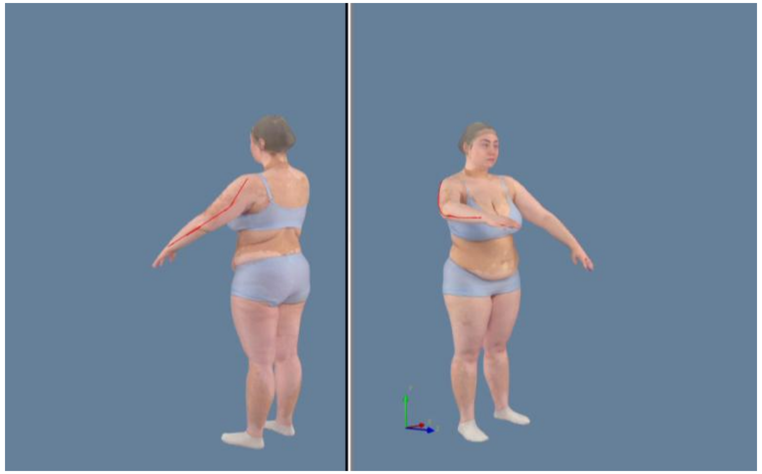
Personalized measurement templates

Personalized measurement sets

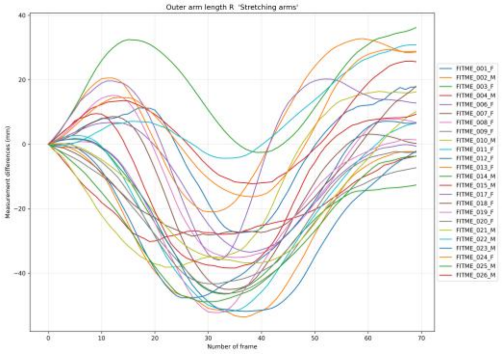
Store

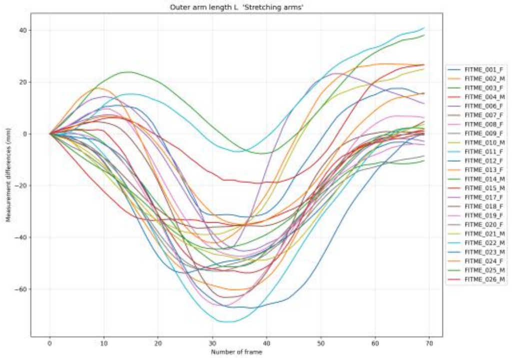
Apply to:
Postures & Sequences
Subjects & Population

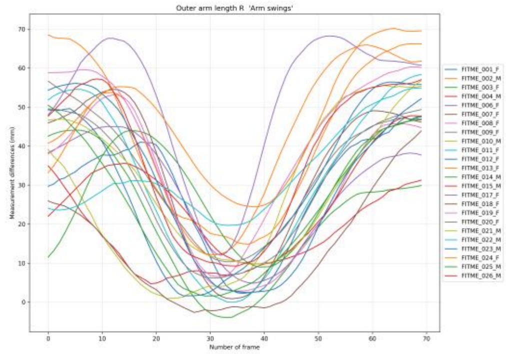
✓ Definitions over dynamic sequences

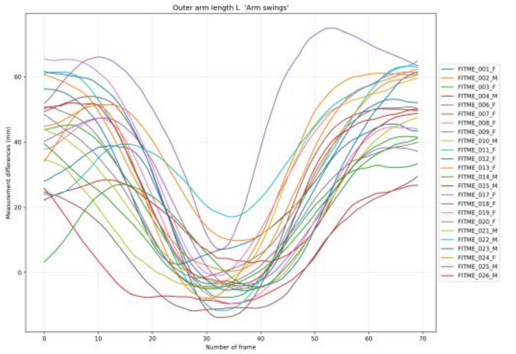


✓ Computed across datasets









Configurable measurement framework

Personalized measurement sets

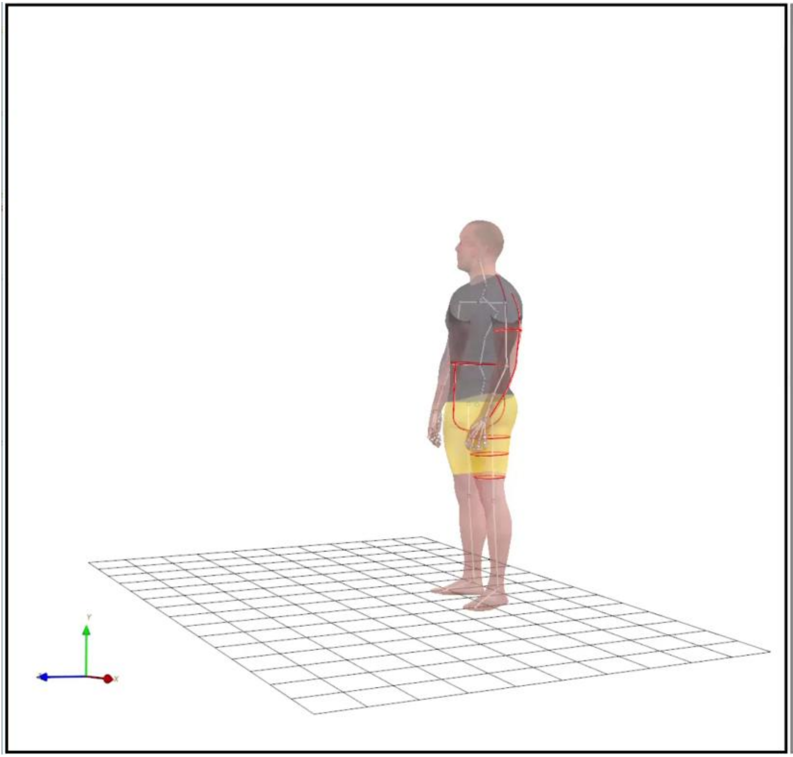
Store

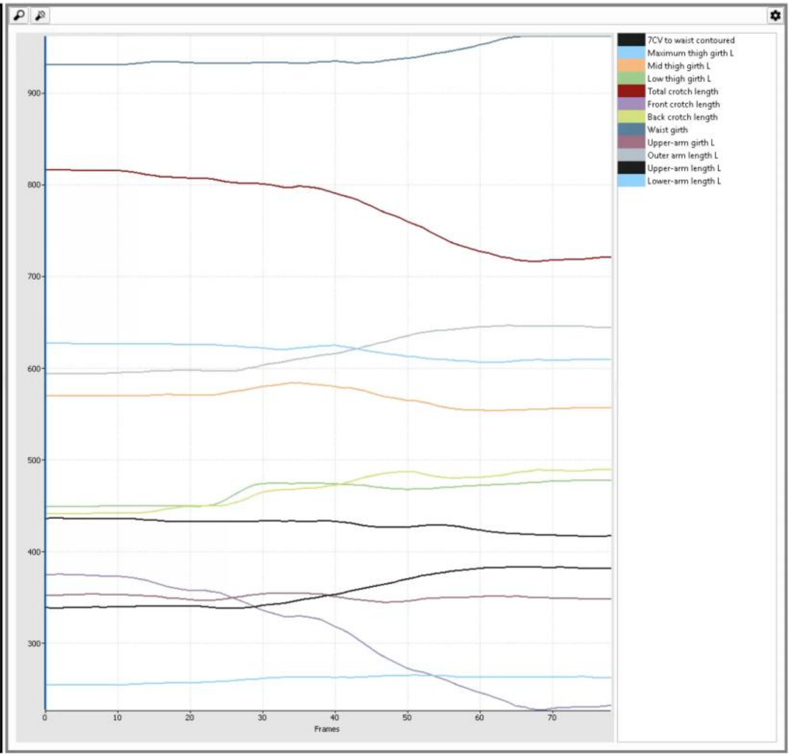
Apply to:

Postures & Sequences

Subjects & Population

✓ Applying measurement definitions to characterize real motion sequences





Example: From standing to kneeling (weapon ready)

Functional anthropometry from motion

3. Functional anthropometry

Body behaviour in motion

Fit / Reach / Ergonomics

Dynamic body capture enables extracting measurements **during motion sequences**

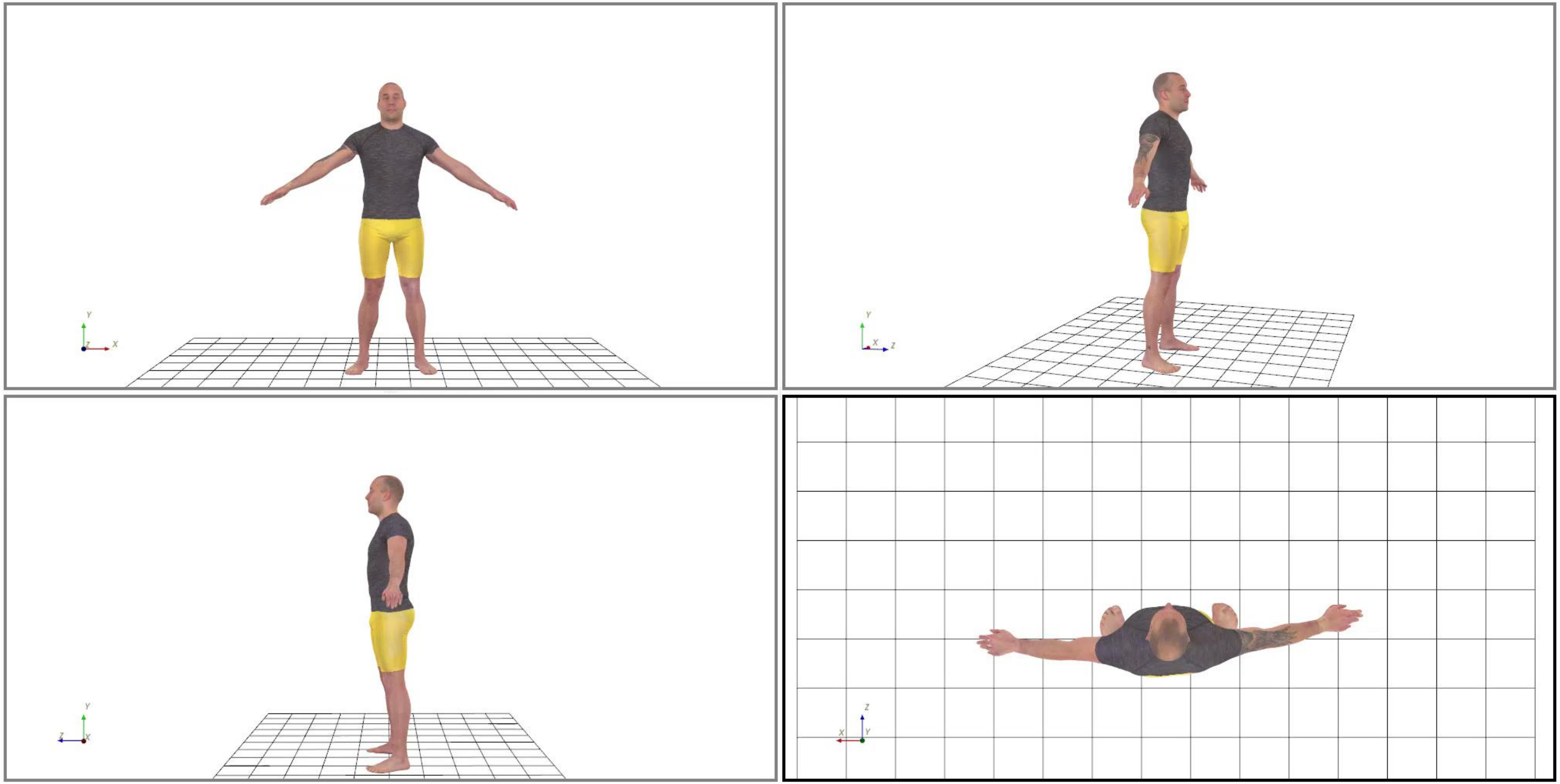
Measurements can be defined to quantify **functional capabilities**

Example applications:

- garment **fitting**
- reachable space
- ergonomics

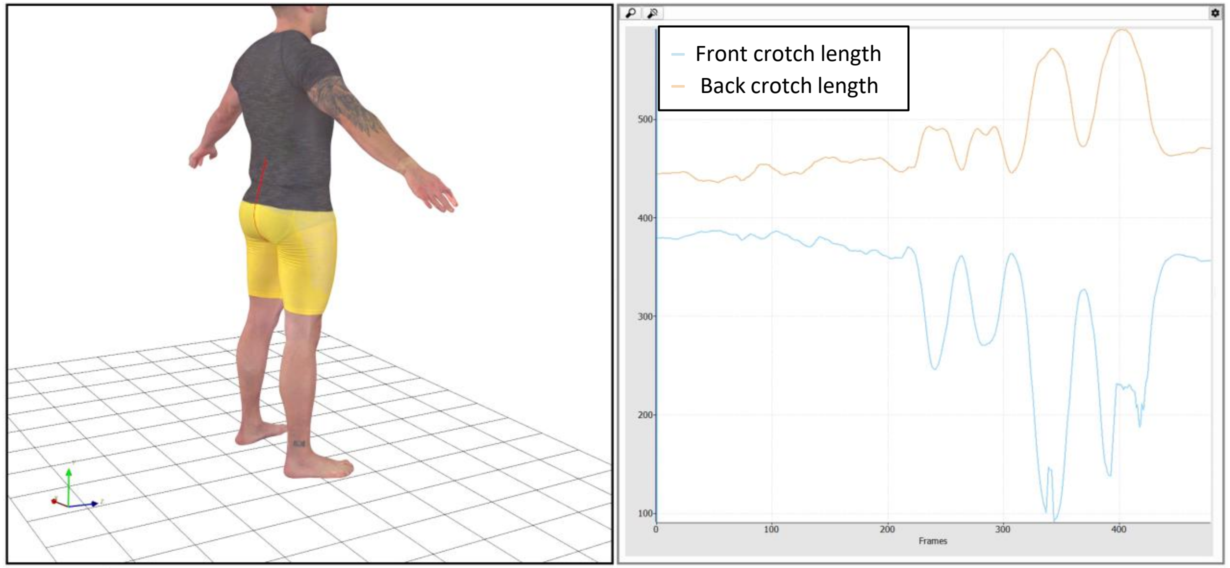
Example of choreography for garment fit

Fitting sequence capture

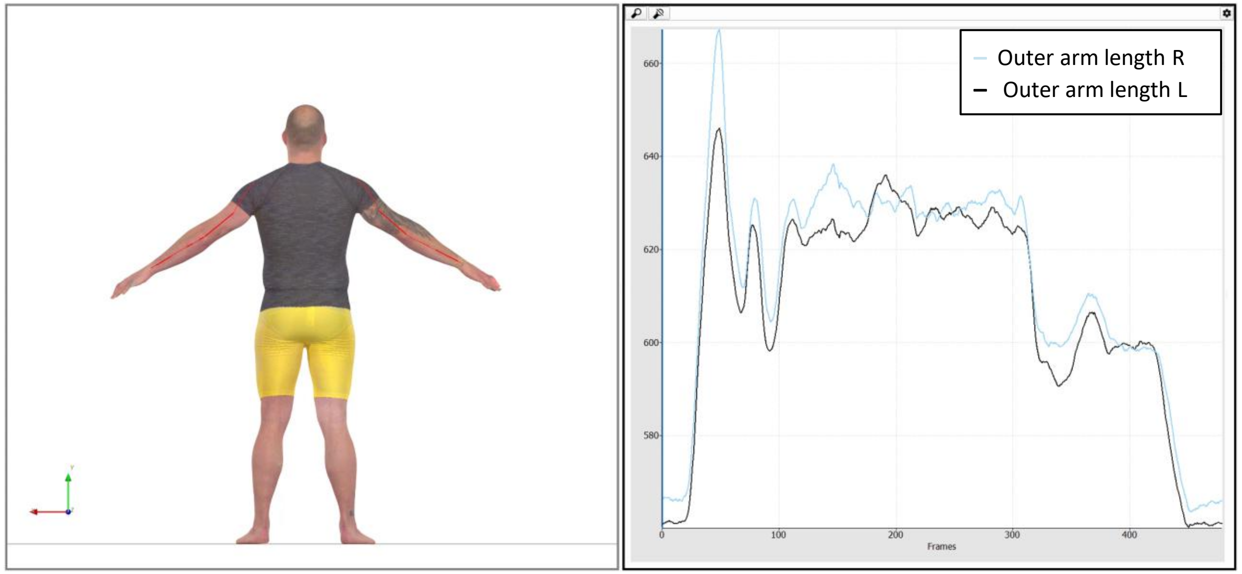


Example of choreography for garment fit

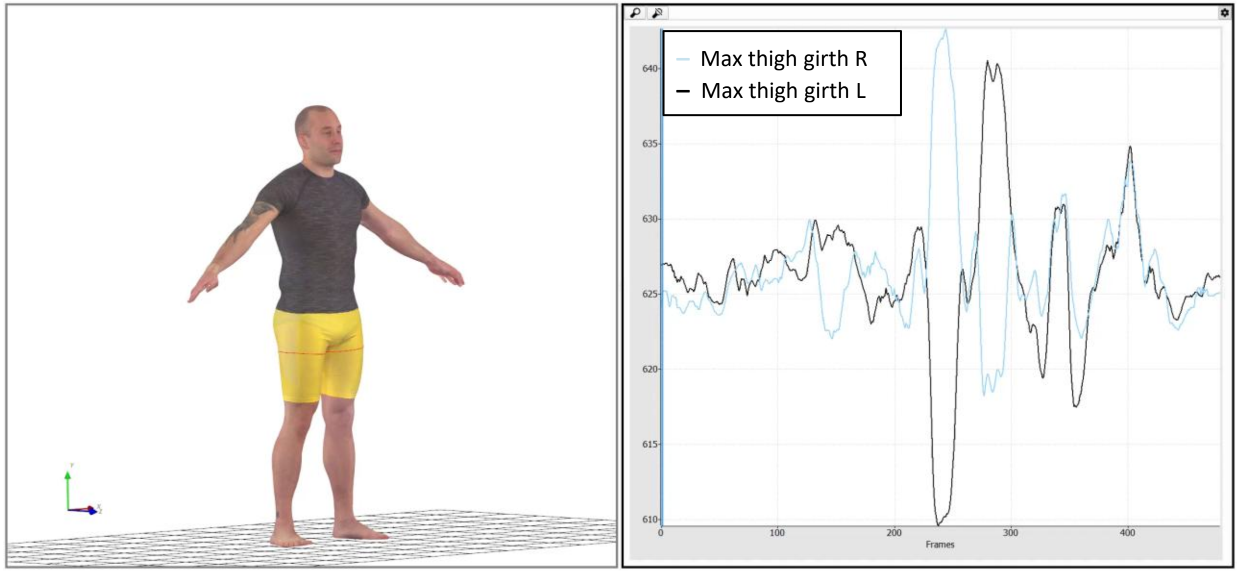
Back & Front Crotch Length



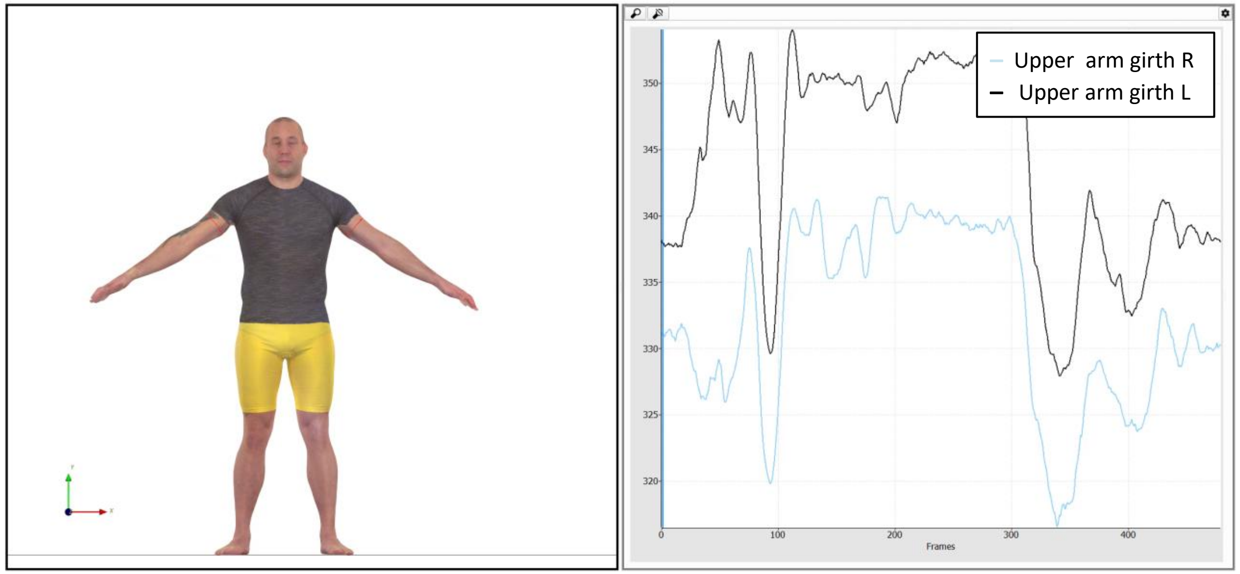
Outer arm length



Maximum thigh girth



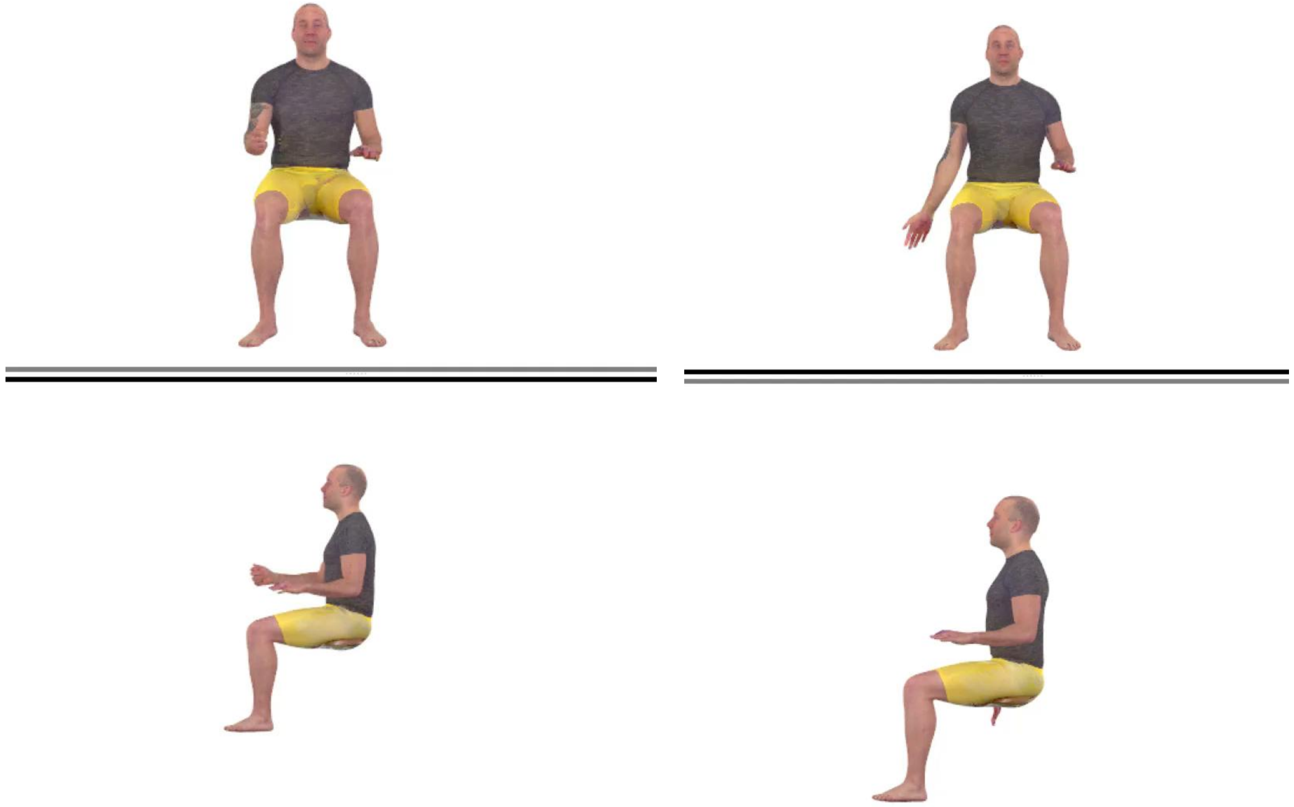
Upper arm girth



Example of choreography for reach & envelopes

Standing posture

Sitting posture



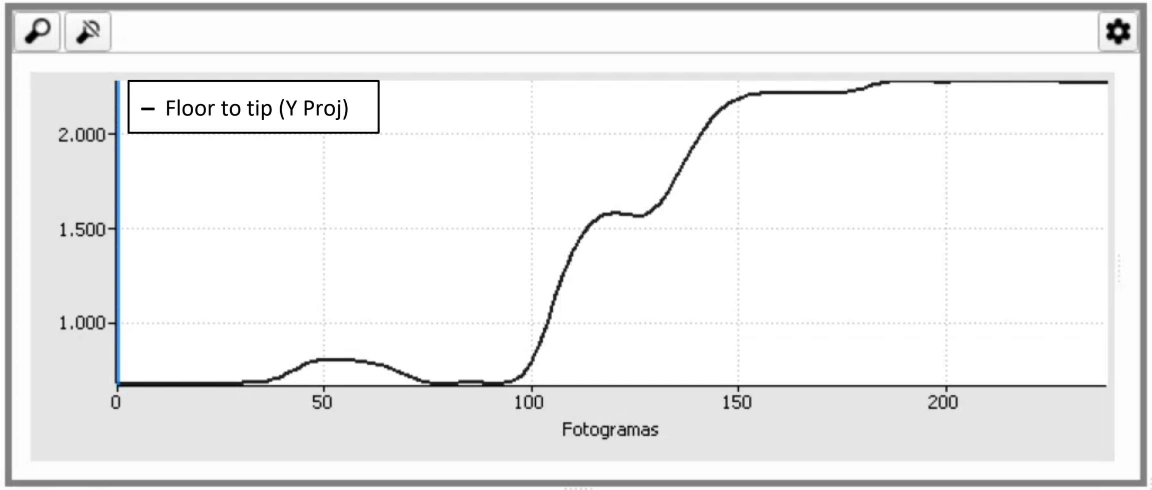
Example of choreography for reach & envelopes

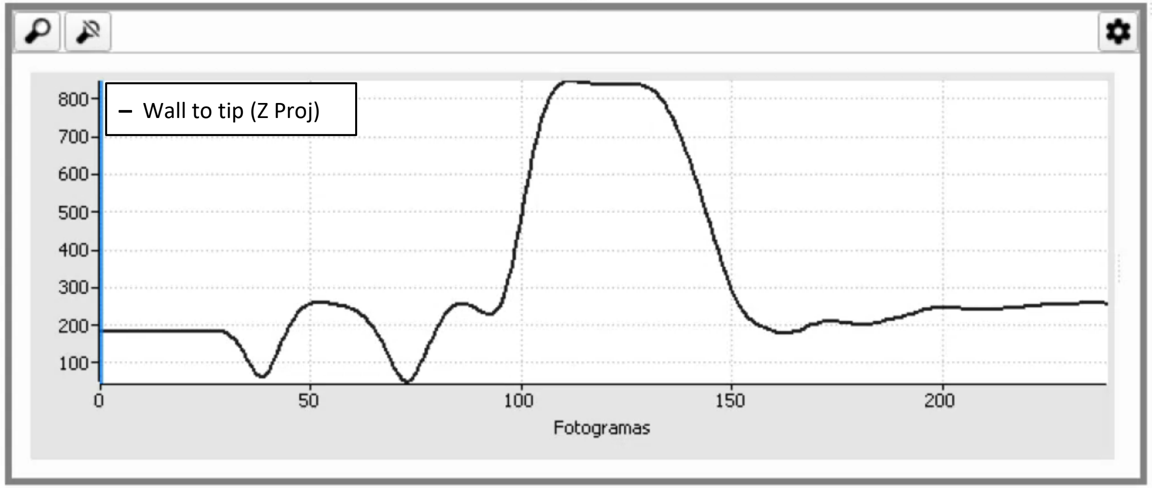
Dynamic reach measurements allow the characterization of **functional reach envelopes** during real movement.

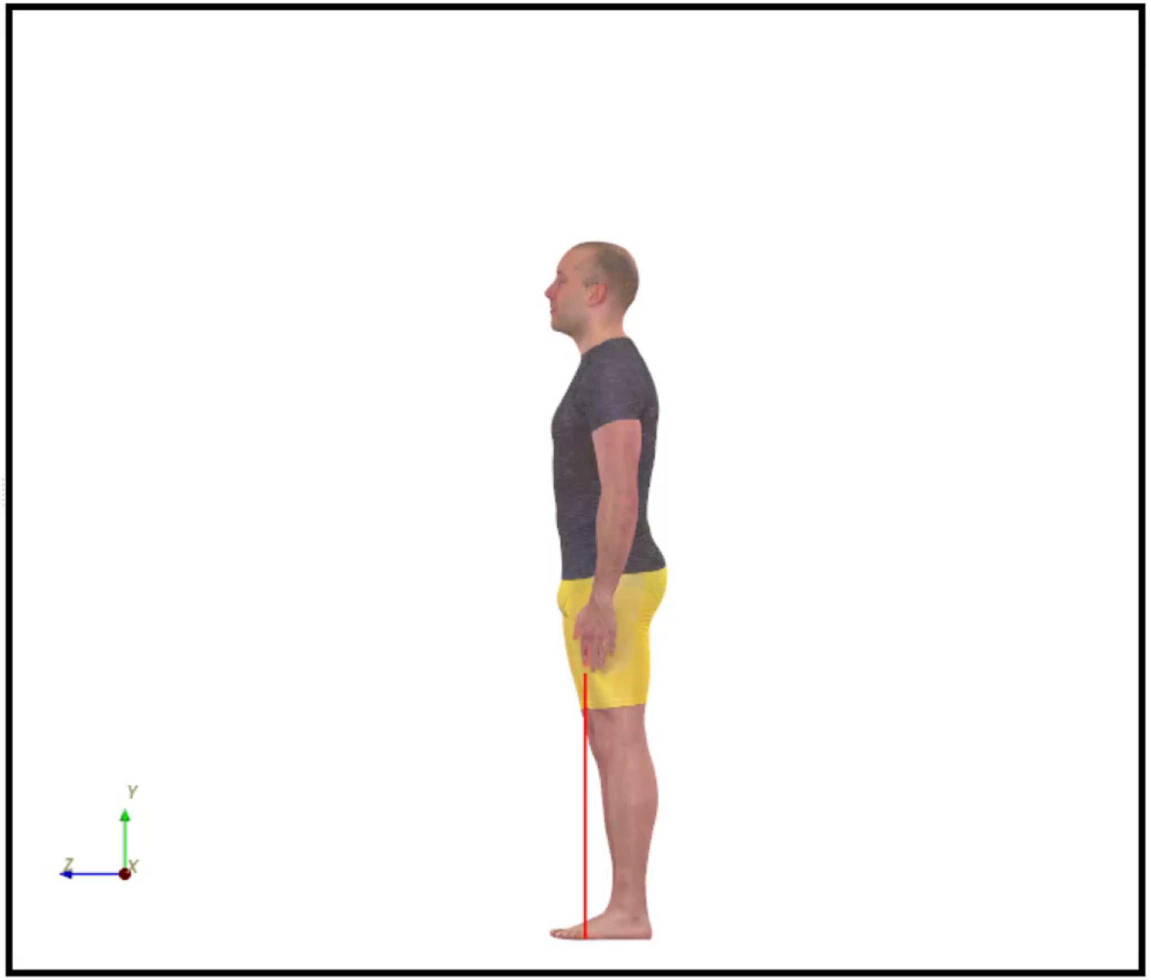
- Vertical reach: floor → fingertip
- Forward reach: wall → fingertip

Standing posture

Flexion-Extension





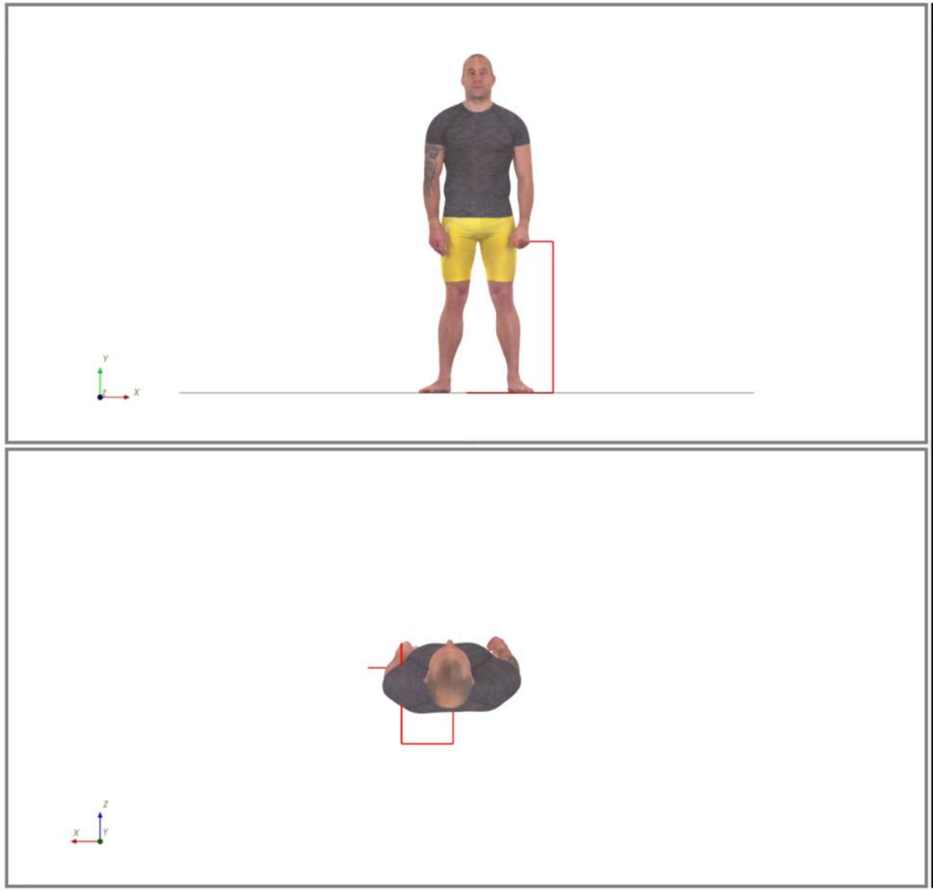


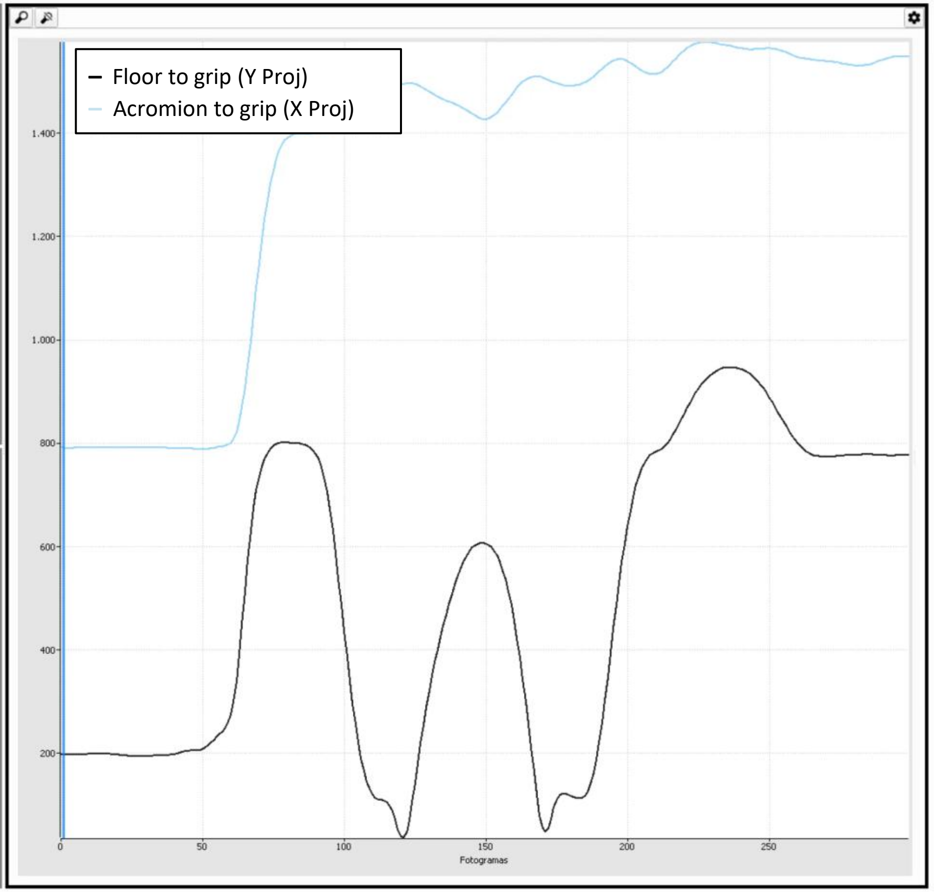
Example of choreography for reach & envelopes

Dynamic reach measurements allow the characterization of **functional reach envelopes** during real movement.

- Vertical reach: floor → grip
- Lateral reach: chest centre → grip

Standing posture
Abduction-Adduction



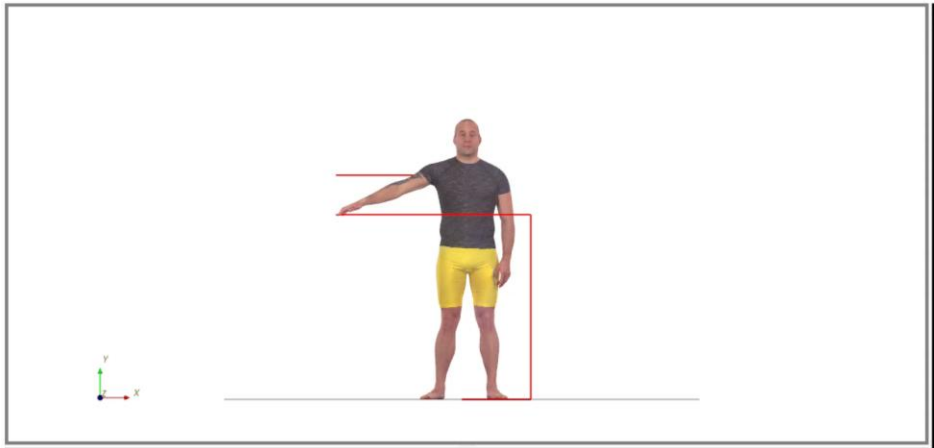


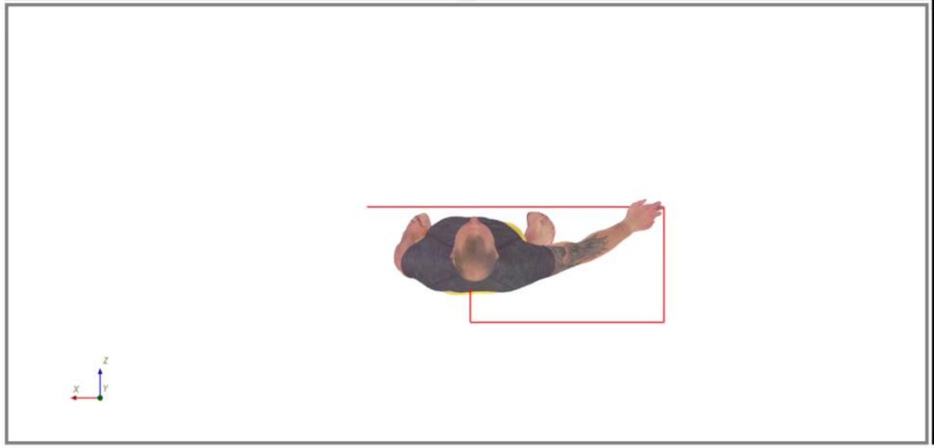
Example of choreography for reach & envelopes

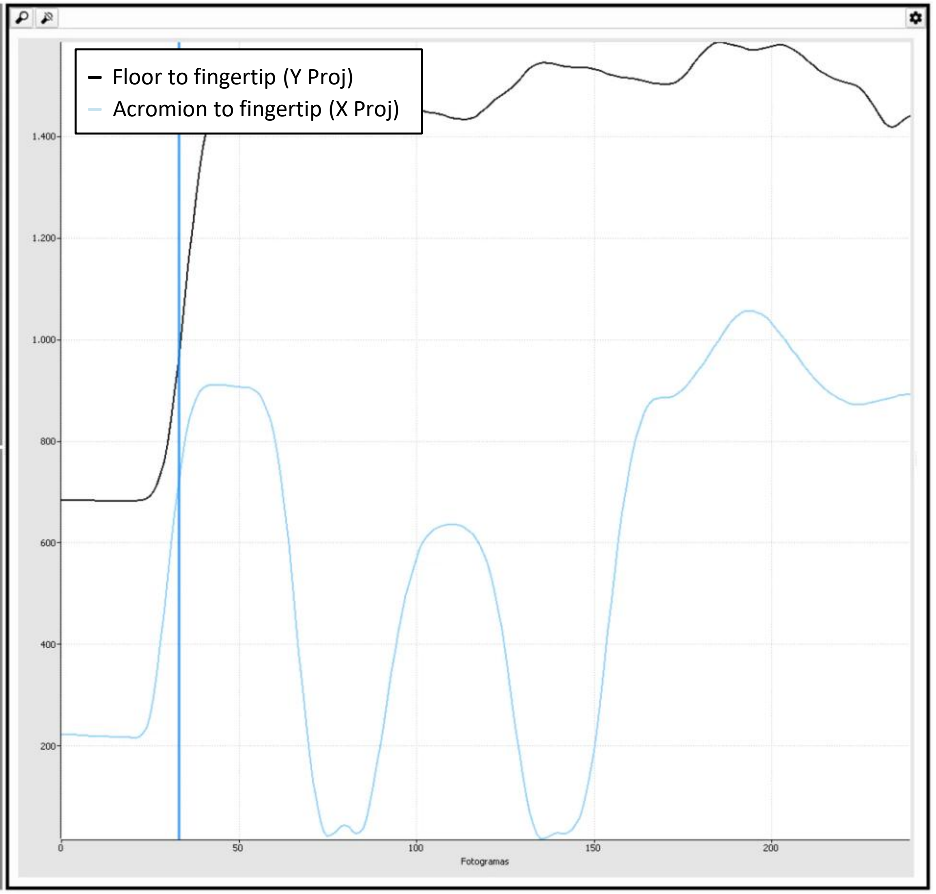
Dynamic reach measurements allow the characterization of **functional reach envelopes** during real movement.
- Vertical reach: floor → finger tip
- Lateral reach: chest centre → finger tip

Standing posture

Abduction-Adduction



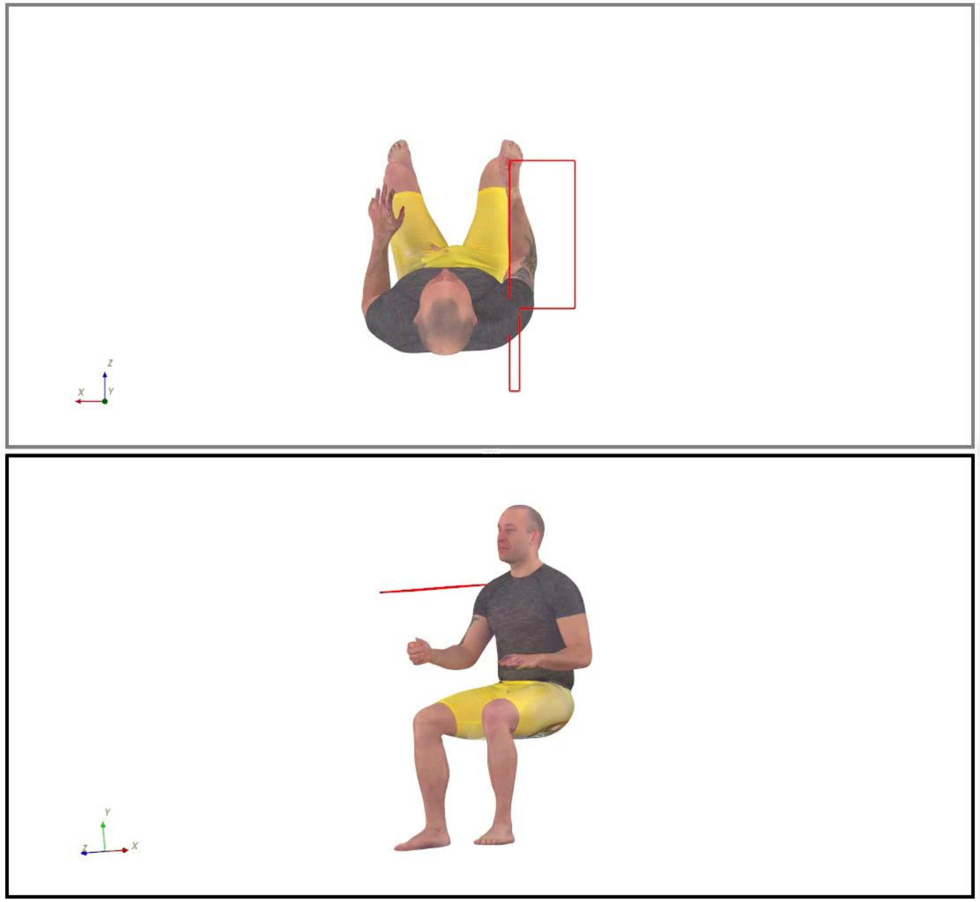


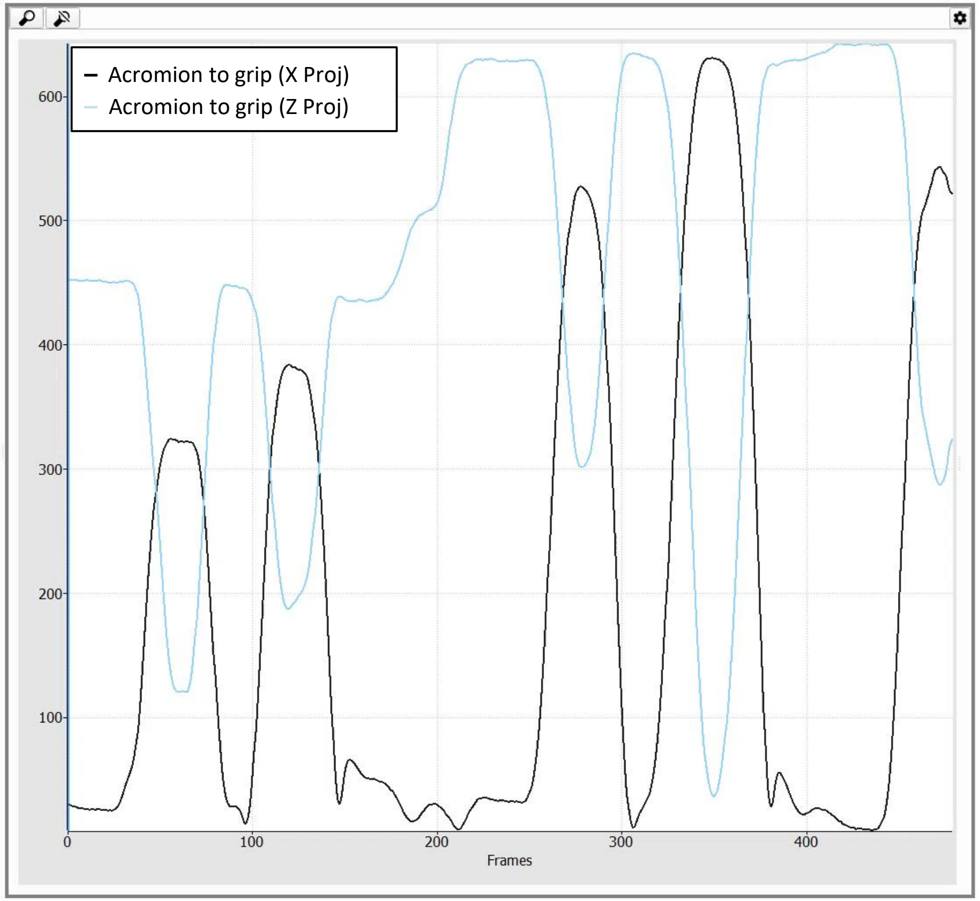


Example of choreography for reach & envelopes

Seating reach measurements for **cabin design**:
- Distance from the shoulder landmark to the hand grip along different axes during the reach sequence.

Sitting posture





Example of choreography for reach & envelopes

Extracting the dynamic reach envelope

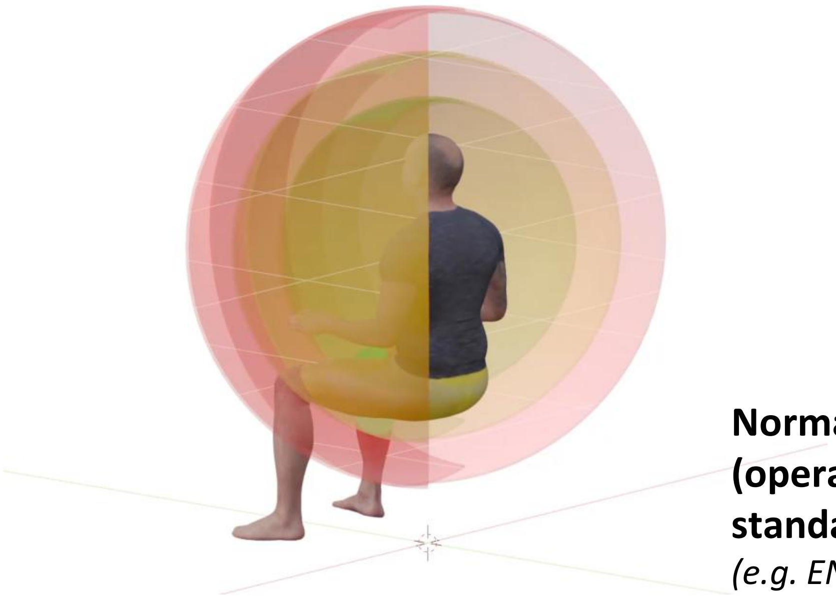
Tracking fingertip trajectory during the movement sequence

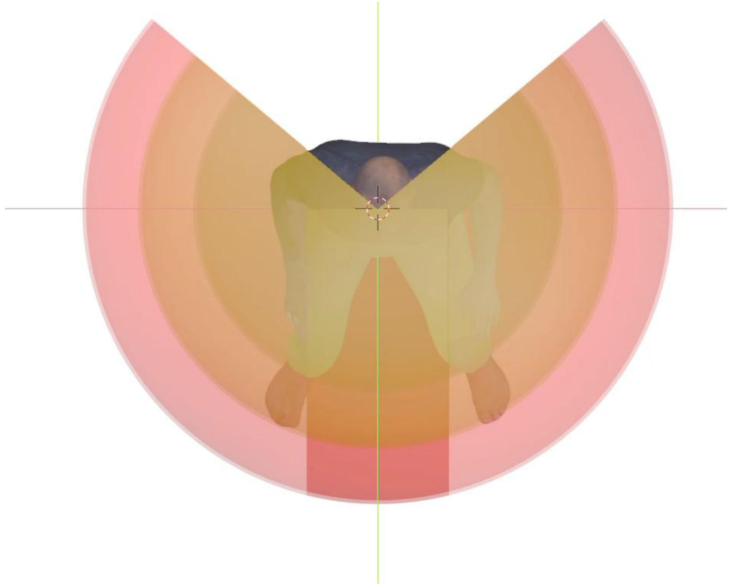
By accumulating these trajectories

Reachable envelope of the operator reconstruction

Example: Reach & Envelopes

Normative reach zones vs measured dynamic reach envelope



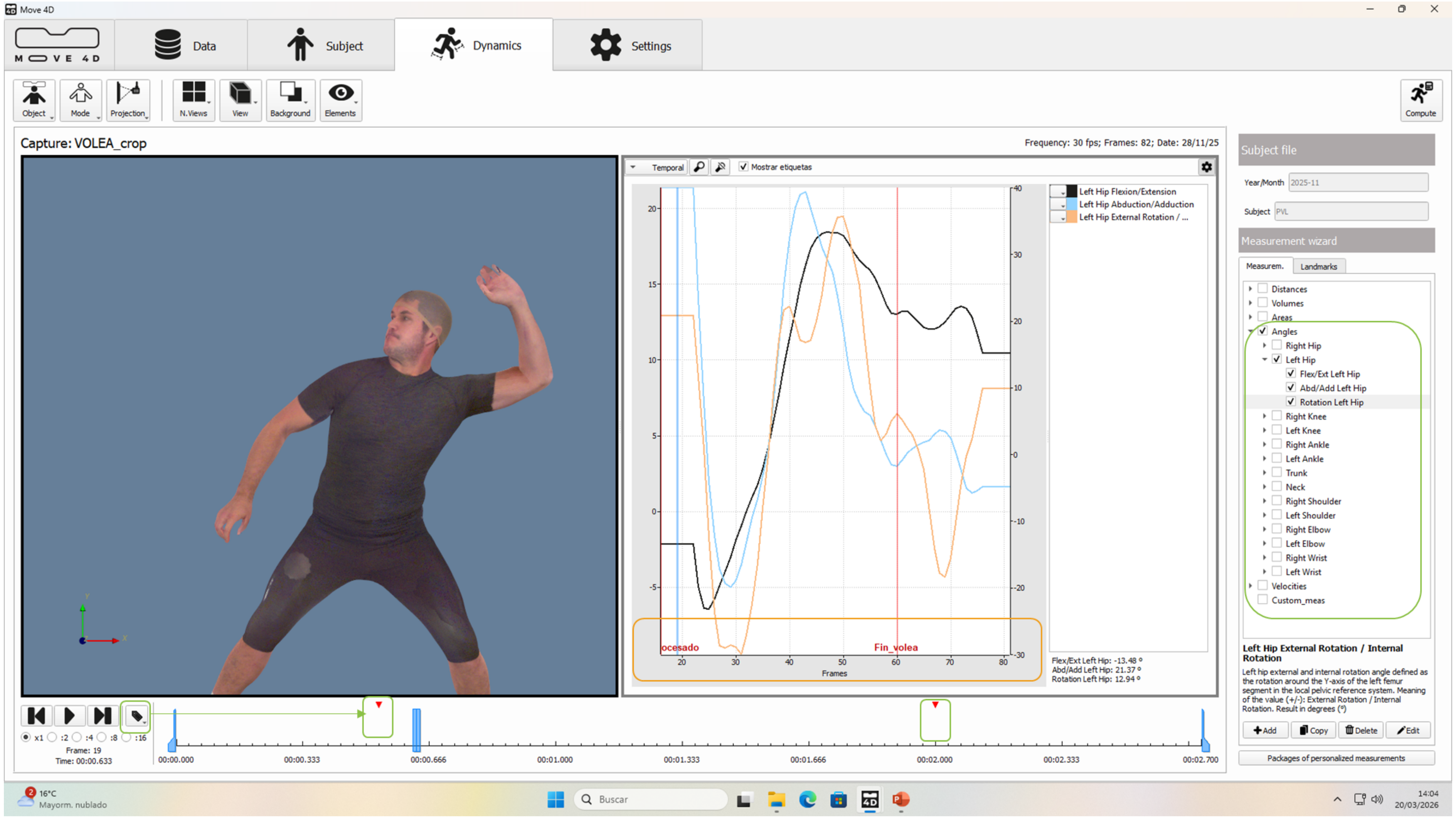


Normative reach zones (operator workstation standards)
(e.g. EN 16186, MIL-STD-1472)

WIP - Short term

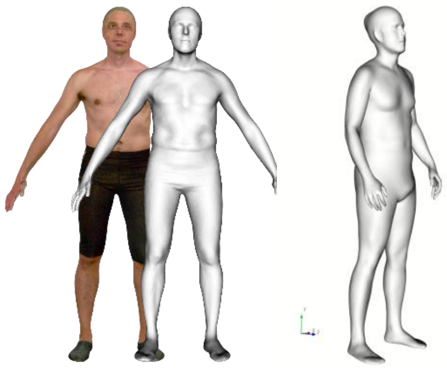
1. Customized biomechanical metrics

2. Labelling of events



WIP – Mid term: Estimating body shape under clothes

Capture undressed
A-POSE + MOTION

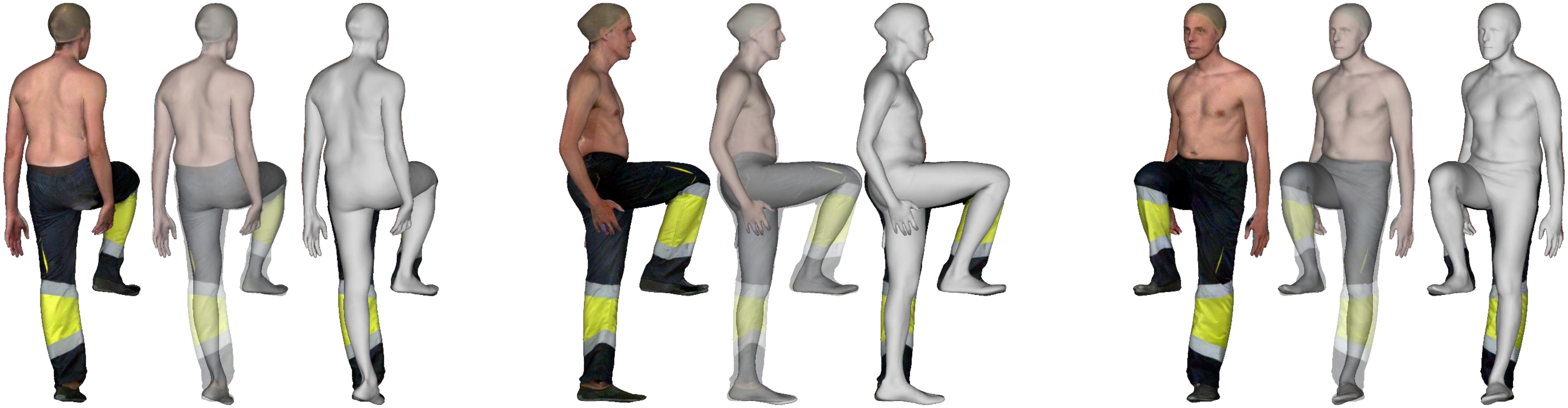


Learn personalized shape (A-POSE)

+

Learn personalized pose-dependent deformation

Capture dressed motion (Ground truth)



Thanks!

Time for Q&A

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The Instituto de Biomecánica (IBV) has been recognized as a **CERVERA Center of Excellence** for the development of the **COMANDO** (CER-20251029), **TACTIX** (CER-20251027) and **GUARDIANES** (CER-20251017) projects, financed by the Ministerio de Ciencia, Innovación y Universidades through the Centro para el Desarrollo Tecnológico y la Innovación E.P.E. (CDTI).

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