

Evaluation of Body Shape as a Space-Feasible Body Composition Assessment

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Background:

- Astronauts on long-duration space flights experience drastic muscle loss due to microgravity, which is ubiquitous to patients with sarcopenia, cachexia, and bedrest (1).
- Drug, diet, and physical activity countermeasures are implemented during the space mission to mitigate the side-effects of microgravity. However, a reliable and space-feasible body composition method is still missing to help assess the countermeasures' effectiveness in real-time (2).
- The objective of this study was to evaluate the use of shape via three-dimensional optical (3DO) imaging as a predictor of body composition in simulated microgravity.

Methods:

- Healthy adults (n=30) were recruited for the ASTRO 3DO study (Table 1).
- Participants received duplicate whole-body 3DO scans while standing and inverted by gravity boots with a 3-camera experimental scanner
- Comparisons were made to a criterion 3DO scanner, Fit3D, and dual-energy X-ray absorptiometry (DXA) scan.
- Inverted scans were used as an analogue for fluid redistribution from gravity changes.
- All 3DO scans were represented with a standardized template, reposed, and transformed into principal components (PCs) space using a highly stratified shape model (3).
- With the PCs, the whole-body and regional body composition estimates were derived from published equations. 3DO body composition estimates were compared to DXA (3).

Results:

- Standing 3DO scans achieved an R² of 0.76, 0.97, and 0.78 with an RMSE of 2.62 kg, 2.04 kg, and 0.06 kg for total fat, total fat-free, and visceral adipose tissue (VAT), respectively, with respects to DXA (Table 2).
- Inverted 3DO scans achieved an R² of 0.52, 0.93, and 0.39 with an RMSE of 2.84 kg, 3.23 kg, and 0.11 kg for total fat, total fat-free, and visceral adipose tissue (VAT), respectively, with respects to DXA.
- Significant anthropometric differences were observed between standing and inverted (Table 3).
- Test-retest precision (Table 4) of inverted 3DO scans had good precision in total fat-free as well as arm, leg, and trunk fat-free mass (%CV = 2.3%, 2.95%, 1.34%, and 1.55%; RMSE = 1.32, 0.12, 0.14, and 0.47 kg, respectively).

Conclusions:

- 3DO imaging is a promising tool for body composition assessment in space. For fat-free mass estimates, which is the source of atrophy in astronauts, 3DO showed to be accurate and precise even with shape changes from fluid redistribution. Further evaluation in actual microgravity will assist in the development of this method.

“3D Optical Imaging Addresses Body Composition Challenges in Space and Shows Feasibility to Monitor Changes Over Time”

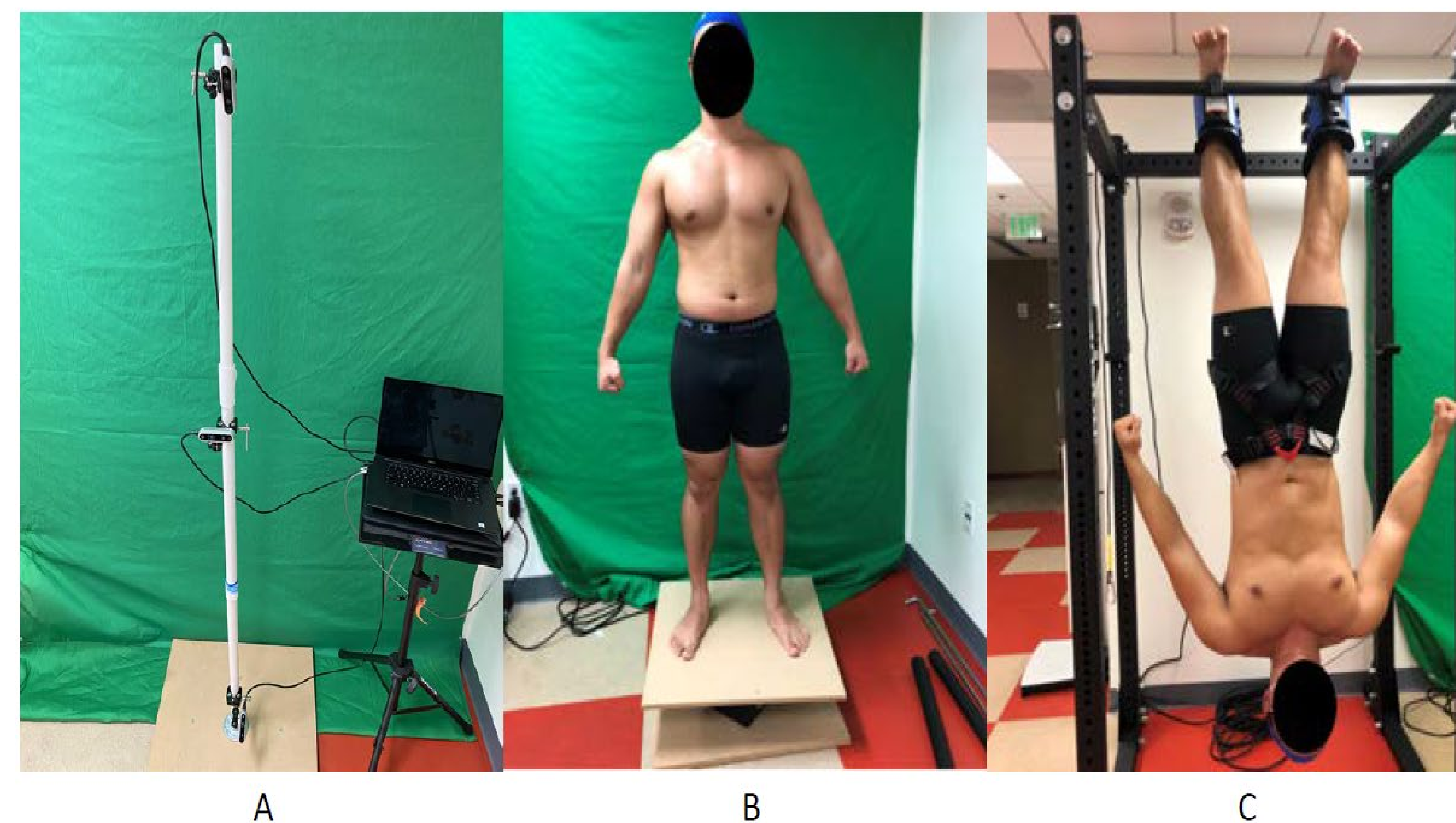


Figure 1. The experimental 3-camera body scanner (A). Participant in position to be scanned in the standing (B) and inverted (C) position.

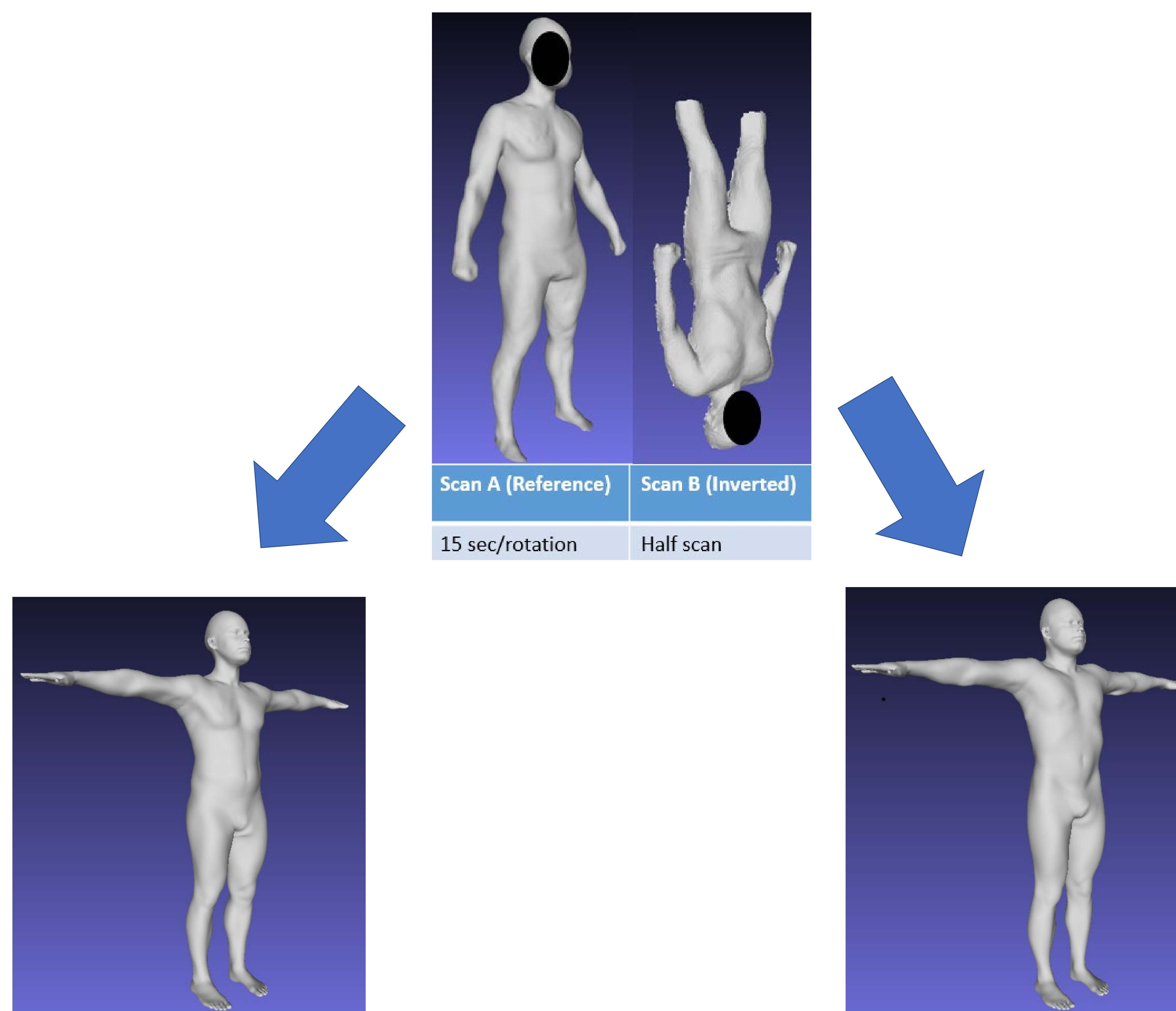


Figure 2. Example meshes from standing and inverted positions (top). Example meshes after templating and reposing (bottom). Meshes of the same person.

Table 1. Sample Characteristics

	Female (N=15)	Male (N=15)	Overall (N=30)
Age (years)			
Mean (SD)	31.1 (9.58)	31.4 (8.35)	31.3 (8.83)
Median [Min, Max]	28.8 [23.1, 59.8]	29.0 [20.3, 51.5]	28.9 [20.3, 59.8]
Height (cm)			
Mean (SD)	162 (6.85)	176 (7.50)	169 (9.82)
Median [Min, Max]	161 [149, 178]	176 [161, 187]	169 [149, 187]
Weight (kg)			
Mean (SD)	64.4 (9.33)	83.0 (13.5)	73.7 (14.8)
Median [Min, Max]	64.8 [46.9, 79.7]	80.2 [56.2, 106]	72.2 [46.9, 106]
BMI (kg/m ²)			
Mean (SD)	24.4 (2.81)	26.8 (3.15)	25.6 (3.17)
Median [Min, Max]	24.0 [20.2, 30.1]	26.9 [21.7, 31.2]	25.5 [20.2, 31.2]
Ethnicity			
Asian	9 (60.0%)	9 (60.0%)	18 (60.0%)
Hispanic	1 (6.7%)	0 (0%)	1 (3.3%)
NHOPi	0 (0%)	1 (6.7%)	1 (3.3%)
White	5 (33.3%)	5 (33.3%)	10 (33.3%)
Total Fat Mass (kg)			
Mean (SD)	17.0 (5.29)	13.4 (5.31)	15.2 (5.53)
Median [Min, Max]	16.8 [10.5, 26.0]	11.7 [7.25, 25.7]	14.1 [7.25, 26.0]
Total Lean Mass (kg)			
Mean (SD)	47.6 (6.05)	70.0 (10.7)	58.8 (14.3)
Median [Min, Max]	47.3 [36.7, 57.3]	71.6 [48.9, 85.3]	54.6 [36.7, 85.3]
Percent Fat (%)			
Mean (SD)	28.4 (5.42)	18.0 (5.16)	23.2 (7.41)
Median [Min, Max]	27.3 [20.5, 37.6]	17.0 [11.4, 27.1]	23.7 [11.4, 37.6]
VAT (kg)			
Mean (SD)	0.178 (0.120)	0.286 (0.115)	0.232 (0.128)
Median [Min, Max]	0.134 [0.0760, 0.516]	0.253 [0.149, 0.595]	0.223 [0.0760, 0.595]

Table 2. Linear Regression Results of 3DO vs. DXA

Outcome	3-Camera vs DXA		Fit3D vs DXA		3-Camera vs Fit3D		3-Camera vs Inverted		Fit3D vs Inverted		DXA vs Inverted	
	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE
Total Fat	0.76	2.62	0.77	2.67	0.9	1.72	0.77	1.96	0.7	2.24	0.52	2.84
Total Lean	0.97	2.04	0.96	2.55	0.99	1.18	0.95	2.71	0.95	2.8	0.93	3.23
Percent Fat	0.7	3.42	0.71	4.07	0.91	1.9	0.64	2.87	0.73	2.47	0.5	3.35
VAT	0.78	0.06	0.68	0.07	0.89	0.04	0.43	0.1	0.3	0.11	0.39	0.11
Arm Fat	0.54	0.26	0.51	0.28	0.86	0.14	0.64	0.2	0.6	0.21	0.21	0.29
Arm Lean	0.94	0.32	0.95	0.28	0.98	0.16	0.95	0.29	0.97	0.24	0.93	0.34
Leg Fat	0.62	0.58	0.69	0.59	0.77	0.45	0.56	0.55	0.38	0.65	0.18	0.75
Leg Lean	0.92	0.62	0.93	0.58	0.98	0.35	0.93	0.51	0.95	0.41	0.86	0.69
Trunk Fat	0.81	1.27	0.82	1.23	0.94	0.72	0.78	1.02	0.64	1.29	0.61	1.36
Trunk Lean	0.94	1.5	0.95	1.36	0.98	0.82	0.95	1.21	0.97	0.93	0.94	1.32

Table 3. Comparison of Anthropometry of 3-Cam Reference vs Inverted Scan

Anthropometry	R ²	RMSE	Mean Difference (cm)	P-Value
Neck Circ.	0.81	1.71	0.2	0.6392
Waist Circ.	0.94	2.01	-3.13	0.0002
Hip Circ.	0.8	1.85	-2.12	0.0138
Thigh Circ.	0.9	0.9	-1.03	0.0223
Arm Circ.	0.88	1.49	1.75	0.0049
Chest Circ.	0.97	1.39	1.53	0.0336

R² and RMSE from linear regression
P-value from paired Student's t-test

Table 4. Test-Retest Precision

	3-Camera (n=30)		Fit3D (n=30)		3-Camera Inverted	
	%CV	RMSE	%CV	RMSE	%CV	RMSE
Total Fat	2.83	0.54	2.39	0.43	7.35	1.32
Total Lean	0.97	0.54	0.78	0.43	2.3	1.32
Percent Fat	2.94	0.75	2.42	0.61	8.31	1.99
VAT	6.62	0.02	5.19	0.01	14.9	0.04
Arm Fat	4.47	0.05	4.43	0.05	9.4	0.11
Arm Lean	2.92	0.11	1.94	0.07	2.95	0.12
Leg Fat	4.42	0.16	3.2	0.11	9	0.32
Leg Lean	2.07	0.2	1.12	0.1	1.34	0.14
Trunk Fat	2.24	0.19	2.16	0.17	6.86	0.56
Trunk Lean	1.83	0.52	0.79	0.22	1.55	0.47

Abbreviations: BMI (body mass index), NHOPi (Native Hawaiian or other Pacific Islander), VAT (visceral adipose tissue), DXA (dual-energy X-ray absorptiometry), Circ (circumferences), R² (coefficient of determination), RMSE (root mean square error), %CV (percent coefficient of determination)

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