Poster # : MM 06

Identifying Associations between Bone Density and Body Shape in Healthy Children

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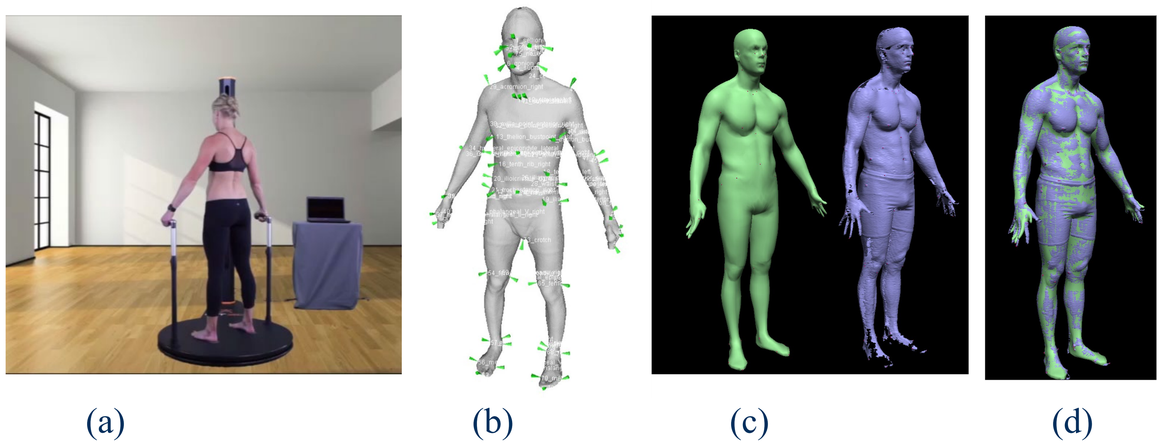
Introduction: Valuable health information such as lean, fat, and bone mass can be extracted from body shape. Different levels of fat and lean mass in children can impact their bone mass. Otherwise healthy children may have low bone density for reasons including low physical activity and malnutrition. The criterion method for quantifying bone mineral content (BMC) and bone mineral density (BMD) in children is dual energy X-ray absorptiometry (DXA). However, because DXA uses ionizing radiation, it can only be used infrequently in children. Also, its cost (device and certified operator) limits its access in underdeveloped areas. In recent years, 3D optical (3DO) imaging has emerged as a versatile tool for health assessment. 3DO is inexpensive, doesn't require a trained operator, and doesn't use ionizing radiation. An alternative paradigm to DXA monitoring may be DXA baseline scans to rule out pathologically low BMD and monitoring frequently with 3DO.

Objectives: To investigate if 3D optical body shape is associated with bone status in healthy children.

Methods:

- Cross sectional study design from multiethnic participants of the Shape Up! Kids Study (n=720, ages 5-17)
- Whole body and lumbar spine DXA scans acquired on three Hologic Discovery/A systems, no NHANES option (UCSF, UHCC, PBRC)
- Duplicate 3DO scans acquired on Fit3D ProScanners (Fit3D, Redwood City, CA)
- 3DO scans were registered using 75 fiducial points from the CAESAR study. Then, a 60,000 vertex template was fit to each scan resulting in 60,000 point registration.



(a) (b) (c) (d)

Figure 1. *(a) Fit3D scanner, (b) 75-point alignment fiducial points, (c) Green 60,000-point template matched to the original purple template, (d) difference in the templat and original image.*

- After registration, principal component analysis (PCA) was used to identify primary modes of variation in 3D body shape and further statistical analysis.
- PCA modes, 476 automated anthropometry variables and demographic variables were related to the DXA measures using simple linear regression.

Results: To date, a total of 109 children have been recruited and after exclusions for scan quality or movement (Table 1.) Subtotal BMC and BMD was highly associated with 3DO anthropometry variables (R2=0.93 and 0.88, respectively) with %CV=3.25 and 1.20, respectively, and to a slightly higher extent that demographic variables. The best prediction of BMD and BMC was from a combination of demographic, anthropometric, and PCA variables (Table 3 and 4).

Table 1. *Population Statistics*

		BOYS					GIRLS				
Variable	**Units**	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Age	years	52	11.8	3.8	5.3	17.4	83	12.7	3.2	5.8	18.0
Weight	kg	42	56.2	27.7	22.3	145.8	66	51.5	17.4	21.3	95.6
Height	cm	42	153.4	19.4	119.1	179.1	65	150.5	14.4	117.1	184.9
BMI	kg/m^2	43	23.4	9.0	14.9	53.4	65	22.3	5.4	14.3	40.1

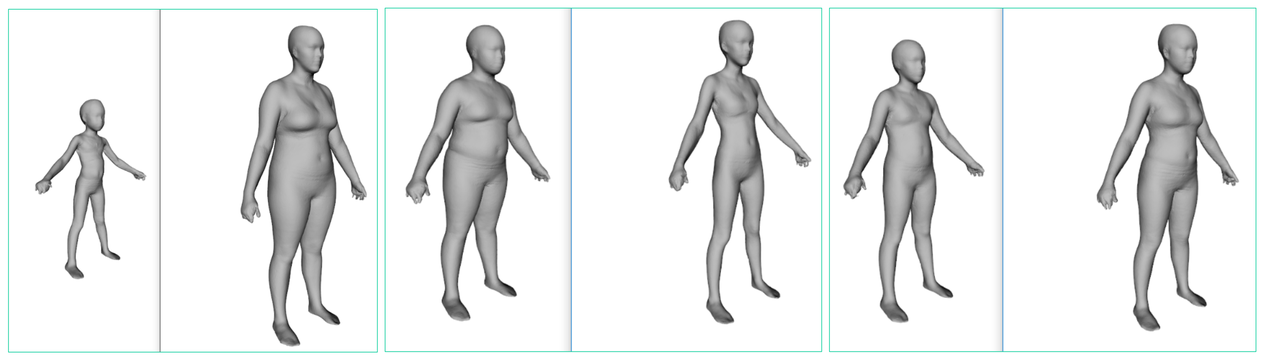


Figure 2: -/+ 3 SD representations of PC1 (left), PC2 (center), and PC3 (right).

Table 2. *R^2 (top) and p-values (below) for the association of DXA and PC modes.*

Variable	PC 01	PC 02	PC 03	PC 04	PC 05	PC 06	PC 07	PC 08	PC 09	PC 10
WBTOT BMC	0.85	0.34	-0.07	0.08	0.03	0.12	0.22	-0.07	0.00	-0.06
	0.00	0.00	0.46	0.43	0.78	0.22	0.02	0.48	0.98	0.54
SUBTOT BMC	0.87	0.34	-0.08	0.05	0.03	0.10	0.21	-0.06	0.01	-0.05
	0.00	0.00	0.45	0.63	0.78	0.30	0.04	0.54	0.90	0.59
L S BMC	0.71	0.39	-0.04	0.07	0.16	0.28	0.24	-0.07	0.08	0.03
	0.00	0.00	0.65	0.47	0.11	0.00	0.01	0.46	0.40	0.78
WBTOT BMD	0.76	0.33	-0.05	0.15	-0.01	0.14	0.23	-0.10	-0.05	-0.14
	0.00	0.00	0.62	0.13	0.94	0.17	0.02	0.31	0.60	0.15
SUBTOT BMD	0.82	0.34	-0.05	0.09	0.00	0.08	0.19	-0.08	-0.04	-0.12
	0.00	0.00	0.59	0.38	0.98	0.41	0.05	0.42	0.68	0.22
LS BMD	0.74	0.32	0.04	0.21	0.01	0.25	0.14	-0.02	-0.04	-0.12
	0.00	0.00	0.67	0.03	0.96	0.01	0.15	0.87	0.69	0.22

Table 3. *Correlations of BMC and BMD to DXA*

Outcome	Demo only		Anthro only		PC only		Anthro/PC		Demo/Anthro/PC	
	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
WBTOT BMC	0.78	0.27	0.89	0.20	0.82	0.23	0.89	0.19	0.91	0.18
WBTOT BMD	0.78	0.08	0.76	0.07	0.72	0.09	0.77	0.07	0.88	0.06
SUBTOT BMC	0.78	0.24	0.90	0.16	0.88	0.18	0.91	0.15	0.93	0.14
SUBTOT BMD	0.79	0.07	0.84	0.06	0.82	0.06	0.85	0.06	0.88	0.05
LS BMD	0.72	0.10	0.75	0.10	0.59	0.12	0.84	0.09	0.85	0.07

Table 4. *Estimates of BMC and BMD to DXA for selected measures*

Outcome	Estimate Equations	Demo/Anthro/PC	
		R^2	RMSE
WBTOT BMC	Height, BMI, waist girth, waist hip ratio, arm surface area, PC 2, PC 6, PC 7, PC 24, PC 33	0.91	0.18
WBTOT BMD	Age, forearm girth, waist hip ratio, arm surface area, PC 5, PC 7, PC10, PC 23, PC 24, PC 33	0.88	0.06
SUBTOT BMC	Height, BMI, waist girth, arm surface area, PC 2, PC 6, PC 7, PC10, PC 21,PC 24, PC 33, PC 36	0.93	0.14
SUBTOT BMD	Height, BMI, waist hip ratio, arm surface area, PC 2, PC 7, PC 10	0.88	0.05
LS BMD	Sex, age, calf girth, waist hip ratio, arm volume, PC 1, PC 7	0.85	0.07

Discussion and Conclusion: Bone health is highly predictable using 3DO body shape scans. Estimates explain approximately 90% of the bone density and mass variance. However, bone pathology is unlikely to be detected. The utility of 3DO may be to monitor lifestyle interventions that target increasing muscle mass and decreasing fat mass with the goal of maximizing peak bone density.

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