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Introduction

- Early childhood is a critical stage for physical growth and cognitive development that forms the foundation for children's future wellbeing;
- **Better understanding growth** patterns in early life is important for developing effective prevention and timely intervention strategies;

Individual Growth Curves



Derivation of adj-FPC2 score

- Calculated the FPC1 and FPC2 scores for WHO "pseudo" children (growth exactly along the WHO percentiles);
- Stratified children in the study cohort based on the FPC1 scores of WHO percentiles (2nd, 5th, 10th, 25th, & 50th-98th);
- Adj-FPC2 score = FPC2 score
 - WHO FPC2 score in the stratum;
- **Adj-FPC2** score characterized the

Risk Factors			
Characteristic/risk factor	Boys (n=270)	Girls (n=225)	Total (n=495)
HAZ at birth	-0.100 ± 1.14	-0.88 ±1.13	-0.94 ± 1.14
Maternal height (cm)	149.91 ± 5.76	149.47 ± 5.14	149.71 ± 5.48
Maternal weight (kg)	48.12 ± 8.50	47.92 ± 8.36	48.023 ± 8.43
Monthly family income (1000 Bangladesh taka) [†]	6.97 ± 3.15	6.97 ± 3.99	6.96 ± 3.55
Maternal education (Y/N)	172 (63.7)	142 (63.1)	314 (63.4)
Exclusive breast-feeding > 6 months (Y/N)	57 (21.1)	48 (21.3)	105 (21.2)
\geq 2 diarrheal episodes in first 6 months (Y/N)	138 (51.1)	112 (49.8)	250 (50.5)

*Data reported as mean \pm SD for continuous measures and number (%) for categorical variables. Abbreviations: HAZ, height-for-age z-score.

Adj-FPC2 as a res	ponse

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Our objective: to characterize early growth patterns in an urban slum cohort of Bangladesh children.

Methods

From Jan 2008 to Dec 2012,

626 children in an urban slum of Dhaka, Bangladesh, were enrolled within 2 weeks of birth and followed up to 5 years;

Anthropometry data were measured at enrollment and every **3 months thereafter;**

Data on outcomes from birth to 2 years of age



FPCA Results

Two leading FPCs: the FPC1 and FPC2 accounted for 93% and 6% of the temporal variation among HAZ curves for boys, and for 96% and 3% for girls;



The mean curves for HAZ (solid lines) and the changes from the mean curves for FPC1 (top) and FPC2 (bottom) respectively wen 2•SD of FPC scores are added to ("+++") or subtracted from ("---")

degree of change in growth, and a positive adj-FPC2 score implied greater deviation of growth, or the catchdown;

		Boys		Girls	
Stratum	WHO Standard (percentile)	No. of Subjects (%)	adj-FPC2	No. of Subjects (%)	adj-FPC2
Stratum 1	2	117 (43.3)	2.04 ± 1.21	92 (40.9)	2.33 ± 0.58
Stratum 2	5	41 (15.2)	1.92 ± 0.98	36 (16.0)	2.23 ± 0.58
Stratum 3	10	41 (15.2)	1.49 ± 1.28	38 (16.9)	2.09 ± 0.48
Stratum 4	25	39 (14.4)	1.68 ± 1.16	36 (16.0)	1.61 ± 0.45
Stratum 5 [†]	50-98	32 (11.9)	1.04 ± 1.22	23 (10.2)	1.47 ± 0.61

*Data reported as mean ± SD or number (%). *Abbreviations*: adj-FPC2: adjusted FPC2 score; WHO, World Health Organization.

Stratum 5 represents children who were classified into the strata of 50th to 98th percentiles due to few children in these strata.



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Risk factor	Coefficient	Р	Coefficient	Р	
Intercept	3.480	< 0.001	2.982	< 0.001	
HAZ at birth	0.941	< 0.001	0.398	< 0.001	
Maternal height	-0.004	0.658	0.011	0.075	
Maternal weight	-0.007	0.314	-0.008	0.026	
Income	-0.027	0.091	-0.008	0.260	
Maternal education	-0.139	0.169	-0.020	0.738	
Exclusive breast-feeding > 6 months	0.374	0.002	-0.063	0.363	
\geq 2 diarrheal episodes in first 6 months	0.020	0.844	-0.056	0.318	
Stratum 2	-0.545	< 0.001	-0.316	< 0.001	
Stratum 3	-1.070	< 0.001	-0.663	< 0.001	
Stratum 4	-1.538	< 0.001	-1.105	< 0.001	
Stratum 5 [†]	-2.623	< 0.001	-1.662	< 0.001	

 $R^2 = 0.62$ for boys and $R^2 = 0.60$ for girls. *Abbreviations*: HAZ, height-for-age z-score.

Stratum 5 represents children who were classified into the strata of 50th to 98th percentiles due to ew children in these strata.

Predictability of FPC scores



FPC1 and adj-FPC2 scores predicted for future stunting (HAZ < -2) at age 3, 4, and 5 (ROCs):

- Boys: 93%, 91% and 92%
- Girls: 91% and 78% in girls

Conclusions



- **Modeling the growth patterns:**
- Height-for-age z-score (HAZ) with \geq 5 measurements (270 boys & 225 girls);
- Functional principal component analysis (FPCA) was used to capture directions of variation among growth curves of the cohort;
- Separate FPCA was carried out for boys and girls;
- FPC scores quantified the deviation of individual growth from the mean curve, and were further adjusted for the WHO growth standards;





- FPC1 captured the overall growth, and a larger positive FPC1 indicated accelerated deceasing curve in HAZ
- FPC2 captured the change in growth, and a larger positive FPC2 score indicated a greater change in growth faltering pattern

- Adj-FPC2 score characterized the downward growth in HAZ, thus growth faltering;
- Adj-FPC scores were positive for all children except 12 boys, indicating that most children in the cohort had downward growth in HAZ;

FPC scores and HAZs

Bo	ys	Girls	
FPC1 Score	FPC2 Score	FPC1 Score	FPC2 Score
-0.849	0.617	-0.971	0.454
-0.940	0.449	-0.982	0.413
-0.996	0.049	-1.000	0.236
-0.980	-0.084	-0.992	0.112
-0.979	-0.082	-0.990	0.103
-0.156	-0.885	-0.047	-0.845
-0.062	-0.904	-0.028	-0.853
	Bo FPC1 Score -0.849 -0.940 -0.996 -0.996 -0.979 -0.156 -0.062	BUBUSFPC1 ScoreFPC2 Score-0.8490.617-0.9400.449-0.9960.049-0.980-0.084-0.979-0.082-0.156-0.885-0.062-0.904	Bby FPC1 Score FPC2 Score FPC1 Score FPC1 Score -0.849 0.617 -0.971 -0.940 0.449 -0.982 -0.996 0.049 -1.000 -0.980 -0.084 -0.992 -0.979 -0.082 -0.990 -0.156 -0.904 -0.028

- The growth patterns in the 1st 2 years of age were characterized by mean curve, FPC1, and FPC2
- The derived adj-FPC2 score quantified the degree of change in growth;
- Factors associated with adj-FPC2 score:
 - FPC1 strata (overall growth)
 - HAZ at birth for boys and girls
 - >6 months of exclusive breastfeeding in boys
 - underweight mother in girls
- FPC1 and adj-FPC2 scores were able to predict the stunting at 3 to 5 years;

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