Design effect in small-scale anthropometric surveys: what parameters influence design effect, and how does this impact survey design?

A meta-analysis of 380 nutrition surveys

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Anthropometric surveys in emergency contexts

- **Information on nutritional status is used to determine severity and monitor progress**
  - Focused on children aged 6-59 months
  - Assessed via cross-sectional surveys
- **Gold-Standard: SRS**
- **More common: Small-scale two-stage cluster surveys**

Design Effect (DEFF)

- **Used to account for loss of precision due to complex survey design**
- **$Var_{complex}$: Var_{SRS}**
- **DEFF = 1 + (B - 1) * ρ**
  - B = mean cluster size
  - ρ = intracluster correlation coefficient (ICC)
- **Direct multiplier of sample size to achieve the same precision as under SRS**

History of design effects in nutrition surveys

- **Default value of 2.0 was first recommended in 1994**
  - "30 x 30" design: 30 clusters of 30 children (total = 900 children)
  - Estimates of wasting, underweight and stunting with a precision of ±5%.
- **Observed DEFF < 2.0**
- **2006 SMART guidelines:**
  - Calculate context-specific sample size and DEFF
  - Use DEFF of 1.5 vs 2.0

Study objectives

1. To describe the DEFFs to help guide survey planning

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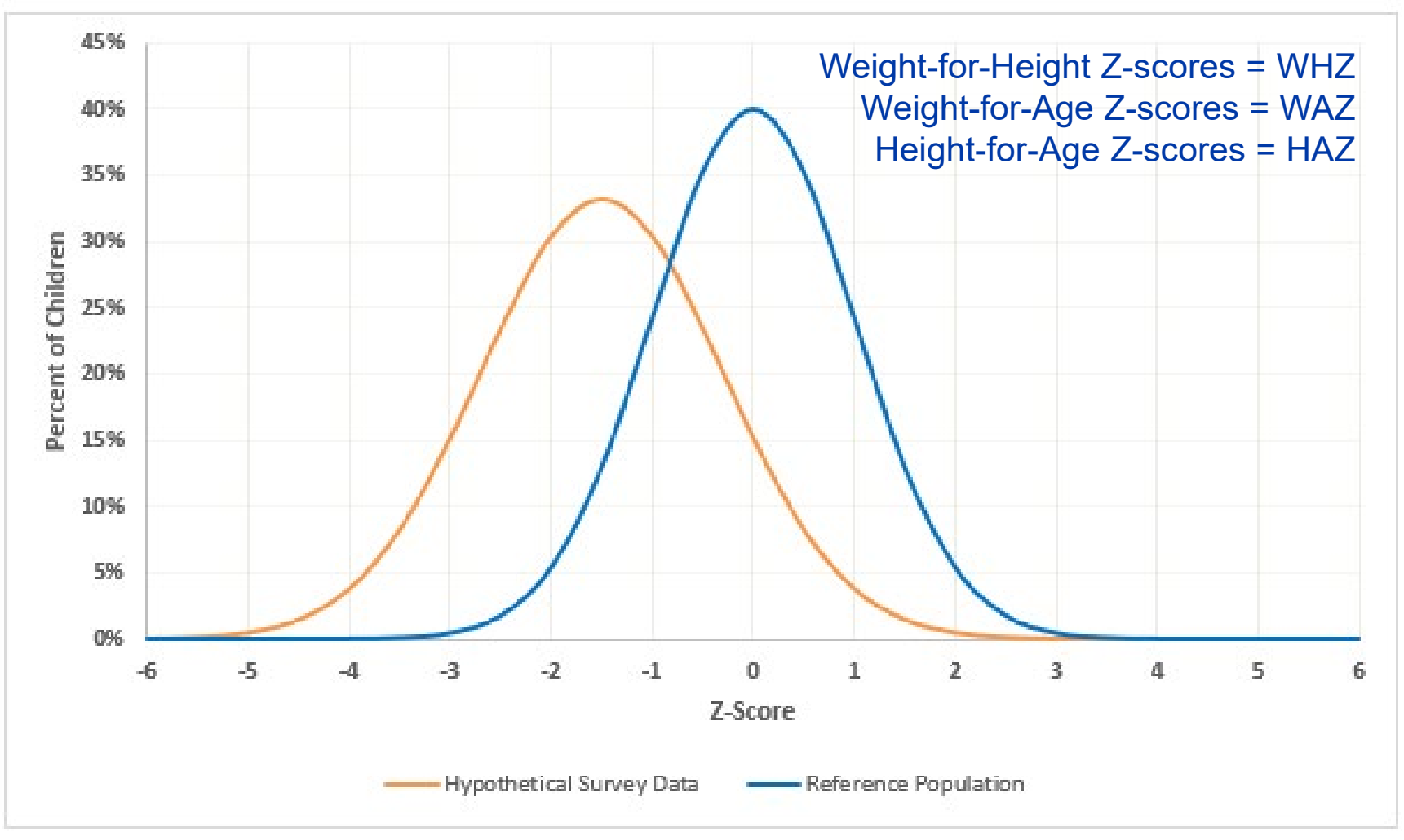
1. To describe the DEFFs to help guide survey planning

2. To evaluate factors associated with DEFF of wasting, underweight, and stunting across small-scale surveys

Study Methods: data acquisition and exclusion criteria

- **Data acquired from Action Contre la Faim (ACF) International**
- **Represents 394 surveys conducted between 2006 and 2013**
- **Survey exclusion criteria:**
  - < 25 clusters
  - < 196 persons
  - > 1500 persons
- **Standard indicators for each child: height, weight, age, sex**
- **Survey year and survey country recorded**
  - Country grouped broadly into regions based on number of surveys

Study Methods: anthropometric Z-scores



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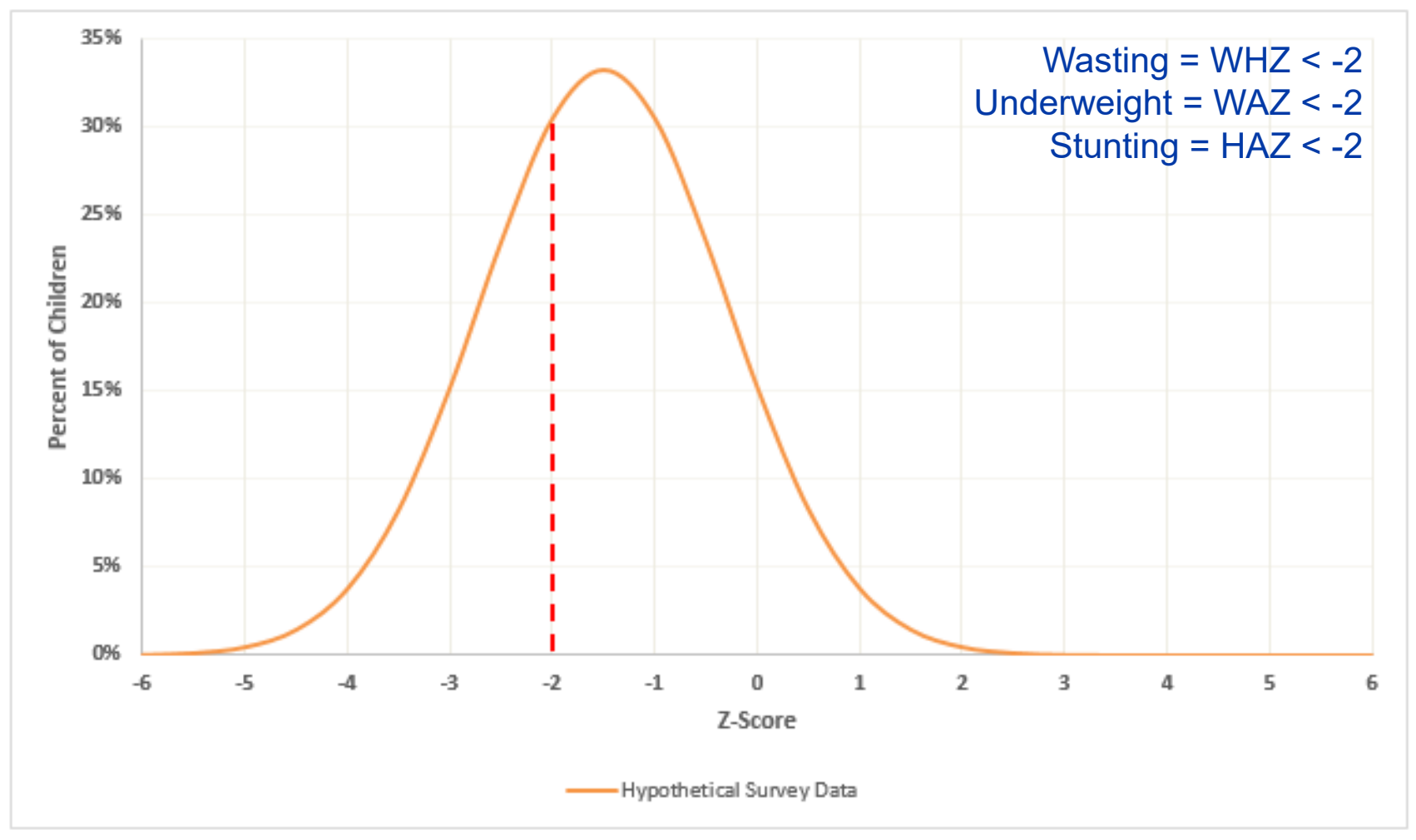


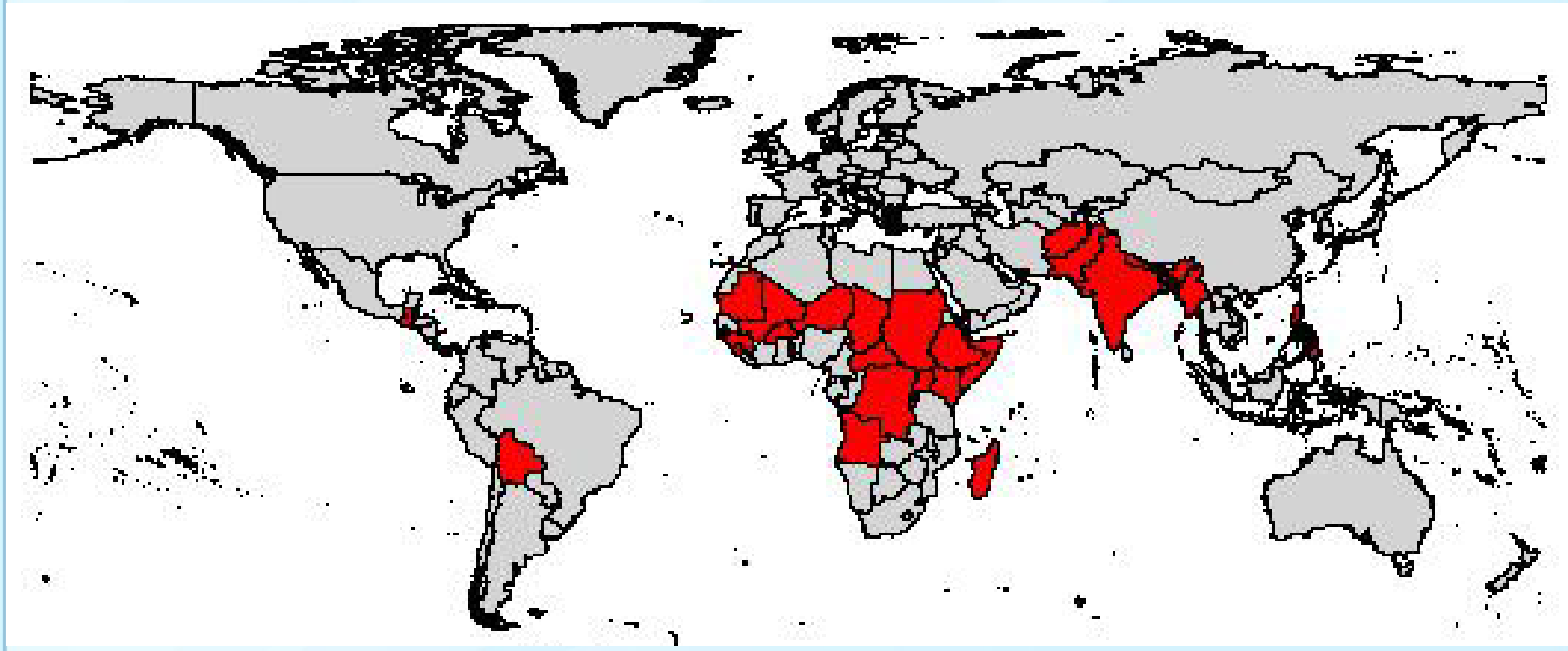
Study Methods: calculating DEFF

- **DEFF was calculated for prevalence of:**
  - Wasting (WHZ < -2 SD)
  - Underweight (WAZ < -2 SD)
  - Stunting (HAZ < -2 SD)
- **Measures of central tendency and dispersion were calculated for DEFF by indicator**
- **The percent of surveys with a DEFF below 2.0 and 1.5 were also computed**

Study Methods: modeling DEFF

- **Univariable and multivariable models built for:**
  - Wasting (WHZ < -2 SD)
  - Underweight (WAZ < -2 SD)
  - Stunting (HAZ < - 2 SD)
- **Included 5 predictors:**
  - Mean Cluster Size
  - Prevalence
  - SD of the continuous Z-scores
    - WHZ, WAZ, HAZ
  - Survey year
  - Survey location
- **By model:**
  - Diagnostics run to exclude outliers
  - Z-score SD < 0.8 were excluded

Study Results



2011 open source global GIS data obtained from DIVA-GIS (http://www.diva-gis.org/Data)

OBJECTIVE 1

Distribution of Design Effects

	Design Effect			
Indicator	**Median (IQR)**	**Range**	**% below 2.00**	**% below 1.50**
Wasting	1.35 (1.10 –1.72)	1.00–5.21	85.79	62.63
Underweight	1.69 (1.35– 2.08)	1.00–4.46	71.32	37.63
Stunting	1.77 (1.41–2.30)	1.00–6.60	62.11	31.05

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OBJECTIVE 2

Modeling design effect: Wasting

	Univariable (n=380)			Multivariable (n=378)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting						
P*(1-P)	2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD	1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size	0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**

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Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

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Underweight						
P*(1-P)	2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD	0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**

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	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
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	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
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	East Africa	0.07	-0.19 – 0.32		0.23	-0.03 – 0.49	
	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
	Democratic Republic of Congo	0.27	0.04 – 0.50		0.03	-0.24 - 0.29	
	Sudan	0.12	-0.13 – 0.37		-0.03	-0.31 - 0.24	
	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
	2009	-0.24	-0.45 - -0.02		-0.17	-0.40 - 0.06	
	2010	-0.20	-0.43 – 0.03		-0.14	-0.39 - 0.10	
	2011	-0.35	-0.58 - -0.11		-0.23	-0.48 - 0.03	
	2012	-0.07	-0.34 – 0.20		-0.02	-0.30 - 0.25	
	2013	-0.41	-0.80 – -0.02		-0.13	-0.55 - 0.29	

Modeling design effect: Underweight

Covariables		Univariable (n=380) Estimate	95% CI	Type III P-value	Multivariable (n=377) Estimate	95% CI	Type III P-value
Underweight							
Location	West Africa	--	--	**0.009**	--	--	**0.005**
	East Africa	0.07	-0.19 – 0.32		0.23	-0.03 – 0.49	
	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
	Democratic Republic of Congo	0.27	0.04 – 0.50		0.03	-0.24 - 0.29	
	Sudan	0.12	-0.13 – 0.37		-0.03	-0.31 - 0.24	
	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
	2009	-0.24	-0.45 - -0.02		-0.17	-0.40 - 0.06	
	2010	-0.20	-0.43 – 0.03		-0.14	-0.39 - 0.10	
	2011	-0.35	-0.58 - -0.11		-0.23	-0.48 - 0.03	
	2012	-0.07	-0.34 – 0.20		-0.02	-0.30 - 0.25	
	2013	-0.41	-0.80 – -0.02		-0.13	-0.55 - 0.29	

Modeling design effect: Underweight

	Univariable (n=380)			Multivariable (n=377)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Underweight						
P*(1-P)	2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD	0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**

Modeling design effect: Underweight

	Univariable (n=380)			Multivariable (n=377)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Underweight						
P*(1-P)	2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD	0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**

Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Stunting						
P*(1-P)	-0.80	-2.38 – 0.78	0.321	-0.45	0.669	0.669
HAZ SD	-0.56	-1.19 – 0.06	0.077	-0.81	-1.51- -0.11	**0.024**
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**

Modeling design effect: Stunting

Covariables		Univariable (n=380) Estimate	95% CI	Type III P-value	Multivariable (n=371) Estimate	95% CI	Type III P-value
Stunting							
Location	West Africa	--	--	**0.035**	--	--	**0.001**
	East Africa	-0.01	-0.36 – 0.33		-0.11	-0.43 - 0.21	
	Central / Southern Africa	0.02	-0.39 – 0.42		0.09	-0.27 - 0.45	
	Democratic Republic of Congo	0.25	-0.06 – 0.56		-0.29	-0.63 – 0.05	
	Sudan	0.36	0.03 – 0.70		-0.19	-0.54 – 0.17	
	Middle East	0.55	0.11 – 1.00		0.52	0.12 – 0.92	
	South Asia	0.09	-0.29 – 0.48		0.31	-0.06 – 0.67	
	Americas	0.17	-0.32 – 0.66		0.35	-0.10 – 0.79	
Survey Year	2006	--	--	**0.008**	--	--	0.083
	2007	-0.36	-0.64 - -0.09		-0.17	-0.42 – 0.08	
	2008	-0.08	-0.33– 0.17		0.11	-0.12 – 0.35	
	2009	-0.41	-0.70 - -0.11		-0.08	-0.38 – 0.21	
	2010	-0.31	-0.63 – 0.00		-0.02	-0.33 – 0.29	
	2011	-0.49	-0.82 - -0.16		-0.30	-0.63 - 0.04	
	2012	-0.17	-0.54 – 0.19		0.09	-0.26 – 0.43	
	2013	-0.63	-1.16 - -0.10		-0.33	-0.87 – 0.20	

Modeling design effect: Stunting

Covariables		Univariable (n=380) Estimate	95% CI	Type III P-value	Multivariable (n=371) Estimate	95% CI	Type III P-value
Stunting							
Location	West Africa	--	--	**0.035**	--	--	**0.001**
	East Africa	-0.01	-0.36 – 0.33		-0.11	-0.43 - 0.21	
	Central / Southern Africa	0.02	-0.39 – 0.42		0.09	-0.27 - 0.45	
	Democratic Republic of Congo	0.25	-0.06 – 0.56		-0.29	-0.63 – 0.05	
	Sudan	0.36	0.03 – 0.70		-0.19	-0.54 – 0.17	
	Middle East	0.55	0.11 – 1.00		0.52	0.12 – 0.92	
	South Asia	0.09	-0.29 – 0.48		0.31	-0.06 – 0.67	
	Americas	0.17	-0.32 – 0.66		0.35	-0.10 – 0.79	
Survey Year	2006	--	--	**0.008**	--	--	0.083
	2007	-0.36	-0.64 - -0.09		-0.17	-0.42 – 0.08	
	2008	-0.08	-0.33– 0.17		0.11	-0.12 – 0.35	
	2009	-0.41	-0.70 - -0.11		-0.08	-0.38 – 0.21	
	2010	-0.31	-0.63 – 0.00		-0.02	-0.33 – 0.29	
	2011	-0.49	-0.82 - -0.16		-0.30	-0.63 - 0.04	
	2012	-0.17	-0.54 – 0.19		0.09	-0.26 – 0.43	
	2013	-0.63	-1.16 - -0.10		-0.33	-0.87 – 0.20	

Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Stunting						
P*(1-P)	-0.80	-2.38 – 0.78	0.321	-0.45	0.669	0.669
HAZ SD	-0.56	-1.19 – 0.06	0.077	-0.81	-1.51- -0.11	**0.024**
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**

Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
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P*(1-P)	-0.80	-2.38 – 0.78	0.321	-0.45	0.669	0.669
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Modeling design effect: Stunting

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Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
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Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**

Modeling design effect: Stunting

Covariables		Univariable (n=380) Estimate	95% CI	Type III P-value	Multivariable (n=371) Estimate	95% CI	Type III P-value
Stunting							
Location	West Africa	--	--	**0.035**	--	--	**0.001**
	East Africa	-0.01	-0.36 – 0.33		-0.11	-0.43 - 0.21	
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	Democratic Republic of Congo	0.25	-0.06 – 0.56		-0.29	-0.63 – 0.05	
	Sudan	0.36	0.03 – 0.70		-0.19	-0.54 – 0.17	
	Middle East	0.55	0.11 – 1.00		0.52	0.12 – 0.92	
	South Asia	0.09	-0.29 – 0.48		0.31	-0.06 – 0.67	
	Americas	0.17	-0.32 – 0.66		0.35	-0.10 – 0.79	
Survey Year	2006	--	--	**0.008**	--	--	0.083
	2007	-0.36	-0.64 - -0.09		-0.17	-0.42 – 0.08	
	2008	-0.08	-0.33– 0.17		0.11	-0.12 – 0.35	
	2009	-0.41	-0.70 - -0.11		-0.08	-0.38 – 0.21	
	2010	-0.31	-0.63 – 0.00		-0.02	-0.33 – 0.29	
	2011	-0.49	-0.82 - -0.16		-0.30	-0.63 - 0.04	
	2012	-0.17	-0.54 – 0.19		0.09	-0.26 – 0.43	
	2013	-0.63	-1.16 - -0.10		-0.33	-0.87 – 0.20	

Modeling design effect: Stunting

Covariables		Univariable (n=380) Estimate	95% CI	Type III P-value	Multivariable (n=371) Estimate	95% CI	Type III P-value
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	Americas	0.17	-0.32 – 0.66		0.35	-0.10 – 0.79	
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	2007	-0.36	-0.64 - -0.09		-0.17	-0.42 – 0.08	
	2008	-0.08	-0.33– 0.17		0.11	-0.12 – 0.35	
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	2010	-0.31	-0.63 – 0.00		-0.02	-0.33 – 0.29	
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	2013	-0.63	-1.16 - -0.10		-0.33	-0.87 – 0.20	

Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
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Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**

Modeling design effect: Stunting

	Univariable (n=380)			Multivariable (n=371)		
Covariables	Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
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P*(1-P)	-0.80	-2.38 – 0.78	0.321	-0.45	0.669	0.669
HAZ SD	-0.56	-1.19 – 0.06	0.077	-0.81	-1.51- -0.11	**0.024**
Mean Cluster Size	0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**

Conclusions – Distribution of Design Effects

- **Median Wasting DEFF ≈ 1.35**
  - Recommended DEFF = 1.5
  - 63% DEFFs <1.5
- **Median Underweight DEFF ≈ 1.69**
  - Recommended DEFF = 2.0
  - 71% DEFFs < 2.0
- **Median Stunting DEFF ≈ 1.77**
  - Recommended DEFF = 2.0
  - 62% DEFFs < 2.0

Conclusions – Modeling design effect

- **Mean cluster size significantly, positively related to DEFF for all three indicators**
- **Prevalence significantly, positively associated with DEFF for wasting, underweight**
  - Non-significant for stunting
- **Survey location significant across all three models**
- **Relationship between Z-score SDs and DEFF unclear – differed across all three models**

Limitations

- Adjusted R^2 values were low
- Analysis only included surveys conducted by ACF
- Most countries were grouped broadly into regions
- Not nationally representative surveys

Recommendations

- Wasting DEFF = 1.5 is appropriate in the absence of other information
- Region-specific estimates should be used where available
- Increases to mean cluster size and prevalence may result in a larger DEFF
- Further research is needed to better understand the relationship between SD and DEFF

Acknowledgements

- **Centers for Disease Control and Prevention (CDC)**
  - Curtis Blanton
  - Eva Leidman
  - Oleg Bilukha
  - Susan Cookson
- **Action Contre la Faim**

Photo by Gonzalo Hohr (Niger) taken from smartmethodology.org

Formulae

- $DEFF = 1 + \rho * (B - 1)$ where:

  ρ = intracluster correlation coefficient

  B= mean cluster size

- $\rho = {S_b^2}/{(S_b^2 + S_w^2)}$ where:

  S_b^2 = between cluster variance

  S_w^2 = within cluster variance

- $n = \frac{p*(1-p) * t^2 * DEFF}{d^2}$, where:

  p = prevalence

  t^2= a Student's t-score with degrees of freedom equal to the number of clusters minus 1 and an alpha of 0.05 (corresponding to 95% confidence level)

  d = half-width of the two-sided 95% confidence interval

  DEFF = design effect, and

  n= target sample size

Regional Groupings

- **Americas**
  - Bolivia
  - Guatemala
  - Haiti
- **South Asia**
  - Bangladesh
  - India
  - Myanmar
  - Nepal
  - Philippines
- **East Africa**
  - Burundi
  - Ethiopia
  - Kenya
  - Somalia
  - South Sudan
  - Uganda
- **Middle East**
  - Pakistan
  - Afghanistan
- **Central / Southern Africa**
  - Angola
  - Central African Republic
  - Madagascar
  - Chad
- **West Africa**
  - Burkina Faso
  - Guinea
  - Mali
  - Mauritania
  - Niger
  - Sierra Leone

Study Methods

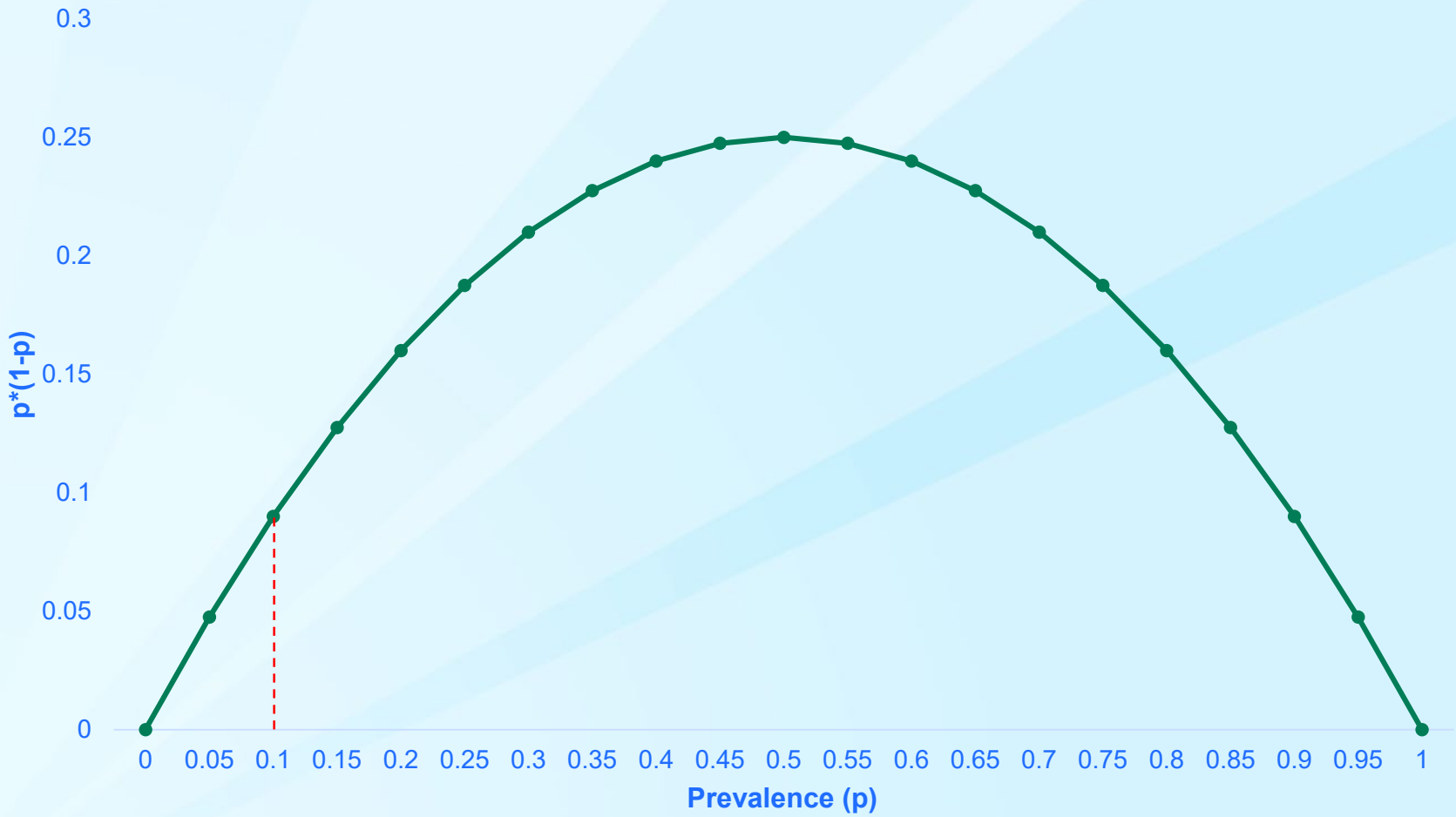
- **For each child, Z-scores were calculated for each of the three main nutrition indicators - Weight-for-Height (WHZ), Weight-for-Age (WAZ), and Height-for-Age (HAZ)**
- **Mean and SD were computed for each survey to describe the Z-score distributions**
- **Prevalence of wasting, stunting and underweight were derived from the continuous Z-score distributions for each survey**
  - Each reflects the proportion of children with Z-scores less than -2 for WHZ, HAZ, and WAZ, respectively
  - Separately for each indicator, outlier observations were excluded from a survey if the observed Z-score of a child fell outside the flexible exclusion range of ±4 Z-scores from the observed survey sample mean
- **Mean, variance, median and IQR for the cluster size and number of clusters was computed to describe the survey design**

Emergency Nutrition Thresholds

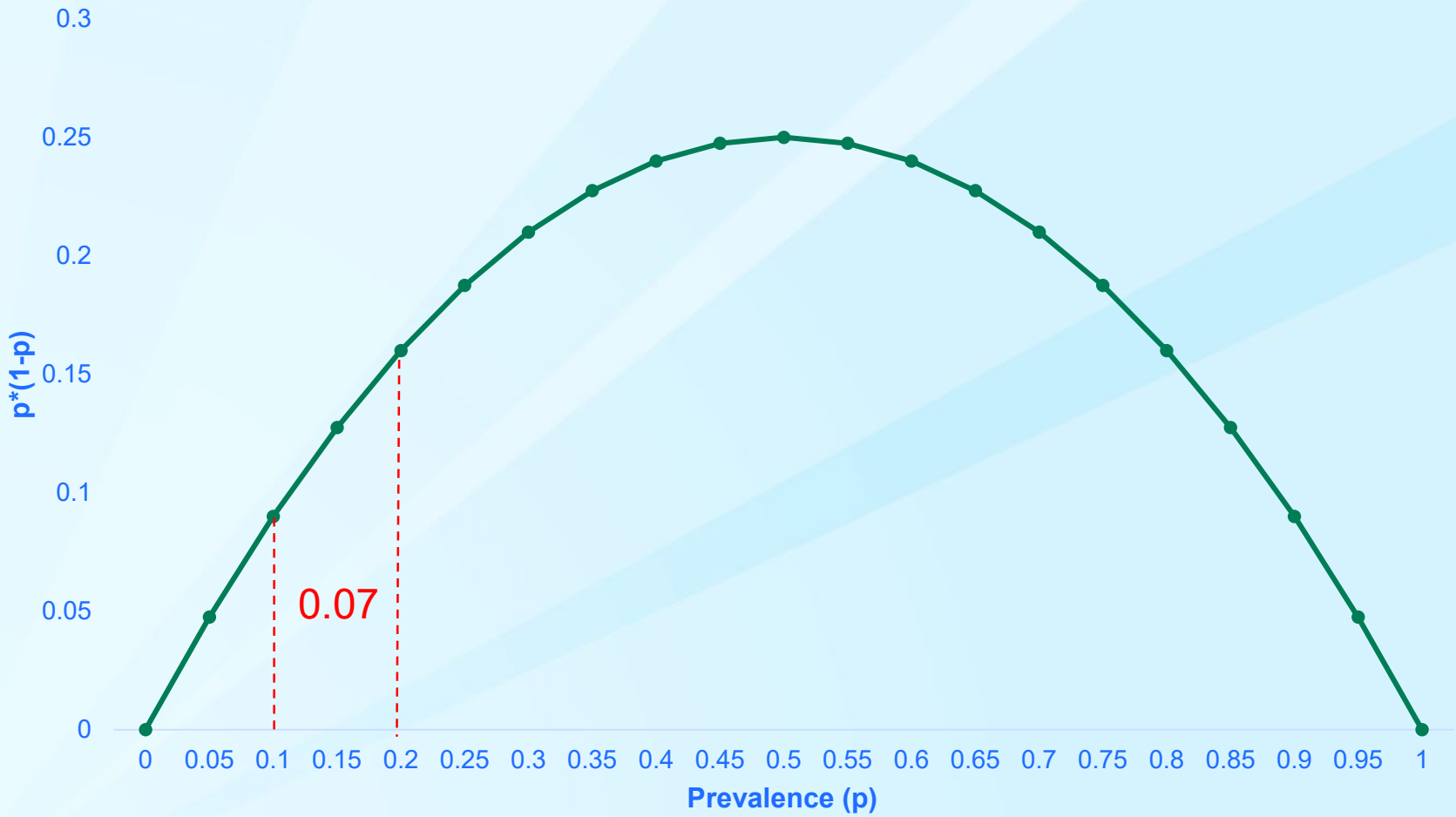
Indicator	Severity of malnutrition by prevalence ranges (%)			
	Low	Medium	High	Very high
Wasting	< 5	5-9	10-14	≥ 15
Underweight	< 10	10-19	20-29	≥ 30
Stunting	< 20	20-29	30-39	≥ 40

Recreated from the WHO Global Database on Child Growth and Malnutrition (http://www.who.int/nutgrowthdb/about/introduction/en/index5.html)

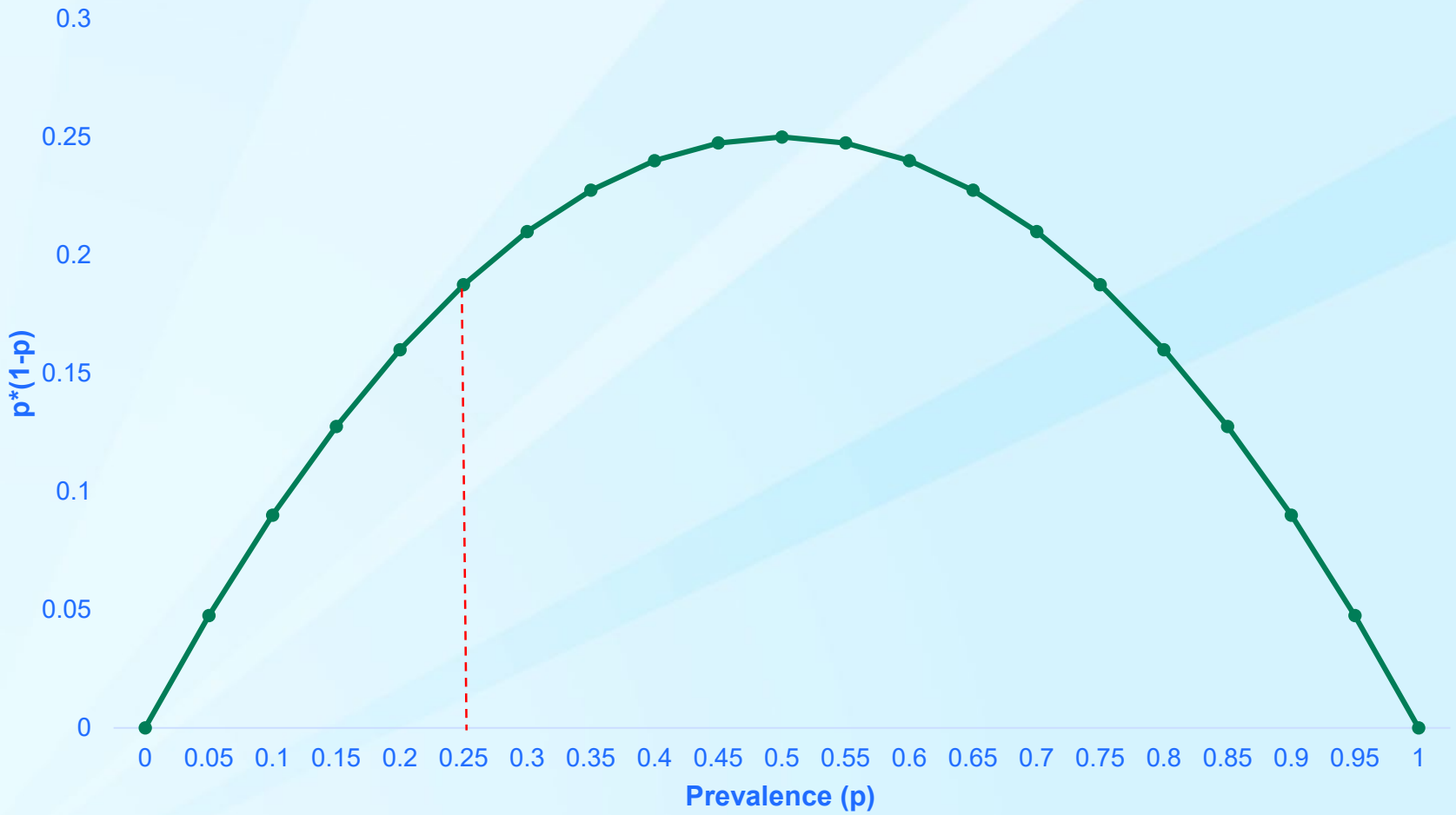
Parabolic p*(1-p) relationship



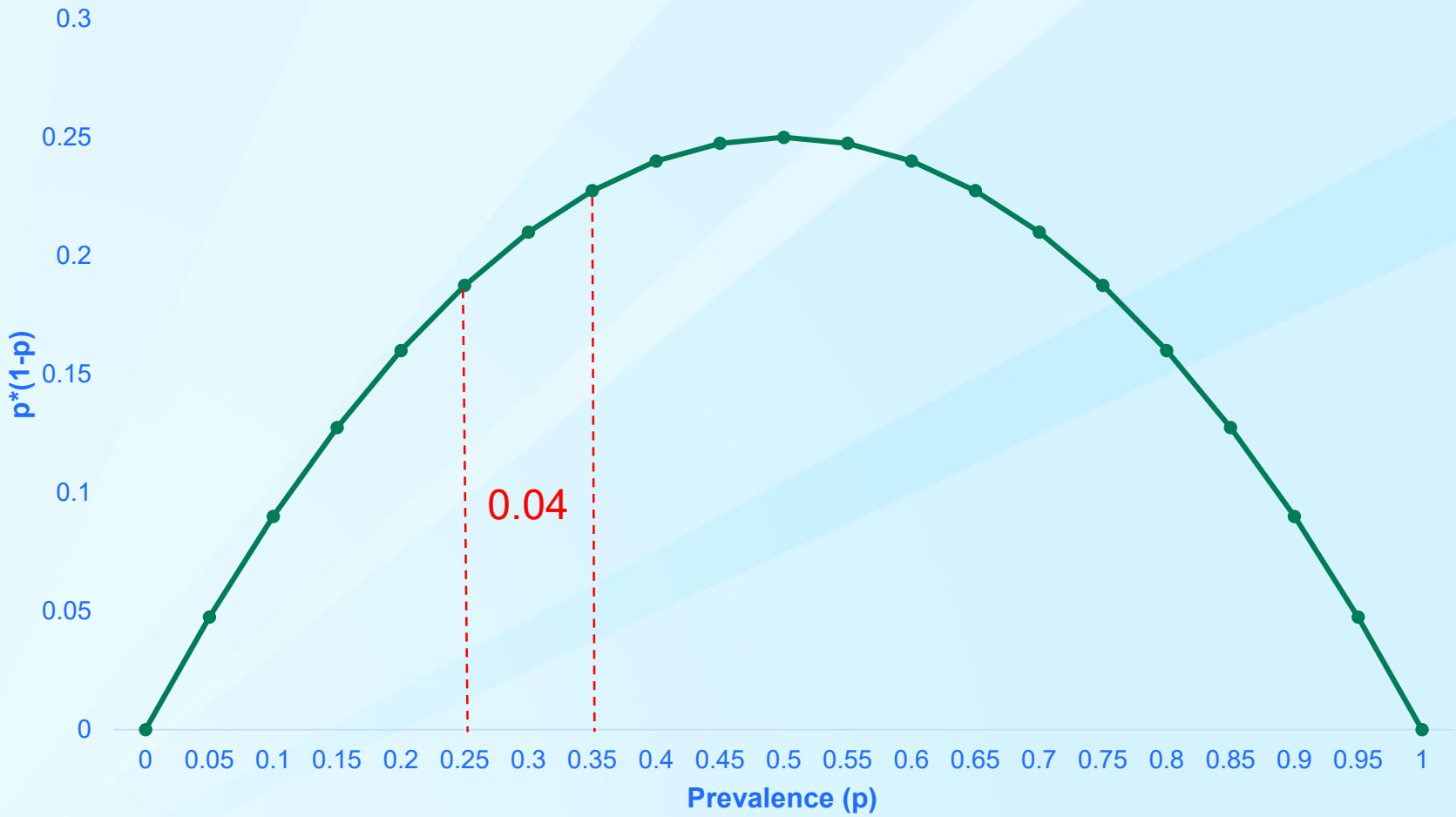
Parabolic p*(1-p) relationship



Parabolic p*(1-p) relationship

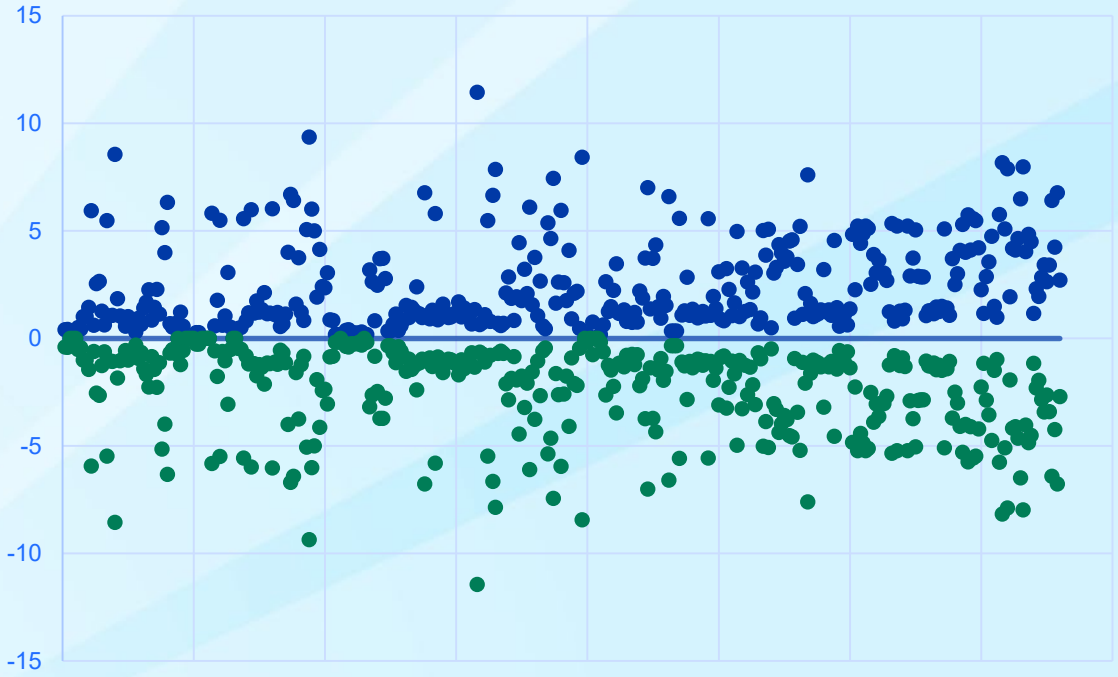


Parabolic p*(1-p) relationship



Variability of cluster size

Quantile	SD
Min	0.00
Q1	0.86
Median	1.42
Q3	3.61
Max	11.44



Modeling design effect: WHZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting							
P*(1-P)		2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD		1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size		0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**
Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

Modeling design effect: WHZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting							
P*(1-P)		2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD		1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size		0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**
Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

Modeling design effect: WHZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting							
P*(1-P)		2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD		1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size		0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**
Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

Modeling design effect: WHZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting							
P*(1-P)		2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD		1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size		0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**
Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

Modeling design effect: WAZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Underweight							
P*(1-P)		2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD		0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size		0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**
Location	West Africa	--	--	**0.009**	--	--	**0.005**
	East Africa	0.07	-0.19 – 0.32		0.23	-0.03 – 0.49	
	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
	Democratic Republic of Congo	0.27	0.04 – 0.50		0.03	-0.24 - 0.29	
	Sudan	0.12	-0.13 – 0.37		-0.03	-0.31 - 0.24	
	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
	2009	-0.24	-0.45 - -0.02		-0.17	-0.40 - 0.06	
	2010	-0.20	-0.43 – 0.03		-0.14	-0.39 - 0.10	
	2011	-0.35	-0.58 - -0.11		-0.23	-0.48 - 0.03	
	2012	-0.07	-0.34 – 0.20		-0.02	-0.30 - 0.25	
	2013	-0.41	-0.80 – -0.02		-0.13	-0.55 - 0.29	

Modeling design effect: WAZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Underweight							
P*(1-P)		2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD		0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size		0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**
Location	West Africa	--	--	**0.009**	--	--	**0.005**
	East Africa	0.07	-0.19 – 0.32		0.23	-0.03 – 0.49	
	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
	Democratic Republic of Congo	0.27	0.04 – 0.50		0.03	-0.24 - 0.29	
	Sudan	0.12	-0.13 – 0.37		-0.03	-0.31 - 0.24	
	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
	2009	-0.24	-0.45 - -0.02		-0.17	-0.40 - 0.06	
	2010	-0.20	-0.43 – 0.03		-0.14	-0.39 - 0.10	
	2011	-0.35	-0.58 - -0.11		-0.23	-0.48 - 0.03	
	2012	-0.07	-0.34 – 0.20		-0.02	-0.30 - 0.25	
	2013	-0.41	-0.80 – -0.02		-0.13	-0.55 - 0.29	

Modeling design effect: WHZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Wasting							
P*(1-P)		2.52	1.51– 3.53	**<0.001**	3.76	2.59 - 4.94	**<0.001**
WHZ SD		1.96	1.27 - 2.65	**<0.001**	0.95	0.20 - 1.70	**0.014**
Mean Cluster Size		0.02	0.01 - 0.02	**<0.001**	0.02	0.00 - 0.03	**0.013**
Location	West Africa	--	--	**0.003**	--	--	**<0.001**
	East Africa	0.20	-0.03 - 0.43		0.22	0.02 - 0.42	
	Central / Southern Africa	-0.02	-0.28 – 0.25		0.07	-0.17 - 0.30	
	Democratic Republic of Congo	0.19	-0.02 – 0.39		0.18	-0.04 - 0.40	
	Sudan	0.17	-0.05 – 0.40		-0.17	-0.39 - 0.05	
	Middle East	0.52	0.22 – 0.81		0.42	0.16 - 0.69	
	South Asia	0.02	-0.23 – 0.28		0.27	0.03 - 0.51	
	Americas	-0.10	-0.43 – 0.22		0.32	0.01 - 0.63	
Survey Year	2006	--	--	**0.003**	--	--	0.091
	2007	-0.16	-0.34 – 0.03		-0.03	-0.19 - 0.13	
	2008	-0.17	-0.34 - - 0.01		-0.05	-0.20 - 0.10	
	2009	-0.30	-0.49 - -0.10		-0.16	-0.35 - 0.03	
	2010	-0.31	-0.52 - -0.10		-0.23	-0.44 - -0.03	
	2011	-0.38	-0.59 - -0.17		-0.30	-0.51 - -0.09	
	2012	-0.21	-0.45 – 0.03		-0.12	-0.35 - 0.10	
	2013	-0.56	-0.91 - -0.21		-0.29	-0.64 - 0.05	

Modeling design effect: WAZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Underweight							
P*(1-P)		2.23	0.93 – 3.53	**<0.001**	2.76	1.17 - 4.35	**<0.001**
WAZ SD		0.98	0.32 - 1.60	**0.002**	0.12	-0.65-0.89	0.753
Mean Cluster Size		0.02	0.01 – 0.03	**<0.001**	0.03	0.02 - 0.04	**<0.001**
Location	West Africa	--	--	**0.009**	--	--	**0.005**
	East Africa	0.07	-0.19 – 0.32		0.23	-0.03 – 0.49	
	Central / Southern Africa	0.05	-0.25 – 0.34		0.12	-0.17 - 0.41	
	Democratic Republic of Congo	0.27	0.04 – 0.50		0.03	-0.24 - 0.29	
	Sudan	0.12	-0.13 – 0.37		-0.03	-0.31 - 0.24	
	Middle East	0.51	0.18 – 0.84		0.51	0.19 - 0.84	
	South Asia	0.00	-0.28 – 0.28		0.17	-0.13 - 0.47	
	Americas	0.14	-0.23 – 0.50		0.51	0.13 - 0.90	
Survey Year	2006	--	--	**0.007**	--	--	0.088
	2007	-0.26	-0.47 - -0.06		-0.21	-0.41 - -0.01	
	2008	-0.01	-0.19 – 0.18		0.04	-0.14 - 0.22	
	2009	-0.24	-0.45 - -0.02		-0.17	-0.40 - 0.06	
	2010	-0.20	-0.43 – 0.03		-0.14	-0.39 - 0.10	
	2011	-0.35	-0.58 - -0.11		-0.23	-0.48 - 0.03	
	2012	-0.07	-0.34 – 0.20		-0.02	-0.30 - 0.25	
	2013	-0.41	-0.80 – -0.02		-0.13	-0.55 - 0.29	

Modeling design effect: HAZ

		Univariable			Multivariable		
Covariables		Estimate	95% CI	Type III P-value	Estimate	95% CI	Type III P-value
Stunting							
P*(1-P)		-0.80	-2.38 – 0.78	0.321	-0.45	0.669	0.669
HAZ SD		-0.56	-1.19 – 0.06	0.077	-0.81	-1.51- -0.11	**0.024**
Mean Cluster Size		0.02	0.01 – 0.03	**<0.001**	0.04	0.02 – 0.06	**<0.001**
Location	West Africa	--	--	**0.035**	--	--	**0.001**
	East Africa	-0.01	-0.36 – 0.33		-0.11	-0.43 - 0.21	
	Central / Southern Africa	0.02	-0.39 – 0.42		0.09	-0.27 - 0.45	
	Democratic Republic of Congo	0.25	-0.06 – 0.56		-0.29	-0.63 – 0.05	
	Sudan	0.36	0.03 – 0.70		-0.19	-0.54 – 0.17	
	Middle East	0.55	0.11 – 1.00		0.52	0.12 – 0.92	
	South Asia	0.09	-0.29 – 0.48		0.31	-0.06 – 0.67	
	Americas	0.17	-0.32 – 0.66		0.35	-0.10 – 0.79	
Survey Year	2006	--	--	**0.008**	--	--	0.083
	2007	-0.36	-0.64 - -0.09		-0.17	-0.42 – 0.08	
	2008	-0.08	-0.33– 0.17		0.11	-0.12 – 0.35	
	2009	-0.41	-0.70 - -0.11		-0.08	-0.38 – 0.21	
	2010	-0.31	-0.63 – 0.00		-0.02	-0.33 – 0.29	
	2011	-0.49	-0.82 - -0.16		-0.30	-0.63 - 0.04	
	2012	-0.17	-0.54 – 0.19		0.09	-0.26 – 0.43	
	2013	-0.63	-1.16 - -0.10		-0.33	-0.87 – 0.20	