SEX DIFFERENCES IN STUNTING: PATTERNS AND MECHANISMS

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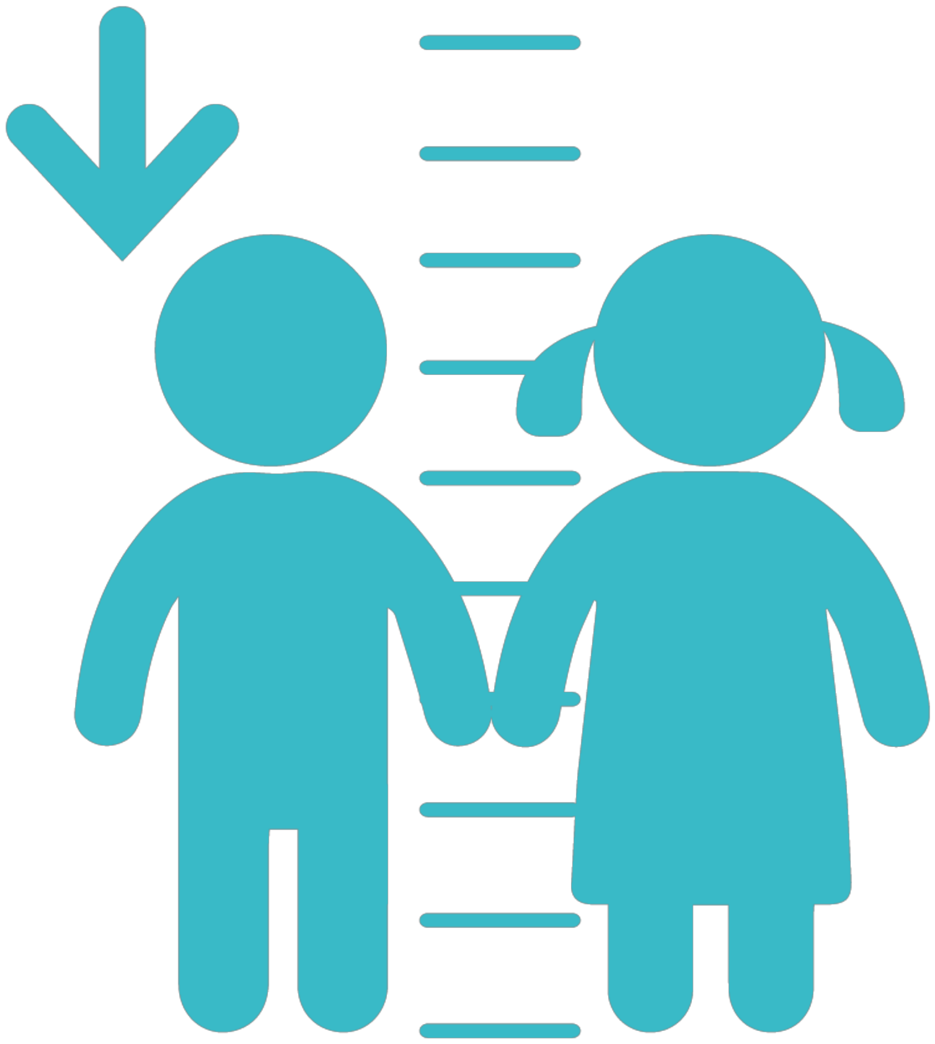
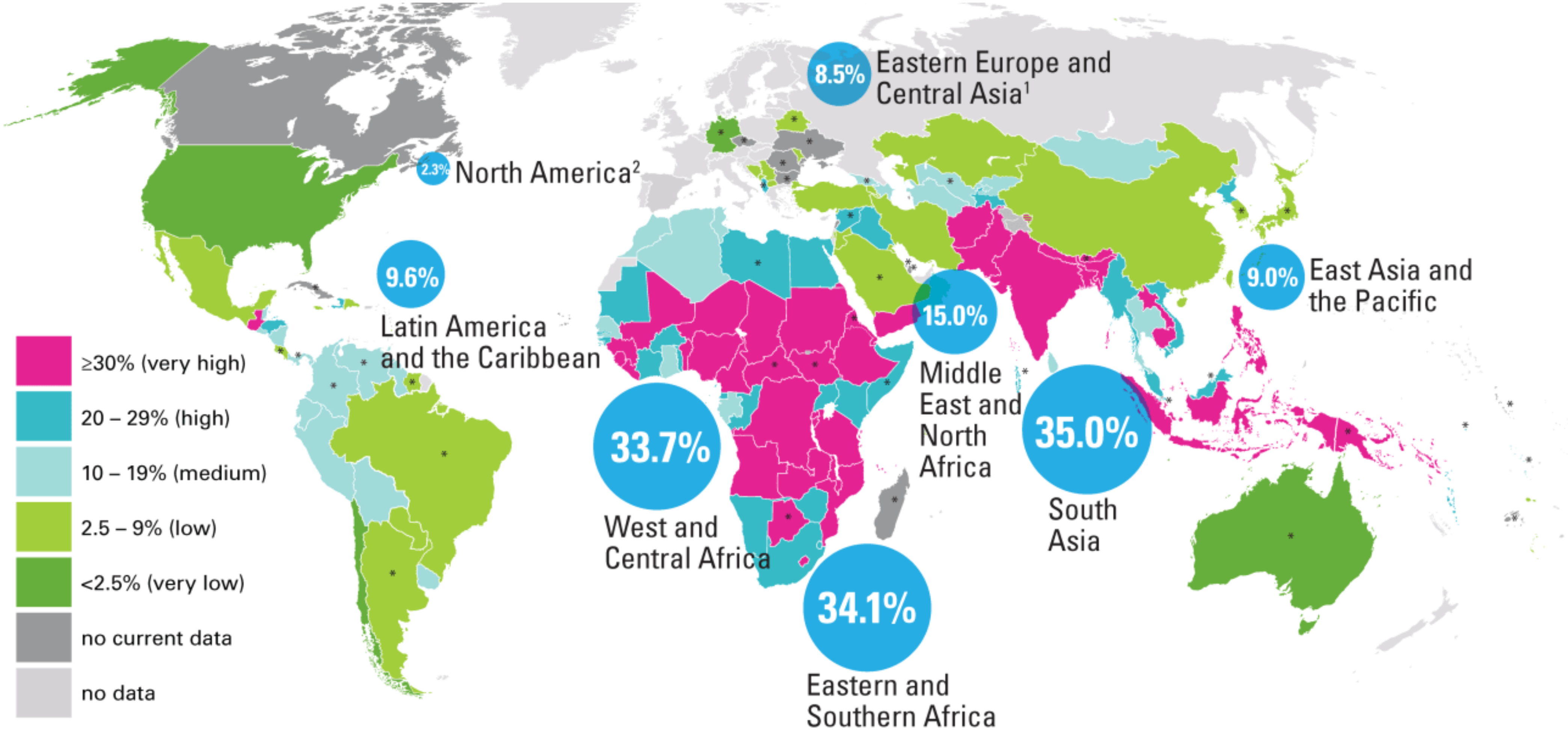


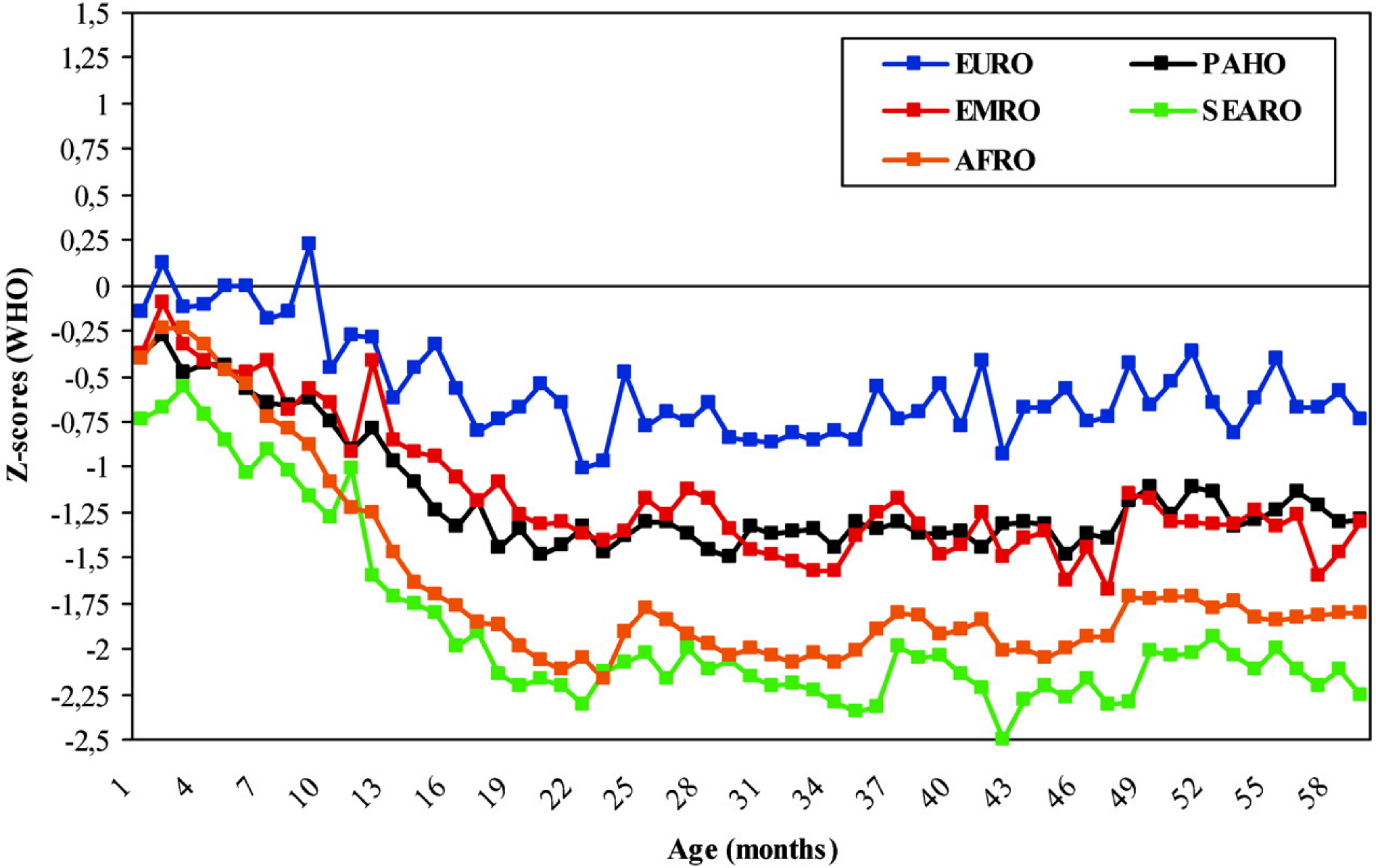
GLOBAL PREVALENCE OF STUNTING



UNICEF 2018

STUNTING BEGINS EARLY

Mean height for age *z* scores by age, relative to the WHO standard, according to region (1–59 months).



Victoria et al, 2010

SEX DIFFERENCES IN STUNTING PREVALENCE

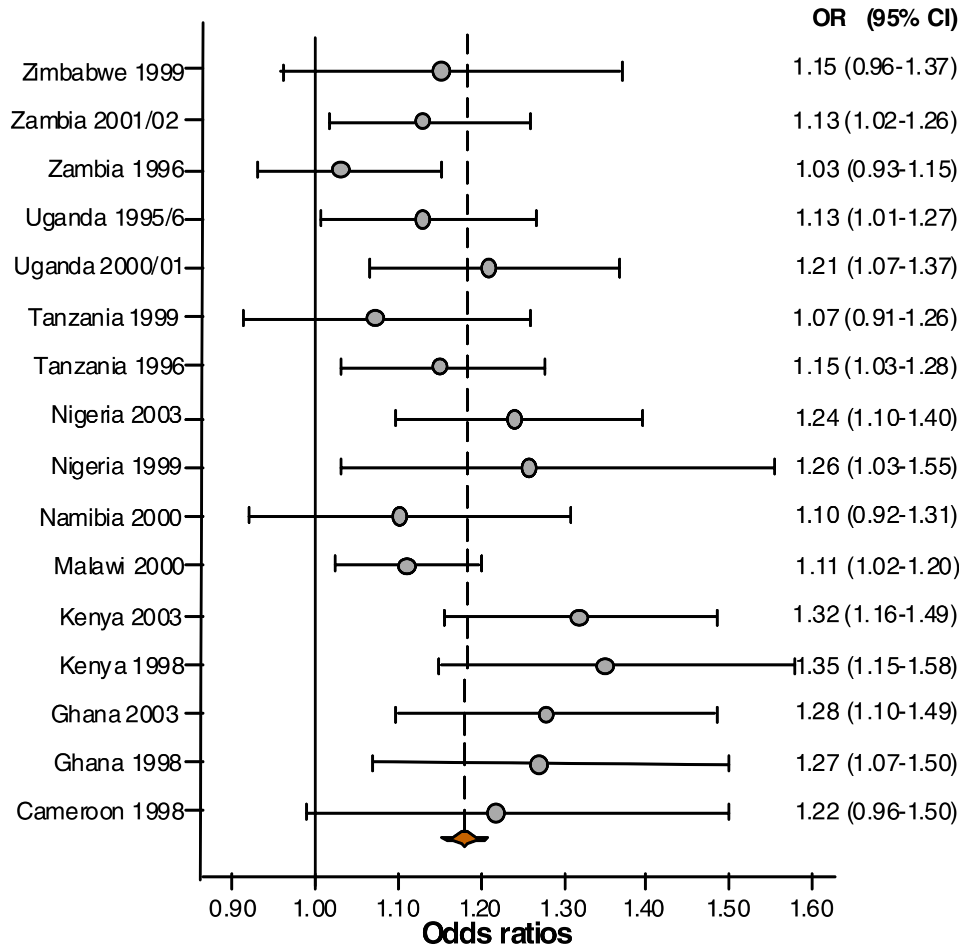
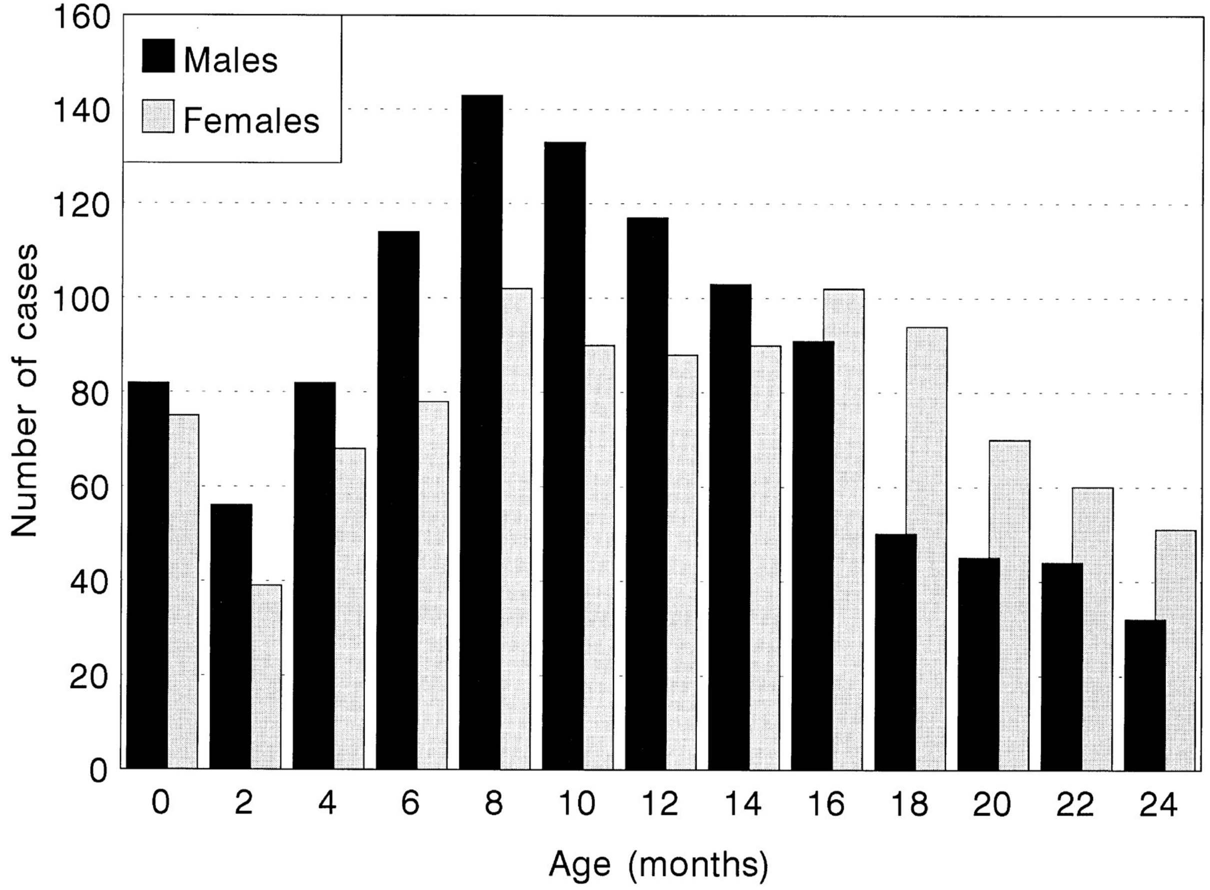


Figure 2
Forest plot of 16 studies indicating the excess of stunting prevalence in male compared to female children. The broken vertical line represents the odds ratio of the pooled results adjusted for child-age and individual study, with the confidence interval corresponding to the width of the diamond. The unbroken vertical line is at the null value (1) of the odds ratios (equivalent to no stunting difference between boys and girls).

Wamani et al, BMC Pediatrics, 2007

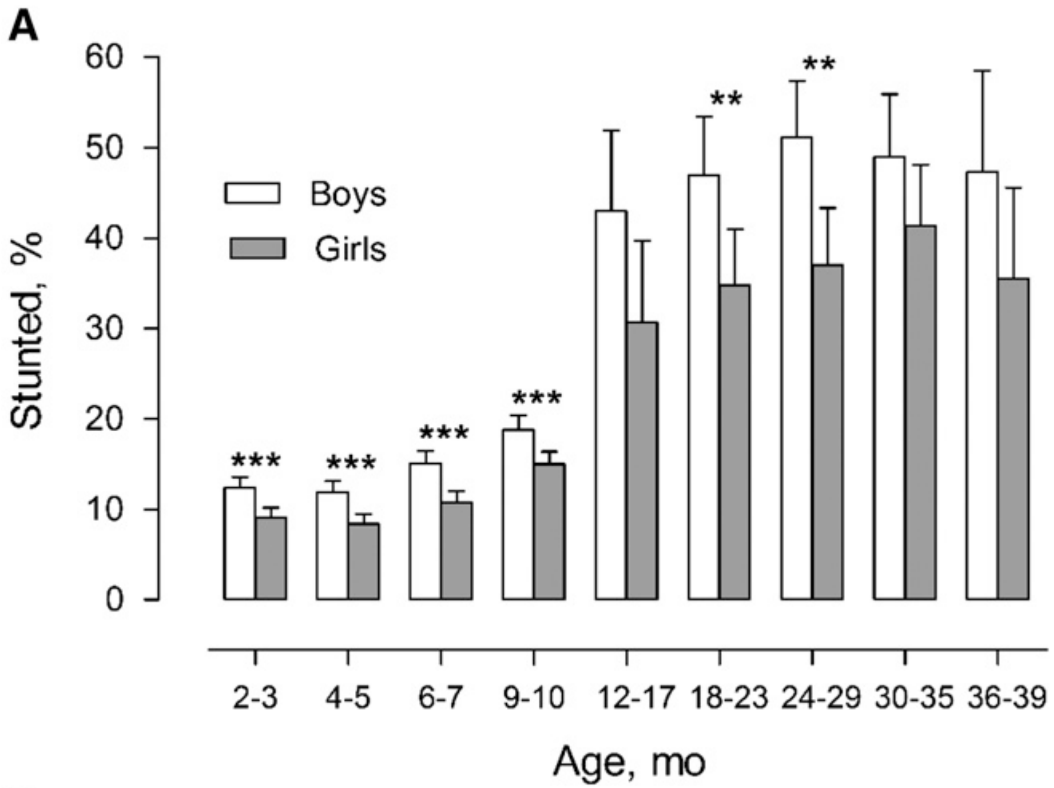
SEX DIFFERENCES BEGIN EARLY IN INFANCY

Filipino Infants



Adair and Guilkey, J Nutrition, 1997

Senegalese Infants



Bork and Diallo, J Nutr 2017

SEX DIFFERENCES SEEN ACROSS MALNUTRITION INDICATORS AND SEVERITY LEVELS

Table 2. Prevalence of severe underweight (W/A<-3SD), severe wasting (W/H<-3SD) and severe stunting (H/A<-3SD) by sex and geographic location.

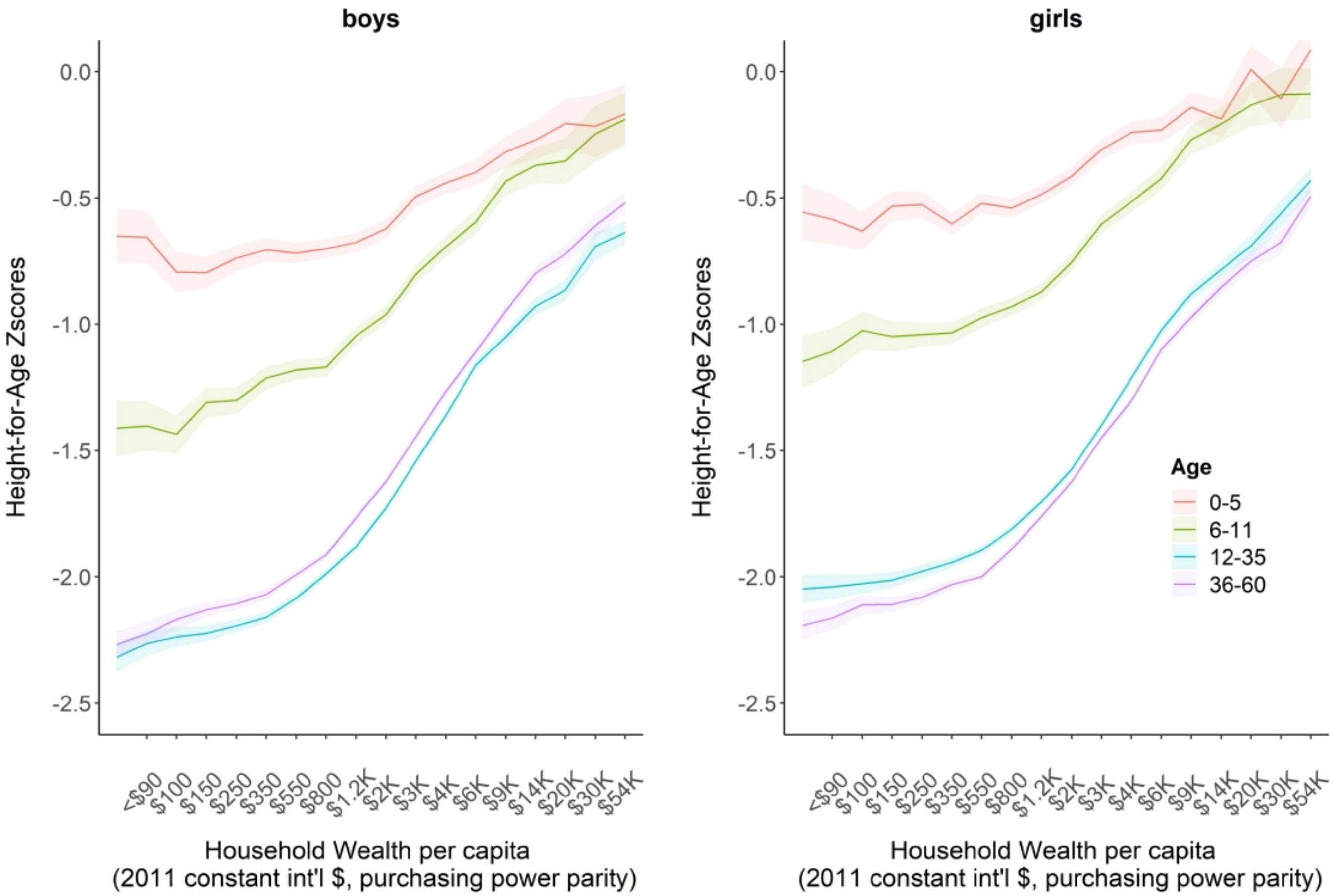
Cluster	Sex		H/A < -3SD		W/H < -3SD		W/A < -3SD	
			Prevalence %	P	Prevalence %	p	Prevalence %	P
Central America (N=28177)	Male	(50.90%)	17.10	<0.001	0.90	<0.05	6.00	<0.001
	Female	(49.10%)	13.10		0.60		4.90	
Central Asia (N=30461)	Male	(50.60%)	32.50	<0.001	3.70	<0.001	16.60	<0.001
	Female	(49.40%)	29.10		2.20		15.20	
South Coast of Asia (N=9526)	Male	(51.10%)	27.50	<0.001	4.10	<0.001	15.40	<0.05
	Female	(48.90%)	22.90		2.60		13.80	
Sahel (N=164246)	Male	(49.90%)	11.90	<0.001	5.70	<0.001	9.20	<0.001
	Female	(50.10%)	8.90		3.70		6.40	
West coast of Africa (N=12757)	Male	(49.90%)	23.50	<0.001	2.60	<0.05	9.10	<0.001
	Female	(50.10%)	18.60		2.00		7.40	
Central Africa (N=83279)	Male	(50.50%)	32.00	<0.001	2.30	<0.001	11.40	<0.001
	Female	(49.50%)	24.20		1.40		8.20	
East Africa (N=38812)	Male	(50.90%)	16.10	<0.001	2.70	<0.001	6.80	<0.001
	Female	(49.10%)	12.00		1.70		6.10	
All countries (N= 67258)	Male	(50.68%)	19.5	<0.001	3.9	<0.001	9.8	<0.001
	Female	(49.32%)	15.0		2.5		7.3	

Diez-Navarro Nutr. clín. diet. hosp. 2017

WHY DO WE SEE THESE PATTERNS?

- Differences in exposures
- Differences in sensitivity
- Differences in needs
- Differences in care practices

CAUSES OF STUNTING: SOCIOECONOMIC STATUS



Hackman and Hruschka, under review

Figure 2. Mean height-for-age z-scores by estimated household wealth per capita for the full sample (by age category and sex). Shaded regions represent 95% confidence intervals around the mean HAZ for a given wealth category. The x-axis reflects the mean wealth of the binned wealth category.

CAUSES OF STUNTING:
ENVIRONMENTAL RISK FACTORS

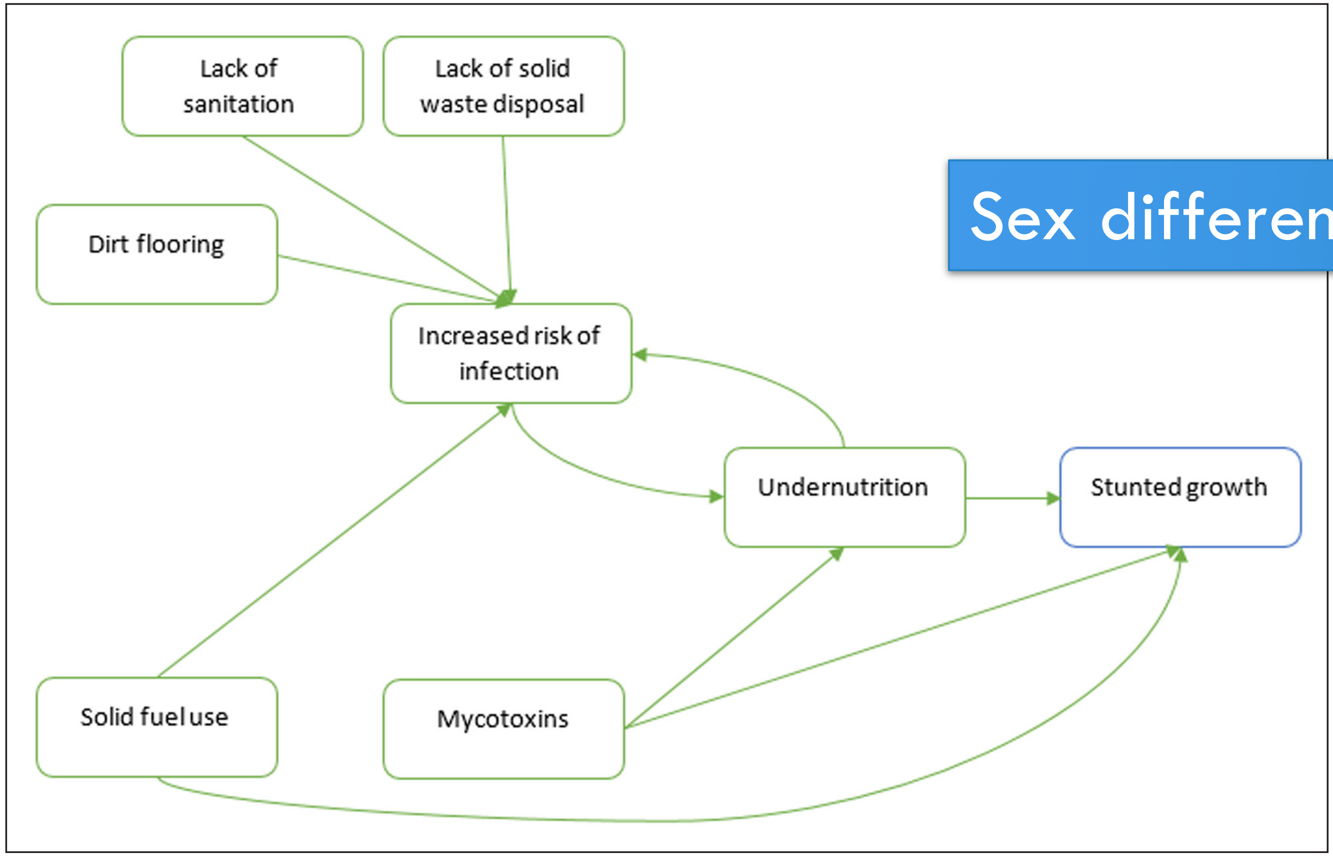


Figure 2: Causal diagram of environmental risk factors and stunting.

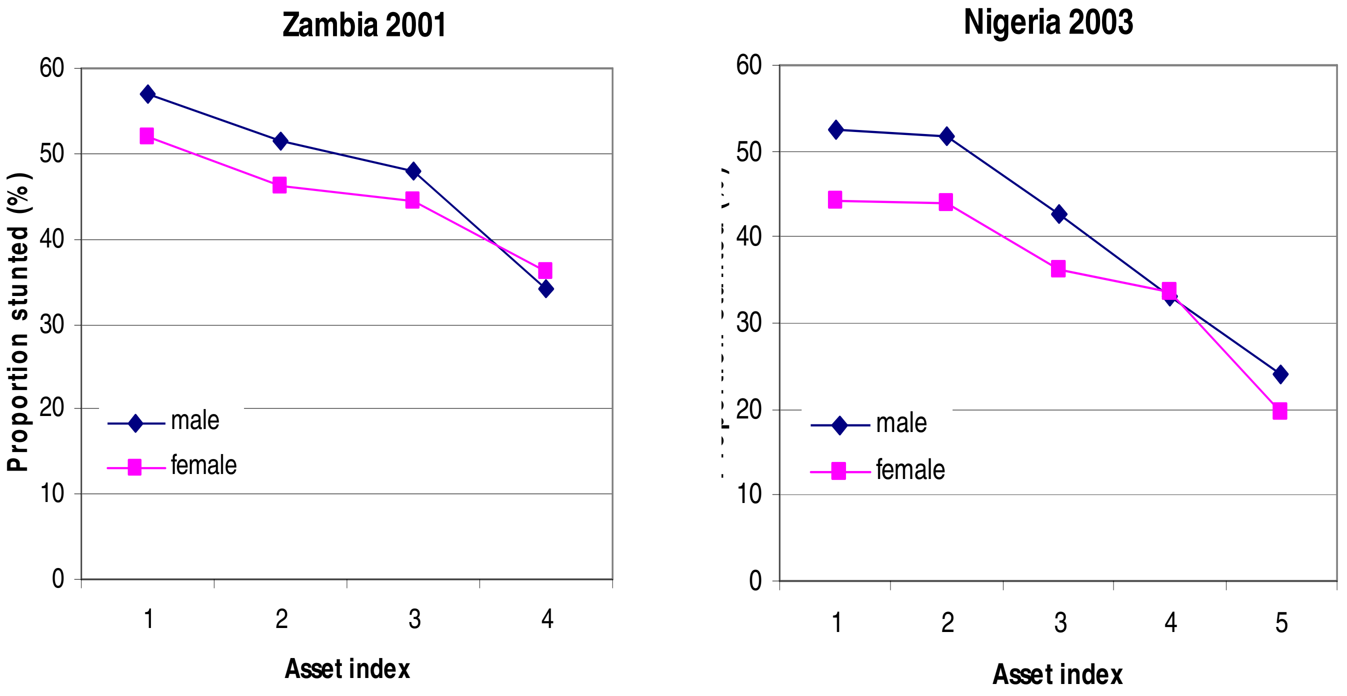
Sex differences in exposures?

Vilcins et al., 2018

INCOME-BASED SEX DIFFERENCES

Evidence for modification by income

- In poorer households more boys were stunted than girls
- No sex differences seen in more socio-economically better off households

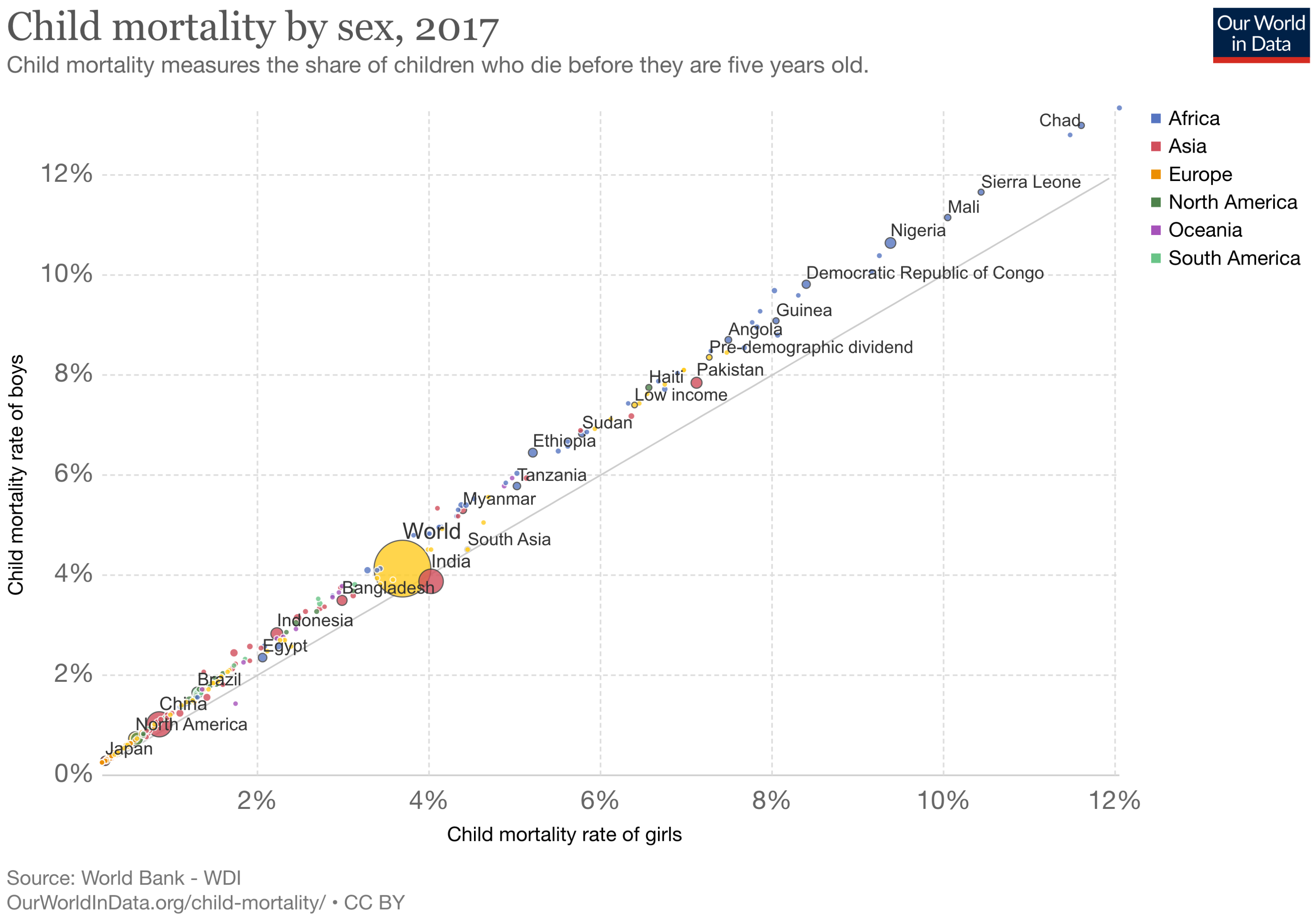


Wamani et al, BMC Pediatrics, 2007

WHY DO WE SEE THESE PATTERNS?

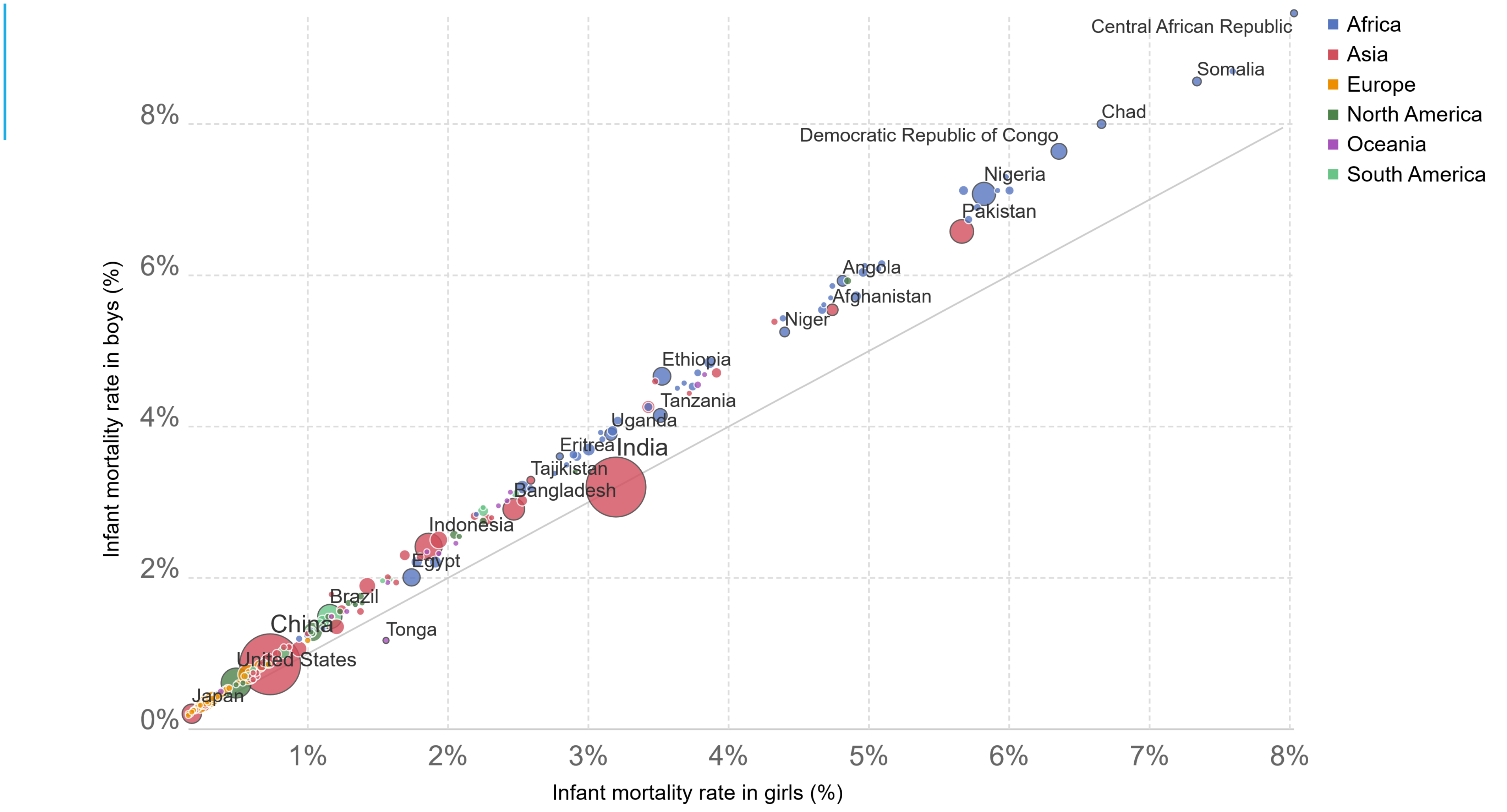
- Differences in exposures
- Differences in sensitivity

“MALE DISADVANTAGE” IN MORTALITY



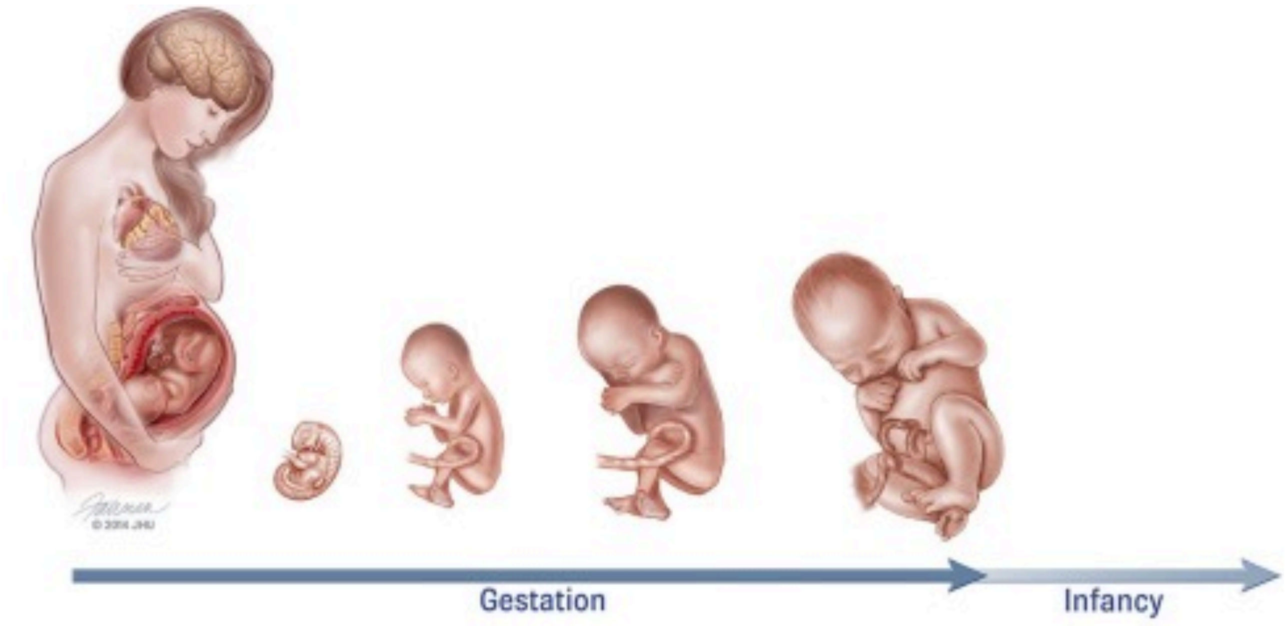
Infant mortality by sex, 2017

Infant mortality measures the share of infants who die before reaching their first birthday.



Source: World Bank

DEVELOPMENTAL ORIGINS: GREATER MALE SUSCEPTIBILITY BEGINS *IN UTERO*



During the prenatal, perinatal, and postpartum periods, being male is associated with:

- ↑ Embryonic loss
- ↓ Hyperemesis of pregnancy
- ↑ Maternal diabetes
- ↑ Pregnancy complications
- ↑ Umbilical cord abnormalities
- ↑ Maternal sympathetic activation
- ↑ Placental Inflammation
- ↑ Cesarean delivery
- Maternal microchimerism

- ↑ Fetal demise
- ↑ Growth restriction
- ↓ Fetal heart rate
- ↑ Fetal heart rate variability
- ↓ Fetal habituation performance
- ↓ Maturation
- ↑ Vulnerability to maternal & environmental exposures

- ↑ Size
- ↑ Preterm birth
- ↑ Mortality
- ↑ Morbidity (including central and respiratory)
- ↑ Fetal distress/autonomic instability
- ↑ Neonatal Narcotic Abstinence Syndrome
- ↑ Fetal Alcohol Spectrum Disorder
- ↑ Sudden unexplained infant death (SUID/SIDS)
- ↑ Cerebral palsy
- ↑ Neurodevelopmental impairment

<u>DiPietro and Voegtline, 2017, Neuroscience</u>

SEX DIFFERENCES IN FETAL GROWTH AND PERINATAL OUTCOMES

	Male	Female
GROWTH-1ST TRIMESTER		
Crown-rump length	Larger	Smaller
GROWTH-2ND TRIMESTER		
Biparietal diameter	Larger	Smaller
Abdominal circumference	Larger	Smaller
GROWTH-3RD TRIMESTER		
Fat mass	9.9% at birth	11% at birth
Lean body mass	Higher	Lower
MATERNAL MORBIDITY		
Mild Pre-eclampsia	Normal growthrate	Reduced growthrate
Maternal obesity	Higher risk of obesity at 1year	No definite effect
Gestational diabetes	High risk of beingoverweight at 5–7 years	No known risk of beingoverweight
OTHER FACTORS		
Placental gene expressions	Minimal gene and protein changes	Multiple gene and proteni changes
Same sex twin pairs	High risk for RDS and low risk for IUGR	High risk for IUGR
IGF-1& IGFBP-3 levels	Lower	Higher

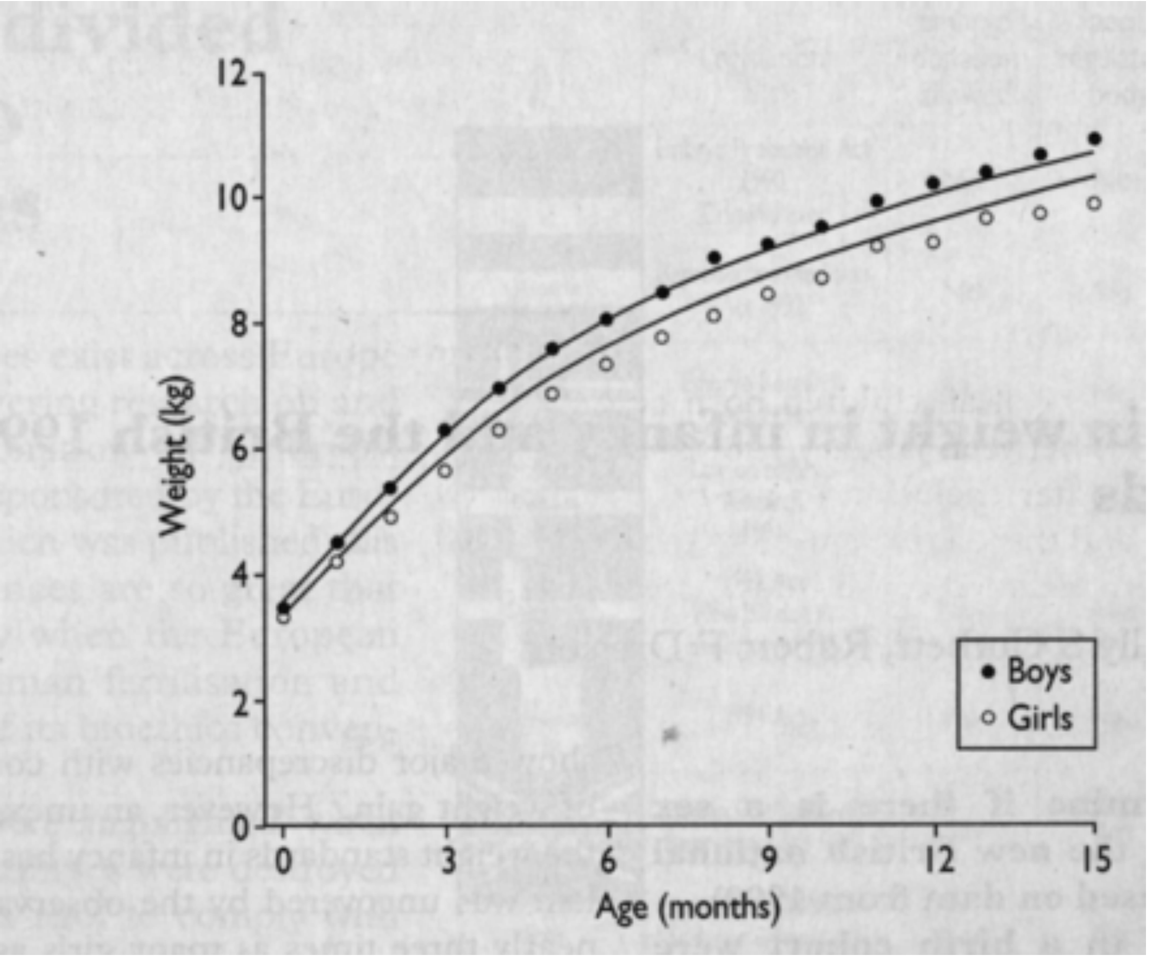
SEX DIFFERENCES IN INFANT GROWTH

Boys:

- Greater birth weight and lean body mass at birth
- Higher linear growth rate and longer at 1 year

Girls:

- Greater fat and % fat at birth
- More peripheral pattern of subcutaneous fat deposition



Wright et al. BMJ 1996

Table 16b. Summary of regression results; Stunting, all variables and sex interaction term

Variable	Multivariate regression (pooled results)			Multivariate regression controlling for all determinants with gender dummy (pooled results)			
	Determinant of nutrtional status	Significance level	Comment	Gender difference	Higher risk for stunting (gender)	Significance level	Comment
SES	Yes	***	Statistically significant lower risk of stunting in wealth quintile 3, 4, 5 compared to quintile 1 (poorest)	No	-	-	
Mother's education	Yes	***	Childred of mother's with longer education have lower risk to become stunted	No	-	-	
Birth order	No	-		Yes	Female	**	Significant for children of birth order 3-5 and 6-10
Preceding Birth Interval	Yes	***	Small impact (< 1%)	Yes	Male	***	Small gender difference (< 1%)
Mother's age at first birth	Yes	*** / *	Lower risk of stunting compared to age group 11-14; p<0.01 for 25-29 years of age, p<0.1 for 20-24 years of age	No	-	-	
Breastfeeding Duration	Yes	***	Due to incomplete data missing information regarding exclusive breastfeeding and solid food supplements, results should be interpret with caution	Yes	Male	**	Small gender difference (< 1%)
Polygamous household	Yes	***	Large impact variable, incraesed risk of stunting among children in polygamous households	No	-	-	
Whether the child was wanted during pregnancy	No	-	No statistically significant difference between "unwanted, "wanted later on" or "wanted"	No	-	-	

Vaidik and Wenzel, 2018

EVIDENCE FOR SEX DIFFERENCES IN SENSITIVITY OF POSTNATAL GROWTH IS INCONCLUSIVE

TABLE 2. Investigations examining sex differences in the effects of environment on growth in height and weight

Source	Area	Age range (years)	Comparison	Results—sex difference[1]
Dreizen et al. (1953)	Alabama	3–16	Children with and without "nutritive failure"	Height differences greater for males; weight differences similar
Hewitt et al. (1955)	England	2–5	Children with illnesses of different severity	Height differences greater for males[2]
Chang et al. (1963)	China	6–18	High and low SES	Differences similar for height; greater in weight for males after age 14
Douglas and Simpson (1964)	Britain	7–15	High and low SES	Differences greater in females[2]
Ashcroft et al. (1966)	Jamaica	5–18	a. High and low SES	a. From ages 15–18 differences greater in males
			b. With U.S. (Stuart-Meredith)	b. Differences greater in males
Frisancho et al. (1971) Frisancho and Garn (1971a,b)	Costa Rica, Honduras, Guatemala	0–20	Children with high and low arm muscle area	Absolute differences greater in males; relative differences similar[2]
Martorell et al. (1975a,b)	Guatemala	0–7	Children differing in days sick with diarrhea	Differences similar
Yarbrough et al. (1975)	Guatemala	0–7	With U.S. (Denver)	Differences similar[3]
Bogin and MacVean (1978)	Guatemala	7–13	High and low SES	Greater differences in male height gain, weight gain differences similar
Garn et al. (1978)	U.S. blacks and whites	0–8	High and low SES	Differences greater for males in whites; similar in blacks
Frisancho et al. (1980)	Peru	6–14	Children differing in skinfolds and arm muscle area	Differences similar[2]
Graham et al. (1980)	Peru	0–18.5	Urban and rural	Differences greater for males
Dewey (1980, 1983)	Mexico	2–4	With well-nourished Mexican	Differences greater for females
Abaheseen et al. (1981)	Saudi Arabia	0–5	With U.S. (NCHS)	Differences greater for females
Chen et al. (1981)	Bangladesh	0–5	With U.S. (Harvard)	Differences greater for females
Malina et al. (1981)	Mexico	6–14	Urban and rural	Differences greater for males
Martorell et al. (1984)	Nepal	3–10	With U.S. (NCHS)	Differences similar

[1]Greater differences refers to cases in which the difference between the comparison groups is statistically significant for only one sex, or cases in which the percentage difference between the comparison groups is greater for one sex.
[2]Study considers only height differences.
[3]Although the authors state that the differences are similar for the sexes, their Figure 3 suggests that the differences are greater for males from 6–9 months, and greater for females from 24–48 months.

EVIDENCE FOR SEX DIFFERENCES IN SENSITIVITY OF POSTNATAL GROWTH IS INCONCLUSIVE

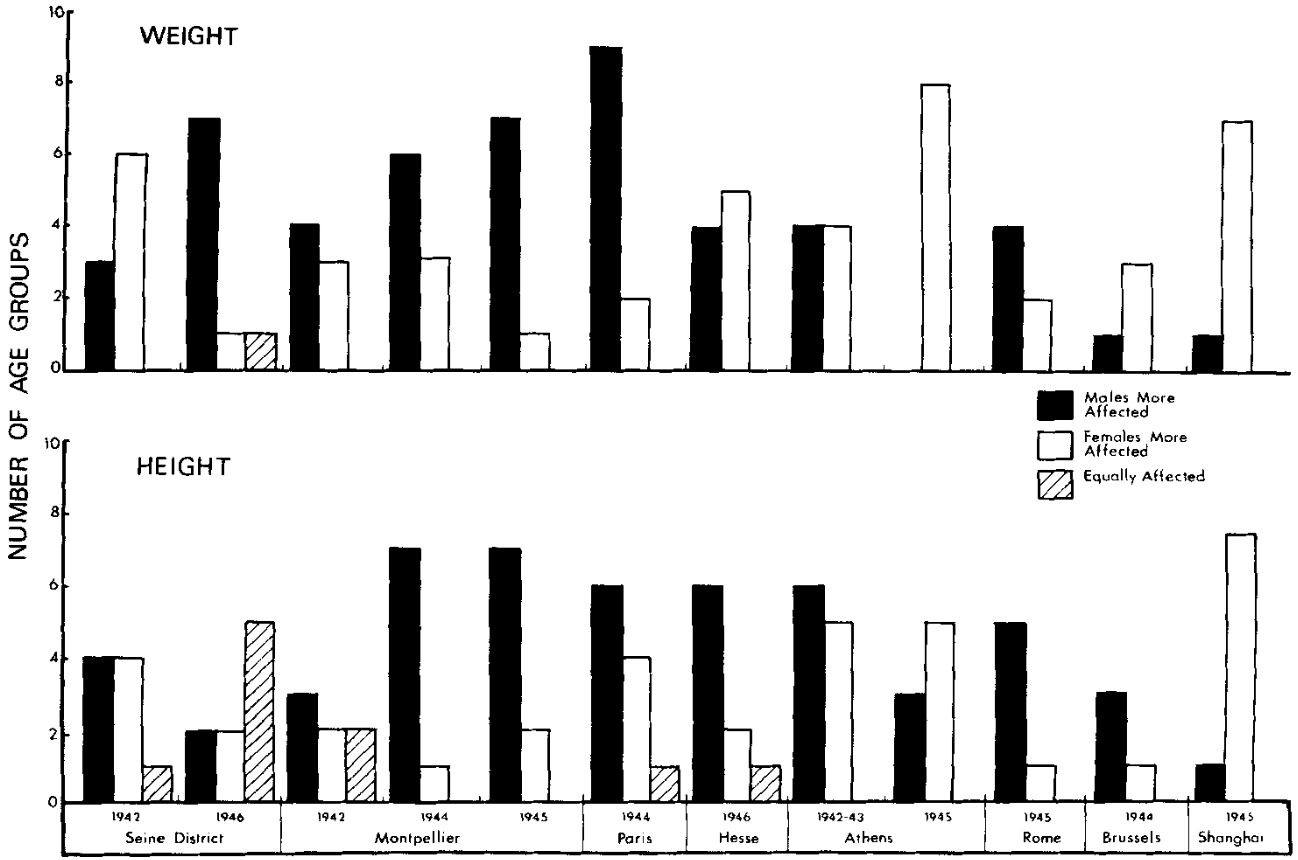


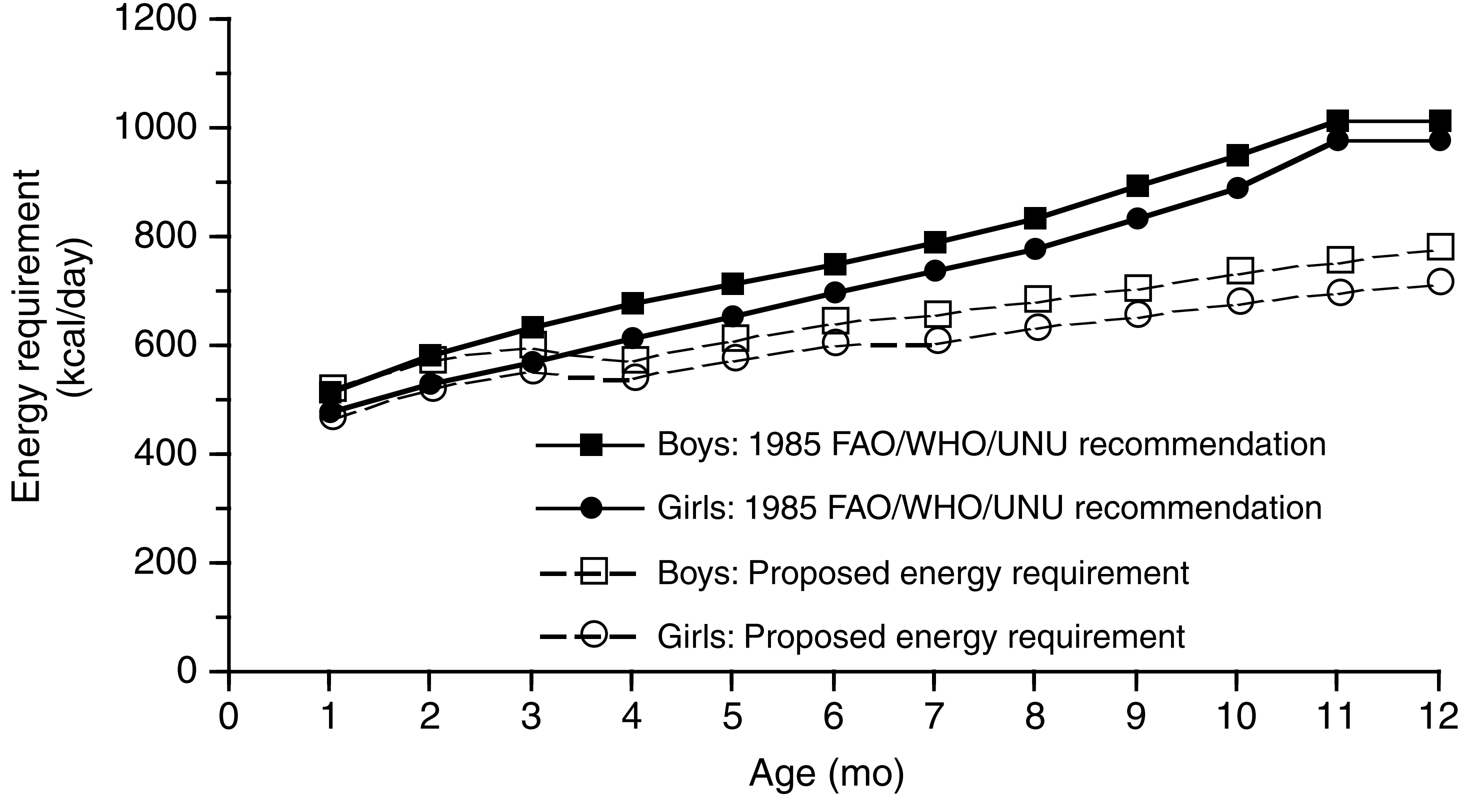
Fig. 2. Comparison of the effects of wartime deprivation on growth of males and females. Based on data in Markowitz (1955).

WHY DO WE SEE THESE PATTERNS?

- Differences in exposures
- Differences in sensitivity
- Differences in needs

SEX DIFFERENCES IN ENERGY REQUIREMENTS

Energy requirements of infants



Butte, 2005, AJCN

MATERNAL PERCEPTION OF NEEDS

Mothers perceived that boys were hungrier than girls were. This perception was derived from the belief that boys are fussier as described in the following quotation:

- *In comparison, the boys are big eaters! Boys cry because they want to breastfeed, and also because they are wet or want to be held. Boys are more demanding because they are boys! In comparison, we, the girls, the little women, well, we are calmer.*

Because boys were perceived to be hungry sooner and less satisfied, mothers perceived that their breast milk “runs out” for boys, saying:

- *“If it is a boy, the milk runs out. Boys breastfeed well, they breastfeed, now the girls do not finish [the breast milk], they breastfeed less.”*

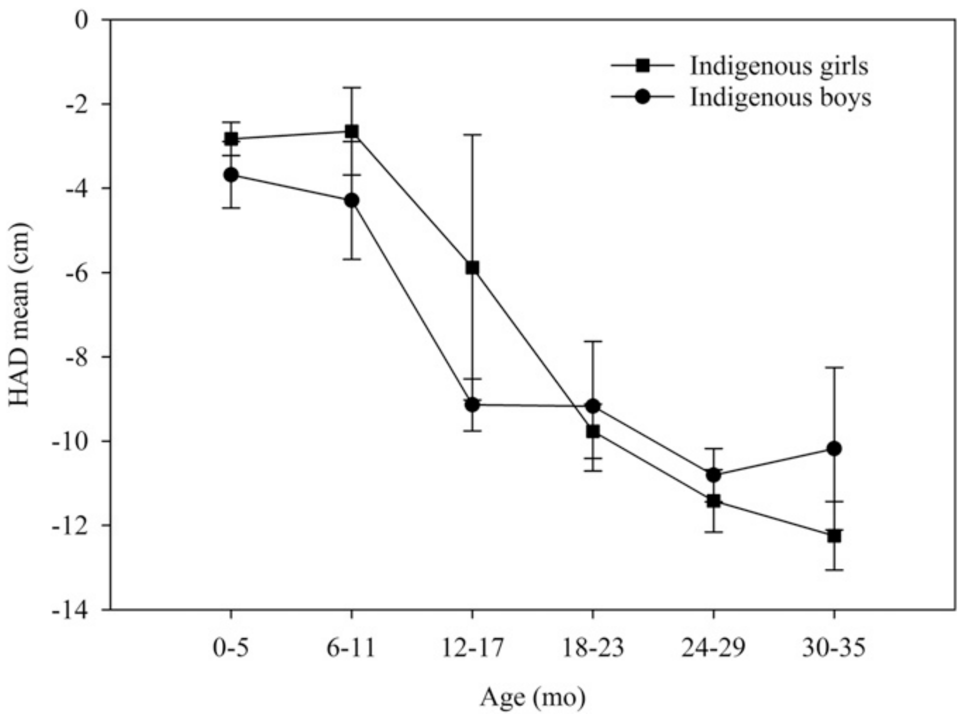


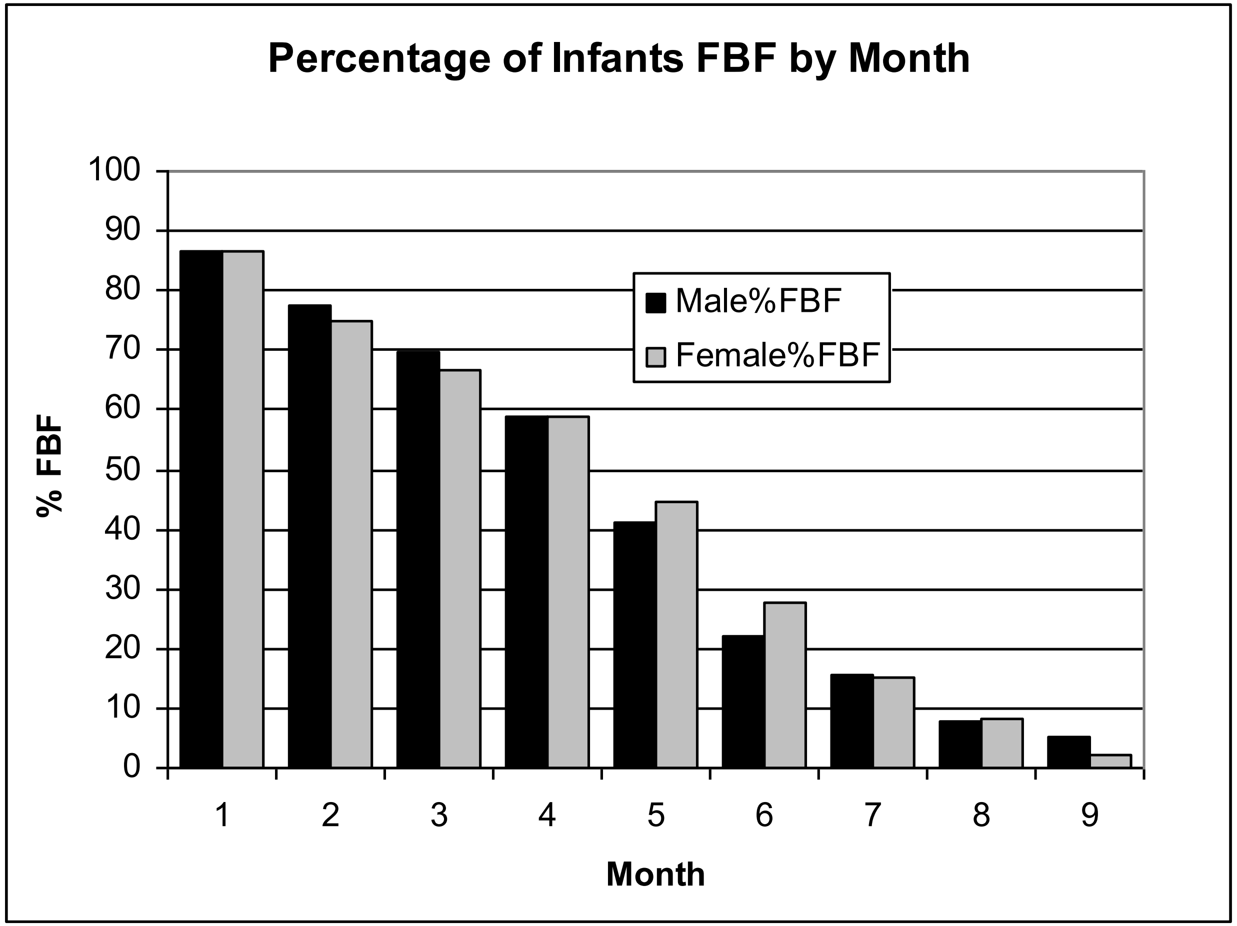
FIGURE 1 Growth curves generated by plotting mean ± SE HADs (in cm) for 6-mo age intervals of indigenous girls and boys with the use of Totonicapán village data disaggregated by age group and sex. *n* values for age groups were as follows: 0–5 mo, 6 girls, 10 boys; 6–11 mo, 11 girls, 12 boys; 12–17 mo, 4 girls, 10 boys; 18–23 mo, 16 girls, 6 boys; 24–29 mo, 7 girls, 15 boys; and 30–35 mo, 16 girls, 6 boys. HAD, height-for-age difference.

Tumilowicz et al., Am J Clin Nutr 2015

SEX DIFFERENCES IN FEEDING PRACTICES

Boys tend to be exclusively breastfed for shorter periods of time

Reasons mothers give for cessation is insufficient milk or infant appetite



Thompson, 2017

SEX DIFFERENCES IN COMPLEMENTARY FEEDING

TABLE 4 Complementary feeding in past 24 h and 7 d by sex and age in rural Senegalese breastfed infants[1]

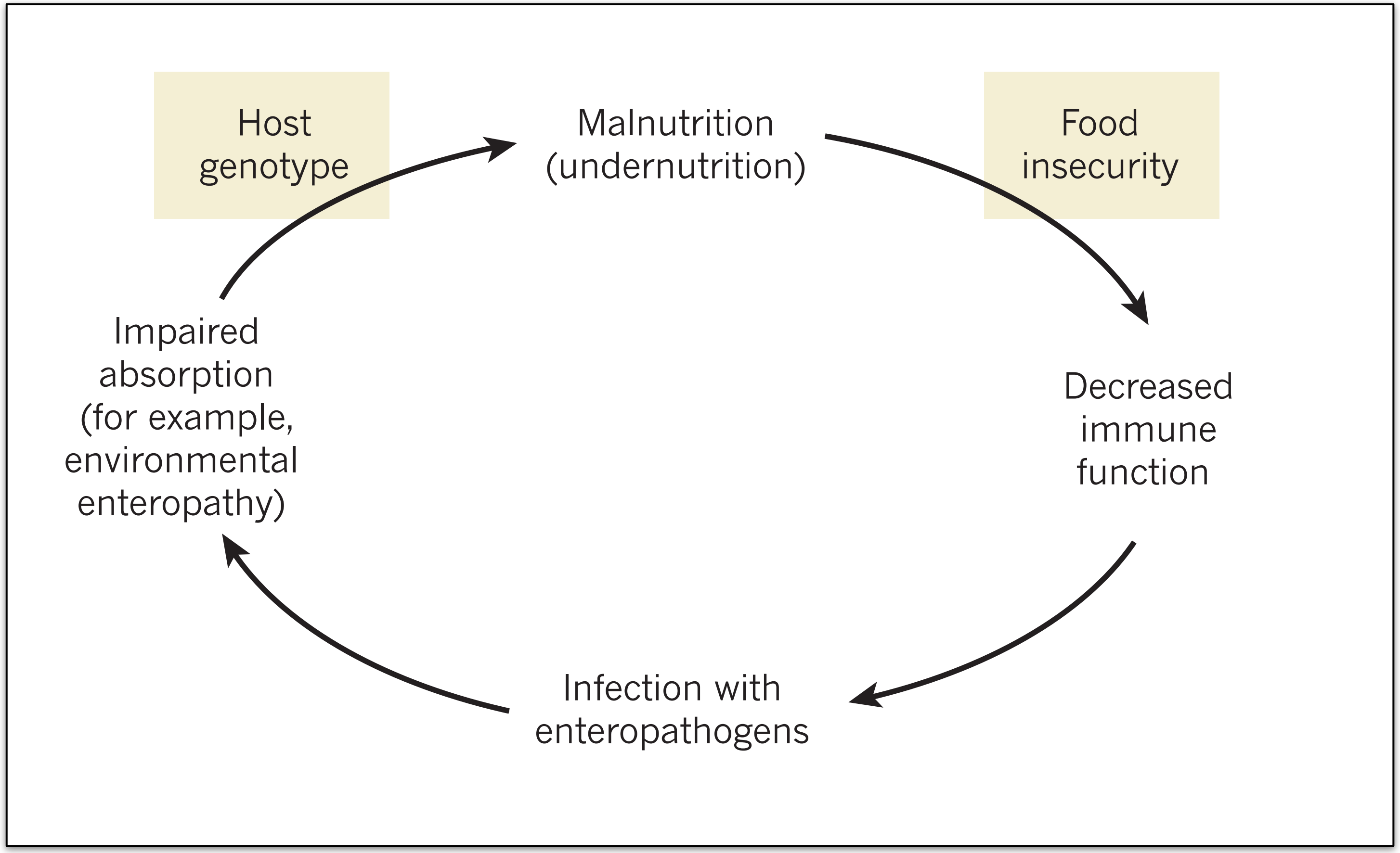
	≥1 meal in past 24 h			≥2 meals in past 24 h			CF all 7 d in past week			CF all 7 d of past week among those fed CF in past 24 h		
Age, mo	Boys	Girls	*P*	Boys	Girls	*P*	Boys	Girls	*P*	Boys	Girls	*P*
2–3	22.5 (888)	18.2 (888)	0.044	13.4 (882)[2]	8.2 (883)	<0.001	15.8 (880)[2]	11.2 (884)	0.005	73.9 (188)	61.6 (159)	0.014
4–5	40.4 (859)	36.6 (834)	0.11	19.3 (852)	16.7 (829)	0.16	29.8 (838)	27.2 (819)	0.24	76.4 (326)	76.4 (292)	0.99
6–7	68.8 (734)	68.7 (761)	0.97	32.0 (732)	31.9 (759)	0.97	61.1 (714)	62.9 (734)	0.46	89.3 (486)	92.8 (497)	0.06
9–10	85.8 (800)	89.5 (791)	0.023	47.9 (795)	51.7 (790)	0.14	81.2 (783)	85.1 (770)	0.037	94.9 (670)	95.1 (689)	0.91

[1] Values are % (*n*). CF, complementary food.
[2] Meal frequency in the past 24 h and 7 d were missing for several children because of maternal difficulties in recall.

A higher meal frequency in the past 24 h was associated with lower mean HAZ at 2–3 and 4–5 mo in both boys and girls

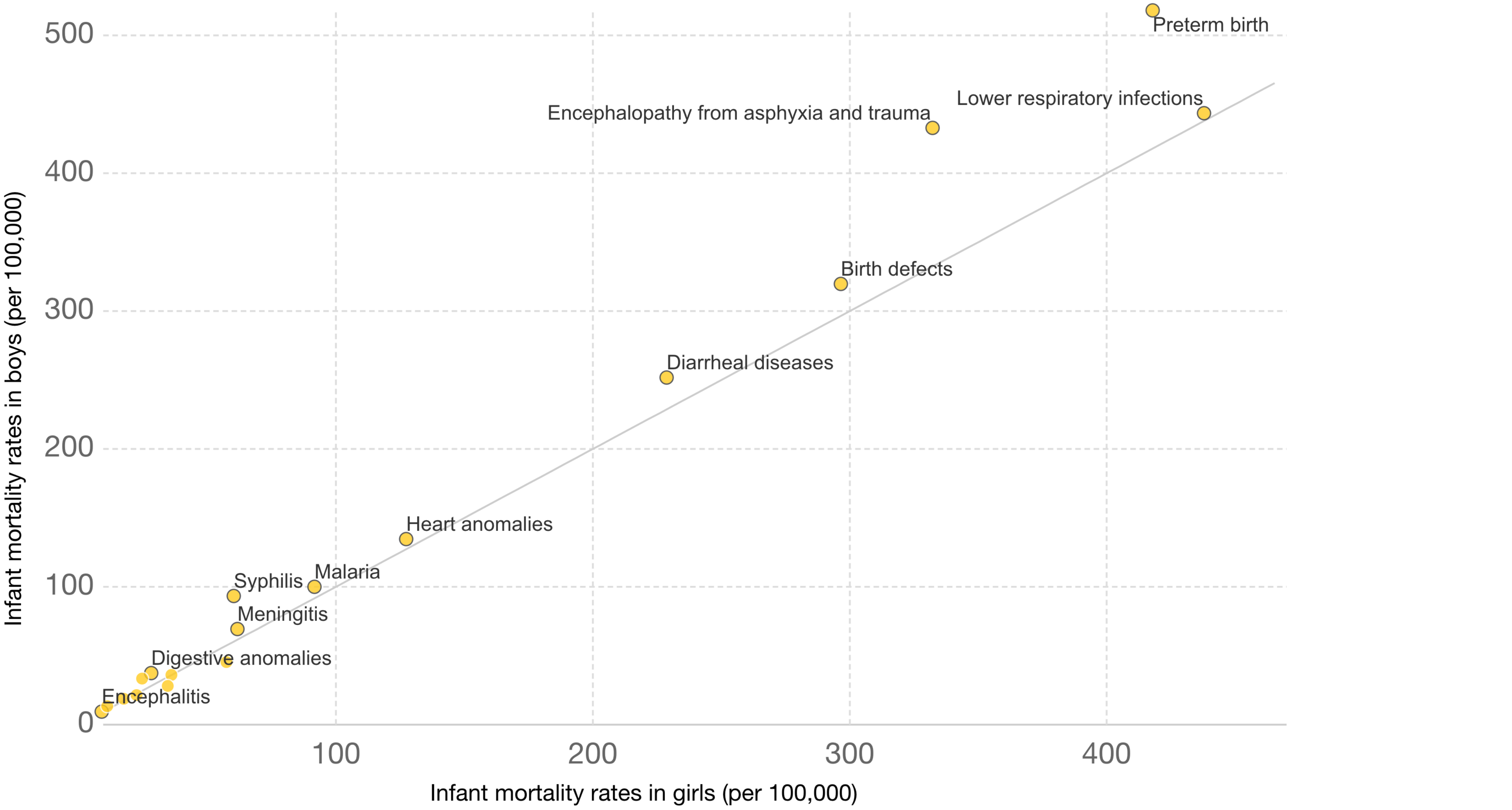
Bork and Diallo, J Nutr 2017

MECHANISM: CYCLICAL MALNUTRITION AND INFECTION



Global infant mortality by cause for boys vs. girls, 2017

Infant mortality rates are the number of deaths of infants under one year old, measured per 100,000. This is shown globally for different causes of death in infant boys versus girls. Causes which lie above the grey line have higher mortality rates in boys relative to girls.



Source: IHME, Global Burden of Disease (2018)

BIOLOGICAL FACTORS: GREATER MALE SUSCEPTIBILITY TO INFECTIOUS DISEASE

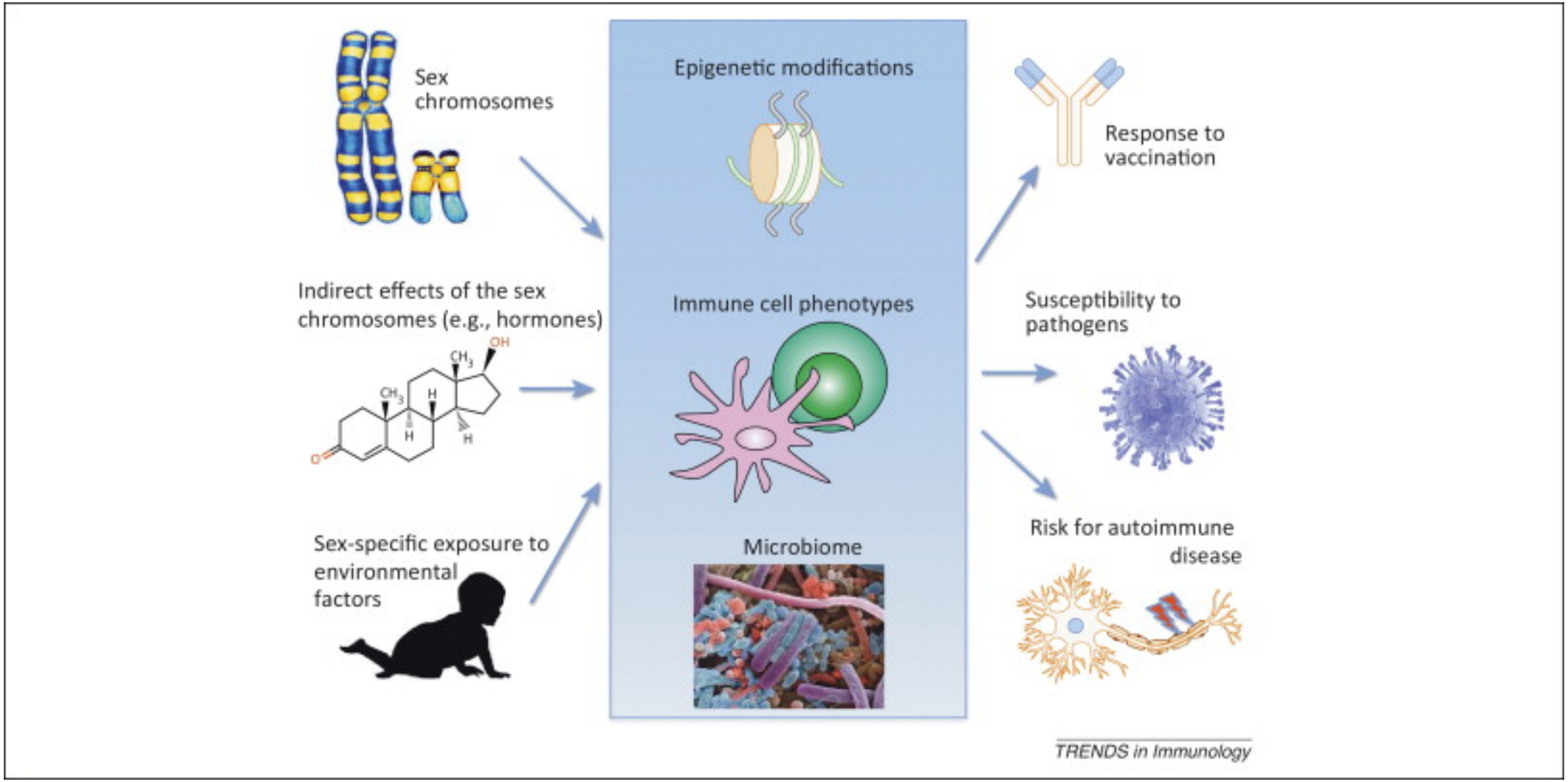
TABLE 2

Sex differences in morbidity and mortality for selected epidemic-prone infectious diseases common among infants and young children

DISEASE	INFANTS	YOUNG CHILDREN (AGE 1–5 YEARS)	POSSIBLE REASONS FOR MALE FEMALE DIFFERENCES SUGGESTED BY INVESTIGATORS
Diarrhoeal disease	Incidence higher for males	Mortality rates often higher for females despite similar or slightly higher incidence rates for males.	Higher incidence rates for male children may be caused by greater male mobility. Higher female case-fatality rates found in some countries may be due to poorer health care.
Acute lower respiratory infections and pneumonia	Mortality rates higher for males	Sex differences in mortality for young children vary. Generally only small differences in incidence rates.	Mortality rates higher for males in infancy probably due to less mature lungs in boys during infancy. This disadvantage abates in early childhood.
Neonatal tetanus	Mortality rates higher for males		It is not known why mortality rates are higher for males.
Measles		Similar infection rates, but higher female mortality rates observed.	Possibly less adequate medical care is provided to girls. Possibly girls are exposed to a larger dose in the home.

WHO, 2007

SEX DIFFERENCES IN IMMUNE FUNCTION



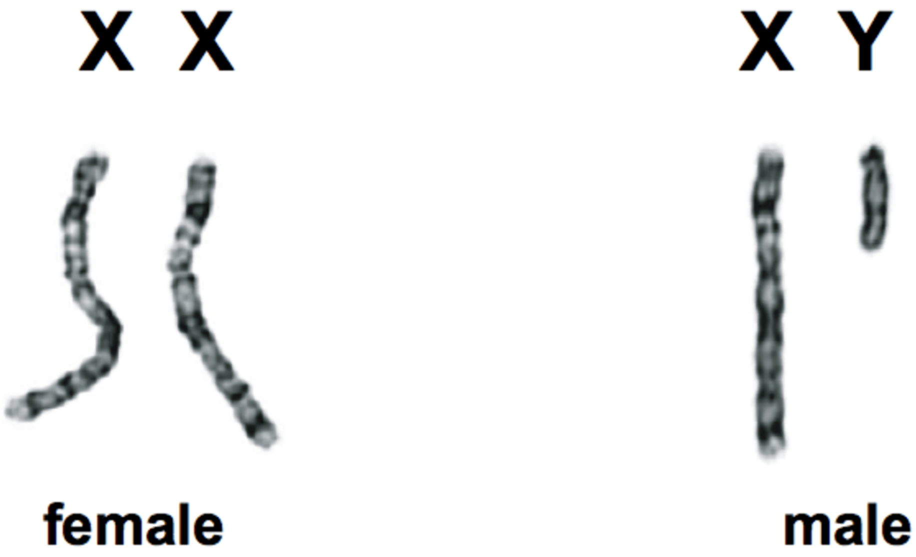
MECHANISMS: SEX CHROMOSOMES AND IMMUNE FUNCTION

X chromosomes contain a larger number of immune-related genes

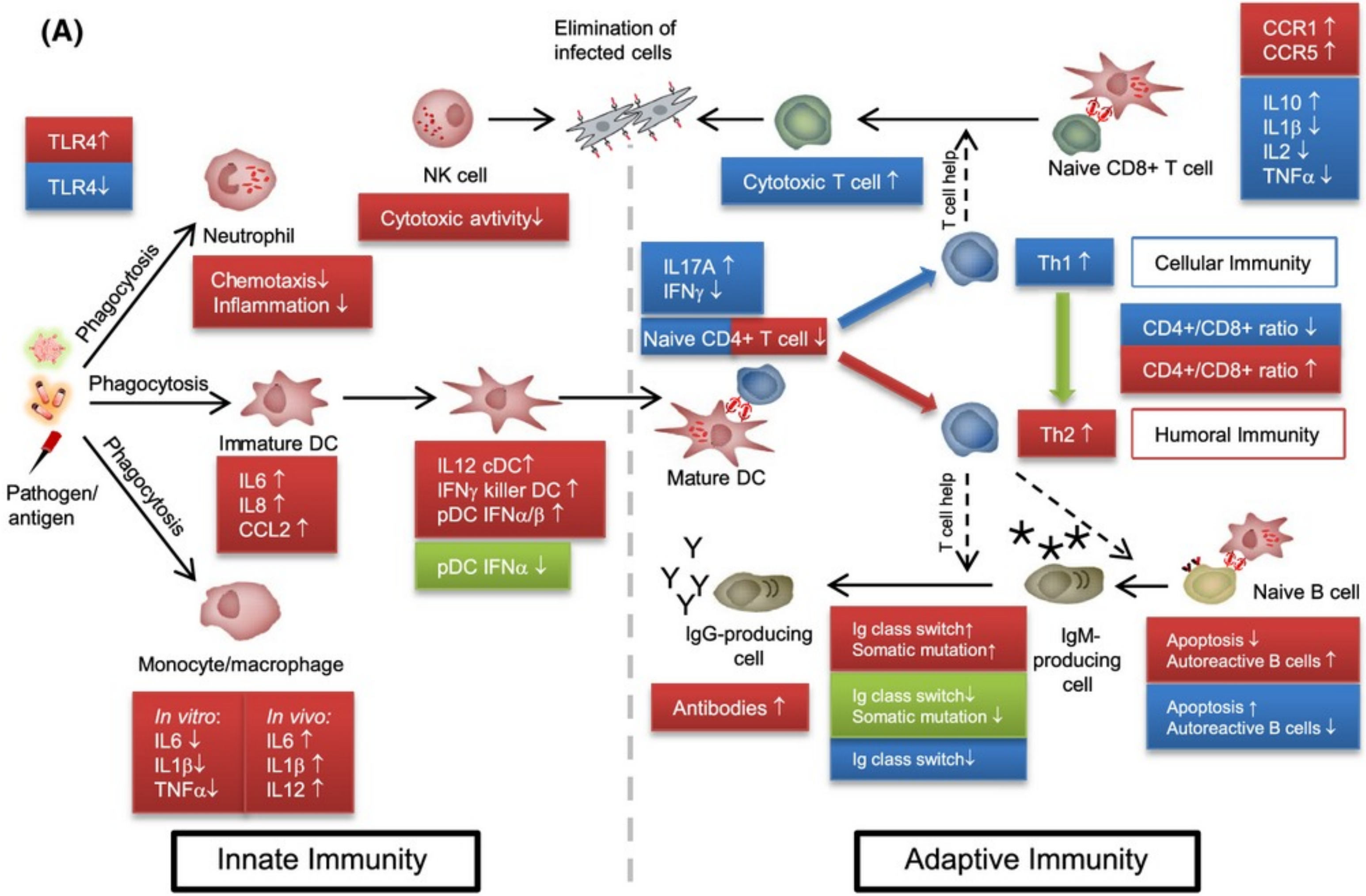
- such as Toll-like receptors, multiple cytokine receptors, genes involved in T-cell and B-cell activity, and transcriptional and translational regulatory factors

Having only 1 X chromosome associated with weaker immune response

- Polymorphism of X-linked genes and cellular mosaicism for X-linked parental alleles may offer additional advantages by providing a more adaptive and balanced innate immune response



SEX HORMONE IMPACTS ON THE IMMUNE SYSTEM



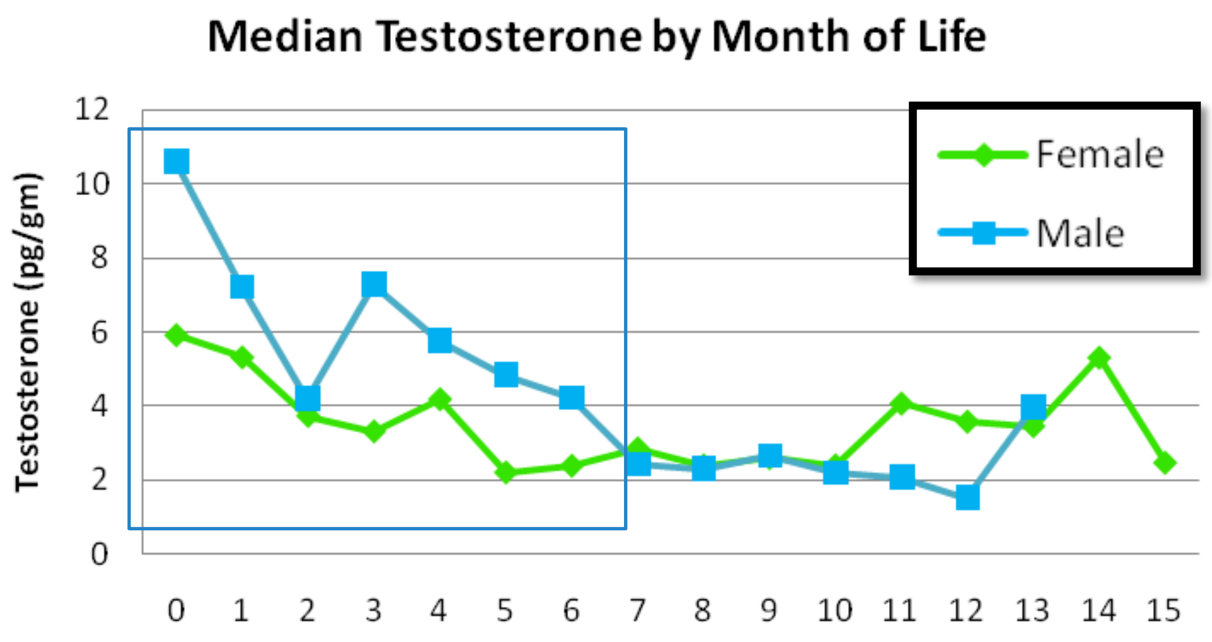
Estrogen effects
Testosterone effects

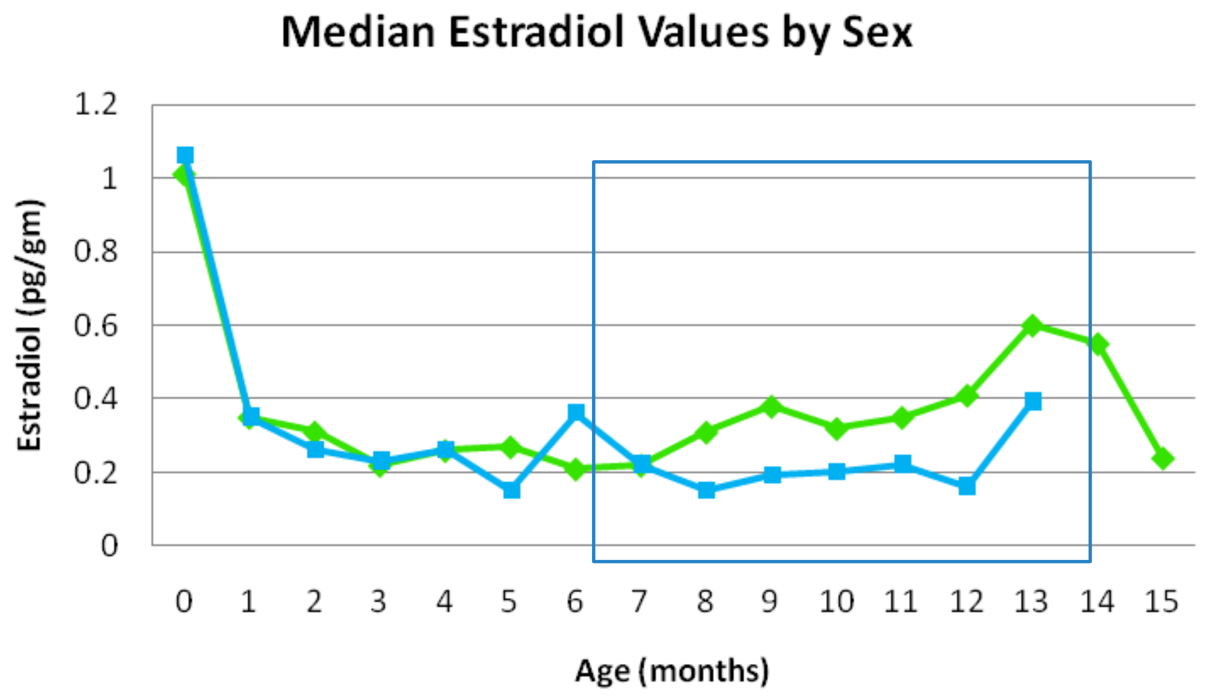
Giefing-Kroll et al, *Aging Cell*, 2015, 14: 309-321

SEX DIFFERENCES IN SEX STEROIDS IN INFANCY

Testosterone is significantly higher in boys before 6 months of age

Estradiol is significantly higher in girls after 6 months of age





IMPLICATIONS OF SEX STEROID PRODUCTION

Sex steroid production in infancy may underlie differences in growth and health outcomes

- Estrogen
  - Promotes fat deposition
  - Inhibits muscle synthesis
  - Lowers metabolic cost of growth
  - Enhances immune function
  - Improves survival

- Testosterone
  - Inhibits fat deposition
  - Promotes lean body mass
  - Increases BMR and metabolic cost of growth
  - Dampens immune function
  - Associated with lower survival?

WHY DO WE SEE THESE PATTERNS?

- Differences in exposures
- Differences in sensitivity
- Differences in needs
- Differences in care practices

SEX DIFFERENCES IN HEALTH CARE

Table 1 Original articles from Asia examining gender-related disparity in healthcare in paediatric populations, categorised by country, presented chronologically

Country	Authors (year)	Type of study	N	Outcome
India	Ganatra *et al* (1994)[62]	Cross-sectional	456	In under-5 children, parents were willing to spend more, travel extra distances, seek care from registered physicians for boys compared to girls
	Griffiths *et al* (2002)[63]	Retrospective	8892	No significant differences by gender in weight for age in the under-5 age group in three Indian states
	Borooah *et al* (2004)[64]	Retrospective	4000	Children—Immunisation rate and likelihood of getting nutritious diet when the mother is illiterate is 5% less in girls than in boys
	Bhan *et al* (2005)[65]	Prospective	85 633	Children—Hospitalisation rates for diarrhoea, acute respiratory infections or other febrile illness were significantly lower for girls
	Sahni *et al* (2008)*[24]	Retrospective	33 524(deliveries)	Single hospital 11 decade review—Second child sex ratios if first born is girl, 716 females versus 1000 males
	Asfaw *et al* (2010)[12]	Cross-sectional	†60th Indian National Sample Survey (NSS) data set	Higher adjusted rate of hospitalisation for boys, higher outside borrowing/extreme measures for boys versus girls for meeting hospitalisation expenditures
	Ramakrishnan *et al* (2011)[13]	Prospective	405	Lesser proportion of girls underwent recommended cardiac surgery for paediatric congenital heart disease
	Singh *et al* (2012)[36]	Cross-sectional	‡1972(1992–93), 3930 (2005–06)	Gender-based within-household inequality against females in immunisation—Persistent but improved in the past 10 years
Nepal	Pokhrel *et al* (2005)[53]	Retrospective	8112	Children—Gender was a factor-determining choice of external care and choice of bearing the expenditure required for treatment with a bias towards males, although not statistically significant.
Bangladesh	Dancer *et al* (2008)[66]	Cross-sectional	5172	2004 Bangladesh Demographic Health Survey (BDHS) analysis—Better nutritional status for males versus females, higher z-scores for height for age
	Rousham *et al* (1996)[52]	Prospective	1366	Height and weight for age—Less for females in landless, poor households
	Mitra *et al* (2000)[20]	Prospective	496	In children, females more likely to die of severe diarrhoea, late presentation to hospital
Pakistan	Nuruddin *et al* (2009)[49]	Cross-sectional	3740	Higher female versus male under-5 mortality, but not attributed to differential healthcare-seeking behaviour
China	Attane *et al* (2009)*[19]	Retrospective	†Census data—Multiple years	Census data analysis—Proves existence of lethal healthcare neglect in females in provinces of China

*Data not directly focusing on healthcare allocation, but significant due to large population-based studies exposing gender-based neglect of girls.
†Numbers not explicitly reported/census data sets.
‡Number of eligible households, two separate cross-sectional time points.

Khera R, Jain S, Lodha R, et al. Arch Dis Child 2014;

SEX DIFFERENCES IN CARE PRACTICES

Results from Tanzania suggest that fathers, but not mothers, preferentially care for sons

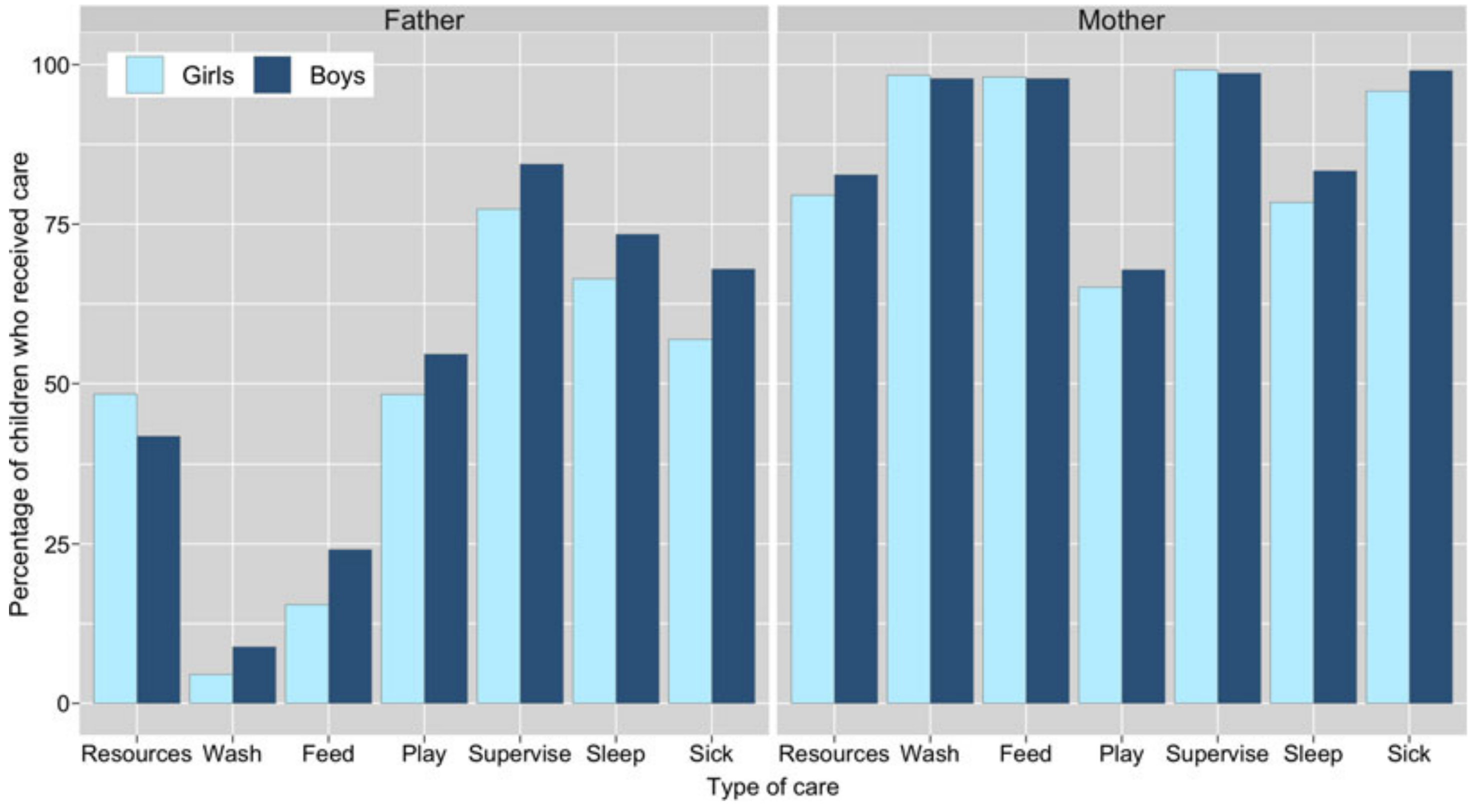


Figure 2. Percentage of children reported to receive material resources in past 3 months and direct/physical care in past 2 weeks from their biological fathers and mothers, by child's sex. Resource provision is from alive mothers (*n* = 801; excluded: 'refusal', *n* = 1) and non-co-resident fathers (*n* = 239; excluded: 'don't know', *n* = 1); direct care is from co-resident parents only (mothers, *n* = 728; fathers, *n* = 547); caring for sick children limited to children who had been sick in past 2 weeks (*n* = 215). Logistic regression analyses show evidence of a difference in care provision by child's sex (for washing, feeding and supervising) from fathers, but not mothers. Odds ratios for each type of care are shown in Table 2.

Hassan et al,,Evolutionary Human Sciences (2019)

SUMMARY: MULTIPLE FACTORS IMPORTANT IN DETERMINING SEX DIFFERENCES IN CHILD HEALTH

TABLE 1
Typical differences between males and females in the infectious disease process

	WHO BECOMES ILL?		COURSE AND OUTCOME	
Life-cycle	**Susceptibility and immunity**	**Exposure**	**Treatment**	**Morbidity and mortality**
Infants	Males have naturally weaker immune systems.	Exposure is similar for male and female infants.	In some countries boys are more often taken for treatment outside the home.	There is greater male mortality from infectious disease.
Children	Levels of immunization for boys and girls are similar in most parts of the world. There are lower rates of immunization of females in south-central Asia.	In some societies there are mobility differences (boys spend more time outside the home), which may account for differences in incidence and mortality for some diseases.	In some countries boys are more often and/or more quickly taken for treatment outside the home.	There are disease-specific differences in severity and outcome. For example, mortality from measles and whooping cough is greater in females. Morbidity and disability may have different consequences for girls and boys.

WHO 2008

SEX DIFFERENCES IN RESPONSE TO INTERVENTION?

Table 1. Effects of prenatal food and micronutrient supplementations on linear growth (16 anthropometric assessments) from birth to 54 months of age, stratified for sex of the child (general lineal models, repeated-measure analyses)

Randomized intervention		Boys No.	Boys HAZ mean (95% CI)	Boys p^a	Boys Stunting, mean % (95% CI)	Boys p^a	Girls No.	Girls HAZ mean (95% CI)	Girls p^a	Girls Stunting, mean % (95% CI)	Girls p^a
Food supplementation	Early invitation (E)	439	−1.55 (−1.64, −1.46)	0.20	31.9 (28.6, 35.2)	0.01	400	−1.50 (−1.58, −1.42)	0.21	29.8 (26.5, 33.0)	0.31
	Usual invitation (U)	405	−1.63 (−1.72, −1.54)		38.4 (34.9,41.8)		390	−1.57 (−1.66, −1.49)		32.1 (28.9, 35.4)	
Micronutrient supplementation	Fe30F	275	−1.50 (−1.61, −1.39)	0.06	32.5 (28.3, 36.7)	0.01	243	−1.52 (−1.63, −1.42)	0.80	31.1 (26.9, 35.2)	0.82
	Fe60F	289	−1.58 (−1.69, −1.47)		32.5 (28.4, 36.6)		277	−1.52 (−1.62, −1.42)		30.0 (26.1, 33.9)	
	MMS	280	−1.69 (−1.80, −1.58)		40.3 (36.2, 44.5)		270	−1.56 (−1.66, −1.46)		31.8 (27.8, 35.7)	
Interaction Food*micronutrients	E-Fe30F	142	−1.44 (−1.60, −1.29)	0.70	28.8 (23.0, 34.7)	0.84	116	−1.51 (−1.66, −1.35)	0.58	31.2 (25.2. 37.2)	0.52
	E-Fe60F	149	−1.57 (−1.72, −1.42)		30.3 (24.6, 36.0)		142	−1.44 (−1.56, −1.30)		27.0 (21.5, 32.4)	
	E-MMS	148	−1.63 (−1.78, −1.48)		36.5 (30.8, 42.2)		142	−1.55 (−1.69, −1.41)		31.1 (25.7, 36.6)	
	U-Fe30F	133	−1.56 (−1.72, −1.40)		36.2 (30.2, 42.2)		127	−1.54 (−1.69, −1.40)		30.9 (25.1, 36.7)	
	U-Fe60F	140	−1.58 (−1.73, −1.43)		34.8 (28.9, 40.6)		135	−1.60 (−1.74, −1.46)		33.1 (27.5, 38.6)	
	U-MMS	132	−1.76 (−1.91, −1.60)		44.1 (38.1, 50.2)		128	−1.58 (−1.72, −1.43)		32.5 (26.7, 38.2)	

CI = confidence interval; HAZ = height-for-age *z* score; Fe30F = 30-mg iron and 400-µg folic acid; Fe60F = 60-mg iron and 400-µg folic acid; MMS = multiple micronutrient supplementation, 15 micronutrients including 30-mg iron and 400-µg folic acid.

[a]Test of between-subject effects.

Khan, Global Health Action, 2013

SUMMARY AND CONCLUSIONS

- Stunting prevalence tends to be higher in boys across infancy and early childhood

- Sex differences may derive from differences in exposure or sensitivity to those exposures but distinguishing biological vs. social factors is complicated

- Sex differences in growth strategies beginning *in utero* may underlie these differences.

  Boys are larger, invest more in growth and have limited ability to respond to energetic limitations

- Boys' faster growth may also indicate that they are not receiving enough breastmilk and lead to earlier CF. In turn, early CF may lead to greater infectious disease. Coupled with boys' lower immune function, this leads to a cyclical relationship between stunting and infectious morbidity

- On a positive note, interventions may have stronger impacts in boys