Pacific Islands Families Study: adverse impact of food insecurity on child body composition

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ABSTRACT

AIM: COVID-19 has exacerbated food insecurity, unemployment, inequities and poverty in Aotearoa. Here, we tested the hypothesis that exposure to malnutrition due to household food insecurity during foetal life and early infancy is associated with body composition in adolescence.

METHODS: As part of the Pacific Islands Families Study, 1,376 Pacific Island mothers were asked questions about food security at six weeks postpartum in the year 2000. At age 14 years, 931 youth completed in-school assessments of height and weight. Of these youth, 10 girls and 10 boys from each weight decile were randomly selected to participate in a nested sub-study involving dual x-ray absorptiometry measurements, which included appendicular skeletal muscle mass (ASMM) and visceral adipose tissue (VAT).

RESULTS: Boys born to families experiencing food insecurity had greater birthweights and greater % fat, less % ASMM and greater % VAT of total weight at age 14 years compared to boys born into food secure households. In contrast, there were no differences in birthweight or body composition at age 14 years by household food insecurity status among girls.

CONCLUSION: This study shows that household food insecurity during early development is associated with higher abdominal and visceral fat in boys, which may have health risks in later life.

The global recession caused by COVID-19 has exacerbated unemployment, inequities and poverty in Aotearoa. Particularly alarming is the growing proportion of New Zealanders facing food insecurity, defined as an insufficient or uncertain supply of nutritionally adequate foods and/or limited ability to acquire culturally appropriate foods in socially acceptable ways.[1] The economic burden of COVID-19 is particularly heavy for Pacific families, who were already disadvantaged before the pandemic. The 2015/16 New Zealand Health Survey found that 37.1% of Pacific children live in food-insecure households, compared to 16.2% of non-Pacific children.[2] Pacific children disproportionately experience food insecurity, with Pacific children 2.3 times more likely to live in food-insecure households compared to non-Pacific (including Māori) children.[2]

Pacific Island people in New Zealand also face a disproportionately high burden of obesity, diabetes and related cardiometabolic disease. The 2019/20 New Zealand Health Survey found that overweight/obesity prevalence among Pacific Island people aged ≥15 years was 89.2% compared to 66.0% among Europeans.[3] These disparities are further magnified among children aged <15 years, with Pacific children being 2.43 times more likely to be overweight/obese compared to non-Pacific children. There exists an extensive body of research linking food insecurity in the first 1,000 days to the development of obesity and related cardiometabolic diseases.[4] Consumers with limited resources may select low-cost, energy-dense foods to conserve money.[5] Approximately 56% of Pacific Islanders in New Zealand live in the most deprived areas of the country.[6] This statistic is higher than for all other ethnic groups. Nationally, access to fast food outlets and exposure to related advertising are greater in more deprived neighbourhoods.[7] Thus, Pacific

Island people in New Zealand are disproportionately exposed to highly obesogenic environments. Indeed, the 2019/20 New Zealand Health Survey found that the prevalence of overweight/obesity among the most deprived quintile (73.6%) was higher than among the least deprived (62.7%).[3] These findings suggest that food insecurity is a key contributor to the high prevalence of obesity among Pacific Island people.

A large body of evidence suggests that foetal life and infancy represent periods of development that are highly sensitive to programming by metabolic factors that influence obesity risk in later life.[8] Indeed, a recent study conducted among American infants found that household food insecurity was associated with greater risk of being overweight and more adipose.[9] Food security for the mother and child in the first 1,000 days of life is crucial for optimal growth and development and lifelong health.[4] During adolescence, a second growth spurt occurs along with the development of secondary sexual characteristics. Patterns of growth and maturation during adolescence may be explained by previous life-course events and influence future cardiometabolic health.[10] However, how food insecurity during the perinatal period influences body size and composition in adolescence is still largely unknown.

In the year 2000, a prospective birth cohort, titled the Pacific Islands Families Study (PIF study), was established to provide insight into the growth and development of Pacific children and their family environments.[11,12] This longitudinal investigation includes 1,398 Pacific infants born at Middlemore Hospital in South Auckland. This number represents between a quarter and a third of all eligible children.[13] South Auckland is home to the highest density (37%) of Pacific Island people in New Zealand. The community is relatively young and has high levels of deprivation.[14] Maternal home interviews covering topics including sociodemographics, culture, child development, family dynamics, lifestyle and health were conducted at approximately six weeks and 1, 2, 4, 6, 9, and 14 years postpartum. Findings from maternal surveys conducted at six weeks postpartum showed that 43.6% of Pacific Island families either "sometimes" or "often" ran out of food in the preceding year.[15]

The unique longitudinal design of the PIF study presents an opportunity to examine how food insecurity experienced *in-utero* is associated with child growth and development. Hence, in this analysis, we report body size and composition among Pacific Islander youth at age 14 years in relation to household food insecurity during pregnancy.

Method

The initial study design and research methods have been reported elsewhere.[11, 12] Briefly, 1,398 children born at Middlemore Hospital in South Auckland between 15 March and 17 December 2000 were recruited to establish the PIF study birth cohort. Infants were deemed eligible for participation in the study if at least one parent was a permanent resident of New Zealand and self-identified as Pacific Islander ethnicity. The cohort is estimated to represent between a quarter and one third of all eligible children born in the region. Birth weight was recorded from hospital records.

When infants were six weeks old, 1,398 mothers answered questions about food security over the last year.[16] Seven questions were asked about food security, all concerning the affordability of food (Table 1). To each question, mothers responded "never," "sometimes" or "often," which were scored 0, 1 and 2 respectively. A total score was derived by summing all seven individual question scores. Total score ≤3 was categorised as food secure and ≥4 as food insecure. These questions have demonstrated the ability to rank households according to severity of food insecurity and construct validity in relation to nutritional status.[17] Mothers were also asked whether they had been diagnosed with diabetes, their household income and the usual number living in their house.

In 2014, 931 (66%) of the original cohort participated in field assessments involving physical measurements and a self-administered online questionnaire. From the 931 youth, a nested subsample of 204 children was drawn by randomly selecting 10 males and 10 females from each decile of body weight. Profiles of the cohort and a nested sub-study at 14–15 years have been reported previously.[18] Heights of the

204 sub-study participants were measured using a SECA 206 stadiometer (Hamburg, Germany). Weights were measured in light clothing using a SECA 703 scale. Body mass index (BMI) was calculated as weight (kg) divided by height (metres) squared. Waist circumference was measured using an inelastic plastic fibre tape and waist-circumference-to-height ratio was calculated as a proxy for abdominal visceral fat. Age, in years, was determined from date of measurement minus date of birth. Body composition was assessed using dual-energy X-ray absorptiometry (DXA, model iDXA, GE-Lunar, Madison, Wisconsin, USA). System software (version 13) outputs were total and regional body mass, fat mass, lean mass and bone mineral content. Percent (%) fat was calculated as 100×total body fat mass/total mass. Appendicular skeletal mass (ASMM) was determined by total limb mass minus the sum of limb fat and wet bone mass, estimated as bone mineral content divided by 0.55.[19] Percentage ASMM was calculated as 100×ASMM/total mass. Further analyses of adiposity were conducted in the android (central) region, delineated caudally by the superior-most aspect of the iliac crest and the cephalad limit defined by 20% of the distance between the caudal limit and the base of the skull.[20] Total abdominal adipose tissue (AAT) and visceral abdominal adipose tissue (VAT) mass were estimated within this region of interest. Percentage VAT of total AAT was calculated as 100×VAT mass/total AAT mass, and % VAT of total weight was calculated as 100×VAT mass/total body mass. Protocols for the nested sub-study were approved by the Central Health and Disability Ethics Committee (ref. 8/CEN/108).

Chi-squared tests were used to examine differences in food insecurity question responses by sex. Depending on normality, independent two-sample t-tests or Mann–Whitney U tests were used to compare body size and composition at 14 years by whether mothers reported food insecurity at six weeks. Statistical analyses were conducted in RStudio version 1.2.1335 (www.rstudio.com). Reported probabilities are two-sided, and p-values <0.05 were considered statistically significant.

Results

In the year 2000, 78% of the cohort reported household size of five or more and 84% reported household income of less than $40,000 per annum. Only 41 mothers (2.9%) in the original cohort (n=1,398) self-reported a "diagnosis of diabetes." There were no differences in income status or household size between food secure and insecure households.

There was no significant difference in prevalence of food insecurity between the original cohort and sub-study (Table 1). In the full cohort, mothers of boys were less likely to report food insecurity compared to mothers of girls (χ^2(1, N=1,398)=5.13, p=0.025). This tendency was also observed in the sub-study but did not reach statistical significance (χ^2(1, N=204)=3.633, p=0.057). In the full cohort, mothers of boys were more likely to report being unable to provide food for special occasions due to lack of money (χ^2(1, N=1,398)=4.70, p=0.034). Within the sub-study, mothers of boys reported fewer occasions of relying on others for food (χ^2(1, N=204)=5.03, p=0.025) and eating less variety of foods due to lack of money (χ^2(1, N=204)=4.374, p=0.036). In the full cohort, birthweight was recorded for 1,381 children (17 missing). Mean birthweights among girls born to food secure households (n=439, 3,488±606(SD)g) and girls born to food insecure households (n=235, 3,571±696g) were not significantly different (mean difference=84g, 95%CI[-185, 17], p=0.104). Mean birthweight among boys born to food secure households (n=500, 3,581±630 g) was 124g lower (95%CI[-222, -26], p=0.013) compared to boys born to food insecure households (vs n=207, 3,705±547g).

Neither boys nor girls exhibited differences in birthweight by food insecurity status in the sub-study (Table 2). At age 14, boys born into food insecure households exhibited 5.5% (95%CI[1.7, 10.6], p=0.008) greater % fat, 1.8% less % ASMM (95%CI[0.2, 3.5], p=0.038) and 0.201% greater % VAT of total weight (95%CI[0.044, 0.429], p=0.013) compared to boys from food secure households. Among girls, body composition at age 14 did not differ significantly by household food insecurity status during gestation.

Table 1: Maternal responses to food security questions at six weeks postpartum.

Question	Sub-study (N=204)			Full cohort (N=1,398)		
	Girls (N=100)	Boys (N=104)	p	Girls (N=681)	Boys (N=717)	p
	% who responded sometimes or often					
Food runs out due to lack of money	51	40	0.160	45	42	0.195
I/we eat less because of lack of money	47	35	0.087	39	34	0.076
The variety of foods I am (we are) able to eat is limited by lack of money	46	32	0.036	42	37	0.071
I/we rely on others to provide food and/or money for food for my/our household when I/we don't have enough money	33	19	0.025	32	28	0.162
I/we make use of special food grants or food banks when I/we do not have enough money for food	14	12	0.837	15	13	0.491
I feel stressed because of not having enough money for food	33	31	0.765	37	32	0.064
I feel stressed because I can't provide the food I want for social occasions	19	15	0.578	27	22	0.034
	% food insecure					
Total score for 7 questions ≥4	33	21	0.057	35	29	0.025

To each question, mothers responded either "never," "sometimes" or "often." For each question the proportion responding never is presented. The three responses were scored 0, 1 and 2 respectively. A total score was derived by summing all seven individual question scores. Total score ≤3 was categorised as food secure and ≥4 as food insecure.

Table 2: Physical characteristics of sub-study children by gender.

	Girls			Boys		
	Food secure (n=67)	**Food insecure (n=33)**	**P**	**Food secure (n=82)**	**Food insecure (n=22)**	**P**
Birthweight, g	3493 (593)	3666 (696)	0.227	3615 (487)	3744 (615)	0.379
Age, y	14.9 (0.5)	15.0 (0.5)	0.271	14.9 (0.4)	14.8 (0.4)	0.243
Weight, kg	*75.4 (64.6, 89.0)*	*80.8 (67.0, 95.1)*	*0.248*	*77.0 (64.7, 100.8)*	92.1 (23.5)	*0.126*
Height, cm	166.5 (5.5)	166.7 (5.8)	0.826	*175.8 (172.3, 180.4)*	175.3 (7.0)	*0.604*
Waist, cm	*81.5 (71.8, 94.8)*	*81.2 (76.6, 96.2)*	*0.399*	*81.1 (71.0, 98.9)*	94.0 (17.2)	*0.077*
Waist/height	*0.49 (0.43, 0.55)*	*0.49 (0.45, 0.59)*	*0.326*	*0.46 (0.42, 0.56)*	0.54 (0.09)	*0.061*
Bone mineral content, g	2639 (375)	2708 (406)	0.415	2976 (557)	2934 (494)	0.724
Lean mass, kg	46.3 (7.6)	48.9 (8.7)	0.146	56.8 (10.7)	58.2 (13.5)	0.606
Fat mass, kg	30.2 (11.5)	33.6 (15.6)	0.261	24.6 (16.0)	30.9 (13.5)	0.070
% fat	37.1 (6.2)	37.8 (7.3)	0.609	24.9 (20.2, 35.1)	**32.2 (8.4)**	0.008
% ASMM	26.4 (2.1)	26.3 (2.4)	0.823	32.6 (29.2, 34.7)	**30.4 (3.4)**	0.038
AAT, kg	2.178 (1.217)	2.582 (1.643)	0.216	1.859 (1.799)	2.453 (1.455)	0.115
% VAT of AAT	15.3 (8.8)	*16.3 (12.4, 24.0)*	*0.177*	*21.98 (12.1, 31.3)*	*23.0 (17.5, 32.4)*	*0.361*
% VAT of total weight	*0.360 (0.145, 0.610)*	*0.505 (0.205, 0.713)*	*0.173*	0.266 (0.144, 0.606)	0.601 (0.230, 829)	**0.013**

Mean (SD) is provided for normally distributed variables, with p-values corresponding to two-sample t-test results. Median (IQR) is provided in italics for non-normally distributed variables with p-values corresponding to Mann–Whitney U test results. Bold text indicates significant difference by food insecurity status at age six weeks. AAT abdominal adipose tissue, ASSM appendicular skeletal muscle mass, VAT visceral adipose tissue.

Discussion

Here, we tested the hypothesis that exposure to malnutrition due to household food insecurity during foetal life and early infancy is associated with body composition in adolescence. In the PIF sub-study, we found that boys born into food insecure households exhibited less % ASMM and greater % fat and % VAT of total weight at age 14. In contrast, body composition of girls at age 14 did not differ significantly by whether mothers reported food insecurity at six weeks postpartum.

These results are significant because skeletal muscle is the primary source of insulin-dependent glucose uptake, and abdominal VAT is associated with increased risk of insulin resistance and metabolic syndrome in adulthood.[21,22] Thus, our results suggest that food insecurity in early development may be associated with serious cardiometabolic health consequences in later life.

Our findings are in line with previous studies indicating sexually dimorphic responses to early metabolic programming. Many[23] (but not all[24–26]) studies in humans and rodents have shown that male offspring are more susceptible to changes in adiposity and body weight in response to maternal obesity during pregnancy. Sexual dimorphism in placental development may underlie sex differences in sensitivity to maternal nutritional status. Eriksson suggests that boys grow more rapidly *in-utero* than girls but invest less in placental growth, which makes boys more vulnerable to fluctuations in maternal energy availability during pregnancy.[27]

Sex differences in the timing of puberty may also contribute to why food insecurity during early development was associated with reduced muscle mass and greater fat mass at age 14 in boys only. Puberty is associated with adipose deposition and increase in % fat in girls. The impacts of food insecurity during early life may be masked by changes in body composition associated with puberty. However, in the full PIF study cohort, birthweight was increased in boys born into food insecure households, but not in girls, suggesting sex differences in sensitivity to maternal nutritional status *in-utero*.

It is also possible that food insecurity during early development affects adolescent body composition more subtly in girls compared to boys, and our subsample may be underpowered for detecting smaller effect sizes. Indeed, adolescent girls born to food insecure families exhibited greater weight and adiposity compared to girls born to food secure families, but these differences did not reach statistical significance.

Our analysis is not without other limitations. First, data concerning maternal BMI and gestational weight gain and hyperglycaemia were not available for inclusion in the analysis. Since food insecurity is broadly associated with obesity in New Zealand, when interpreting our results we have assumed that mothers who reported food insecurity at six weeks postpartum were more likely to have been overweight or obese. Mothers who report food insecurity may also be more likely to exhibit hyperglycaemia during pregnancy, which has been associated with adolescent obesity.[29] Variables including number of children, size of household and less income per household member are collinear and likely to correlate with the ability to access a reliable and nutritious supply of food for the family. Collection of longitudinal data on maternal nutritional status during pregnancy would have helped clarify the practical implications of our results.

Second, answers to food insecurity questions were only collected once during the study. Thus, our study design is not able to distinguish whether food insecurity during early development is sufficient to impact body composition during adolescence. Although foetal life and early infancy are considered critical periods of development, more precise longitudinal tracking of food insecurity status is necessary to understand how sensitivity to nutritional status changes throughout childhood. Among the PIF study cohort, it is likely food security not only persisted but perhaps intensified in adolescence as the quantity and cost of food consumed by the family increases. We have previously shown that food choices and frequency remained relatively consistent between ages four and six.[30] However, more breakfast cereal and less fruit were consumed at age six, indicating a potential increase in consumption of energy dense foods and decrease in nutritional quality as

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children age and gain weight. Increases in appetite may drive greater consumption of cheap, energy dense foods in adolescence, particularly among boys, and contribute to the significant association between food insecurity and adolescent body composition in boys.

Finally, we again recognise that our analysis is limited by a relatively small sample size for the sub-study of adolescents who underwent DXA scans.

In summary, food insecurity during early life was associated with greater adiposity and decreased ASMM in adolescent boys. Further longitudinal studies are necessary to understand the sex-specific effects of early metabolic programming. This study shows that household food insecurity during early development may continue to impact cardiometabolic health years down the line. As the COVID-19 pandemic continues to plunge more families into poverty, ensuring accessibility to nutritious foods is more important now than ever. Without action, we risk endangering a generation of children and increasing inequity by location and ethnic group.

Competing interests:
Nil.

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