

BMJ Open Mediating effects of early health on the relationship between early poverty and long-term health outcomes of children: a birth cohort study

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ABSTRACT

Objective This study analyses the mediating effects of early health prior to age 3 on the association between early poverty and the health outcomes of children at age 12.

Design Population-based longitudinal birth cohort study.

Setting Taiwan Birth Cohort Study (TBCS), 2005–2017.

Participants 16 847 TBCS children born in 2005 and followed up at 18 months, 3, 5, 8 and 12 years with available data on poverty and health status.

Main outcome measures Child's general health, measured by the mothers' ratings of their child's health, and hospitalisation experience at 12 years of age.

Results Among the TBCS children, the prevalence of fair/poor health and hospitalisation was 20.8% and 2.5% at age 12. The ORs of experiencing fair/poor health and hospitalisation at age 12 were 1.33 (95% CI 1.21 to 1.45) and 1.35 (1.07 to 1.69) for early poverty, respectively. When early poor health was added in the multiple logistic regression models, the effects of early poverty were attenuated on poor general health and no longer significant on hospitalisation for children aged 12 years. Mediation analysis showed that 50%–87% of the total effect of early poverty on health at age 12 was mediated by early health status before age 3.

Conclusions Our findings suggest that poor health in early life plays as a significant mediator in the relationship between early poverty and the long-term health outcomes of children. Universal health coverage thus should be achieved to prevent the adverse health effects of poverty throughout the life course, as one of the most important strategies for children growing up in poverty.

INTRODUCTION

Nearly one in three children around the world live in poverty.¹ Poverty exposure in early life is an important factor for poor health in childhood.^{2–4} Children living in poverty frequently have little access to nutritious foods, safe water, sanitation facilities, shelter and health-care, which renders them more vulnerable to illness and disease.^{5 6} Empirical studies have demonstrated that poor children have a higher risk of experiencing adverse health

Strengths and limitations of this study

- This is the first study designed to explore the mediating effects of general health in early life on the association between early poverty and later health of children in Asia.
- This study included 16 847 children from the population-based longitudinal birth cohort study in Taiwan, with information on poverty and health conditions at baseline and 12-year follow-up.
- We measured two types of general health indicators of children, considering both objective and subjective aspects of health to ensure that our findings are robust.
- Lack of information on biological factors and biomarkers which would allow the exploration of the epigenetic mechanisms for biological and environmental interactions in early life.

outcomes and death than their less impoverished peers.^{7–11}

Health conditions during the crucial early childhood period shape lifelong health.¹² Since the Barker hypothesis was first introduced in the 1990s, the long-term effects of early developmental experiences on health and disease risk into adulthood have been recognised and investigated.^{13–16} As a result, the WHO has adopted a life course approach for the prevention and control of non-communicable diseases.^{17–19} With the launch of the Sustainable Development Goals in 2015, the United Nations further proposed updated global strategies to improve women's, children's and adolescents' health by taking a life-course approach.²⁰

However, early poverty, early health conditions and long-term health outcomes of children have rarely been examined at the same time.^{21–23} According to the life course perspective, different socioeconomic statuses in early years may result in various health trajectories in early childhood that in turn affect children's future health status.²⁴ In this

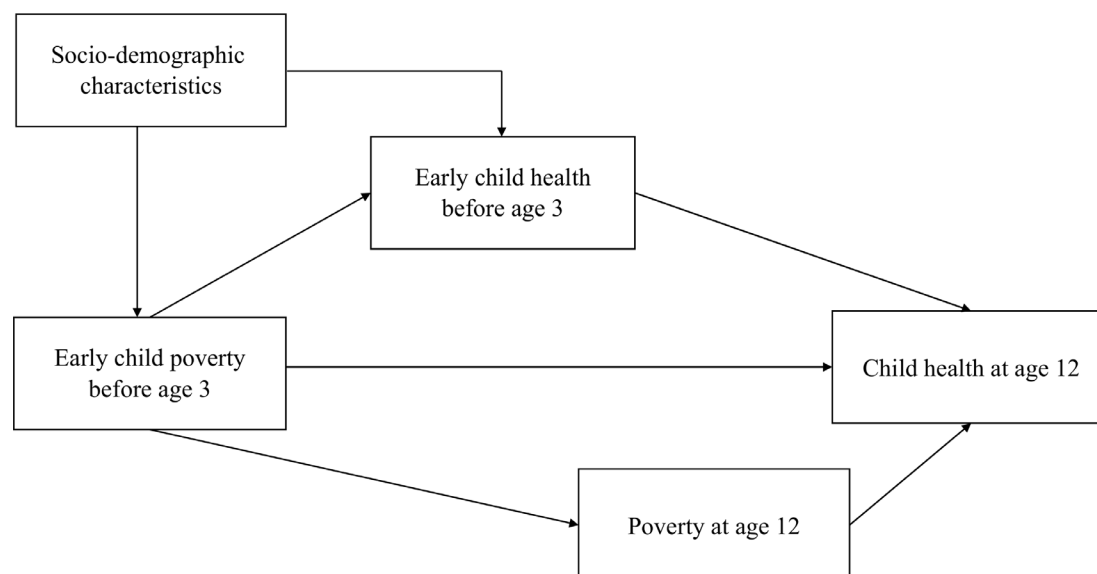


Figure 1 Conceptual model.

study, we aimed to examine the mediating effects of early health conditions on the relationship between poverty status prior to age 3 and the health outcomes of children up to age of 12 by using data from a nationwide, longitudinal birth cohort study in Taiwan. **Figure 1** presents the conceptual framework of this study.

METHODS

Study population

The Taiwan Birth Cohort Study (TBCS) is a nationally representative, longitudinal cohort study of children in Taiwan. Details of the objectives, design, instruments and sample characteristics of the TBCS have been described in a previous publication.²⁵ The cohort consists of 21 248 babies born in 2005 and data collection began with a face-to-face interview by trained staff with the mother at the child's age of 6 months. Five waves of follow-up surveys were conducted at 18 months, 3 years, 5 years, 8 years and 12 years of age. Retention rates were 94.9%, 93.7%, 92.8%, 91.8% and 88.5%, respectively, for the follow-up surveys. A total of 16 847 children who completed all 6 waves of TBCS surveys were included in our analysis, with data available for analyses including family poverty status and the child's health status.

Health outcomes

Health outcomes in this study included the child's general health and hospitalisation (described below) at 12 years of age. Children's general health status was rated by the mother with one question: 'Would you say your child's health in general, is very good, good, fair, poor, or very poor?' Responses were dichotomised as fair/poor (fair, poor, or very poor) versus good (very good or good). Children's hospitalisation was measured with one question: 'Whether the child has been hospitalised in the previous year?' and was classified as yes versus no.

Early poverty and early poor health

We investigated early poverty and early poor health as primary predictors of subsequent health outcomes. Early poverty was defined as a child having lived before age three in a family with a monthly income of less than New Taiwan dollars (NT\$) 30 000 (about US\$1000 or Great Britain pound (GBP) 750). Children with fair/poor general health before age 3 and having been hospitalised at any time from birth to age 3 years were used as indicators of early poor health. The distribution of diagnoses for children's hospitalisation using the International Classification of Diseases (ICD) codes is provided in online supplemental appendix 1. In addition, under the National Health Insurance, all children in Taiwan have equal access to healthcare with a moderate cost sharing.^{26 27}

Covariates

Covariates of our study included child and maternal characteristics correlated with child health, with data collected at 6 months of age. Child characteristics included sex, birth order, low birth weight (infants born weighing <2500 g), preterm (infants born after <37 gestation weeks) and predominant breast feeding. Predominant breast feeding was defined as infants who were predominantly breastfed for more than 120 days after birth.²⁸ Maternal characteristics included mother's age at the child's birth (less than 25 years, 25–29 years, 30–34 years and greater than 35 years), maternal nationality (Taiwanese vs foreign-born (China, Southeast Asia or others)) and the mother's level of education (junior high school or below, senior high school and college and above). Further, considering the health facilities and the utilisation of healthcare may vary across regions, we included children's residential locality at 6 months of age as covariates. Residential locality was categorised as rural and urban according to the definition of administrative divisions in Taiwan. We also controlled

Table 1 Baseline characteristics of participants in the Taiwan Birth Cohort Study children

Characteristics	All N (%)	Fair/poor health at 12 years of age		P value	Child hospitalisation at 12 years of age		P value
		No n (%)	Yes n (%)		No n (%)	Yes n (%)	
Total	16 847 (100.0)	13 340 (79.2)	3 507 (20.8)		16 432 (97.5)	415 (2.5)	
Poverty status							
Early child poverty				<0.001			0.010
No	13 542 (80.4)	10 852 (80.1)	2 690 (19.9)		13 229 (97.7)	313 (2.3)	
Yes	3 305 (19.6)	2 488 (75.3)	817 (24.7)		3 203 (96.9)	102 (3.1)	
Poverty at age 12				<0.001			0.028
No	15 118 (89.7)	12 107 (80.1)	3 011 (19.9)		14 759 (97.6)	359 (2.4)	
Yes	1 729 (10.3)	1 233 (71.3)	496 (28.7)		1 673 (96.8)	56 (3.2)	
Child characteristics							
Sex				0.375			0.004
Girl	8 000 (47.5)	6 358 (79.5)	1 642 (20.5)		7 832 (97.9)	168 (2.1)	
Boy	8 847 (52.5)	6 982 (78.9)	1 865 (21.1)		8 600 (97.2)	247 (2.8)	
Birth order				0.003			0.788
First	8 432 (50.1)	6 598 (78.3)	1 834 (21.7)		8 227 (97.6)	205 (2.4)	
Second and higher	8 415 (49.9)	6 742 (80.1)	1 673 (19.9)		8 205 (97.5)	210 (2.5)	
Low birth weight	1 135 (6.7)	836 (73.7)	299 (26.3)	<0.001	1 101 (97.0)	34 (3.0)	0.231
Preterm	1 397 (8.3)	1 063 (76.1)	334 (23.9)	0.003	1 354 (96.9)	43 (3.1)	0.122
Predominant breast feeding	2 637 (15.6)	2 138 (81.1)	499 (18.9)	0.009	2 563 (97.2)	74 (2.8)	0.216
Maternal characteristics							
Age at birth of the child (years)				0.021			0.753
≤24	2 289 (13.6)	1 759 (76.9)	530 (23.2)		2 230 (97.4)	59 (2.6)	
25–29	5 511 (32.7)	4 370 (79.3)	1 141 (20.7)		5 367 (97.4)	144 (2.6)	
30–34	6 143 (36.5)	4 910 (79.9)	1 233 (20.1)		6 000 (97.7)	143 (2.3)	
≥35	2 904 (17.2)	2 301 (79.2)	603 (20.8)		2 835 (97.6)	69 (2.4)	
Nationality				0.134			0.039
Taiwanese	14 836 (88.1)	11 722 (79.0)	3 114 (21.0)		14 484 (97.6)	352 (2.4)	
Foreign-born	2 011 (11.9)	1 618 (80.4)	393 (19.6)		1 948 (96.9)	63 (3.1)	
Education				0.054			0.001
≤Junior high school	2 230 (13.2)	1 728 (77.5)	502 (22.5)		2 155 (96.6)	75 (3.4)	
Senior high school	6 705 (39.8)	5 298 (79.0)	1 407 (21.0)		6 528 (97.4)	177 (2.6)	
≥College	7 912 (46.9)	6 314 (79.8)	1 598 (20.2)		7 749 (97.9)	163 (2.1)	
Residential locality				0.179			0.146
Urban	11 986 (71.2)	9 523 (79.4)	2 463 (20.6)		11 704 (97.6)	282 (2.3)	
Rural	4 861 (28.8)	3 817 (78.5)	1 044 (21.5)		4 728 (97.3)	133 (2.7)	

Table 2 Bivariate correlation between early poverty and early poor health prior to age 3

	Early child fair/poor health			P value	Early child hospitalisation		
	All	No	Yes		No	Yes	P value
	N (%)	n (%)	n (%)		n (%)	n (%)	
Total	16847 (100.0)	10225 (60.7)	6622 (39.3)		11041 (65.4)	5839 (34.6)	
Early child poverty				<0.001			<0.001
No	13542 (100.0)	8370 (61.8)	5172 (38.2)		8944 (66.0)	4598 (34.0)	
Yes	3305 (100.0)	1855 (56.1)	1450 (43.9)		2079 (62.9)	1226 (37.1)	

for concurrent family poverty status when the child's health status was measured at 12 years of age.

Statistical analysis

We conducted a χ^2 test to assess potential differences in demographic characteristics between children who had poor and good health outcomes at 12 years of age. Next, we used logistic regression to explore the data for the associations between early poverty, early poor health and child health outcomes. Further, the causal mediation analysis was undertaken to compute the standardised estimates to assess the direct effect, indirect effect, total effect and the proportion mediated via early health conditions and current poverty for the relationships of early poverty and health outcomes, while adjusting for the covariates.²⁹ All analyses were conducted using SAS software V.9.4 (SAS Institute).

RESULTS

Sociodemographic characteristics

Table 1 shows the sociodemographic characteristics of the TBCS children and their relationship with children's health outcomes at 12 years of age. Of the 16847 children included in the study, 19.6% and 10.3% experienced poverty during the first 3 years of life and at age 12 years, respectively, 52.5% were boys, 50.1% were first-born, 6.7% were born weighing less than 2500 g, 8.3% were born before 37 weeks' gestation and 15.6% received breast milk as the predominant source of nourishment more than 120 days after birth.

Overall, 20.8% (n=3507) and 2.5% (n=415) of the children were reported to be in fair/poor health and hospitalised at age 12, respectively. Children living in poverty, being first-born, low birth weight, preterm, non-predominantly breastfed and born to mothers under 24 years of age were more likely to be in fair/poor health at age 12. Children who experienced early poverty, were boys, had foreign-born or mothers with low-level education were more likely to be hospitalised at age 12.

Early poverty and early poor health

Of the children in our study, 39.3% (n=6622) had fair/poor health and 34.6% (n=5839) were hospitalised at least once during their first 3 years of life (table 2). Early poverty was linked to higher rates of early child fair/poor health and early child hospitalisation (both $p<0.001$).

Early poverty, early poor health and child general health

Table 3 shows that general health at age 12 was significantly associated with both poverty and poor health in early life (all $p<0.001$). Compared with children who did not experience poverty early in life, children who did were much more likely to have poorer health at age 12 (24.7% vs 19.9%, crude OR 1.33, 95% CI 1.21 to 1.45). Similarly, children who had been in fair/poor health (30.8% vs 14.3%, crude OR 2.67, 95% CI 2.47 to 2.88) or hospitalised (23.4% vs 19.5%, crude OR 1.27, 95% CI 1.17 to 1.37) prior to age 3 had poorer general health at age 12, compared with children who had never been in fair/poor health or hospitalised prior to age 3, respectively.

The direct effects of early poverty on children's general health at age 12 were slightly attenuated as early health status was added in the multiple logistic regression models. As shown in model 1 and model 2 of table 3, both early child fair/poor health and early child hospitalisation can predict fair/poor general health in later childhood. In addition, model 3 and model 4 indicate that the effects of early poverty were reduced substantially, after controlling for current poverty. Model 5 shows that the results remained significant even after adjusting for early poverty, early child fair/poor health, early child hospitalisation and current poverty simultaneously.

Early poverty, early poor health and child hospitalisation

Generally, the effects of early poverty and early poor health on child hospitalisation were similar to the effects on child general health. Children who had experienced poverty and poor health early in life had higher rates of hospitalisation at age 12 (table 4). The hospitalisation rate at age 12 was 3.1% for children experiencing early poverty, compared with 2.3% for children not experiencing early poverty (crude OR 1.35, 95% CI 1.07 to 1.69), and the hospitalisation rate was 2.8% for children with early fair/poor health, compared with 2.3% for children reported to be in good health during the first 3 years of life (crude OR 1.24, 95% CI 1.02 to 1.51). The similar figures for the crude ORs of being hospitalised at age 12 were 1.60 (95% CI 1.32 to 1.95) for early child hospitalisation.

Although a similar pattern of results also emerged in multiple logistic regression models, the relationships between early poverty and child hospitalisation at age 12 were no longer significant when the covariates were considered simultaneously. There was no significant

Table 3 Association between early poverty and early poor health prior to age 3 and mothers' perception of child's health at 12 years of age

		Model 1		Model 2		Model 3		Model 4		Model 5	
		No of fair/poor health	% of fair/poor health	Crude odds ratio (95% CI)	P value	Adjusted OR* (95% CI)	P value	Adjusted OR* (95% CI)	P value	Adjusted OR* (95% CI)	P value
Fair/poor health at 12 years of age											
Early poverty											
Yes	3305	817	24.7	1.33 (1.21 to 1.45)	<0.001	1.25 (1.13 to 1.39)	<0.001	1.31 (1.19 to 1.45)	<0.001	1.15 (1.03 to 1.28)	0.011
No	13542	2690	19.9	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Early child fair/poor health											
Yes	6622	2042	30.8	2.67 (2.47 to 2.88)	<0.001	2.64 (2.44 to 2.85)	<0.001	-	<0.001	2.62 (2.43 to 2.83)	<0.001
No	10225	1465	14.3	Reference	Reference	Reference	Reference	-	Reference	-	Reference
Early child hospitalisation											
Yes	5824	1363	23.4	1.27 (1.17 to 1.37)	<0.001	-	1.25 (1.15 to 1.35)	<0.001	1.24 (1.15 to 1.34)	1.09 (1.00 to 1.18)	0.039
No	11023	2144	19.5	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Poverty at age 12											
Yes	1729	496	28.7	1.62 (1.45 to 1.81)	<0.001	-	-	1.47 (1.29 to 1.67)	<0.001	1.51 (1.33 to 1.70)	<0.001
No	15118	3011	19.9	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference

*Adjusted for child's characteristics (sex, birth order, low birth weight, preterm, breast feeding), maternal characteristics (mother's age at birth of the child, nationality, and education) and residential locality.

Table 4 Association between early poverty and early poor health prior to age 3 and children's hospitalisation at 12 years of age

		Child hospitalisation at 12 years of age													
		Model 1		Model 2		Model 3		Model 4		Model 5					
No	No of child hospitalisation	% of child hospitalisation	Crude odds ratio (95% CI)	P value	Adjusted OR* (95% CI)	P value	Adjusted OR* (95% CI)	P value	Adjusted OR* (95% CI)	P value	Adjusted OR* (95% CI)				
Early poverty															
Yes	3305	102	3.1	1.35 (1.07 to 1.69)	0.010	1.15 (0.90 to 1.49)	0.266	1.16 (0.90 to 1.50)	0.242	1.12 (0.86 to 1.46)	0.384	1.13 (0.87 to 1.47)	0.360	1.12 (0.86 to 1.46)	0.387
No	13542	313	2.3	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Early child fair/poor health															
Yes	6622	184	2.8	1.24 (1.02 to 1.51)	0.034	1.21 (0.99 to 1.48)	0.061	–	1.21 (0.99 to 1.47)	0.064	–	–	1.14 (0.93 to 1.39)	0.211	
No	10225	231	2.3	Reference	Reference	Reference	–	–	Reference	–	–	–	Reference	Reference	
Early child hospitalisation															
Yes	5824	189	3.2	1.60 (1.32 to 1.95)	<0.001	–	1.55 (1.27 to 1.89)	<0.001	–	1.55 (1.27 to 1.88)	<0.001	1.52 (1.24 to 1.85)	<0.001		
No	11023	226	2.1	Reference	–	–	Reference	–	–	Reference	–	Reference	Reference		
Poverty at age 12															
Yes	1729	56	3.2	1.38 (1.03 to 1.83)	0.029	–	–	1.13 (0.83 to 1.55)	0.450	1.13 (0.83 to 1.55)	0.444	1.12 (0.82 to 1.54)	0.466		
No	15118	359	2.4	Reference	–	–	–	Reference	–	Reference	–	Reference	Reference		

*Adjusted for child's characteristics (sex, birth order, low birth weight, preterm, breast feeding), maternal characteristics (mother's age at birth of the child, nationality, and education) and residential locality.

Table 5 Mediating effects on the association between early poverty prior to age 3 and the health outcomes of children at age 12

Health outcomes	Indirect (mediated) effect	Direct effect of early child poverty	Total effect (direct plus indirect)	Proportion of total effect mediated (%)	Ratio of indirect to direct
Child fair/poor health at age 12					
Early child fair/poor health as mediator	0.315	0.046	0.361	87.37	6.91
Early child hospitalisation as mediator	0.060	0.060	0.120	50.04	1.00
Current poverty at age 12 as a mediator	0.067	0.037	0.104	64.84	1.84
Child hospitalisation at age 12					
Early child fair/poor health as mediator	0.078	0.061	0.139	56.36	1.29
Early child hospitalisation as mediator	0.121	0.061	0.182	66.37	1.97
Current poverty at age 12 as a mediator	0.035	0.052	0.087	40.06	0.67

association between early fair/poor general health and child hospitalisation at age 12 when early poverty status was considered together (model 1: adjusted OR 1.21, 95% CI 0.99 to 1.48), while the effect of early child hospitalisation remained strong on child hospitalisation at age 12 after controlling for early poverty, current poverty and early child fair/poor health (model 5: adjusted OR 1.52, 95% CI 1.24 to 1.85).

Mediation effects

For the mediation effects, this study builds two pathways of the impact of early poverty on later health of children. One is through early health conditions prior to age 3 and the other is through current poverty at age 12.

First, we found that early health conditions substantially mediated the relationship between early child poverty and child health outcomes at age 12 (table 5). The proportion of the total effect of early child poverty on child fair/poor health at age 12 mediated by early child fair/poor health was 87.3%, and the proportion was 50.0% while early child hospitalisation was used as a mediator. Early child fair/poor health and early child hospitalisation also mediated the association between early child poverty and child hospitalisation at age 12. Less than half of the total effects of early child poverty on child hospitalisation at age 12 occurred directly via early child poverty, whereas 56.3% and 66.3% of the effects occurred through early child fair/poor health and early child hospitalisation, respectively.

Second, our results also revealed that early poverty can affect child health outcomes through current poverty at age 12. The indirect effects through current poverty accounted for 40%–60% of the total effect of early child poverty on child fair/poor health and child hospitalisation at age 12.

DISCUSSION

Principal findings

Using data from the TBCS, we discovered that both early poverty and early poor health have significant negative

effects on the health of school-aged children. However, the effect of early poverty was attenuated when early health conditions were considered simultaneously as predictors of children's later health, indicating that children experiencing early poverty tend to have poor health prior to age 3 which results in long-term adverse health outcomes for children at age 12.

Strengths and weaknesses of the study

There are two main strengths of this study. First, the use of a large population-based birth cohort study with a long follow-up period revealed the temporal relationship of early poverty and health outcomes in middle childhood and provides insight regarding the pathway through early poor health. Furthermore, the large sample size provided enough statistical power for the analysis of rare events among various subgroups, such as the hospitalisation rates of poor and non-poor children. Second, we measured two types of general health indicators of children, considering both objective (child hospitalisation) and subjective (mother-reported child health status) aspects of health, to ensure that our findings are robust. However, this study has some limitations. There is lack of information on biological factors and biomarkers which would allow the exploration of the epigenetic mechanisms for biological and environmental interactions in early life. Moreover, as cohort studies are observational, children are not randomly assigned to poor and non-poor families in early childhood. Although we have controlled sociodemographic variables and change in poverty status in our analysis,^{8 30} it is not always possible to consider all relevant confounders. Hence, we should be very cautious when making causal inferences of early poverty, early poor health and later health in this study.

Comparison with other studies and interpretation of the results

Our data indicate that 34.6% of children have been hospitalised at least once by the age of 3, and respiratory

symptoms, infection and digestive disorders were the most leading causes, which is in accordance with the rate of child hospitalisation in Taiwan.³¹ Consistent with the findings of other studies, the results of this study also revealed that child hospitalisation was associated with low socioeconomic status.^{3 32 33} Guttman *et al*³² found that low income adequacy was statistically significant related to the risk of hospitalisation. The study conducted in Taiwan also revealed that children living in poverty had higher hospital admission rates and lengths of stays for acute injuries, poisonings and lower respiratory infections than high-income children.³⁴

Importantly, the present results lend some credence to the developmental origins of health and disease hypothesis that health status during the first 3 years of life is negatively influenced by early poverty status and sets a foundation for the development of subsequent health status.^{15 24 35} Previous research indicates specific biological processes to explain how environmental insults during early life, such as undernutrition or maternal stress, exert their programming effects, including changes in cell allocation, organ structure or the activity of the neuroendocrine system, and lead to permanent health problems in future life.^{15 36} However, most previous studies were based on animal models, and thus, the biological mechanisms that link early poverty to later health outcomes in humans are mostly undiscovered.¹⁵

CONCLUSION

Early poverty is a crucial social determinant of child health. Our findings suggest that poor health in early life plays as a significant mediator in the relationship between early poverty and the long-term health outcomes throughout the life course. Universal health coverage thus should be achieved to prevent and mitigate the adverse health effects of poverty, as one of the most important strategies for children growing up in poverty.

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Contributors W-LC conceived the study, analysed the data, interpreted the results, drafted and revised the manuscript. T-IC conceived the study, interpreted the results and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. T-IC is the author responsible for the overall content as the guarantor.

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Patient consent for publication Not applicable.

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