Association between early-life exposure to the Great Chinese Famine and poor physical function later in life: a cross-sectional study

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ABSTRACT

Objectives This study aimed to evaluate the association between early-life exposure to the Great Chinese Famine (1959–1961) and the prevalence of poor physical function in midlife.

Design A population-based historical prospective study was performed as part of a wider cross-sectional survey. Exposure to famine was defined by birthdate, and participants were divided into non-exposed group, fetal-exposed group and infant-exposed group.

Setting and participants A total of 3595 subjects were enrolled into the study from the China Health and Retirement Longitudinal Study (CHARLS) 2015 based on random selection of households that had at least one member aged 45 years old and older in 28 provinces of mainland China.

Main outcome measures Physical function status was assessed by a six-item self-report on the Barthel scale which rated basic activities of daily living (BADL).

Results 743 (20.7%) out of all participants were exposed to the Great Chinese Famine in their fetal periods, while 1550 (43.1%) participants were exposed at the age of an infant. The prevalence of poor physical function in the non-exposed group, fetal period-exposed group and infant period-exposed group were 12.3%, 15.5% and 17.0%, respectively. Among males, after stratification by gender and severity of famine, the prevalence of poor physical function in the fetal period was significantly higher (OR 2.40, 95% CI 1.18 to 4.89, p=0.015) than the non-exposed group in severely affected areas, even after adjusting for the number of chronic diseases, place of residence, smoking and alcohol drinking habits, marital status, educational level and body mass index. A similar connection between prenatal and early postnatal exposure to the Great Chinese Famine and the prevalence of poor physical function in midlife, however, was not observed from female adults.

Conclusions Males who were exposed to the Great Chinese Famine (1959–1961) present considerably decreased physical function in their later life.

INTRODUCTION

The Framework of Life-Course Epidemiology proposes that physical growth and development taking place during the lifecycle, including prenatal life and childhood, have long-term effects and consequences on health and function in adulthood. Within this framework, the Developmental Origins of Health and Disease (DOHaD) assumes that physical adaptations are responses to life; this might decrease the real effect of famine exposure on physical function. Stringent quality control measures were applied in every stage of the CHARLS 2015 tracking survey, which ensured the quality of our study. Selection bias was inevitable due to excess mortality in early life; this might decrease the real effect of famine exposure on physical function. Self-reported prevalence based on the Barthel scale could be lower than the real prevalence of poor physical function.

Strengthen and limitation of this study

- This is the first study that evaluated the association between prenatal and early postnatal exposure to the Great Chinese Famine and the prevalence of poor physical function in midlife.
- The study applied the China Health and Retirement Longitudinal Study (CHARLS) 2015 tracking survey, which is a nationally representative longitudinal survey.
- Stringent quality control measures were applied in every stage of the CHARLS 2015 tracking survey, which ensured the quality of our study.
- Selection bias was inevitable due to excess mortality in early life; this might decrease the real effect of famine exposure on physical function.
- Self-reported prevalence based on the Barthel scale could be lower than the real prevalence of poor physical function.
with at least one member who aged 45 years old and above, from the 450 communities, 150 counties, 28 provinces of mainland China. The CHARLS 2015 also collected data on height and weight, which was carried out by trained interviewers. To correct for non-response and sampling frame errors in each step of the CHARLS, the CHARLS team created separate weights for individuals and households. The datasets analysed in the current study are available online (http://charls.pku.edu.cn/zh-CN/page/data/2015-charls-wave4).23

Defining famine groups
Participants were divided into a non-exposed group and two famine-exposed groups (fetal-exposed and infant-exposed) by birthdate. The Great Chinese Famine started in January 1959 and ended in October 1961. Due to the fact that the exact dates on which the Great Chinese famine began and ended were not precise, and in order to minimise classification bias, participants born between 1 January 1959 and 30 September 1959 and between 1 October 1961 and 30 September 1962 were excluded.14 The birthdates of the three groups were 10/01/1962 to 09/30/1964 (non-exposed group), 10/01/1959 to 09/30/1961 (fetal stage-exposed group) and 01/01/1956 to 12/31/1958 (infant stage-exposed group).

Sample
In the current study, 4667 participants were enrolled into three groups defined by birthdates. After excluding 1072 participants with missing data of body mass index (BMI) or functional limitations, 3595 subjects participated in the study (figure 1).

Famine severity
Since different provinces in mainland China vary from climate, population density and policies regarding the shortage of foods, the severity of famine fluctuated sharply across regions.24 Excess mortality was the change in mortality rate from the average in 1956–1958 to the highest value among the period of 1959–1962 and was used to reflect the severity of famine exposure in the current study, which is consistent with previous studies.14 24 The regions with excess mortality of 100% were used to differentiate the severely affected areas from the mildly affected areas in this study.25

Figure 1 Flow chart on the sample selection methods in each step. BADL, basic activities of daily living; BMI, body mass index.

METHODS
Database
This study was based on nationwide data derived from the CHARLS 2015, which was aimed at providing a high-quality public database with a wide range of information to meet the needs of scientific and policy researchers on ageing-related issues. A total number of 21,096 individuals from 12,225 households were interviewed through a face-to-face questionnaire, and the data collection of the survey was performed from July 2015 to August 2015. The representative samples were collected through a four-stage, stratified, cluster sampling method22 of households...
without help’, ‘need help’ or ‘unable to do’ in at least one of the six activities.

Assessment of covariates
Covariates such as demographics (birthdate, gender, residence place, education, marital status), lifestyles (smoking and alcohol drinking) and 14 types of self-reported chronic diseases were collected during face-to-face in-house interviews conducted by trained interviewers, and general obesity (body mass index (BMI)) was calculated from the height and weight of the biomarker data. Further, place of residence included urban and rural areas. Educational level was grouped into four stages: primary school or below, middle school, high school, college or above. Marital status was classified into ‘living with spouse’ (married with spouse present, cohabiting) and ‘living without spouse’ (married but temporarily not living with spouse for reasons such as work, separated, divorced, widowed or never married). Smoking status was characterised into ‘never smoked’, ‘past smoking’ and ‘currently smoking’ (smoked at least one cigarette per day in the last year). Alcohol drinking status was categorised into ‘never drank’ and ‘drinker’ (drank at least once per month in the last year). The diagnosis of 14 types of chronic diseases was based on whether the respondents had been diagnosed with any of the following conditions: hypertension, dyslipidaemia, diabetes or elevated blood sugar; malignant tumours such as cancer, chronic lung disease, liver disease, heart disease, stroke, kidney disease, stomach disease or digestive system disease; emotional and mental problems, memory-related diseases, arthritis/rheumatism, and asthma. Participants who replied ‘yes’ were described as suffering from the diagnosed disease, while participants who responded ‘no’ were deemed disease-free. BMI was categorised as underweight (<18.5 kg/m²), normal (18.5–23.9 kg/m²), overweight (24.0–27.9 kg/m²) or obese (≥28.0 kg/m²) based on the Chinese criteria.28

Statistical analysis
Continuous variables were expressed as mean±SD and categorical variables were expressed as frequency (percentages). The χ² test was used to compare differences in basic characteristics and the prevalence of poor physical function between the two famine-exposed groups and the non-exposed group.

The association between exposure to famine and poor physical function was determined with binary logistic regression analysis. The unadjusted results and results adjusted for different covariates are presented. Results were adjusted by gender, famine severity, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and BMI. In consideration of the possibility that severity of famine might affect people differently, and that early-life exposure affected men and women differently, severity-stratified famine and sex-stratified analyses were applied. Data were expressed as OR and 95% CI. A two-sided p value≤0.05 was considered statistically significant for all analyses. All statistical analyses were conducted with IBM SPSS Statistics V.17 for Windows (IBM SPSS, Chicago, IL, USA).

Patient and public involvement
In the present study, we used the data from CHARLS, which is a nationally representative longitudinal survey. The Patients or the public were not involved.

RESULTS
The basic characteristics of the study population are shown in table 1. A total of 3595 participants were involved in the study. The results showed that 743 (20.7%) participants were exposed to the Great Chinese Famine in the fetal period, while 1550 (43.1%) participants were exposed as infants. The prevalence of poor physical function among individuals in the non-exposed group, fetal-exposed group and infant-exposed group was 12.3%, 15.5% and 17.0%, respectively. Compared with the unexposed group, the prevalence of poor physical function was significantly higher in the fetal period-exposed and the infant-exposed groups (p=0.002).

Table 2 shows the prevalence and prevalence of poor physical function. The fetal period-exposed (OR 1.32, 95% CI 1.01 to 1.71, p=0.041) and infant period-exposed (OR 1.42, 95% CI 1.14 to 1.76, p=0.002) groups had significantly high prevalence of poor physical function after adjustment for gender, severity of famine, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and BMI, compared with the non-exposed group. The same procedures were conducted in analysing the prevalence of high difficulty with dressing, bathing or showering, eating, getting in or out of bed, using the toilet and control of urination and defecation. Compared with the non-exposed group, it was observed that all the famine-exposed groups had significantly increased the prevalence of high difficulty with using the toilet and difficulty with bathing or showering after adjustment for multiple covariates. The infant-exposed group had a significantly higher prevalence of difficulty with dressing (p<0.05). However, no consistent associations were found concerning high difficulty with eating, getting in or out of bed and controlling urination and defecation (p>0.05).

Table 3 presents the prevalence of poor physical function of the exposed groups, relative to the non-exposed group stratified by severity of famine across the entire mainland China. In less severely affected famine areas, compared with the non-exposed group, only the OR of poor physical function for infant-exposed group was statistically significant (OR 1.44, 95% CI 1.09 to 1.91, p=0.010) even after adjusting for gender, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and BMI (OR 1.41, 95% CI 1.06 to 1.87, p=0.018). No consistent association in the fetal period-exposed group was found in poor physical
function (p>0.05). However, in severely affected famine area, the OR of poor physical function for infant-exposed (OR 1.55, 95% CI 1.03 to 2.34, p=0.037) and infant groups (OR 1.45, 95% CI 1.03 to 2.03, p=0.033) were statistically significant, compared with the non-exposed group, after adjusting for multiple covariates.

Stratified analysis by gender and severity of famine is displayed in table 4 and figure 2. Among males, when compared with the non-exposed group, exposure at the fetal period (OR 2.43, 95% CI 1.20 to 4.94, p=0.014) significantly increased the prevalence of poor physical function after adjusting for number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and BMI in severely affected areas. No consistent associations between fetal and infant-exposed groups were found in less seriously affected famine areas (p>0.05). Among females, the adjusted prevalence of poor physical function for two exposed groups suggested no statistically significant differences (p>0.05).

Figure 2 outlines the absolute prevalence of poor physical function. In females, the absolute prevalence of poor physical function is higher than in males. It is observed in both less-severely and severely famine-affected regions. There is no difference at all for females by exposure severity, with subjects exposed at early infancy showing the highest prevalence of poor physical function, followed by those exposed in utero.

| Characteristics            | Non-exposed group | Fetal period-exposed group | Infant period-exposed group | P value |
|----------------------------|-------------------|----------------------------|-----------------------------|---------|
| Birthdate                  | 10/1/1962–9/30/1964 | 10/1/1959–9/30/1961 | 01/01/1956–12/31/1958       |         |
| n                          | 1302              | 743                        | 1550                        |         |
| Female, n (%)              | 708 (54.4)        | 412 (55.5)                 | 805 (51.9)                  | 0.216   |
| Born in severely affected area, n (%) | 531 (40.8) | 252 (33.9) | 580 (37.4) | 0.008   |
| Urban, n (%)               | 532 (40.9)        | 279 (37.6)                 | 573 (37.0)                  | 0.087   |
| Living with spouse, n (%)  | 1165 (89.5)       | 653 (87.9)                 | 1351 (87.2)                 | 0.157   |
| Smoking, n (%)             |                   |                            |                             |         |
| Never                      | 822 (63.1)        | 445 (59.9)                 | 894 (57.7)                  | 0.024   |
| Past                       | 119 (9.1)         | 84 (11.3)                  | 190 (12.3)                  |         |
| Current                    | 361 (27.7)        | 214 (28.8)                 | 466 (30.1)                  |         |
| Alcohol drinking, n (%)    | 387 (29.7)        | 213 (28.7)                 | 423 (27.3)                  | 0.354   |
| Chronic diseases, n (%)    |                   |                            |                             |         |
| 0                          | 379 (29.1)        | 209 (28.1)                 | 440 (28.4)                  | 0.694   |
| 1                          | 371 (28.5)        | 200 (26.9)                 | 422 (27.2)                  |         |
| 2                          | 240 (18.4)        | 155 (20.9)                 | 307 (19.8)                  |         |
| 3                          | 147 (11.3)        | 89 (12.0)                  | 177 (11.4)                  |         |
| 4                          | 97 (7.5)          | 49 (6.6)                   | 98 (6.3)                    |         |
| ≥5 (multiple)              | 68 (5.2)          | 41 (5.5)                   | 106 (6.8)                   |         |
| Education level, n (%)     |                   |                            |                             |         |
| Primary school or below    | 602 (46.2)        | 356 (47.9)                 | 929 (59.9)                  | <0.001  |
| Middle school              | 488 (37.5)        | 218 (29.3)                 | 379 (24.5)                  |         |
| High school                | 173 (13.3)        | 157 (21.1)                 | 224 (14.5)                  |         |
| College school or above    | 39 (4.61)         | 12 (1.6)                   | 18 (1.2)                    |         |
| General obesity (BMI), n (%)|                   |                            |                             |         |
| Underweight                | 43 (3.3)          | 22 (3.0)                   | 81 (5.2)                    | 0.001   |
| Normal weight              | 557 (42.8)        | 345 (46.4)                 | 721 (46.5)                  |         |
| Overweight                 | 473 (36.3)        | 261 (35.1)                 | 546 (35.2)                  |         |
| Obese                      | 229 (17.6)        | 115 (15.5)                 | 202 (13.0)                  |         |
| Prevalence of poor physical function, n (%) | 160 (12.3) | 115 (15.5) | 264 (17.0) | 0.002   |

Bold values means P<0.05, statistical significant level.

BMI, body mass index.
DISCUSSION

This is the first study to suggest a relation between early-life undernutrition and poor physical function using national data from China. It was observed that early-life exposure to the Great Chinese Famine significantly increased the prevalence of poor physical function in midlife. After stratifying by gender and famine, it was found that only fetal exposure to severe famine resulted in considerably increased prevalence of poor physical function in male adults. However, the absolute prevalence of poor physical function in females was higher compared with males. It was observed in both less-severely and severely famine-affected regions. These results suggested that early-life poor nutritional might be a critical factor for physical function development in their midlife.

The sensitivity analyses with a different definition of the outcome (two answers or more of ‘have some difficulties but still can do without help’, ‘needs help’ and ‘unable to do’) show the same result that the fetal period-exposed (OR 1.34, 95% CI 0.89 to 2.51, p=0.158) and infant period-exposed (OR 1.48, 95% CI 1.07 to 2.06, p=0.019) groups had higher prevalence of poor physical function after adjustment for gender, severity of famine, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and BMI compared with the non-exposed group. The definition of the outcome in this study is effective and appropriate.

Table 2  Comparison of prevalence of poor physical function between famine-exposed groups and non-exposed group*

| Difficulty with dressing | Prevalence | Crude model | Adjusted model† |
|-------------------------|------------|-------------|-----------------|
|                         | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group       | 34 (2.6)   | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group     | 29 (3.9)   | 1.52 (0.92 to 2.51) | 0.106 | 1.54 (0.93 to 2.56) | 0.095 |
| Infant-exposed group    | 71 (4.6)   | 1.79 (1.18 to 2.71) | **0.006** | 1.72 (1.13 to 2.62) | **0.012** |

| Difficulty with bathing or showering | Prevalence | Crude model | Adjusted model† |
|-------------------------------------|------------|-------------|-----------------|
|                                     | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group                   | 35 (2.7)   | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group                | 32 (4.3)   | 1.63 (1.00 to 2.65) | 0.050 | 1.66 (1.02 to 2.72) | **0.044** |
| Infant-exposed group               | 77 (5.0)   | 1.89 (1.26 to 2.84) | **0.002** | 1.75 (1.16 to 2.65) | **0.008** |

| Difficulty with getting in or out of bed | Prevalence | Crude model | Adjusted model† |
|-----------------------------------------|------------|-------------|-----------------|
|                                        | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group                      | 57 (4.4)   | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group                   | 37 (5.0)   | 1.15 (0.75 to 1.75) | 0.532 | 1.14 (0.74 to 1.75) | 0.553 |
| Infant-exposed group                  | 76 (4.9)   | 1.13 (0.79 to 1.60) | 0.508 | 1.06 (0.74 to 1.51) | 0.760 |

| Difficulty with using the toilet | Prevalence | Crude model | Adjusted model† |
|---------------------------------|------------|-------------|-----------------|
|                                 | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group               | 94 (7.2)   | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group             | 76 (10.2)  | 1.46 (1.07 to 2.01) | **0.018** | 1.46 (1.06 to 2.02) | **0.021** |
| Infant-exposed group            | 175 (11.3) | 1.64 (1.26 to 2.13) | **<0.001** | 1.61 (1.23 to 2.11) | **<0.001** |

| Difficulty with controlling urination and defecation | Prevalence | Crude model | Adjusted model† |
|------------------------------------------------------|------------|-------------|-----------------|
|                                                      | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group                                   | 32 (2.5)   | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group      | 16 (2.2)   | 0.87 (0.48 to 1.60) | 0.662 | 0.89 (0.48 to 1.63) | 0.694 |
| Infant-exposed group     | 49 (3.2)   | 1.30 (0.83 to 2.04) | 0.261 | 1.20 (0.76 to 1.90) | 0.435 |

| Poor physical function | Prevalence | Crude model | Adjusted model† |
|------------------------|------------|-------------|-----------------|
|                        | %          | OR (95% CI) | P value         | OR (95% CI) | P value |
| Non-exposed group      | 160 (12.3) | Ref.        | Ref.            | Ref.        |
| Fetal-exposed group    | 115 (15.5) | 1.31 (1.01 to 1.69) | **0.042** | 1.32 (1.01 to 1.71) | **0.041** |
| Infant-exposed group   | 264 (17.0)| 1.47 (1.19 to 1.81) | **<0.001** | 1.42 (1.14 to 1.76) | **0.002** |

*Calculations were made using binary logistic regression analysis. OR represents the ratio of the probability of poor physical function for those who were exposed to famine, compared with those who were not exposed to famine, at 95% CIs.
†Adjusted for gender, famine severity, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and body mass index.
Bold values means P≤0.05, statistical significant level.
The current study focused on physical function as the primary outcome and noticed that fetal exposure to the severe Great Chinese Famine significantly increased the prevalence of poor physical function in later life. There are no existing studies on direct assessment of the effect of the Great Chinese Famine exposure in early life on physical function in middle age. However, a recent study explained that a good childhood health status increases the probability of better adult physical function by 14% (95% CI 12% to 17%).29 This implies that early-life stages could be critical periods for physical function in midlife.12 The development of the musculoskeletal system might account for

### Table 3 Prevalence of poor physical function in birth groups in the Great Chinese Famine area*

|                      | Prevalence | Crude model | Adjusted model† |
|----------------------|------------|-------------|-----------------|
|                      | %          | OR (95% CI) | P value         | OR (95% CI)    | P value          |
| **Less severely affected famine area** |            |             |                 |               |                 |
| Non-exposed group    | 91 (11.8)  | Ref.        | Ref.            |               |                 |
| Fetal-exposed group  | 67 (13.6)  | 1.18 (0.84 to 1.66) | 0.335 | 1.20 (0.85 to 1.69) | 0.309 |
| Infant-exposed group | 157 (16.2) | 1.44 (1.09 to 1.91) | **0.010** | 1.41 (1.06 to 1.87) | **0.018** |
| **Severely affected famine area** |            |             |                 |               |                 |
| Non-exposed group    | 69 (13.0)  | Ref.        | Ref.            |               |                 |
| Fetal-exposed group  | 48 (19.0)  | 1.58 (1.05 to 2.36) | **0.027** | 1.55 (1.03 to 2.34) | **0.037** |
| Infant-exposed group | 107 (18.4) | 1.52 (1.09 to 2.10) | **0.013** | 1.45 (1.03 to 2.03) | **0.033** |

*Calculations were made using binary logistic regression analysis. OR represents the ratio of the probability of poor physical function for those who were exposed to famine, compared with those who were not exposed to famine, at 95% CIs.
†Adjusted for gender, number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and body mass index.
Bold values means P≤0.05, statistical significant level.

### Table 4 Prevalence of poor physical function in birth groups by gender and severity of the Great Chinese Famine area*

|                      | Prevalence | Crude model | Adjusted model† |
|----------------------|------------|-------------|-----------------|
|                      | n (%)      | OR (95% CI) | P value         | OR (95% CI)    | P value          |
| **Less severely affected famine area** |            |             |                 |               |                 |
| Male                 |            |             |                 |               |                 |
| Non-exposed group    | 26 (7.6)   | Ref.        | Ref.            |               |                 |
| Fetal period-exposed group | 19 (8.4) | 1.11 (0.60 to 2.06) | 0.732 | 1.12 (0.60 to 2.08) | 0.733 |
| Infant period-exposed group | 53 (11.3) | 1.55 (0.95 to 2.53) | 0.082 | 1.45 (0.88 to 2.38) | 0.144 |
| Female               |            |             |                 |               |                 |
| Non-exposed group    | 65 (15.2)  | Ref.        | Ref.            |               |                 |
| Fetal period-exposed group | 48 (18.2) | 1.24 (0.82 to 1.87) | 0.301 | 1.21 (0.80 to 1.84) | 0.366 |
| Infant period-exposed group | 104 (20.8) | 1.47 (1.05 to 2.07) | **0.027** | 1.37 (0.97 to 1.95) | 0.076 |
| **Severely affected famine area** |            |             |                 |               |                 |
| Male                 |            |             |                 |               |                 |
| Non-exposed group    | 20 (8.0)   | Ref.        | Ref.            |               |                 |
| Fetal period-exposed group | 17 (16.3) | 2.26 (1.13 to 4.51) | **0.021** | 2.43 (1.20 to 4.94) | **0.014** |
| Infant period-exposed group | 37 (13.5) | 1.80 (1.02 to 3.20) | **0.044** | 1.66 (0.92 to 3.00) | 0.096 |
| Female               |            |             |                 |               |                 |
| Non-exposed group    | 49 (17.5)  | Ref.        | Ref.            |               |                 |
| Fetal period-exposed group | 31 (20.9) | 1.25 (0.76 to 2.06) | 0.385 | 1.24 (0.74 to 2.06) | 0.416 |
| Infant period-exposed group | 70 (22.9) | 1.40 (0.93 to 2.10) | 0.107 | 1.34 (0.88 to 2.03) | 0.168 |

*Calculations were made using binary logistic regression analysis. OR represents the ratio of the probability of poor physical function for those who were exposed to famine, compared with those who were not exposed to famine, at 95% CIs.
†Adjusted for number of chronic diseases, place of residence, smoking, alcohol drinking, marital status, educational level and body mass index.
Bold values means P≤0.05, statistical significant level.
these associations since protein deficiency due to famine may affect growth to optimal size. Nutrient factors affect the development of an optimal muscle mass which partly determines late life muscle mass and function.6

In the present study, it was observed that fetal and infant exposure to the Great Chinese Famine significantly increased the prevalence of high difficulty with using toilet and bathing or showering, while infant exposure significantly increased the prevalence of difficulty with dressing. However, no consistent results were observed for difficulty with eating, getting in or out of bed and control of urination and defecation. The results revealed that the effects of famine exposure on disability in BADL in late life involved using the toilet, dressing, and bathing or showering.

The current study had combined further direct evidence in human beings for the fetal origin hypothesis.30 31 The findings in this investigation are consistent with the results of the Dutch study which reported that exposure to prenatal undernutrition among males was associated with poor physical function in their later life.9 The poor physical function in later life due to fetal stage exposure was more obvious in male than in female survivors. This seemed to be contradictory to the reported effect of severity of famine exposure on the sexes, in which the survival of male children was given preference over that of female children due to the tradition of ‘preferring boys to girls’.32 This was inconsistent with chronic lung diseases.25

One explanation for the sex-specific effects could be the differences in skeletal muscle metabolism: women have high metabolic flexibility in which substrate oxidation is readily adapted by nutrient availability.33 Another explanation is that when muscle mass is affected, the higher relative loss of muscle mass might be seen in men than in women because adult men have greater total lean mass and a lower fat mass than adult women.34 These gender gaps are consistent with the reports of the Dutch famine literature. Besides, the same study cohort described the sex-specific effects of prenatal undernutrition.35

There are some limitations in this study. One major limitation is selection bias which was caused by excess mortality in early life and ‘preferring boys to girls’ attitude common in China. The Great Chinese Famine might have spared the stronger and healthier subjects and gotten rid of the weaker ones. And the loss of girl participants in the exposed group may add to the explanation of the lack of associations between undernutrition and poor physical function in female in the current study. This selection bias may decrease the real effect of famine exposure on physical function,28 which did relatively reduce the trustworthiness of the study. Second, the present study lacks objective indicators of birth characteristics that reflect the severity of famine exposure. Such indicators include birth weight and head circumference which were used in other Chinese famine studies.14 36 Third, due to the fact that the Great Chinese Famine lasted for 3 years (1959–1961), the fetal period-exposed group was separated from the infant-exposed group. Fourth, there was a potential information bias which may result from the subjective nature of the outcome variable. Besides, the time lag within the data collection process, the investigation and analysis of data, and the arriving of results are another limitations that need to be recognised. Notwithstanding these limitations, this study used national data from CHARLS 2015 which had broad representation, and suggested that early-life exposure to the Great Chinese Famine significantly increased the prevalence of poor physical function in middle-age life.

CONCLUSION

These results indicate that exposure to the Great Chinese famine significantly increased the prevalence of poor physical function in later life, especially fetal exposure in males who had a distinctly higher prevalence of poor physical function in middle-age life.

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Patient consent for publication Obtained.

Ethics approval The Medical Ethics Committee of Peking University granted the present study exemption from review. All the participants were informed and consented to the protocol of the study. As the main approach of this study was cross-sectional analysis by collecting data from the CHARLS 2015, there were not many ethical concerns.

Provenance and peer review Not commissioned; externally peer reviewed.
Data sharing statement  The datasets analysed in the current study are available online (http://charls.pku.edu.cn/zh-CN/page/data/2015-charls-wave4).

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