Association of Body Mass Index with Risk of Household Catastrophic Health Expenditure in China: A Population-Based Cohort Study

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Abstract: Catastrophic health expenditure (CHE) is a major obstacle to achieving universal health coverage, and body mass index (BMI) is linked to both health and economy. We aimed to explore the association of BMI with the risk of CHE to provide advice for reducing CHE. We used national cohort data from the China Family Panel Studies, which comprised 33,598 individuals (14,607 households) from 25 provinces between 2010 to 2018. We used multivariate Cox proportional hazard models to estimate adjusted hazard ratios (aHRs) and 95% confidence interval (CI) for CHE in participants at underweight, overweight, and obesity, compared with those at normal weight. Restricted cubic splines were employed to model the association of continuous BMI scale with risk of CHE. We found that families with female household heads at underweight had a 42% higher risk of CHE (aHR = 1.42, 95%CI: 1.16–1.75), and those at overweight had a 26% increased risk of CHE (aHR = 1.26, 95%CI: 1.09–1.47), compared with those at normal weight. A weak U-shaped curve for the association of continuous BMI with risk of CHE in female-headed households (p for non-linear = 0.0008) was observed, which was not significant in male-headed households (p for non-linear = 0.8725). In female-headed households, underweight and overweight BMI are connected with a higher risk of CHE. Concerted efforts should be made to keep a normal BMI to prevent CHE.

Keywords: catastrophic health expenditure; body mass index; universal health coverage
sociodemographic confounders, physical multimorbidity was significantly associated with an increased number of outpatient visits (odds ratio = 1.29, 95% confident interval (CI): 1.27–1.31), inpatient days spent (odds ratio = 1.38, 95%CI: 1.35–1.41), and likelihood of CHE (odds ratio = 1.29, 95%CI: 1.26–1.32). As for economic factors, a series of studies revealed that families with lower socioeconomic status, such as lower family income, lower education level, and higher unemployment, were more likely to incur CHE [7–9]. Therefore, in order to eliminate CHE and move to UHC, one of the key points is finding ways to light the heavy health-economic burden.

Body mass index is an indicator for overweight and obesity, which is associated with lots of health problems. A system review and meta-analysis reported that the all-cause mortality increased approximately log-linearly with body mass index (BMI) for a hazard ratio (HR) of 1.26 to 2.44 per 5 kg/m$^2$ units higher BMI in Europe, North America, east Asia, Australia, and New Zealand [10]. The adverse impact of BMI on health may be presented after a long period and modified by growth. Blond et al. [11] found that compared with children in the lowest BMI level, those in several higher BMI trajectories were associated with higher mean waist circumference, lower high-density lipoprotein (HDL), and higher risk of diabetes in adulthood, while these associations can be reversed when adjusting for adult BMI. In addition, lower BMI is also connected with some health problems. Qu and colleagues reported that midlife underweight and late-life underweight conferred 1.39- and 1.64-fold excess risk for cognitive impairment and dementia, and this association was also found in other studies [12,13]. Besides the close relation with health, as a result of interactions between inheritance, environmental, socioeconomic, and life experience, BMI is also identified as a socioeconomic indicator [14]. Compared with individuals at normal BMI, the median increases of mean total annual healthcare costs were 12% for overweight and 36% for obesity individuals [15].

Overall, BMI plays a role in individual’s health condition and medical costs, which may cause a connection to CHE. However, current studies are mainly about the national financial burden of obesity or the effect of economic status on obesity, rarely about association of BMI with risk of household CHE [16,17]. This study aimed to explore the relationship between BMI and risk of CHE in a national longitudinal study based on the China Family Panel Studies, and further wanted to provide more ways to reduce the incidence of CHE.

2. Materials and Methods

2.1. Study Design and Participants

The China Family Panel Studies (CFPS), which was implemented by the Institute of Social Science Survey (ISSS) of Peking University, is a nationally-representative follow-up interview study covering 25 out of 31 provinces/municipalities in China, and representing nearly 94.5% of the total population [18]. The CFPS is intended to collect individual, family, and community-level data every two years. A baseline survey was conducted between April 2010 and February 2011, and follow-up data of 2012, 2014, 2016, and 2018 waves were available to be downloaded from the CFPS official website (http://www.isss.pku.edu.cn/cfps/ accessed on 1 July 2022). The study was approved by the Peking University Biomedical Ethics Review Committee (protocol code IRB00001052-14010). All participants signed informed consent before enrolled.

In this study, we used all waves data interested from adult questionnaire and family questionnaire of the CFPS. Baseline survey interviewed 35,720 adults (aged ≥ 16) and 14,607 households. Additionally, among the 14,607 households totally interviewed, 11,634, 11,238, 10,540, and 9698 were successfully tracked in 2012, 2014, 2016, and 2018. In our study, households who incurred CHE at baseline (n = 2146), were lost to follow-up without any information of CHE (n = 1245), and had missing data of baseline characteristics (n = 31) were excluded. Finally, a total of 11,185 households (heads) were included in this study (Figure 1).
were interviewed face-to-face by well-trained local interviewers with a series of structured questionnaires aided by computer-assisted personal interviewing technology. The contents of these questionnaires were thorough and comprehensive as the design team of the CFPS learned from the approaches and experiences of earlier successful research programs, such as the Panel Study of Income Dynamics, the National Longitudinal Surveys of Youth, the Health and Retirement Study, and so on [19]. The major contents of interest in our study included demographic characteristics (gender, age, marital status, education, medical insurance, and so on) and health-related characteristics (weight, height, self-reported health status, diagnosed chronic diseases in the past 6 months, the utilization of health services, smoking, drinking, and so on) in the adult questionnaire, and socioeconomic characteristics (residence, household income, household expenditures and so on) in the family questionnaire.

We conducted a population-based cohort study based on the CFPS. First, we calculated baseline BMI as weight (kg)/height² (m²). Then, based on underweight defined by WHO and Chinese criteria for overweight and obesity, we divided participants into four groups according to their BMI values: people at normal weight (18.5 kg/m² ≤ BMI < 24 kg/m², unexposed group); people at underweight (BMI < 18.5 kg/m², exposed group 1); people at overweight (24 kg/m² ≤ BMI < 28 kg/m², exposed group 2); and people at obesity (BMI ≥ 28 kg/m², exposed group 3) [20,21]. Finally, we followed them up until they had CHE or the interview ended.

2.3. Outcome

In this study, a household with CHE was defined as household OOP medical expenditure exceeded 40% of household’s capacity to pay (defined as total household expenditure minus household food expenditure) [22]. In the CFPS, a family member was defined by marriage, blood, or adoptive relationship and an on-going economic tie [19]. The household head was identified as the key decision maker when household faced important matters.
and decisions. The household OOP health payments were measured as the expenditure on medical care, including outpatient and inpatient care and other types of healthcare, of all family members excluding reimbursed spending in last year. The household food expenditure was estimated as the sum of monthly meal expenses multiplied by 12, and the total household expenditure in last year was calculated as the sum of monthly daily expenditures (food, daily used commodities and necessities, transportation, and so on) multiplied by 12 plus yearly special expenditures (electricity, medical care, clothing, and so on).

2.4. Covariates

Covariates in this study include: (i) demographic characteristics: gender (male, female), age group (16–39, 40–49, 50–49, ≥60), marital status (married/partnered, other), education (illiterate/semiliterate, primary school, middle school, high school and above), and insurance (without any insurance, urban employee basic medical insurance (UEBMI), urban resident basic medical insurance (URBMI), new rural cooperative medical scheme (NRCMS), other); (ii) health-related characteristics: self-reported health (good, medium, poor), chronic diseases (yes, no), outpatient services (yes, no), inpatient services (yes, no), current smoking (yes, no), and drinking (yes, no); (iii) socioeconomic characteristics: residence (urban, rural), family economic level (four classes), family size (1–2, 3–4, ≥5), and socioeconomic development level (four classes).

The outpatient services were obtained from question “Whether have outpatient care in the past two weeks”, and the inpatient services were measured by “How many times were you hospitalized due to illness last year”. The family economic level was classified by the quartiles of household annual income (lowest: <14,420 CNY; lower: 14,420–25,530 CNY; higher: 25,531–43,704 CNY; highest: ≥43,705 CNY). Socioeconomic development level in this study was identified by the quartiles of 2010 per capita gross regional product (GRP, lowest: <21,182 CNY; lower: 21,182–27,132 CNY; higher: 27,133–42,354 CNY; highest: ≥42,355 CNY), which were obtained from the 2010 China Statistical Yearbook [23].

2.5. Statistical Analysis

The baseline characteristics of the participants were described as mean ± standard deviation (SD) for continuous variables or frequencies and percentages for categorical variables. The Person $\chi^2$ test was used to compare the difference in distributions of characteristics according to BMI group.

We calculated the incidence rates (number of events divided by accumulated person-month) and used the univariate and multivariate Cox proportional hazard models to estimate the HRs and 95%CIs of CHE among participants at underweight, overweight, and obesity, compared with those at normal weight. Time to CHE event was defined as the period from the month of baseline survey to the month when household head first reported OOP medical costs exceeding 40% of non-food expenditure. Additionally, the censored time was calculated as the period from the baseline survey month to the last available wave survey month for those households who did not have CHE events until the investigation ended or who were recorded as without CHE in this survey wave but were lost to follow up in the next survey wave.

To examine the robustness of our findings, we performed three sensitivity analyses. First, we established three models adjusted for different covariates to estimate adjusted hazard ratios (aHRs) and their CIs. In model 1, we adjusted demographic characteristics, including gender (male, female), age group (16–39, 40–49, 50–49, ≥60), marital status (married/partnered, other), education (illiterate/semiliterate, primary school, middle school, high school and above), and insurance (none, UEBMI, URBMI, NRCMS, other) based on univariate model. In model 2, we further included health-related characteristics, including self-reported health (good, medium, poor), chronic diseases (yes, no), outpatient services (yes, no), inpatient services (yes, no), current smoking (yes, no), and drinking (yes, no). In model 3 (final fully-adjusted model), besides those factors included in model 2, we also adjusted for socioeconomic characteristics, including residence (urban, rural),
family economic level (lowest, lower, higher, highest), family size (1–2, 3–4, ≥5), and socioeconomic development level (lowest, lower, higher, highest). Second, we transferred the categorical variables age group and family economic level into continuous variables and conducted the same analysis in final model. Third, we used nightlight intensity (also divided into four classes according to the quartiles of 2010 province-level mean nightlight intensity [24]) to indicate socioeconomic development rather than GRP in final model.

Furthermore, the analysis was stratified by age group, insurance, chronic diseases, self-reported health, current smoking and drinking, outpatient services, inpatient services, residence, socioeconomic development level, and family economic level in the fully adjusted model with the stratified variables removed. We also used restricted cubic splines with knots at 5th, 35th, 65th, and 95th percentiles to flexibly model the association of the continuous scale of BMI with CHE incidence after adjusting covariates. Additionally, we tested the potential non-linear association by using a likelihood ratio test to compare the model with only a linear term against the model with linear and cubic spline terms. Because it is widely known that male and female have different body compositions, such as lean mass and fat mass, these analyses were stratified by gender.

All of the data were analyzed in R 4.2.1 (R Core Team, Vienna, Austria). Two-side p-value less than 0.05 was considered to be significant.

3. Results

3.1. Baseline Characteristics

Among all of 11,185 participants, the mean (SD) age was 48.3 (12.9) years, and 7864 (70.3%) were male, 3321 (29.7%) were female, 9836 (87.9%) were married or partnered, and only 1394 (12.5%) participants did not have any medical insurance (Table 1). At baseline, 6833 (61.1%), 831 (7.4%), 2825 (25.3%), and 696 (6.2%) participants were in the normal weight, underweight, overweight, and obesity group, respectively. Overall, except inpatient services, the distribution of baseline characteristics among participants in four BMI groups was significant different (all p-value < 0.05).

Table 1. Distribution of baseline characteristics among participants with different BMI group.

| Characteristics          | Total (n = 11,185, %) | Normal (n = 6833, %) | Underweight (n = 831, %) | Overweight (n = 2825, %) | Obesity (n = 696, %) | χ²  | p-Value |
|--------------------------|------------------------|-----------------------|--------------------------|--------------------------|----------------------|-----|---------|
| Gender                   |                        |                       |                          |                          |                      |     |         |
| Male                     | 7864 (70.3)            | 4859 (71.1)           | 508 (61.1)               | 2000 (70.8)              | 497 (71.4)           |     |         |
| Female                   | 3321 (29.7)            | 1974 (28.9)           | 323 (38.9)               | 825 (29.2)               | 199 (28.6)           |     |         |
| Age group                |                        |                       |                          |                          |                      |     |         |
| 16–39                    | 2843 (25.4)            | 1777 (26.0)           | 223 (26.8)               | 656 (23.2)               | 187 (26.9)           | 36.359 | <0.001  |
| 40–49                    | 3452 (30.9)            | 2134 (31.2)           | 159 (19.1)               | 937 (33.2)               | 222 (31.9)           |     |         |
| 50–59                    | 2689 (24.0)            | 1602 (23.4)           | 173 (20.8)               | 746 (26.4)               | 168 (24.1)           | 150.112 | <0.001  |
| ≥60                      | 2201 (19.7)            | 1320 (19.3)           | 276 (33.2)               | 486 (17.2)               | 119 (17.1)           |     |         |
| Marital status           |                        |                       |                          |                          |                      |     |         |
| Married/partnered        | 9836 (87.9)            | 6013 (88.0)           | 619 (74.5)               | 2571 (91.0)              | 633 (90.9)           | 172.815 | <0.001  |
| Other                    | 1349 (12.1)            | 820 (12.0)            | 212 (25.5)               | 254 (9.0)                | 63 (9.1)             |     |         |
| Education                |                        |                       |                          |                          |                      |     |         |
| Illiterate/semiliterate  | 2732 (24.4)            | 1749 (25.6)           | 316 (38.0)               | 546 (19.3)               | 121 (17.4)           | 229.064 | <0.001  |
| Primary school           | 2649 (23.7)            | 1698 (24.9)           | 204 (24.5)               | 604 (21.4)               | 143 (20.5)           |     |         |
| Middle school            | 3461 (30.9)            | 2069 (30.3)           | 207 (24.9)               | 951 (33.7)               | 234 (33.6)           |     |         |
| High school and above    | 2343 (20.9)            | 1317 (19.3)           | 104 (12.5)               | 724 (25.6)               | 198 (28.4)           | 241.867 | <0.001  |
| Insurance                |                        |                       |                          |                          |                      |     |         |
| None                     | 1394 (12.5)            | 833 (12.2)            | 121 (14.6)               | 346 (12.2)               | 94 (13.5)            |     |         |
| UEBMI                    | 1354 (12.1)            | 692 (10.1)            | 43 (5.2)                 | 471 (16.7)               | 148 (21.3)           |     |         |
| URBMI                    | 757 (6.8)              | 426 (6.2)             | 39 (4.7)                 | 237 (8.4)                | 55 (7.9)             |     |         |
| NRCMS                    | 6685 (59.8)            | 4318 (63.2)           | 532 (64.0)               | 1506 (53.3)              | 329 (47.3)           |     |         |
| Other                    | 995 (8.9)              | 564 (8.3)             | 96 (11.6)                | 265 (9.4)                | 70 (10.1)            |     |         |
Table 1. Cont.

| Characteristics          | Total   | BMI Group          | χ²  | p-Value |
|--------------------------|---------|--------------------|-----|---------|
|                          | (n = 11,185, %) | Normal (n = 6833, %) | Underweight (n = 831, %) | Overweight (n = 2825, %) | Obesity (n = 696, %) |
|                          |         |                   |     |         |
| Self-reported health     |         |                   |     |         |
| Good                     | 5279 (47.2) | 3279 (48.0)       | 296 (35.6) | 1395 (49.4) | 309 (44.4) |
| Medium                   | 4237 (37.9) | 2557 (37.4)       | 324 (39.0) | 1077 (38.1) | 279 (40.1) |
| Poor                     | 1669 (14.9) | 997 (14.6)        | 211 (25.4) | 353 (12.5)  | 108 (15.5)  |
| Outpatient services      |         |                   |     |         |
| No                       | 9113 (81.5) | 5569 (81.5)       | 636 (76.5) | 2342 (82.9) | 566 (81.3) |
| Yes                      | 2072 (18.5) | 1264 (18.5)       | 195 (23.5) | 483 (17.1)  | 130 (18.7)  |
| Inpatient services       |         |                   |     |         |
| No                       | 10,512 (94.0) | 6432 (94.1)      | 779 (93.7) | 2652 (93.9) | 649 (93.2) |
| Yes                      | 673 (6.0)   | 401 (5.9)         | 52 (6.3)   | 173 (6.1)   | 47 (6.8)   |
| Chronic diseases         |         |                   |     |         |
| No                       | 9550 (85.4) | 5940 (86.9)       | 696 (83.8) | 2355 (83.4) | 559 (80.3) |
| Yes                      | 1635 (14.6) | 893 (13.1)        | 135 (16.2) | 470 (16.6)  | 137 (19.7) |
| Smoking                  |         |                   |     |         |
| No                       | 6053 (54.1) | 3543 (51.9)       | 460 (55.4) | 1649 (58.4) | 401 (57.6) |
| Yes                      | 5132 (45.9) | 2920 (48.1)       | 371 (44.6) | 1176 (41.6) | 295 (42.4) |
| Drinking                 |         |                   |     |         |
| No                       | 8364 (74.8) | 5091 (74.5)       | 671 (80.7) | 2099 (74.3) | 503 (72.3) |
| Yes                      | 2821 (25.2) | 1742 (25.5)       | 160 (19.3) | 726 (25.7)  | 193 (27.7) |
| Residence                |         |                   |     |         |
| urban                    | 5084 (45.5) | 2828 (41.4)       | 292 (35.1) | 1548 (54.8) | 416 (59.8) |
| rural                    | 6101 (54.5) | 4005 (58.6)       | 539 (64.9) | 1277 (45.2) | 280 (40.2) |
| Family size              |         |                   |     |         |
| 1–2                      | 2165 (19.4) | 1245 (18.2)       | 191 (23.0) | 592 (21.0)  | 137 (19.7) |
| 3–4                      | 5431 (48.6) | 3249 (47.5)       | 344 (41.4) | 1457 (51.6) | 381 (54.7) |
| ≥5                       | 3589 (32.1) | 2339 (34.2)       | 296 (35.6) | 776 (27.5)  | 178 (25.6) |
| Family economic level    |         |                   |     |         |
| Lowest                   | 2941 (26.3) | 1863 (27.3)       | 325 (39.1) | 625 (22.1)  | 128 (18.4) |
| Lower                    | 2567 (23.0) | 1642 (24.0)       | 167 (20.1) | 616 (21.8)  | 142 (20.4) |
| Higher                   | 3164 (28.3) | 1910 (28.0)       | 222 (26.7) | 824 (29.2)  | 208 (29.9) |
| Highest                  | 2513 (22.5) | 1418 (20.8)       | 117 (14.1) | 760 (26.9)  | 218 (31.3) |
| Socioeconomic development level | | | | | |
| Lowest                   | 2358 (21.1) | 1615 (23.6)       | 268 (32.3) | 401 (14.2)  | 74 (10.6)  |
| Lower                    | 3234 (28.9) | 1930 (28.2)       | 211 (25.4) | 907 (32.1)  | 186 (26.7) |
| Higher                   | 2015 (18.0) | 1201 (17.6)       | 111 (13.4) | 528 (18.7)  | 175 (25.1) |
| Highest                  | 3578 (32.0) | 2087 (30.5)       | 241 (29.0) | 989 (35.0)  | 261 (37.5) |

Notes: BMI: body mass index; UEBMI: urban employee basic medical insurance; URBMI: urban resident basic medical insurance; NRCMS: new rural cooperative medical scheme.

3.2. Risk of CHE

During a median (interquartile range) of 95 (50–97) person-month of follow-up, a total 3275 households incurred CHE with an incidence rate of 3.85 per 1000 person-month. The incident number (incidence rate) of CHE was 1968 (3.77 per 1000 person-month) for participants at normal weight, 298 (5.08 per 1000 person-month) for those at underweight, 822 (3.82 per 1000 person-month) for those at overweight, and 187 (3.47 per 1000 person-month) for those at obesity.

In total, the significant association of BMI with a risk of CHE was only observed in participants at underweight, compared with those at normal weight (Table 2). In the unadjusted model, compared with individuals at normal weight, those at underweight had a 38% increased risk of CHE (crude hazard ratio = 1.38, 95%CI: 1.22–1.55). Additionally, in fully adjusted model (Model 3), participants at underweight had a 15% higher risk of CHE than those at normal weight (Table 2 and Supplementary Materials Table S1, aHR = 1.15, 95%CI: 1.02–1.31).
Table 2. Univariate and multivariate Cox proportional hazard analyses for association of BMI with risk of CHE stratified by gender.

| BMI Groups | Events/Incidence Rate * | Univariate Model | Model 1 | Model 2 | Model 3 |
|------------|-------------------------|------------------|---------|---------|---------|
|            | cHR (95%CI) p-Value     | aHR (95%CI) p-Value | aHR (95%CI) p-Value | aHR (95%CI) p-Value | aHR (95%CI) p-Value |
| Total      | 3275/3.85               | Ref. <0.001      | Ref. 0.008 | Ref. 0.036 | Ref. 0.023 |
| Normal     | 1968/3.77               | 1.18            | 1.06     | 1.06     | 1.06     |
| Underweight| 298/5.08                | (1.22–1.55)     | (1.04–1.34) | (1.01–1.29) | (1.02–1.31) |
| Overweight | 822/3.82                | 1.06            | 0.162    | 0.177    | 0.210    |
| Obesity    | 187/3.47                | 1.06            | 0.98     | 0.98     | 0.98     |
| Male       | 2288/3.79               | 0.293           | 0.840    | 0.750    | 0.747    |
| Normal     | 1449/3.87               | Ref.            | Ref.     | Ref.     | Ref.     |
| Underweight| 180/4.94                | 1.29 (1.11–1.51) | 1.07 (0.92–1.26) | 1.03 (0.88–1.21) | 0.706 (0.90–1.23) |
| Overweight | 543/3.53                | 1.98 (0.82–1.00) | 1.64 (0.88–1.08) | 0.98 (0.89–1.08) | 0.702 (0.88–1.07) |
| Obesity    | 116/2.99                | 0.89 (0.77–0.93) | 0.89 (0.73–1.07) | 0.88 (0.73–1.07) | 0.916 (0.72–1.05) |
| Female     | 987/4.00                | Ref.            | Ref.     | Ref.     | Ref.     |
| Normal     | 519/3.49                | Ref.            | Ref.     | Ref.     | Ref.     |
| Underweight| 118/5.32                | 1.57 (1.28–1.91) | 1.43 (1.17–1.75) | 1.42 (1.16–1.74) | 1.42 (1.16–1.75) |
| Overweight | 279/4.57                | 1.28 (1.14–1.52) | 1.28 (1.10–1.48) | 1.26 (1.09–1.46) | 1.26 (1.09–1.47) |
| Obesity    | 71/4.72                 | 0.17 (1.06–1.73) | 0.123 (0.96–1.58) | 0.103 (0.94–1.56) | 0.132 (0.95–1.57) |

Notes: BMI: body mass index; CHE: catastrophic health expenditure; cHR: crude hazard ratio; aHR: adjusted hazard ratio; CI: confident interval; Ref.: Reference. Model 1: Hazard ratio was adjusted for demographic characteristics, including gender, age group, education, marital status, and insurance. Model 2: Hazard ratio was additionally adjusted for health-related characteristics, including self-reported health, current smoking, drinking, chronic disease, and outpatient and inpatient services. Model 3: Hazard ratio was further adjusted for socioeconomic characteristics (residence, family economic level, family size, and socioeconomic development level), besides those factors included in model 2. * Per 1000 person-month.

In fully adjusted model (Model 3) for female participants, compared with those at normal weight, individuals at underweight (aHR = 1.42, 95%CI: 1.16–1.75) and overweight (aHR = 1.26, 95%CI: 1.09–1.47) had a 42% and 26% increased risk of CHE, respectively, while there were no significant connections between BMI and CHE observed in male (Table 2).

In Figure 2, we further used restricted cubic splines to flexibly model and visualize the relationship between continuous scale of BMI and risk of CHE by gender. Though a nonlinear relation was significant only in female individuals, the risk of CHE increased when BMI decreased below the medians for the total and for the female heads. Additionally, just above the median BMI, a slight increased risk of CHE with higher BMI was observed in female.

3.3. Sensitivity Analyses and Subgroup Analyses

In the sensitivity analyses, the associations of underweight and overweight with a risk of CHE was robust with different characteristics adjusted (demographic characteristics, health-related characteristics, socioeconomic characteristics); or categorical variables age group and family economic level changed into continuous variables; or socioeconomic development level indicated by nightlight intensity rather than GRP in female individuals (Supplementary Materials Table S2).

In subgroup analyses, the associations of underweight and overweight with a risk of CHE in female were significant in individuals aged 50–59 years, NRCMS, not currently smoking, having undergone outpatient services, and not having undergone inpatient services (Table 3, all p-value < 0.05).
Figure 2. Restricted cubic splines analyses for association between BMI and risk of CHE stratified by gender. Notes: BMI: body mass index; aHR: adjusted hazard ratio; CI: confident interval. aHR (95%CI) was adjusted for all covariates, including demographic characteristics (gender, age group, education, marital status, and insurance), health-related characteristics (self-reported health, current smoking, drinking, chronic disease, outpatient and inpatient services), and socioeconomic characteristics (residence, family economic level, family size, and socioeconomic development level).

Table 3. Subgroup analyses for association of underweight and overweight with risk of CHE in female participants.

| Subgroup | Normal Weight (Events/Objects) | Underweight | p-Value | Overweight | p-Value |
|----------|-------------------------------|-------------|---------|------------|---------|
| All      | 519/1974                      | 118/323     | 0.213   | 279/825    | 0.724   |
| Age group |                               |             |         |            |         |
| 16–39    | 109/662                       | 25/120      | 0.213   | 35/181     | 0.724   |
| 40–49    | 127/575                       | 24/70       | 0.042 * | 70/262     | 0.150   |
| 50–59    | 125/400                       | 24/47       | 0.025 * | 99/238     | 0.008 * |
| ≥60      | 158/337                       | 45/86       | 0.240   | 75/144     | 0.078   |
| Insurance |                               |             |         |            |         |
| None     | 74/291                        | 17/51       | 0.232   | 39/132     | 0.402   |
| UEBMI    | 48/254                        | 3/18        | 0.863   | 28/127     | 0.994   |
| URBMI    | 48/187                        | 4/20        | 0.845   | 32/88      | 0.283   |
| NRCMS    | 301/1029                      | 81/189      | 0.001 * | 151/407    | 0.033 * |
| Other    | 48/213                        | 13/45       | 0.117   | 29/71      | 0.052   |
| Self-reported health |    |             |         |            |         |
| Good     | 175/823                       | 34/122      | 0.443   | 104/327    | 0.005 * |
| Medium   | 199/791                       | 43/126      | 0.014 * | 108/335    | 0.095   |
| Poor     | 145/360                       | 41/75       | 0.022 * | 67/163     | 0.573   |
| Current smoking |                       |             |         |            |         |
| No       | 491/1876                      | 113/307     | <0.001 *| 269/810    | 0.005 * |
| Yes      | 28/98                         | 5/16        | 0.639   | 10/15      | 0.061   |
| Current drinking |                       |             |         |            |         |
| No       | 504/1910                      | 115/314     | 0.001 * | 262/791    | 0.007 * |
| Yes      | 15/64                         | 3/9         | 0.386   | 17/34      | 0.008 * |
| Chronic diseases |                       |             |         |            |         |
| No       | 416/1678                      | 89/266      | 0.004 * | 205/667    | 0.008 * |
| Yes      | 103/296                       | 29/57       | 0.036 * | 74/158     | 0.061   |
Table 3. Cont.

| Subgroup                        | Normal Weight (Events/Objects) | Underweight | Overweight |
|---------------------------------|-------------------------------|-------------|------------|
|                                 | Events/Objects                | aHR (95%CI) | p-Value    | Events/Objects | aHR (95%CI) | p-Value    |
| Outpatient services             |                               |             |            |               |             |            |
| No                              | 381/1511                      | 71/239      | 1.17 (0.90–1.51) | 0.239 | 202/641 | 1.19 (1.00–1.42) | 0.053 |
| Yes                             | 138/463                       | 47/84       | 2.17 (1.53–3.07) | <0.001 * | 77/184 | 1.36 (1.02–1.82) | 0.038 * |
| Inpatient services              |                               |             |            |               |             |            |
| No                              | 476/1830                      | 110/295     | 1.45 (1.18–1.80) | 0.001 * | 261/768 | 1.30 (1.12–1.52) | 0.001 * |
| Yes                             | 43/144                        | 8/28        | 0.98 (0.43–2.25) | 0.969 | 18/57 | 0.63 (0.32–1.25) | 0.189 |
| Residence                       |                               |             |            |               |             |            |
| Urban                           | 240/1048                      | 35/138      | 1.17 (0.81–1.68) | 0.404 | 162/508 | 1.24 (1.01–1.52) | 0.044 * |
| Rural                           | 279/926                       | 83/185      | 1.60 (1.25–2.06) | <0.001 * | 117/317 | 1.27 (1.02–1.58) | 0.036 * |
| Socioeconomic development level |                               |             |            |               |             |            |
| Lowest                          | 89/351                        | 33/75       | 1.86 (1.23–2.82) | 0.003 * | 33/93 | 1.32 (0.87–2.00) | 0.192 |
| Lower                           | 162/603                       | 26/89       | 0.99 (0.65–1.52) | 0.974 | 99/291 | 1.23 (0.95–1.60) | 0.121 |
| Higher                          | 91/320                        | 14/41       | 1.64 (0.92–2.94) | 0.096 | 58/140 | 1.47 (1.04–2.07) | 0.029 * |
| Highest                         | 177/700                       | 45/118      | 1.33 (0.94–1.9) | 0.108 | 89/301 | 1.08 (0.84–1.41) | 0.541 |

Notes: BMI: body mass index; CHE: catastrophic health expenditure; aHR: adjusted hazard ratio; CI: confident interval; UEBMI: urban employee basic medical insurance; URBMI: urban resident basic medical insurance; NRCMS: new rural cooperative medical scheme. * p < 0.05.

4. Discussions

As we know, there is a bi-directional relationship between health and poverty, and CHE is a good example for interpreting this phenomenon: poor health conditions cause higher medical costs, which may push a household into poverty if the economic burden is unaffordable, and further leads to worse health. In order to reduce CHE incidence and move further towards UHC, more focus should be paid to detecting and resolving the factors of CHE. In this study, we found that families with female household heads at underweight and overweight had a higher risk of CHE than those at normal weight. Integrated efforts should be made to maintain a normal BMI to not only prevent health problems, but also to avoid CHE incidents.

Our results discovered that female people at underweight had a 42% higher risk of CHE (aHR = 1.42, 95%CI: 1.16–1.75) and those at overweight had a 26% increased risk of CHE (aHR = 1.26, 95%CI: 1.09–1.47), compared with those at normal weight. From the definition of CHE, it is not difficult to find that there are two main causes to trigger CHE, high OOP payments for healthcare and large non-food household expenditures or low family income. The former appears to be somewhat connected with health effects and medical insurance, and the latter is somewhat relevant to economic factors. It is common knowledge that higher BMI is related to worse health [25–27]. A recently published article revealed that high BMI was the third risk factors contributing to the global cancer burden of age-standardized disability-adjusted life years rates (133.9 per 100,000 person-years) [25]. Another Mendelian randomization study also demonstrated that higher BMI was associated with increased risk of most cardiovascular conditions [26]. Meanwhile, there is also a close linkage between lower BMI and poor health [28]. Additionally, a great number of studies revealed a U-shaped curve between BMI and some health outcomes, like all-cause mortality and heart diseases [29,30]. That is to say, both lower BMI and higher BMI can have a negative impact on health, which may increase the OOP expense for healthcare.

Nevertheless, in this study, the stronger effect on CHE of underweight, rather than overweight, may be more explained by economic connections. A study, focusing on the contribution of socioeconomic factors to the variation of BMI in 59-low-income and middle-
income countries, found that women in the wealthiest group had a 2.3 kg/m² higher BMI than those in the poorest group [31]. Similarly, Razak et al. [32] revealed that the prevalence of BMI lower than 16 kg/m² was associated with poverty and low education levels, and this prevalence did not increase over time in most countries studied. Since lower BMI is relevant to poverty and, furthermore, linked to poverty-related diseases [33], the association of poverty and health, as well as lower socioeconomic level with risk of CHE is widely verified [7–9], and it cannot be difficult to understand that underweight BMI is related to higher incidence of CHE.

In the gender-stratified restricted cubic splines analyses, we found that a light lean U-shaped curve for the association of continuous BMI with risk of CHE in female individuals ($p$ for non-linear = 0.0008), which was not significant in male individuals ($p$ for nonlinear = 0.8725). Overall, compared with male-headed households, female-headed households were more likely to have a lower socioeconomic status, such as having a smaller family size, living in rural areas, not having enough food to eat, and so on, which made them more vulnerable to financial problems [34]. Several systematic-reviews and meta-analyses discovered that the pooled prevalence of food insecurity among female-headed households is 66.1% (95%CI: 54.61–77.60), with a 40–94% higher risk of developing food insecurity than male-headed households [35–37]. Insecure food situations, including insufficient food, unsafe food resources, uncertainty about the access to food, and the experience of hunger, is highly related with food patterns and unhealthy BMI [38,39]. The explanation for the U-shaped curve for continuous BMI with risk of CHE in female individuals, on the one hand, is that poor families often do not receive enough food and are more likely to eat contaminated food, which are factors linked to lower BMI and worse health. On the other hand, with financial strain, most households in poverty will often turn to low energy-cost but high energy-density food, like those foods of grains, added sugars, and fats, which is related to fast BMI growth [40,41].

In order to cut the apparent link between BMI and CHE, the main methods are health promotion and financial protection. First, the potential cost of healthcare should be reduced by minimizing or delaying the onset of diseases, especially chronic and severe disease that requires long-term care. Second, a complete medical security system should be established and provided for those who are sick, and special targeted protection measures should be implemented for those at high risk of a CHE event. For example, the government of China launched catastrophic medical insurance (critical illness insurance) in 2012 and it was implemented nationwide in 2016 after city-based testing, which aimed to reimburse patients whose OOP health expenditure exceeding a predetermined basic medical insurance level [42]. Third, for key populations, such as female-headed households and families with extreme poverty, interventions regarding the protection of basic living and primary health services should be expanded.

Our study is a useful design to evaluate the effect of BMI on household CHE. However, there are still several limitations in our study. First, data for calculating BMI and CHE, including weight, height, family medical expenditure, family total expenditure, and family food expenditure were mainly based on self-reported answers, which could be affected by recalling bias. Second, as some family members were not always living at home, their real expenditures in last year may be unclear to access from household heads. Third, though our study adjusted a range of potential confounders, there still are some extent unadjusted confounders. Fourth, as the CFPS is designed for the Chinese population and some observations were excluded in our study, the representation for the global population is limited, which needs further research.

5. Conclusions

Our study found that underweight and overweight BMI are associated with a higher risk of CHE incidence, compared with normal BMI, in female-headed households. Additionally, a weak U-shaped curve was observed between the continuous scale of BMI and CHE incidence among female-headed households. Concerted efforts should be made to encourage the public to maintain normal weight. Moreover, to receive UHC by 2030,
timely preventive interventions concerning CHE need to be implemented among the key populations.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu14194014/s1, Table S1: Fully-adjusted Cox proportional hazard model analysis for the association of BMI with risk of CHE, Table S2: Sensitivity analyses for association of BMI with risk of CHE in total participants and female participants.

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**Institutional Review Board Statement:** The CFPS was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Biomedical Ethics Review Committee of Peking University (protocol code IRB00001052-14010, approved on 10 January 2010).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the CFPS.

**Data Availability Statement:** All waves’ data from the CFPS can be downloaded from the CFPS official website (http://www.isss.pku.edu.cn/cfps/ accessed on 1 July 2022).

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**References**

1. Universal Health Coverage. Available online: https://www.who.int/health-topics/universal-health-coverage#tab=tab_1 (accessed on 6 August 2022).
2. Sustainable Development Goals—SDG Indicators Metadata Repository. Available online: https://unstats.un.org/sdgs/metadata/ (accessed on 28 August 2022).
3. Tracking Universal Health Coverage: 2021 Global Monitoring Report. Available online: https://cdn.who.int/media/docs/default-source/world-health-data-platform/events/tracking-universal-health-coverage-2021-global-monitoring-report_uhc-day.pdf?sfvrsn=fd5c65c6_5&download=true (accessed on 6 August 2022).
4. Doshmangir, L.; Hasanpoor, E.; Abou Jaoude, G.J.; Eshtiagh, B.; Haghparast-Bidgoli, H. Incidence of Catastrophic Health Expenditure and Its Determinants in Cancer Patients: A Systematic Review and Meta-analysis. *Appl. Health Econ. Health Policy* **2021**, *19*, 839–855. [CrossRef] [PubMed]
5. Zhao, Y.; Atun, R.; Oldenburg, B.; McPake, B.; Tang, S.; Mercer, S.W.; Cowling, T.E.; Sum, G.; Qin, V.M.; Lee, J.T. Physical multimorbidity, health service use, and catastrophic health expenditure by socioeconomic groups in China: An analysis of population-based panel data. *Lancet Global Health* **2020**, *8*, e840–e849. [CrossRef] [PubMed]
6. Mulaga, A.N.; Kamndaya, M.S.; Masangwi, S.J. Examining the incidence of catastrophic health expenditures and its determinants using multilevel logistic regression in Malawi. *PloS ONE* **2021**, *16*, e0248752. [CrossRef]
7. Njagi, P.; Arsenijevic, J.; Groot, W. Understanding variations in catastrophic health expenditure, its underlying determinants and impoverishment in Sub-Saharan African countries: A scoping review. *Syst. Rev.* **2018**, *7*, 136. [CrossRef]
8. Sun, C.Y.; Shi, J.F.; Fu, W.Q.; Zhang, X.; Liu, G.X.; Chen, W.Q.; He, J. Catastrophic Health Expenditure and Its Determinants Among Households With Breast Cancer Patients in China: A Multicentre, Cross-Sectional Survey. *Front. Public Health* **2021**, *9*, 704700. [CrossRef]
9. Fu, Y.; Chen, M.; Si, L. Multimorbidity and catastrophic health expenditure among patients with diabetes in China: A nationwide population-based study. *BMJ Global Health* **2022**, *7*, e007714. [CrossRef]
29. Sasazuki, S.; Inoue, M.; Tsuji, I.; Sugawara, Y.; Tamakoshi, A.; Matsuo, K.; Wakai, K.; Nagata, C.; Tanaka, K.; Mizoue, T.; et al. A prospective study of body mass index and cause-specific mortality: The Japanese Health and Nutrition Examination Survey Cohort Study. *Lancet* 2016, 388, 776–783. [CrossRef]

30. Aune, D.; Sen, A.; Mori, T.; Vu, T.N.; Subramanian, S.V.; Norat, T.; Romundstad, P.; Vatten, L.J.; Tonstad, S.; Romundstad, P. Body mass index and all-cause mortality: Individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet* 2016, 388, 776–783. [CrossRef]

31. Blond, K.; Aarestrup, J.; Vistisen, D.; Bjerregaard, L.G.; Jensen, G.B.; Petersen, J.; Nordestgaard, B.G.; Jørgensen, M.E.; Jensen, B.W.; Baker, J.L. Associations between body mass index trajectories in childhood and cardiovascular risk factors in adulthood. *Atherosclerosis* 2020, 314, 10–17. [CrossRef]

32. Razak, F.; Corsi, D.J.; Slutsky, A.S.; Kurpad, A.; Berkman, L.; Laupacis, A.; Subramanian, S.V. Prevalence of Body Mass Index (BMI). Available online: https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index?introPage=intro_3.html (accessed on 17 September 2022).

33. Chen, J.; Zha, S.; Hou, J.; Lu, K.; Qiu, Y.; Yang, R.; Li, L.; Yang, Y.; Xu, L. Dose-response relationship between body mass index and waist circumference for risk factors of certain related diseases in Chinese adults—Study on optimal cut-off points of body mass index and waist circumference in Chinese adults. *Biomed. Environ. Sci.* 2015, 115, 89–96. [CrossRef]

34. Body Mass Index (BMI). Available online: https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index?introPage=intro_3.html (accessed on 17 September 2022).

35. Boneya, D.J.; Ahmed, A.A.; Yalew, A.W. The effect of gender on food insecurity among HIV-infected people receiving antiretroviral therapy: A systematic review and meta-analysis. *PLoS ONE* 2019, 14, e0209903. [CrossRef] [PubMed]
37. Jung, N.M.; de Bairros, F.S.; Pattussi, M.P.; Pauli, S.; Neutzling, M.B. Gender differences in the prevalence of household food insecurity: A systematic review and meta-analysis. *Public Health Nutr.* 2017, 20, 902–916. [CrossRef] [PubMed]

38. Alaimo, K.; Briefel, R.R.; Frongillo, E.A., Jr.; Olson, C.M. Food insufficiency exists in the United States: Results from the third National Health and Nutrition Examination Survey (NHANES III). *Am. J. Public Health* 1998, 88, 419–426. [CrossRef]

39. Sarlio-Lähteenkorva, S.; Lahelma, E. Food insecurity is associated with past and present economic disadvantage and body mass index. *J. Nutr.* 2001, 131, 2880–2884. [CrossRef]

40. Drewnowski, A.; Specter, S.E. Poverty and obesity: The role of energy density and energy costs. *Am. J. Clin. Nutr.* 2004, 79, 6–16. [CrossRef]

41. Elfassy, T.; Glymour, M.M.; Kershaw, K.N.; Carnethon, M.; Llabre, M.M.; Lewis, C.E.; Schneiderman, N.; Al Hazzouri, A.Z. Association Between Sustained Poverty and Changes in Body Mass Index, 1990-2015: The Coronary Artery Risk Development in Young Adults Study. *Am. J. Epidemiol.* 2018, 187, 1240–1249. [CrossRef] [PubMed]

42. Li, H.; Jiang, L. Catastrophic medical insurance in China. *Lancet* 2017, 390, 1724–1725. [CrossRef]