



# Social contexts and cross-national differences in association between adverse childhood experiences and frailty index

Qing Wang<sup>a,b,\*</sup>

<sup>a</sup> Department of Biostatistics, School of Public Health, Cheeloo College of Medicine, Shandong University, Jinan, Shandong, China

<sup>b</sup> National Institute of Health Data Science of China, Shandong University, Jinan, Shandong, China

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## ABSTRACT

Cross-national differences in the health implication of adverse childhood experiences have been documented. The differences may be shaped by macro- and micro-social context. However, previous studies failed to consider the role of micro-level social contexts, where adverse childhood experiences happen, in affecting the cross-national differences. The study aims to estimate the association between adverse childhood experiences and Frailty Index across countries and micro-social contexts, and then reveal how cross-national difference in the association between adverse childhood experiences and Frailty Index were shaped by social contexts. Adulthood information were collected from three waves of the Survey of Health, Ageing and Retirement in Europe in 2010, 2013, and 2015, and the China Health and Retirement Longitudinal Study data from in 2013, 2015 and 2018, respectively. Frailty index was measured based on 35 health measurements. Eleven adversities, including intrafamilial aggression and neglect, family dynamics, and socioeconomic status etc, were extracted from the life history survey of the two datasets, conducted in 2017 and 2014, respectively. Weighted Linear regression models and the smoothing-differencing method were applied. Experiencing three or more adversities was associated with increase in frailty index level in Europe and China. The effect size ranged from 0.015 (95%CI: 0.011–0.019) in China to 0.030 (95%CI: 0.025–0.034) in Germanic countries. Poor parent-child relationship, parental absence/death were ACEs in terms of frail in European countries but not in China. In a context where adversities were moderately likely to happen, the association between experiencing adverse childhood experiences and Frailty Index were greatest. Cross-national differences of adverse childhood experiences effects were most derived from this social context. These findings highlight the importance of micro-social contexts while mitigating early life stress to promote life-course health. Individuals who were moderately likely to experience adversity should be paid special attention in terms of health implication of adverse childhood experiences.

## 1. Introduction

The Sustainable Development Goals significantly focus on early childhood development to secure lifelong health (United Nations, 2015). In the context of coronavirus disease 2019 (COVID-19), there are concerns that responses to the pandemic might have decreased investment in childhood development and increased exposure to adverse childhood experiences (ACEs) (Bryant et al., 2020; Kaukinen, 2020). ACEs refer to various potentially stressful experiences that can affect children while growing up (Bellis et al., 2019). An increasing number of empirical studies have identified associations between ACEs and various health outcomes throughout the life course across countries (Bellis et al., 2019). Considering the profound effects on life-long health consequences,

precise interventions are much needed to determine the most vulnerable population to ACEs in the context of resources limitations resulting from COVID-19.

Notably, the association between adverse childhood experiences and later health were found to vary by countries. More than a biological insult, an ACE is a potential indicator of the socialization (Neppi et al., 2016; Danese & McEwen, 2022). Cross-national differences may a reflect of divergence in macro-social contexts (Linden et al., 2020; Verropoulou & Serafetinidou, 2019). Furthermore, micro-social contexts could alter a person's social companionship, social resources, stress reactivity and coping capacities, and then affect the cross-national differences of ACEs effects (Trinidad, 2021). However, previous studies have left open the question of the role of micro-social context. Thus, this

\* Department of Biostatistics, School of Public Health, Cheeloo College of Medicine, Shandong University, Jinan, Shandong, China.

E-mail addresses: [wangqing1984@126.com](mailto:wangqing1984@126.com), [201999000066@sdu.edu.cn](mailto:201999000066@sdu.edu.cn).

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study aims to reveal how social context shaped ACEs negative effects and then the cross-national differences in the ACEs effects by comparing the heterogeneous effects of ACEs in China and European societies. Our study may have important policy implications for early childhood development and their life-course health by designing differential and precise intervention measurements based on social contexts in the contexts of COVID-19 (Bryant et al., 2020; Kaukinen, 2020).

### 1.1. Cross-national differences in ACEs effects

ACEs is considered to affect life-course health via disparate biological mechanisms, including, but not limited to, the hypothalamic-pituitary-adrenal axis, DNA methylation in key genes, telomere length shortening, increased cortisol levels, and chronic inflammation (Furman et al., 2019; Lang et al., 2020). A rising number of empirical studies have shown a positive association between ACEs and life-course health in North America, European countries, Africa, and Asia (Bellis et al., 2019; El Mhamdi et al., 2017; Furman et al., 2019; Goodman et al., 2022; Herrmann et al., 2018; Iob et al., 2020; Jin & Liu, 2018; Koyama et al., 2022; Lang et al., 2020; Mlouki et al., 2023; Monnat & Chandler, 2015; Poole et al., 2017; Shonkoff & Garner, 2012; Tan & Mao, 2023; Tani et al., 2021). Health consequences cover both physical health (including general health, morbidity and mortality of cancer, cardiovascular disease, and respiratory diseases) and mental health (including depression and cognitive impairment) at a later age (Dannefer, 2020; Sieber et al., 2020; Verropoulou & Serafetinidou, 2019). The most widely used ACE scale, that is, the Kaiser Permanente ACE Study, includes 10 items generated based on a sample of primarily white and educated individuals (Bellis et al., 2019). Recently, an additional set of expanded ACEs (e.g., socioeconomic deprivation, serious childhood illness, or injury) has been found to be associated with life-course health outcomes (Baldwin et al., 2021; Bethell et al., 2019; Godoy et al., 2021; Li et al., 2021; Rod et al., 2020; Wang, 2022; Warrier et al., 2021).

Nevertheless, cross-national differences in ACEs effects were also documented. Older Chinese people were found to be insensitive to family dynamics (e.g., household substance abuse, household criminality) (Wang, 2022), while family dynamics are typical ACE types in Western society (Hughes et al., 2017; Lang et al., 2020). In addition, the effect size of certain ACE varied greatly among countries. Take effects of childhood socioeconomic circumstances as an example. In European countries, the indicator had an independent, far-reaching impact on physical health at a later age (Sieber et al., 2020; Verropoulou & Serafetinidou, 2019), while childhood socioeconomic circumstances predicted a very small and negative effect on physical health in older age for the residents of China, and even lower mortality among Japanese aged 75 years or older (Li et al., 2021; Wang et al., 2019; Dinsa et al., 2012; Tani et al., 2016).

### 1.2. Social context and ACEs effects

Cross-national differences in ACEs effects may reflect divergence in macro-social context; meanwhile, micro-social contexts may shape the ACEs effects and their cross-national difference. Cross-national differences in ACEs effects may be to some extent explained by various social resource redistribution, indicated by welfare regime (Verropoulou & Serafetinidou, 2019). Welfare regime essentially means the choice and formulation of a corresponding economic system, and a value system in a sense embodies the nature of a social economic and cultural system (Sieber et al., 2020). Welfare regime could reduce the prevalence of adversities and alleviate the ACEs effects by providing social resource and support (Sieber et al., 2019). Several empirical studies have suggested that more supportive welfare regimes were more likely to alleviate adversities the ACEs effects through the provision of higher benefits (Linden et al., 2020; Verropoulou & Serafetinidou, 2019).

Macro-social contexts can be grouped into five welfare regimes to reflect similarities in our study areas (Sieber et al., 2020). The Nordic

welfare model, implemented in Norway, Sweden, Finland, Denmark and the Netherlands, supports the universal and equitable distribution of social benefits. The Bismarckian model includes Austria, France, Germany, Belgium, Luxembourg and Switzerland, which is minimally redistributive. The model is known for its "status differentiating" welfare programs where benefits are related to earnings and administered by employers. The Southern model, implemented in Italy, Spain, Greece and Portugal, is based on the principle that socially unprotected members should be supported by family; coverage of services is insufficient. The Eastern European model includes Poland, Bulgaria, Ukraine, the Czech Republic, Hungary and Slovakia, which were shortage of fund, but are strong redistribution to prevent poverty and involvement from family members. For China, when the elderly we study were children, they grew up in a system inspired by an egalitarian ethos, with a low-level protection. Due to economic transition, they have gone through a limited and fragile welfare regime. However, the regime is currently characterized by "Commonly benefitted", and equality is the national core value during this transitional period (Zheng, 2002). Considering these characteristics, we hypothesize that the Scandinavian welfare regime will be the most able to compensate accumulation of disadvantage, whereas the Bismarckian welfare regime will be less efficient. For other regimes, less clear results are expected.

Micro-social contexts are also acknowledged as having a role in expanding or reducing the ACEs effects, and consequently cross-national differences in the ACEs effects (Trinidad, 2021). The cross-national differences may not equally distribute across micro-social contexts. Micro-contexts refer to the context where ACEs happen and the context of the children who are accessible in one's social environment in life cycle (Datar et al., 2023; Trinidad, 2021). The social mobility model has revealed that changes of the micro-social context over the life course will lead to variations in their health (Dronavalli et al., 2023; Wang & Kang, 2019). However, previous literature has left open the question of how contexts where ACEs happen matter for ACEs' negative effects. A more advantage micro-social context where ACEs happen usually suggest children can be less frequently affected by ACEs, and rely on additional socioeconomic resources and social support compensating adversities (McEwen & McEwen, 2017; Wang et al., 2019). However, some studies suggest that those from disadvantaged backgrounds may learn from others and be able to cope with adversities better (Hostinar & Miller, 2019; Trinidad, 2021). This raises imperatives for contextualizing ACEs while estimating the ACEs effects. Furthermore, divergence in the prevalence of ACEs in China and Europe may suggest different micro-social context where ACEs happen (Hughes et al., 2017). Therefore, the present study investigated micro-contexts where ACEs happen more strongly predicted negative health in later age in Europe and China and then contributed to cross-national differences.

### 1.3. Research purposes and hypotheses

Using a large sample, this study aimed to compare ACEs effects among China and European societies having differential macro-social contexts based on the association of 11 ACEs with the frailty index (FI). The FI is a widely used indicator of overall age-related health risks, which may help to understand the comprehensive effects of ACEs in terms of aging health (Fan et al., 2020). Subsequently, the study revealed how micro-social context shaped ACEs negative effects and then the cross-national differences in the ACEs effects by comparing the heterogeneous effects of ACEs in China and European countries across micro-social contexts. Research hypotheses include the following: (1) the ACEs effects differ across countries, and more supportive welfare regimes are more likely to alleviate adversities the ACEs effects. The Scandinavian welfare regime may be the most able to compensate accumulation of disadvantage; (2) the ACEs effects vary by micro-social contexts, and social contexts where ACEs happen matter for cross-national differences in ACEs effects. Our study may have important policy implications for early childhood development and their

life-course health by designing differential and precise intervention measurements based on social contexts (Bryant et al., 2020; Kaukinen, 2020).

## 2. Materials and methods

### 2.1. Data source

This study used cross-national data from the Survey of Health, Ageing and Retirement in Europe (SHARE) and China Health and Retirement Longitudinal Study (CHARLS), which collected information on health and life history of middle aged and elderly people in 27 European countries (aged over 50) ([share-eric.eu](http://share-eric.eu)) and China (aged over 45) ([pku.edu.cn](http://pku.edu.cn)) (Calvó-Perxas et al., 2021; Zhao et al., 2014). To obtain the most observations with complete measure of frailty, adulthood information was obtained from three waves of SHARE data that were collected in 2010, 2013, and 2015, and CHARLS data in 2013, 2015 and 2018, respectively. The SHARE and CHARLS life history survey, conducted in 2017 and 2014, collected the life history information of all live respondents in the previous waves. Based on individual ID, the life history information of all live respondents was merged with adulthood information.

Participants were eligible for the analyses if they participated in the retrospective life-course data and had at least one complete measure of frailty in SHARE or CHARLS data, which included 66964 participants. A more detailed description of the study design and sampling procedure can be found in the cohort profile of SHARE or CHARLS. After exclusion of participants under age of 50, with missing information on any ACE components, demographic and socioeconomic status, there were 43928 participants with complete data. Fig. 1 presents the flow chart, and Fig. S1 shows the data filtering process distinguished by SHARE and CHARLS. Furthermore, multiple imputation was applied for the sample using 10 imputed data sets with the multiple imputation method by chained equations (Supplementary Text 1). Finally, the sample size consisted of 66964 participants, covering 15382, 11313, 15103, 15414 and 9752 participants in Nordic countries, Germanic countries, Latin European countries, Eastern European countries and China, respectively.

### 2.2. Measures

#### 2.2.1. Adverse childhood experiences

Eleven individual ACEs, including intrafamilial aggression, family dynamics, loss or threat of loss within the family, socioeconomic status, and neighborhood quality, were assessed (Table S1). Furthermore, we conceptualized 11 ACEs as cumulative scores based on the total number of ACEs experienced. Responses to each individual ACE were dichotomized as “Yes” or “No,” and summed to generate a cumulative ACE score for each participant, ranging from 0 to 11. Following Bellis et al. (2019), Wang et al. (2022) and Hughes et al. (2017), we further categorized participants into 2 groups for comparison based on the mean cumulative ACE scores ( $<3$ , or  $\geq 3$ ).

#### 2.2.2. Frailty index

We selected 35 attributes to calculate the FI. Each attribute was categorized or mapped into the 0.00–1.00 interval, with 0.00 indicating the absence of a deficit and 1.00 indicating the maximal expression of the deficit (Table S2). The FI was calculated for each respondent as the summed scores based on fulfillment of the attributes present in a person divided by 35 (the total number of measured attributes). Thus, the FI is a continuous variable that ranges from 0.00 to 1.00, with a higher value indicating a worse frailty status. Following previous literature, we did not assign weights to the individual indicators (Fan et al., 2020).

### 2.3. Statistical analysis

Weighted linear regression model was constructed to examine the association with FI levels at a later age. ACE indicators included the number of ACEs and individual ACEs. The interaction terms of ACE indicators and country dummy variables were included to compare the association between ACEs and FI among China and European societies. Demographic characteristics and adult socioeconomic status were controlled. Socioeconomic status in adults was measured by educational attainment (illiterate, elementary school, junior high school, and high school or above) and job status (retired, unemployed, or employed). Demographic variables included sex, marital status (unmarried, single, divorced, or separated in the study period), age and age squared. The

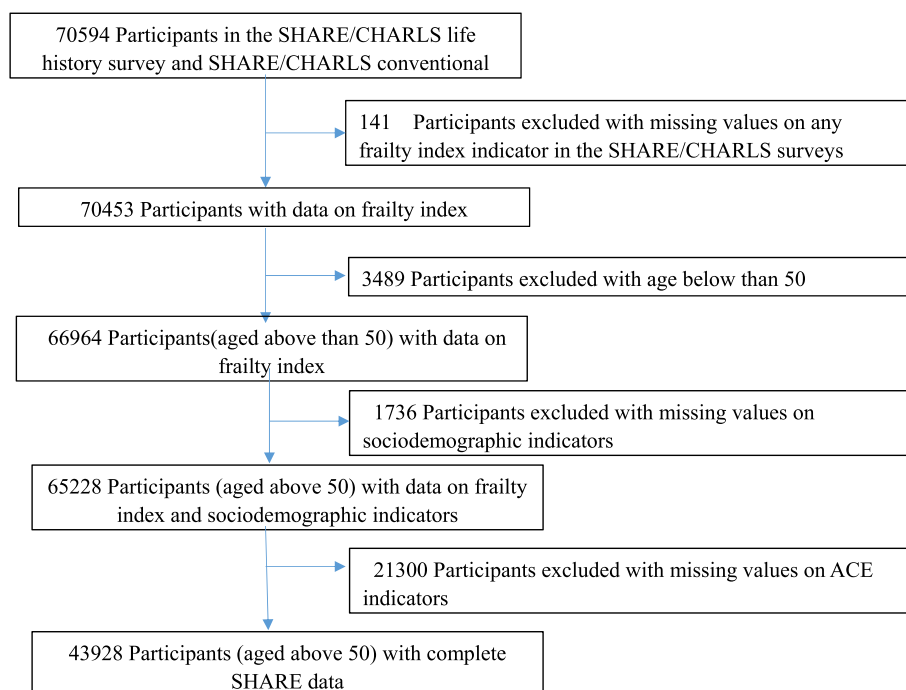


Fig. 1. Flow chart.

inverse probability of treatment weighting based on propensity score weighting was calculated to balance the distribution of demographic characteristics among individuals with cumulative ACE score  $<3$ , or  $\geq 3$ . As a robust check, propensity score matching was conducted that tries to limit the sample to those who are matched in terms of similar probabilities of adversities exposure. Afterward, regression analysis were applied among the matched sample. Details on the calculation of propensity score matching are presented in [Supplementary Text 2](#). In addition, weighted Tobit model was applied since the FI is a score limited between zero and one.

Furthermore, the smoothing-differencing method was applied to reveal whether the association between ACEs and FI changed with different micro-contexts in China and European societies (Xie et al., 2012). The method was conducted with these three steps: (i) matching individuals with 3 or more ACEs with those without based on the propensity score; (ii) fitting nonparametric regressions of FI on the propensity scores for individuals with cumulative ACE score  $<3$ , or  $\geq 3$ , separately; and (iii) take the difference in the nonparametric regression lines between the two groups at different levels of propensity (Xie et al., 2012). Five separate graphs were created for China and European societies with the x-axis representing the continuous propensity score and the y-axis representing the observed coefficient differences between individuals with ACEs and those without on FI.

In order to ascertain if the patterns observed from the graphs were significant, the stratification-multilevel method was used. First, five balanced propensity score strata was created based on the shape of the nonparametric function obtained from the smoothing-differencing method and the ease in interpretation. The samples were divided from the ones least likely (stratum 1) to most likely have an ACE (stratum 5). Cutoff points were determined for each stratum where there are no significant differences in the average values of covariates between groups with cumulative ACE score  $<3$ , or  $\geq 3$ . Then the stratum-specific conditional average treatment effects were estimated. For every propensity score stratum, linear regression models were applied. Two-tailed  $P < .05$  indicated statistical significance. Odds ratios (ORs) and 95% CIs are reported. STATA version 15 (StataCorp LLC) was used for all calculations.

**Table 1**  
Participant descriptive statistics.

(%)	Nordic countries (N = 15382)	Germanic countries (N = 11313)	Latin European countries (N = 15103)	Eastern European countries (N = 15414)	China (N = 9752)
FI, mean (95%CI)	0.156 (0.154–0.158)	0.131 (0.129–0.133)	0.127 (0.125–0.129)	0.155 (0.153–0.157)	0.165 (0.164–0.167)
Number of ACEs $>3$	26.5	28.8	32.5	38.9	61.9
Parental physical maltreatment	27.8	17.6	25.3	22.4	26.4
Emotional neglect	22.9	28.3	35.3	33.4	61.0
Low parental education	16.9	9.6	8.1	43.9	55.0
Parental unemployment	13.7	16.2	14.0	15.0	10.5
Family financial problems	32.5	26.6	22.0	27.5	40.2
Childhood hunger	2.9	3.6	2.7	3.5	24.1
Self-reported poor childhood health	9.9	16.4	11.8	9.3	12.9
Serious childhood illness or injury	12.4	14.8	15.9	9.7	8.1
Parental death	11.9	19.2	16.0	21.6	18.7
Parental absence	4.4	5.6	4.7	4.6	7.7
Poor parent-child relationship	12.7	19.2	24.3	17.6	18.9
Poor peer relationship	14.1	17.1	25.8	23.1	33.7
Age, mean(95%CI),y	66.8 (66.7–67.0)	67.8 (67.6–67.9)	66.8 (66.7–67.0)	68.0 (67.9–68.2)	61.2 (61.0–61.2)
Female	58.4	57.1	55.3	56.1	51.8
Married	72.6	66.5	69.4	75.0	83.8
Education					
Illiterate	2.9	0.3	0.8	11.7	30.1
Primary school	15.3	9.3	10.5	32.6	18.7
Junior high school	19.7	15.6	14.0	17.6	21.7
Senior high school or above	62.1	74.8	74.6	38.1	29.5
Retired or unemployed	72.2	64.2	36.4	60.7	54.9

ACE: Adverse childhood experience; FI: Frailty index.

### 3. Results

#### 3.1. Descriptive statistics

[Table 1](#) presents the descriptive statistics. The mean [95% CI] age ranged from 61.2 [61.0, 61.2] years in China to 68.0 [67.9, 68.2] in Eastern European countries, with 51.8–58.4% women. During the study period, the mean FI level was highest in China [0.16 (95%CI: 0.156, 0.160)], followed by Eastern European countries [0.155 (95%CI: 0.153, 0.157)] and Nordic countries [0.156 (95%CI: 0.154, 0.158)]. The FI was lowest [0.127 (95%CI: 0.125, 0.129)] in Latin countries. Educational attainment, and job status varied significantly among these countries. Participants in China reported the lowest education level, while those in Germanic countries had the highest educational attainment. Meanwhile, the cumulative ACE scores were much higher in China (prevalence of Number of ACE $\geq 3$ : Europe vs China: approximate 30% VS 61.9%). The prevalence of individual ACE ranged from 3.1% (child hunger) to 35.4% (emotional neglect) in European countries. The most prevalence ACE was also emotional neglect (35%) in China, but the least common individual ACE was poor parent-child relationship (6.9%).

#### 3.2. Association between accumulative scores of ACEs and FI by Europe and China

The effect size of experiencing three or more ACEs on FI varied by countries, ranging from 0.015 (95%CI: 0.011–0.019) in China to 0.030 (95%CI: 0.025–0.034) in Germanic countries. The mean changes in FI associated with ACEs would be 1.5–3 times of standard deviation for FI. For those under age of 65, the mean FI was 0.117 (95%CI: 0.0116–0.0118), while the FI grew to 0.147 (95%CI: 0.0145–0.0148) among participants aged between 65 and 75. The effect size of experiencing three or more ACEs were similar to the gap in the FI between the two age groups. Judging from the interaction term of the country dummy variables and the accumulative ACEs score, three or more ACEs led to an additional increase in FI level in Europe in comparison with China ([Table 2](#)). Regression after propensity score matching also achieved similar results ([Supplementary Text 2](#)). In addition, results from regression using complete cases and weighted Tobit model were

**Table 2**  
Association between accumulative ACE scores and FI using imputed data.

Coef.(95%CI)	Nordic countries	Germanic countries	Latin European countries	Eastern European countries	China	Total sample with interaction terms
	(N = 15382)	(N = 11313)	(N = 15103)	(N = 15414)	(N = 9752)	
Number of ACE >2	0.021 (0.015–0.026)	0.030 (0.024–0.035)	0.022(0.019–0.026)	0.023(0.018–0.028)	0.015 (0.011–0.019)	0.015(0.011–0.019)
Number of ACE >2& Nordic countries						0.009(0.004–0.015)
Number of ACE >2& Germanic countries						0.014(0.009–0.020)
Number of ACE >2& Latin European countries						0.008(0.002–0.013)
Number of ACE >2& Eastern European countries						0.013(0.007–0.018)

ACE: Adverse childhood experience; FI: Frailty index.

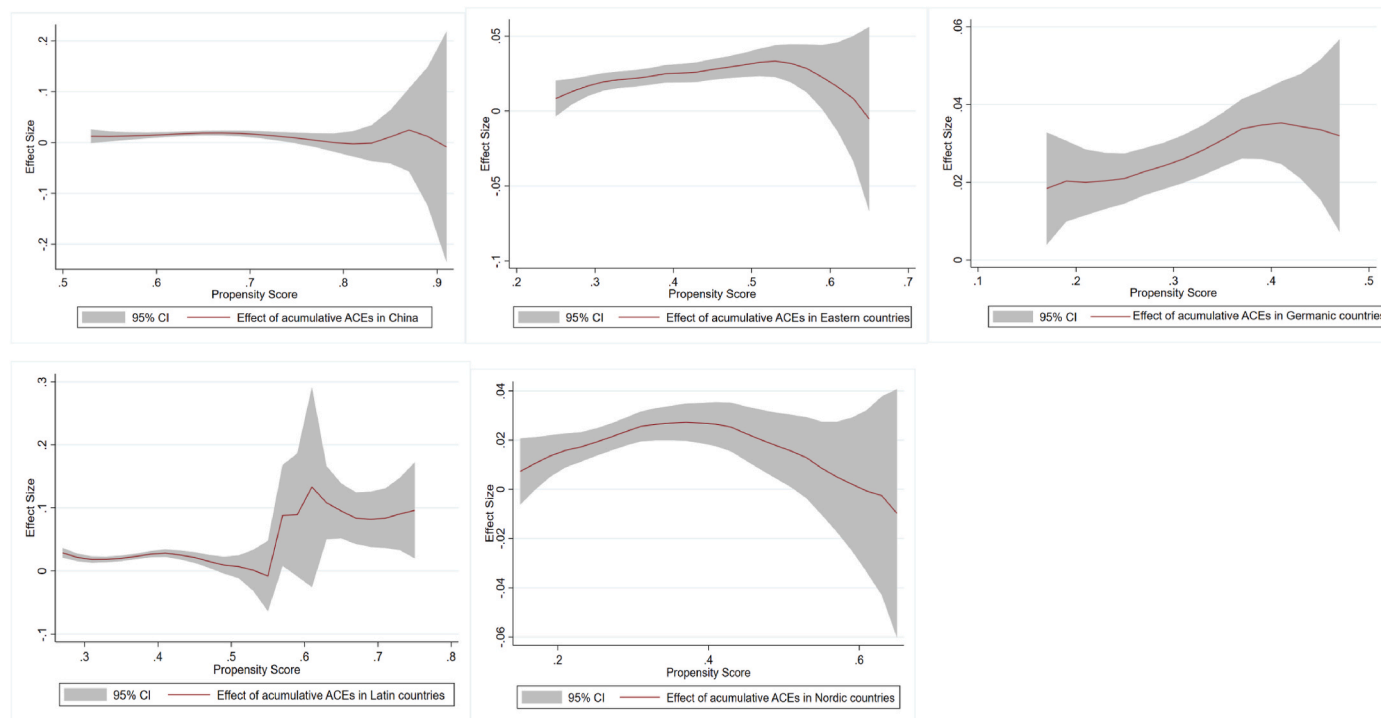
consistent (Tables S3 and S4).

Although adversities in childhood are suggested to, on average, affect FI at an older age, these effects may vary depending on the propensity for ACEs. Fig. 2 presents smoothing-differencing heterogeneity results. Chinese participants were more likely to experience ACEs than their Europe counterparts. The propensity for ACEs ranged from 0.5 to 0.9 in China, while the score was between 0.2 and 0.7 in Europe. The results were in agreement with descriptive statistics of ACE distribution in these countries. Fig. 2 show an inverted U shape in Europe and China, which indicates those who were moderately likely to experience adversity were most affected by ACE. Table 3 presents heterogeneous effect estimates by propensity score strata. The results were in line with the results in Fig. 2. For individuals least likely to experience three or more adversities, those who experienced it were associated with an 0.012(95%CI: 0.004–0.02), 0.021 (95%CI: 0.012–0.031), 0.016(95%CI: 0.011–0.021), 0.011(95%CI: 0.005–0.017), and 0.014 (95%CI: 0.006–0.021) increase in FI in Nordic countries, Germanic countries, Latin European countries, Eastern European countries, and China,

respectively. The effect size increased to 0.031(95%CI: 0.019–0.044), 0.029(95%CI: 0.019–0.039), 0.025(95%CI: 0.016–0.034), 0.029(95%CI: 0.017–0.041), and 0.022 (95%CI: 0.013–0.03) for individuals medium likely to experience more than 2 adversities. However, the effect became insignificant for individuals most likely to experience ACEs in Nordic countries, Eastern European countries and China. The exception was Latin European countries, the great effect size [0.078 (95%CI: 0.02–0.137)] occurred for individuals most likely to experience ACEs. Notably, judging from the coefficient and their 95% CIs, which have overlap to some extent, the differences cross some strata were not significantly great. However, the basic shapes were not affected.

3.3. Association between individual ACEs and FI in Europe and China

Table 4 present the association between individual ACEs and FI in Europe countries and China. ACEs constitutions differed by countries. Parental physical maltreatment, family financial problems, serious childhood illness or injury, poor peer relationship were common ACEs in



**Fig. 2.** Association between accumulative ACEs and FI across social contexts in Europe and China  
ACE: Adverse childhood experience; FI: Frailty index. Propensity score refers to the propensity for experiencing three or more ACEs.

**Table 3**  
Association between individual ACE and FI across micro-social contexts using imputed data.

Coef.(95%CI)	Nordic countries	Germanic countries	Latin European countries	Eastern European countries	China
	(N = 15382)	(N = 11313)	(N = 15103)	(N = 15414)	(N = 9752)
Least likely	0.012(0.004–0.02)	0.021(0.012–0.031)	0.016(0.011–0.021)	0.011(0.005–0.017)	0.014(0.006–0.021)
Less likely	0.022(0.015–0.029)	0.02(0.013–0.028)	0.022(0.016–0.029)	0.027(0.018–0.036)	0.016(0.009–0.023)
Medium likely	0.031(0.019–0.044)	0.029(0.019–0.039)	0.025(0.016–0.034)	0.029(0.017–0.041)	0.022(0.013–0.03)
More likely	0.023(0.008–0.039)	0.037(0.023–0.05)	0.023(0.014–0.031)	0.032(0.024–0.04)	0.011(-0.001–0.024)
Most likely	0.004(-0.044–0.052)	0.037(0.019–0.055)	0.078(0.02–0.137)	0.016(-0.032–0.064)	0.022(-0.018–0.062)

ACE: Adverse childhood experience; FI: Frailty index.

**Table 4**  
Association between individual ACE and FI using imputed data.

Coef.(95%CI)	Nordic countries	Germanic countries	Latin European countries	Eastern European countries	China
	(N = 15382)	(N = 11313)	(N = 15103)	(N = 15414)	(N = 9752)
Parental physical maltreatment	0.005(0.001–0.009)	0.016(0.01–0.021)	0.01(0.005–0.014)	0.011(0.006–0.016)	0.009(0.005–0.013)
Emotional neglect	0.001(-0.004–0.005)	-0.01(-0.014–0.006)	0.002(-0.002–0.007)	-0.004(-0.009–0.001)	-0.002(-0.006–0.002)
Low parental education	0.004(-0.001–0.009)	-0.01(-0.016–0.003)	0.014(0.008–0.02)	0.012(0.008–0.016)	0.007(0.003–0.011)
Parental unemployment	0.002(-0.004–0.008)	0.002(-0.005–0.009)	0.005(-0.001–0.01)	0.011(0.004–0.017)	0.004(-0.002–0.01)
Family financial problems	0.015(0.011–0.019)	0.02(0.015–0.026)	0.012(0.007–0.017)	0.019(0.014–0.024)	0.015(0.011–0.019)
Childhood hunger	0.014(0.002–0.026)	0.053(0.04–0.067)	0.006(-0.005–0.017)	0.032(0.019–0.045)	-0.007(-0.012–0.003)
Serious childhood illness or injury	0.013(0.007–0.018)	0.016(0.01–0.022)	0.011(0.006–0.015)	0.016(0.009–0.023)	0.024(0.017–0.031)
Parental absence	0.012(0.001–0.023)	0.018(0.009–0.028)	0.012(0.002–0.021)	0.03(0.017–0.042)	-0.004(-0.012–0.004)
Parental death	0.006(0–0.012)	0.023(0.017–0.028)	0.009(0.004–0.014)	0.01(0.005–0.015)	0.002(-0.003–0.007)
Poor parent-child relationship	0.009(0.003–0.015)	0.006(0.001–0.011)	0.009(0.005–0.013)	0.005(0.001–0.01)	0.002(-0.003–0.006)
Poor peer relationship	0.01(0.006–0.015)	0.006(0.001–0.01)	0.005(0.002–0.009)	0(-0.003–0.004)	0.016(0.011–0.02)

ACE: Adverse childhood experience; FI: Frailty index.

all the countries. Poor parent-child relationship, parental absence/death, child hunger were ACEs influencing FI in European countries but not in China. Notably, after adjusting for other individual ACEs, emotional neglect was not associated with FI in Europe and China, which were inconsistent with previous literature. The estimated effects size of individual ACEs using complete data and weighted tobit model were similar (Tables S5 and S6).

The association were more complicated while accounting for the likelihood of experiencing ACEs. Heterogeneous association between individual ACEs and FI were found in China and European countries, which are presented in Figs. S2–S6. In most cases, individuals who were moderately likely to experience adversity predicted the greatest decrease in FI while experience the individual ACEs. For example, emotional neglect was not associated with FI at population-level in China, but FI for those in the middle context (the likelihood of experiencing ACEs was approximately 50%) were negatively affected by parental emotional neglect. In addition, similar heterogeneous association were found for parental physical maltreatment, self-reported poor health, family financial problems, and serious childhood illness or injury. Exceptions were also observed. European individuals who were least likely to experience childhood hunger and parental death predicted the greatest decrease in FI when experiencing the adversities. To be concluded, the great differences in the ACEs association between Europe and China concentrated on the context where ACEs were medium likely to happen.

## 4. Discussion

### 4.1. Associations between ACEs and FI

In this large, population-based, cross-national study, we observed associations between ACEs and FI in older age; the higher the disadvantages during childhood, the higher the FI. Our results are consistent with those of previous studies, which found a significant association between ACEs and multiple health problems in different countries

(Danese & McEwen, 2022; Dannefer, 2020; Furman et al., 2019; Herrmann et al., 2018; Job et al., 2020; Jin & Liu, 2018; Lang et al., 2020; Linden et al., 2020; Shonkoff & Garner, 2012; Sieber et al., 2020; Verropoulou & Serafetinidou, 2019). Furthermore, in line with previous studies, in addition to conventional ACEs, additional ACEs (e.g., poor parent-child relationship, peer relationship) were associated with FI in some countries (Baldwin et al., 2021; Bethell et al., 2019; Godoy et al., 2021; Hughes et al., 2017; Li et al., 2021; Rod et al., 2020; Wang, 2022; Warrier et al., 2021). Notably, emotional neglect, which has been found to be associated with health risks in previous studies, was not significantly related to FI in our samples. The potential explanation may be that the spurious association between emotional neglect and health risks reflects the effects of other individual ACEs, which have not been accounted for in previous studies.

### 4.2. Cross-national differences in association between ACEs and FI

This study adds to emerging evidence that the extent to which ACEs influence health outcomes varies across countries. Judging from the interaction between country dummy variable and prevalence of ACEs, two or more ACEs led to an additional increase in FI level in European countries compared to China. Parental absence/death and Poor parent-child relationship were identified as risk factors of FI in Europe rather than in China. Divergence in national differences in the association between ACEs and FI may be partly explained by macro-social contexts, suggested by Verropoulou and Serafetinidou (2019) and Linden et al. (2020). As expected, the association were stronger in Germanic countries compared to other countries, which may be related to its “less protective” welfare programs. These smaller association in China may be due to the great efforts made by the Chinese government to promote social justice. Over 85% of the Chinese middle-aged and older population regarded their socioeconomic status as better than that of their childhood, which attenuated the negative effects of ACEs (Wang & Kang, 2019). In addition, the national differences could be further shaped by micro-social contexts indicating different likelihoods of ACEs. Previous

studies suggested that childhood adversities do not happen in a vacuum and the consequences may vary according to different micro-contexts (Fagan & Novak, 2018; Negriff, 2020; Trinidad, 2021; Wang et al., 2019). We further estimated the heterogeneous association between ACEs and FI across micro-social contexts in Europe and China.

#### 4.3. Heterogeneous association between ACEs and FI in Europe and China

This study revealed that the consequences of ACEs were not similar for everyone, and cross-national differences in health implications of ACEs were affected by micro-social contexts with different likelihoods of ACEs. In general, the association between ACEs and FI exhibited that those who were least or most likely to experience adversity experience were less affected by ACEs while experiencing childhood adversities. The conclusions agreed with studies that often highlight the protective impact of advantage position (McEwen & McEwen, 2017; Wang et al., 2019), while those from disadvantaged backgrounds may learn from others and be able to cope with adversities better (Hostinar & Miller, 2019; Trinidad, 2021). The study suggests that childhood disadvantage is not always bad for FI, but the extent of which is shaped by social context where ACEs happen.

Because of heterogeneous association between ACEs and FI resulting from micro-social context, the cross-national differences in the ACEs association may concentrate on population in certain context (e.g., people in a context with a medium likelihood of the ACE), instead of the whole population. Even though the average effects of an individual ACE were insignificant, some population may suffer a decrease in FI due to experiencing the ACEs, and cross-national differences could be observed among the sub-sample. For example, cross-national differences between European countries and China in the association of emotion neglect and FI was found only among the populations growing up in a context with a medium likelihood of the ACE. The results suggest the importance of the role of social context.

#### 4.4. Contributions and limitations

This study is the first to compare ACEs constitutions between Chinese and European while considering the individual's propensity of having ACEs. The study complements current literature by suggesting social dimensions of ACEs, which contributes to understanding the role of social context to the cross-national differences in ACEs constitutions. Our results may help to identify the most vulnerable populations to ACEs in terms of health and design more precise interventions in the contexts of resource limitations due to COVID-19. However, this study has several limitations. First, our findings highlight the importance of context in the effects of ACEs; however, this study is an observational study, and the potential mechanisms cannot be recognized in the study. Second, because of data limitations, the indicators to measure childhood status did not include some common ACEs (e.g., sexual abuse), and they were retrospective self-evaluations. We have no way to correct for the bias of childhood status. Nonetheless, the reliability of self-retrospective childhood status was supported by comparing responses to common questions in the follow-up data and life history survey.<sup>33</sup> Third, the study was limited by sample selection, as people exposed to multiple childhood adversities might never be included in surveys (e.g., due to premature death). Fourth, the differences in the prevalence of people who had three or more ACEs and mean age between China and Europe may contribute to the ACEs effect. The study applied PSM and weighted analyses to correct the potential bias.

#### 4.5. Policy implications

First, because of the negative ACEs effects, an integrated health policy is highly recommended to maximize life-course health in both Europe and China, focusing on those with adverse experiences. A series of additional ACEs found to be associated with FI, so we may want to

expand ACEs to include childhood low socioeconomic circumstances and poor peer relationship etc. Second, the ACEs effects may be related to macro-social contexts, thus a protective welfare regime should be considered. Third, the association were not equally distributed among people with different micro-social contexts. Individuals growing up in a context with a medium likelihood of ACEs tended to be most affected while experiencing ACE, and thus should be paid special attention, especially in the context of COVID-19.

## 5. Conclusions

In this cross-sectional study, a cumulative ACEs score was positively associated with FI. In addition to conventional ACEs, additional ACEs (such as poor peer relationship and family financial problems) contributed to increases in FI. However, the association between ACEs and FI varied by country, with a stronger effect among European countries. In terms of FI, parental unemployment and childhood hunger were identified as ACE constitutions in Europe rather than in China. Macro-social contexts may explain the cross-national differences. Furthermore, the association between ACEs and FI and the related cross-national differences were shaped by micro-social contexts. Usually, the association were greatest in a context with a medium likelihood of ACEs. The gap in the association among the population in the above social context also contributed the most to the cross-national differences of the association between ACEs and FI. Thus, a integrated policy on health promotion should be designed and implemented to deal with ACEs, accounting for social context. Although this study is the first study to compare the constitution of ACEs across Europe and China accounting for social context, the study could not determine the the underlying mechanisms. Ethical statement

This CHARLS survey was approved by the ethics committee of the Institutional Review Board of Peking University (NO. IRB00001052-11014). Since 2010(wave 4), SHARE was reviewed and approved by the Ethics Council of the Max Planck Society. The Council first dealt with parts of the project at its meeting on 19.10.2011 – not conclusively – and later at its meetings on 15.2.2012, 13.6.2012, 19.2.2014, 23.2.2016, 14.6.2018, 29.5.2020 and 8.6.2021(Waves 4–9) in detail. Informed consents were obtained from the participants.

#### Author statement

Qing Wang: Resources, Writing - review & editing, Conceptualization, Methodology, Data curation, Investigation, Validation, Writing - original draft & review & editing.

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None.

#### Availability of data and materials

The data is open access data.

#### Declaration of competing interest

The authors declare that they have no competing interests.

#### Data availability

I have shared the link to my data.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2023.101408> underlying mechanisms.

## Abbreviations

ACEs	Adverse childhood experiences
FI	Frailty Index
COVID-19	coronavirus disease 2019
ORs	Odds ratios
CIs	confidence intervals

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