# Stock volatility and hospital admissions for cardiovascular disease: results from the National Insurance Claims for Epidemiological Research (NICER) study

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## Summary

**Background** The association between stock volatility and cardiovascular diseases (CVD) was described during the 2008 Global Stock Market Crash; however, whether the finding in an occasional stock market crash is spurious remains unclear.

**Methods** A time-series design was used to evaluate the association between short-term exposure to daily returns of two major indices and daily hospital admissions for CVD and its subtypes based on claims data from the National Insurance Claims for Epidemiological Research (NICER) study covering 174 major cities in China. The average percentage change in daily hospital admissions for cause-specific CVD per 1% change in daily index returns was calculated because the Chinese stock market policy limits its change by 10% of the previous day's closing price. A Poisson regression in a generalised additive model was used to assess the city-specific association; then, overall national estimations were pooled by random-effects meta-analysis.

**Findings** Totally 8,234,164 hospital admissions for CVD were recorded during 2014–2017. Points of the Shanghai closing indices ranged from 1991·3 to 5166·4. A U-shaped association was observed between daily index returns and CVD admissions. Changes of 1% in daily returns of the Shanghai index corresponded to 1·28%(95%CI: 1·04%–1·53%), 1·25%(0·99%–1·51%), 1·42%(1·13%–1·72%), and 1·14%(0·39%–1·89%) increases in hospital admissions for total CVD, ischaemic heart disease, stroke, or heart failure on the same day, respectively. Similar results were observed for the Shenzhen index.

**Interpretation** Stock market volatility is associated with an increased CVD admission.

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**Keywords:** Cardiovascular diseases; Stock volatility; Claims data; Time-series analysis

## Introduction

Accumulating studies have demonstrated the association between wealth and health.[1–3] It is generally hypothesised that loss of wealth was associated with an increased risk of all-cause mortality.[4] However, stock market volatility may trigger dynamic changes in wealth bidirectionally within a brief period.[5] Previous studies have explored the association between short-term stock

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## Research in context

### *Evidence before this study*

We searched PubMed for studies published before April 16th, 2022, without language restrictions for full papers, using the terms ("stock" OR "finance") AND ("cardiovascular disease" OR "coronary heart disease" OR "ischaemic heart disease" OR "myocardial infarction" OR "stroke" OR "heart failure"). Of the 1951 articles identified, only eight articles reported the association between stock volatility and cardiovascular disease during the Global Stock Market Crash of 2008. However, these studies reported inconsistent associations of cardiovascular outcomes regarding mortality, hospital admission, or different subtypes. Whether the association is spurious, found in an occasional stock market crash, or the stock volatility may consistently be associated with cardiovascular disease remains unclear.

### *Added value of this study*

During the Chinese stock market turbulence between 2014 and 2017, daily returns of the Shanghai or Shenzhen index were significantly associated with increased admissions for cardiovascular disease, including ischaemic heart disease, stroke, and heart failure, at the national level in China. The U-shaped associations were observed consistently between daily returns of the Shanghai or Shenzhen index and admissions for cardiovascular disease.

### *Implications of all the available evidence*

Our study uses the most extensive data to expand the body of knowledge on the relationship between wealth and health, particularly cardiovascular health.

volatility and cardiovascular disease (CVD).[6–12] However, these studies used different outcome definitions regarding mortality, hospital admission, or different subtypes, and more importantly, reported inconsistent associations between stock volatility and CVD outcomes. They were subject to the limitations of a single site, single CVD subtype, or small sample size. Moreover, they were all conducted during the Global Stock Market Crash of 2008, marking the beginning of the Great Recession in the 21st century's first decade. A series of natural disasters and extreme weather (e.g., the Sichuan earthquake, a South snowstorm in China, and Hurricane Ike in the United States) also happened simultaneously. Some previous studies suggested close links between these natural disasters and an increased occurrence of CVD.[13,14] In addition, all previous studies did not consider fine particles or particulate matter 2·5 ($PM_{2·5}$) as an important emerging risk factor of CVD.[15] It remains unknown whether the association is spurious found in an occasional stock market crash or the stock volatility may consistently be associated with CVD onset.

From a historical perspective, the stock market often changes periodically. From 2014 to 2017, two major stock composite indices in China's stock market (i.e., the Shanghai and Shenzhen Stock Exchange Composite Indices) experienced an unexpected rise and fall.[5] We have another unique opportunity to examine the association between stock volatility and CVD in the second decade of this century. In addition, far fewer previous studies investigated the short-term changes in stock volatility and CVD morbidity.[6–12] (Figure 1) Considering the rapid change in stock price, hospital admission (including those with less severe disease conditions), widely used as the disease onset proxy, is expected to be more sensitive than mortality itself. Thus, hospital admissions for CVD subtypes can better evaluate the temporal sequence between the short-term change of stock volatility and the clinical presentation of CVD.[15]

This study hypothesised that short-term changes in stock volatility in bidirectional ways (both rise and fall) might be associated with a higher risk of hospital admission for CVD and its subtypes. We conducted a time-series analysis using nationwide claims data during 2014-2017 from the National Insurance Claims for Epidemiological Research (NICER) study in 174 major cities in China.

## Methods

### Study sites

A total of 174 cities in China were included in our analysis based on the accessibility of cardiovascular disease data and the feasibility of model fitting. We excluded 49 cities (1) without ICD-10 code or diagnostic text information; or (2) having insufficient daily admission counts due to the feasibility of model fit. Locations of the 174 cities were illustrated in Supplementary Figure S1.

### Data collection

Hospital admissions of CVD were extracted from the previously described NICER study.[16] In brief, China has three primary schemes for health insurance: the urban employee basic medical insurance (UEBMI) for urban employees or retired individuals in cities, urban resident basic medical insurance for urban residents without formal employment (including children), and the new rural cooperative medical scheme for rural residents. These three schemes already covered more than 92% of the population by 2011.[17] Private medical insurance has little coverage in China and is generally supplementary to the basic schemes. All employers in urban areas, including government agencies and institutions, state-owned enterprises, private businesses, social organisations, and other private entities and their employees (retirees included), are obligated to enroll in UEBMI. At the end of 2016, the UEBMI database

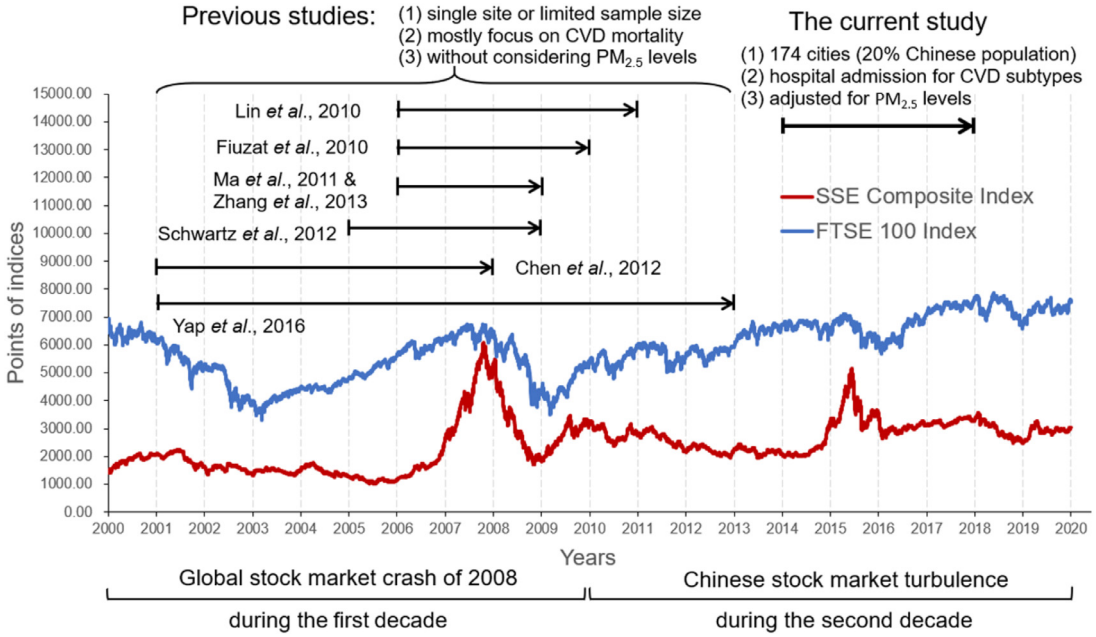


**Figure 1.** Illustration of the current study and comparison with previous studies.
SSE = Shanghai Stock Exchang; FTSE = Financial Times Stock Exchange; CVD = cardiovascular disease.

had 0·28 billion beneficiaries and covered 223 Chinese cities.[16] Considering the nature of our study, daily hospital admissions for total CVD, including ischemic heart disease (I20-I25), stroke (I60-I63), and heart failure (I50), were obtained from the UEBMI only during the study period from January 2014 to December 2017. According to ICD-10 codes and text of primary diagnosis, we extracted data on the date of admission, sex, and patient age for each access. Claims data were anonymised for research purposes. This study was approved by the Peking University Institutional Review Board (IRB00001052-18012-Exemption), which granted a consent waiver because of deidentified administrative databases.

Daily information on Shanghai and Shenzhen Stock Exchange Composite Indices, including the maximal, minimal, closing, and change of indices, were obtained from the Wind Economic Database during the study period. The index's daily return was calculated by the percentage of today's change in the previous day's closing price.[18]

$$\text{Daily return} = \frac{\text{the closing price of today} - \text{the closing price of the previous day}}{\text{the closing price of the previous day}}$$

Previous studies have shown that ambient air pollutants such as fine particles matter ($PM_{2.5}$) and meteorological conditions such as temperature and relative humidity affect cardiovascular disease admissions.[15,16,19,20] Therefore, we also collected daily mean $PM_{2.5}$ data from the National Air Pollution Monitoring System and meteorological data (daily mean air temperature and relative humidity) in each city from the China Meteorological Data Sharing Service System.

### Statistical analysis

We applied a two-stage analytical approach to estimate the regional and national average estimations between daily returns of each stock index (i.e., the Shanghai or Shenzhen index returns) and daily hospital admissions for CVD in separate models.[21,22] In the first stage, we used absolute index returns without considering their direction. We fitted a Poisson regression in a generalised additive model for each city to estimate the associations between short-term exposure to absolute index returns and daily hospital admissions for CVD and subtypes. The generalised additive model has been widely used in environmental epidemiological studies to evaluate the short-term effects of air pollutants exposure and previous studies to explore the association between stock and diseases.[15,21] Similar to previous studies,[15,19,20,23] we adjusted the association with daily mean $PM_{2.5}$, temperature, relative humidity, calendar time, public holiday, and day of the week in the model. A natural cubic spline function of calendar time with seven degrees of freedom per year was incorporated into the model to adjust for seasonality and time trends. Traditional risk factors at the individual level (e.g., sex, age, and comorbidities) could be self-controlled with time-series analysis.[6,15] $PM_{2.5}$, temperature, and relative

humidity were controlled using natural cubic splines with three degrees of freedom.[21] Two indicator variables for public holidays and day of the week were also included in the model. The model was described as shown below:

$$\begin{aligned}\mathrm{Log}[E(Y_t)] = {} & \beta_0 + \beta_1 X_t + \beta_2 \text{day of the week} \\ & + \beta_3 \text{public holiday} \\ & + s(\text{calendar time}, df = 7/\text{year}) \\ & + s(\text{temperature}, df = 3) \\ & + s(\text{relative humidity}, df = 3) \\ & + s(PM_{2.5})\end{aligned}$$

where $E(Y_t)$ was expected count of admissions on day t; $X_t$ was the absolute Shanghai or Shenzhen index returns on day t; $\beta_1$ was log rate ratio of hospital admission associated with a unit increase of absolute index returns; s( ) referred to natural cubic spline function; and df means degrees of freedom.

We fitted the model with different lag structures to examine the lag patterns and temporal relationship between absolute index returns and admissions. Lag 0 referred to the association between absolute index returns and the risk of admissions on the same day; lag 1 referred to the previous one-day absolute index returns; and lag 01 or lag 02 were also conducted, which referred to the risk of disease associated with average absolute index returns on the same and previous one or two days of admission, respectively. We chose lag 0 as our primary analysis for the association between absolute index returns and admissions because it may produce the most prominent estimate. In the second stage, random-effects meta-analysis was used to pool city-specific estimates at the national level.

In addition to the absolute index returns, we also consider the direction and range of daily index returns.[6,7] We examine the shape association between daily Shanghai or Shenzhen index returns and admissions for CVD (lag 0 and lag 1). We categorised all days (excluding weekends and legal holidays) from 2014 to 2017 into five groups (large decline, small decline, basically unchanged, small rise, and large rise) according to the direction and range of daily index returns. Based on the five categories, Poisson regression in a generalised additive model was used to analyse the association between different categories and cardiovascular admissions in each city. Then, to generate the overall estimates at the national level, city-specific estimates for specific daily return categories were firstly pooled by random-effects meta-analysis to produce overall categorical estimations. Alternatively, these city-specific estimates for specific daily return categories were also fitted by locally weighted scatterplot smoothing (LOWESS) regression to produce continuous exposure-response relationship curves. Finally, estimations by categorical groups or continuous curves were overlaid to compare the consistency.

Stratified analyses by sex, age (18–64, 65–74, and ≥75), and gross domestic products (GDP) relative level (divided into three equal parts: low, medium, and high) were conducted. Z-test was used to assess statistically significant differences in the estimates between subgroups. In addition, we conducted a meta-regression model to evaluate whether the relationship between absolute index returns and CVD admissions will be affected by city characteristics, i.e., annual average $PM_{2.5}$, temperature, relative humidity, and GDP of each city as continuous variables.[15]

### Sensitivity analysis

We conducted several sensitivity analyses to assess the robustness of the estimates: (1) pooled city-specific estimates only in cities with data range ≥ 3 years or < 3 years; (2) changed the degrees of freedom for calendar time (6-12 per year), temperature (4-6), and relative humidity (4-6), respectively;[8] (3) examined the association between $PM_{2.5}$ and CVD admissions; and (4) fitted a quasi-Poisson regression and a zero-inflated Poisson regression using generalised additive models to examine the over-dispersion and zero-inflation of the CVD outcomes.

We conducted statistical analyses in R version 3·6·0 (R Foundation for Statistical Computing, Vienna, Austria) with packages (mgcv version 1·8-36, ggplot2 version 3·3·5, and metafor version 3·0-2). The two-side test was used, and the significance level was 0·05. The results are reported as percentage changes and 95% confidence intervals in daily hospital admissions associated with an incremental increase in composite indices returns of 1%.

### Role of the funding source

The funders of this study did not influence nor participate in the study design, data collection, data analysis, data interpretation, or drafting of the paper. The corresponding authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

Between January 1st, 2014, and December 31st, 2017, we identified 8,234,164 hospital admissions for CVD in 174 cities. The summary statistics on daily hospital admission of all CVD and major subtypes of CVD, Shanghai and Shenzhen Stock Exchange Composite Index, air pollution, and weather conditions were shown in Table 1. A median (p25, p75) of 16·0(6·0, 38·0) hospital

| | Min | P (25) | Median | P (75) | Max |
|---|---|---|---|---|---|
| **Daily hospital admissions** | | | | | |
| All cardiovascular diseases | 1·0 | 6·0 | 16·0 | 38·0 | 1789·0 |
| Ischaemic heart disease | 1·0 | 3·0 | 9·0 | 22·0 | 1237·0 |
| Stroke | 1·0 | 3·0 | 8·0 | 19·0 | 437·0 |
| Heart failure | 0·0 | 0·0 | 0·0 | 1·0 | 352·0 |
| **Shanghai Stock Exchange Composite Index** | | | | | |
| Daily returns (%) | −8·5 | −0·2 | 0·0 | 0·3 | 5·8 |
| Daily absolute returns (%) | 0·0 | 0·0 | 0·2 | 0·8 | 8·5 |
| **Shenzhen Stock Exchange Composite Index** | | | | | |
| Daily returns (%) | −8·2 | -0·2 | 0·0 | 0·6 | 6·5 |
| Daily absolute returns (%) | 0·0 | 0·0 | 0·4 | 1·1 | 8·2 |
| **Air pollution and weather conditions** | | | | | |
| Temperature (°C) | −38·8 | 6·7 | 16·0 | 23·0 | 42·3 |
| Relative humidity (%) | 5·0 | 55·0 | 70·0 | 82·0 | 100·0 |
| $PM_{2·5}$ ($\mu$g/m3) | 0·0 | 25·0 | 41·0 | 65·0 | 703·0 |

***Table 1*: The summary statistics on the variable used in the current study from 2014 to 2017.**
$PM_{2·5}$ = particulate matter with aerodynamic diameter ≤2·5 $\mu$m; SD = standard deviation; P (25) = 25th percentile; P (75) = 75th percentile.

admissions per day was observed for total CVD, 9·0(3·0, 22·0) for ischaemic heart disease, and 8·0(3·0, 19·0) for stroke, respectively.

As shown in Figure 2, both Shanghai and Shenzhen indices experienced huge volatility during the study period. For the Shanghai index, points of the closing index ranged from 1991·3 to 5166·4, and the minimal and maximal values of daily returns were -8·5% and 5·8%, respectively. Similarly, for the Shenzhen index, points of the closing index ranged from 1007·3 to 3140·7, and the minimal and maximal values of daily returns were -8·2% and 6·5%, respectively.

We assessed the shape association between the daily return of the Shanghai or Shenzhen index and all CVD on the same day (lag 0), which was a clear U-shape. When the index rises or falls slightly (daily returns of the Shanghai index fluctuate between -1·75% and 0·19%, or daily returns of the Shenzhen index fluctuate between -1·00% and 0·19%), the admissions are unchanged. Further, we explore the shape association between the daily returns of the Shanghai or Shenzhen index and one-day lagged CVD admissions using lag 1 pattern, from which consistent results were obtained (Figure 3). The association was more symmetric at 0 when the association between daily return and one-day lagged CVD admissions. When the index fluctuates significantly, the hospital admissions of CVD increase in both directions with similar slopes. The greater the fluctuation, the more the admissions, especially for the Shanghai index. Therefore, we used absolute index return in the following analyses.

The daily absolute Shanghai or Shenzhen index returns were significantly associated with increased admissions for total CVD, ischaemic heart disease, stroke, and heart failure at the national level (Figure 4). Changes of 1% in daily Shanghai index returns were associated with 1·28%(95%CI: 1·04% to 1·53%), 1·25%


**Figure 2.** Daily closing indices of the Shanghai and Shenzhen Stock Exchange Composite Index from January 2014 to December 2017.
Daily closing indexes of the Shanghai and Shenzhen Stock Exchange Composite Index were used to print the curve.

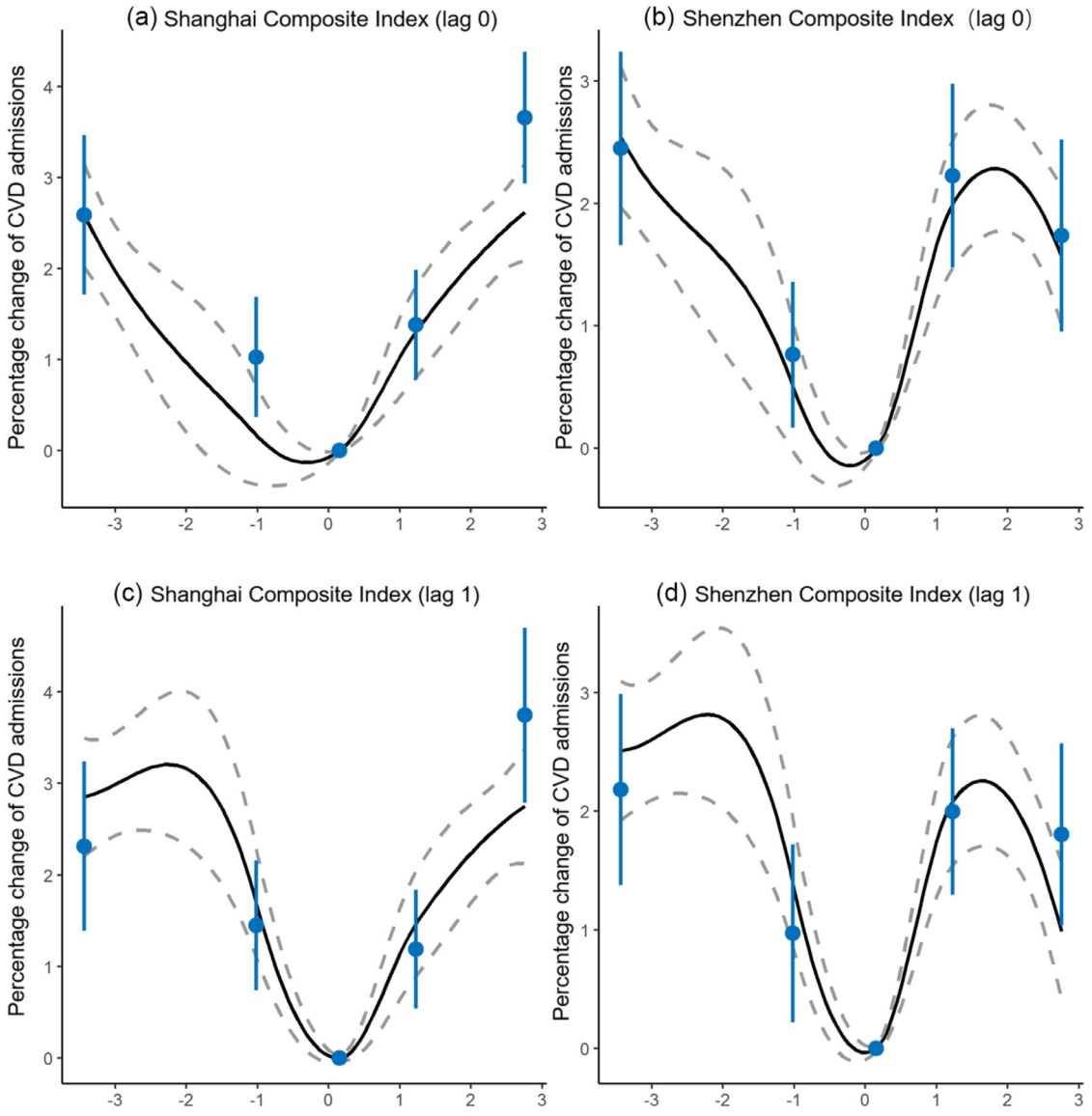


**Figure 3.** National average exposure-response association curve* between daily Shanghai or Shenzhen index returns and percentage change (%) in daily hospital admissions for total cardiovascular disease in 174 Chinese cities, 2014–17.

* Adjusted for daily mean $PM_{2.5}$, temperature, relative humidity, calendar time, and day of the week.

Lag 0 referred to the association between absolute index returns and the risk of admissions on the same day; lag 1 referred to the previous one-day absolute index returns.

(0·99% to 1·51%), 1·42%(1·13% to 1·72%), and 1·14%(0·39% to 1·89%) increase in hospital admissions for total CVD, ischaemic heart disease, stroke, and heart failure on the same day, respectively. Similarly, a change of 1% in daily Shenzhen index returns corresponded to 1·13% (95%CI: 0·90% to 1·35%), 1·11%(0·88% to 1·34%), 1·26%(0·99% to 1·53%), and 1·23%(0·51% to 1·96%) increases in hospital admissions for total CVD, ischaemic heart disease, stroke, and heart failure on the same day, respectively. Statistically significant associations were still observed for the average absolute index returns on the same and previous admission (lag 01) except for heart failure. In Supplementary Figure S2, we showed the city-specific associations grouped by the geographical regions in China. The estimates by different geographical regions were broadly similar.

For each major CVD subtype, we provided the subgroup associations between absolute daily returns of the Shanghai index (lag 0) and hospital admissions by sex, age, and GDP relative levels (Figure 5). The association between daily absolute index returns and admissions was broadly similar among different subgroups. In

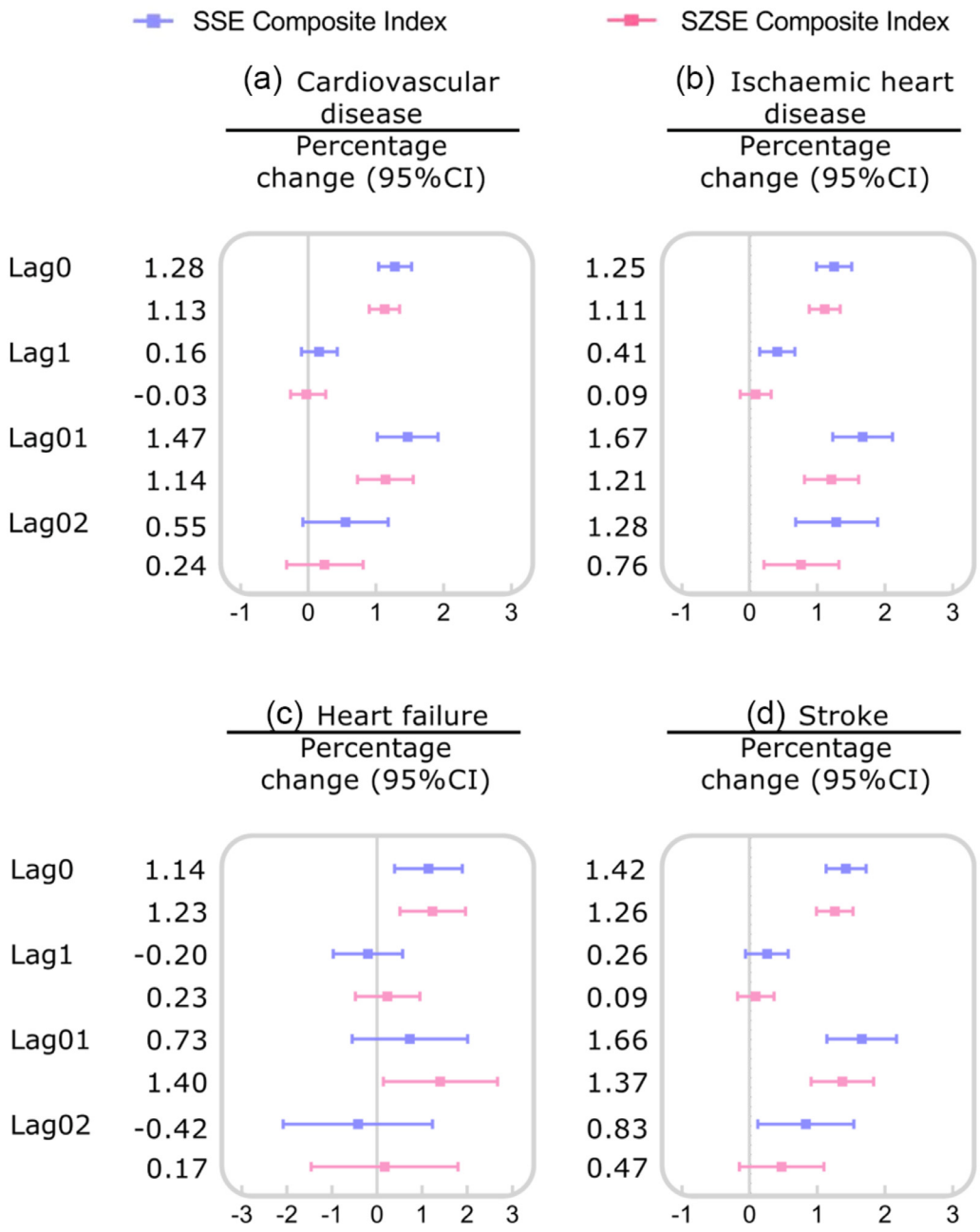


**Figure 4.** National average percentage change (%) in daily hospital admissions* for cause-specific cardiovascular diseases per 1% change in daily Shanghai or Shenzhen index returns on different lag days in Chinese cities, 2014–17.

SSE = Shanghai Stock Exchange; SZSE = Shenzhen Stock Exchange; CI = confidence interval.

* Adjusted for daily mean $PM_{2.5}$, temperature, relative humidity, calendar time, public holidays, and day of the week.

Seven cities (Chizhou, Dongguan, Hetian, Lvliang, Wuwei, Yunfu, and Zhongwei) were excluded for stroke.

Lag 0 referred to the association between absolute index returns and the risk of admissions on the same day; lag 1 referred to the previous one-day absolute index returns. Lag 01 or lag 02 referred to the risk of disease associated with average absolute index returns on the same and last one or two days of admission.

Supplementary Table S1, we showed those city characteristics did not modify the acute effect of daily returns on hospital admissions for CVD. In sensitivity analysis, the effect estimate was similar to the change of degrees of freedom and the restriction on cities' study periods (Supplementary Table S2). The association between $PM_{2.5}$ and CVD admissions was consistent with previously published estimates (Supplementary Table S3).[15]

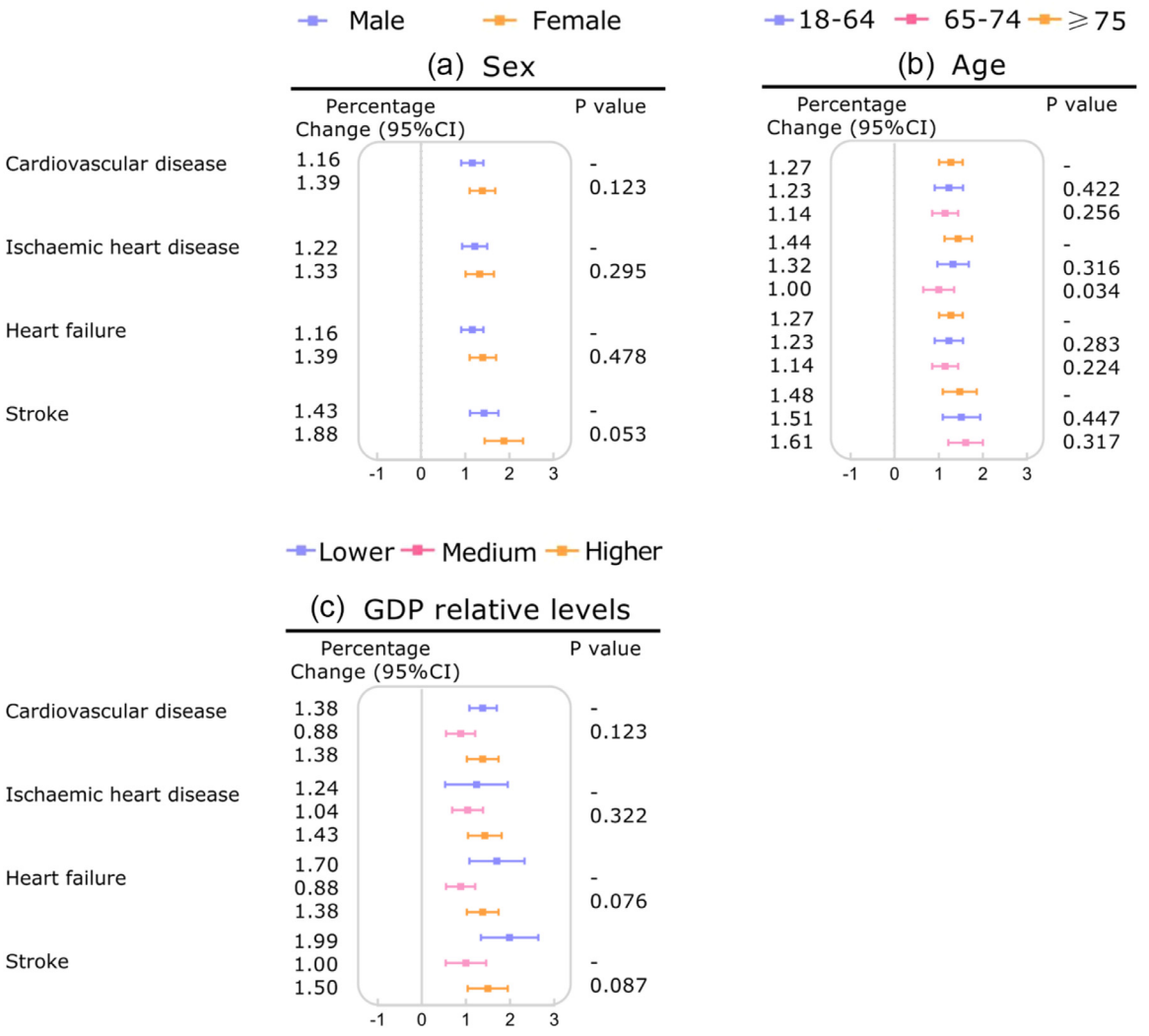


**Figure 5.** National average percentage change in daily hospital admissions* for cause-specific cardiovascular diseases per 1% change in concurrent day returns of Shanghai Composite Index (lag 0) stratified by sex (a), age (b), and GDP relative level (c).
GDP = gross domestic products; CI = confidence interval.
*Adjusted for daily mean $PM_{2.5}$, temperature, relative humidity, calendar time, public holidays and day of the week.
7 cities (Chizhou, Dongguan, Hetian, Lvliang, Wuwei, Yunfu, Zhongwei) were excluded for stroke.
Lag 0 referred to the association between absolute index returns and the risk of admissions on the same day.

The quasi-Poisson regression and the zero-inflated Poisson regression showed consistent results (Supplementary Table S4).

## Discussion

To the best of our knowledge, this study is the largest one to examine the short-term association between exposure to stock market volatility and hospital admissions for major CVD subtypes. We found that daily returns of the Shanghai or Shenzhen index were significantly associated with increased admissions for total CVD, ischaemic heart disease, stroke, and heart failure at the national level.

Compared with previous studies during the Global Stock Market Crash of 2008,[6–12] our study has the unique opportunity to confirm the association between stock volatility and CVD during the latest Chinese stock market turbulence of 2015, which means the association was not spurious found occasionally and less likely to be influenced by the contemporaneous natural disasters (e.g., 2008 Sichuan earthquake or South snowstorm in China).[13] Our analysis of heart failure admissions was consistent with the study in Singapore. At the same time, for a 1% change in daily return, our point estimations (1·14% and 1·23% for Shanghai or Shenzhen index, respectively) were slightly lower than those in Singapore (IRR 1·026 is approximately equal to 2·

6%).[10] Moreover, our point estimations on ischaemic heart disease were lower than those in the previous study from Shanghai (1·25% versus 1·87%).[6] However, $PM_{2.5}$, as an important emerging risk factor of CVD, was not considered in all previous studies. After adjustment for $PM_{2.5}$ levels, our conservative estimations seemed more reasonable.

Stratified analyses showed that sex, age, or GDP did not modify the acute effect of daily returns on hospital admissions for CVD. Similarly, the annual average temperature, relative humidity, $PM_{2.5}$ and GDP of each city did not modify the effect either in the multivariable meta-regression model. This implied that the influence of stock market volatility on CVD admissions at the population level was independent. Unlike other traditional risk factors, which may be reported to have a stronger relation to CVD for the older population, we did not find significant disparities in age-stratified analysis, suggesting the relationship between wealth and health may not greatly interact with age. As emotion fluctuations due to the index change, some studies showed that acute anger or emotional upset was associated with the onset of myocardial infarction and stroke.[24,25] However, these studies also did not find significant disparities in age-stratified analysis. Further investigation with detailed individual-level information about older people is still needed.

In addition to the absolute index returns in this study, considering the direction and range of daily index returns, we found that the association between daily returns and total CVD admissions was U-shaped. The two sides of the curve were almost symmetrical and linear. It suggested that the influence of the stock index on hospital admissions was only relevant to the magnitude of stock change but not to the direction. Two previous studies[6,7] conducted in Shanghai also found a U-shaped relationship between the index change and coronary heart disease or stroke death, consistent with our findings.

It is reasonable to speculate that stress may play an essential role in the association.[26] Both rise and fall of the index may cause substantial emotional and physiological changes. Several studies showed a significant association between negative wealth shocks and short-term clinically relevant health changes, including anger or emotional upset, substantial mental and physical stresses, increased risk of depression and anxiety, and impaired cardiovascular functions.[27–30] There is sufficient epidemiological evidence to show that mental stress caused by emergencies can increase the risk of CVD. For example, the Hanshin earthquake in 1995[31] and the March 11th earthquake in 2011[32] were all related to the increased risk of CVD. Moreover, acute exposure to anger or emotional upset and stress with transient effects that may act as triggers has also been explored for myocardial infarction and stroke.[24,25] However, regarding the association between the fluctuation of stock market and CVD, our study design cannot draw a conclusion on causality. Further investigations are still warranted.

### Strengths and limitations of this study

Our study has several strengths. First, it includes 174 cities in China, diverse geographical features, and social-economic status. Second, using more than 8 million hospital admissions of CVD, our study has a large sample size and sufficient statistical power. Finally, we systematically examined the relationship between daily returns of two major composite indices in China and major CVD subtypes admissions with consistent research design and analysis methods. The effects could be compared in the same framework.

Our study also had some limitations. First, our study is naturally ecological, where the existence of ecological fallacy limits the capability for causal inference. We assumed that the stock market directly or indirectly influenced the population. The securities market in China is expanding, and the number of investors is growing (Supplementary Figure S3).[33] Moreover, besides directly taking bids in the stock market, many investors may also choose the bonds, funds or derivatives markets, which were also affected by stock fluctuations. In addition, wealth change is not limited to personal investment but is often shown as a family asset, especially in China. Sudden stock market fluctuations, especially the significant change of the index in trend, may reflect the underlying economic environment related to almost everyone in the society, such as the reduction of employment opportunities and the slowdown of economic growth. To our knowledge, previously published studies have found an association between the stock market crash and unemployment or economic recession.[34–36] In this regard, the exposure-response relationship between wealth and health seems reasonable. Previous studies found an association between stock volatility and cardiovascular outcomes during the Global Stock Market Crash of 2008. We chose another unique significant stock market fluctuation in China and confirmed the consistent results, which may support that the findings were observed consistently rather than by chance.

Second, we noted that only urban employed and retired individuals were included in this analysis. The associations of urban residents without formal employment or rural residents were unclear. Because of the differences in sociodemographic characteristics and economic status between rural and urban areas, the results and conclusions of our study may not be generalised to the rural population. Third, as in other environmental health studies using a large administrative health database,[37,38] data on individual-level risk factors were unavailable in our study, limiting our ability to adjust for confounding. However, in our study, daily counts of CVD hospitalisation and the index change

were linked by date and were therefore analysed with time-series analyses. It is commonly used to assess the association between short-term exposures and acute events. By design, time-series analysis examines the same population repeatedly over time under varying exposure conditions and therefore had a self-control design to control the confounding by slowly varying risk factors at the individual level (e.g. smoking status). However, sudden changes in patients' risk factors (e.g. accidents, anger, or emotional upset caused by other conditions) and simultaneous events at the population level may still confound the association. Further investigation with detailed individual and population-level information is still needed. Finally, our study only used the index's daily return as the exposure, which may not reflect the stock market's performance from multiple dimensions and perspectives.

## Conclusions

Our study suggested that stock market volatility (both fall and rise) is associated with an increased risk of hospital admission for CVD and subtypes at the national level. The findings of our study expand the body of knowledge on the relationship between wealth and health, particularly cardiovascular health.

## Contributors

All authors were involved in the study design, data analysis, and revision of the manuscript and read and approved the final manuscript. Drs Pei Gao and Xun Tang contributed equally as corresponding authors. Dr. Pei Gao had full access to all the data in the study, Drs Pei Gao and Xun Tang took responsibility for the integrity of the data and the accuracy of the data analysis. All authors approved the final version of the manuscript.

## Data sharing statement

No additional data is available.

## Declaration of interests

The authors declare no competing interests.

## Ethical approval

This study was approved by the Peking University Institutional Review Board (IRB00001052-18012-Exemption), which granted a consent waiver because of deidentified administrative databases.

## Funding

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## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lanwpc.2022.100595.

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