Stock volatility as a risk factor for coronary heart disease death

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Aims
The volatility of financial markets may cause substantial emotional and physical stress among investors. We hypothesize that this may have adverse effects on cardiovascular health. The Chinese stock markets were extremely volatile between 2006 and 2008. We, therefore, examined the relationship between daily change of the Shanghai Stock Exchange (SSE) Composite Index (referred as the Index) and coronary heart disease (CHD) deaths from January 1, 2006, to December 31, 2008 in Shanghai, the financial capital of China.

Methods and results
Daily death and stock performance data were collected from the Shanghai Center for Disease Control and Prevention and SSE, respectively. Data were analysed with over-dispersed generalized linear Poisson models, controlling for long-term and seasonal trends of CHD mortality, day of the week, Index closing value, weather conditions, and air pollution levels. We observed a U-shaped relationship between the Index change and CHD deaths: both rising and falling of the Index were associated with more deaths and the fewest deaths coincided with little or no change of the index. We also examined the absolute daily change of the Index in relation to CHD deaths: in a 1-day lag model, each 100-point change of the Index corresponded to 5.17% (95% confidence interval: 1.71, 8.63%) increase in CHD deaths. Further analysis showed that the association was stronger for out-of-hospital CHD death than for in-hospital death.

Conclusion
We found that CHD deaths fluctuated with daily stock changes in Shanghai, suggesting that stock volatility may adversely affect cardiovascular health.

Keywords
Coronary heart disease • Stock volatility • Time-series analysis

Introduction
Coronary heart disease (CHD) is a common cause of death and the leading cause of severe long-term disability in developed countries and some developing countries.1,2 In addition to a number of well-established traditional risk factors (e.g. smoking, high blood pressure, diabetes), chronic and acute social and emotional stresses may increase the risk of CHD or worsen the symptoms of CHD patients.3,4 For example, previous studies showed a link between traumatic events such as the September 11, 2001 attack,5 the Hurricane Katrina in 2005,6 the earthquakes in Wenchuan7 and Los Angeles,6,8 and an increased occurrence of cardiac events. Further, higher cardiovascular mortality was observed during holidays such as Christmas in the USA.10,31 The fluctuations of stock market and financial difficulties may represent substantial mental and physical stresses that adversely affect cardiovascular health. In particular, the financial markets of major world economies were extremely volatile in the past several years. However, to the best of our knowledge, few studies have investigated the potential impact of financial market volatility on cardiovascular health.

In a short period of 3 years (2006–2008), the Chinese stock markets experienced unprecedented growth and collapse. Unlike developed countries, the Chinese stock markets are full of inexperienced individual investors who often gamble with their investments and have unrealistic expectations of financial returns.12 We, therefore, examined the relationship between daily changes of the Shanghai Stock Exchange (SSE) Composite Index (referred to hereafter as the Index) and CHD deaths during 2006–2008 in Shanghai, the financial capital of China.
Methods

Exposure and outcome ascertaintions

Shanghai has a population of 13.7 million at the end of 2008, approximately 1% of the Chinese population. Our analyses of daily deaths were restricted to permanent residents of the nine urban districts of Shanghai (~6.5 million in 2008), as the daily counts of deaths for these individuals are accurately documented at the Shanghai Center for Disease Control and Prevention (SCDC). These Districts include Huangpu, Jin’an, Luwan, Xuhui, Yangpu, Changning, Yangpu, Putuo, and Zhabei. Of these urban residents, the male-to-female ratio was 1.01 in 2008 and 11.9% of the population were 65 years and older.

Daily counts of deaths due to CHD between 1 January 2006 and 31 December 2008 were obtained from the SCDC. In Shanghai, death certificates are completed at the time of death either by community doctors for deaths at home or by hospital doctors for deaths at the hospitals. Death certificate routinely collects information on name, sex, ethnicity, occupation, identification number, marital status, education achievement, name of last employer, date of birth, date of death, age at death, location of death, home address, causes of death, and the name of the hospital where death occurred. Information is then electronically submitted to the SCDC through an internal computer network. According to the law, all deaths in Shanghai must be reported to appropriate authorities before cremation. The causes of death are coded according to the International Classification of Diseases, 10th revision (ICD-10). Coronary heart disease deaths were defined as that either an underlying cause of death or contributing cause of death was CHD (ICD-10 codes: 120-I25).

Daily stock performances during the observational period, including the opening, maximal, minimal, closing, change, and percent of change (% of the Index), were obtained from the SSE website (www.sse.com.cn).

Previous studies have shown that weather conditions and ambient air pollution affect CHD mortality;12,14; we therefore collected daily weather (temperature and relative humidity) and air pollution [particulate matter with aerodynamic diameter less than 10 μm (PM10) and ozone (O3)] data from the Shanghai Meteorological Bureau and Shanghai Environmental Monitoring Center, respectively.

Previously, the mortality, weather, and air pollution data in Shanghai were validated by an independent auditing team assigned by the Health Effects Institute for the Public Health and Air Pollution in Asia (PAPA) study.13 The team checked a sample of the original death certificates and monitoring records and validated the generation process of mortality, weather, and air pollution data used for the time-series analysis.

Statistical analysis

Daily counts of CHD deaths and the Index change were linked by date and were therefore analysed with time-series analyses.15 Time-series analysis is commonly used to assess the association between short-term exposures and acute events, such as daily concentrations of air pollutants in relation to mortality. By design, time-series analysis examines the same population repeatedly over time under varying exposure conditions, and therefore time-invariant population characteristics (e.g. cigarette smoking and hypertension) have little effects on the analyses.15 Because the daily counts of deaths approximately follow a Poisson distribution and the relationship between mortality and explanatory variables is mostly nonlinear, we used over-dispersed generalized linear Poisson models (quasi-likelihood) with natural spline (ns) smoothers to analyse the CHD mortality, Index change, and covariate data.16

In the basic model, we incorporated smoothed spline functions of time, which accommodate both nonlinear and non-monotonic patterns between CHD mortality and time and thus offer flexible model to control for long-term and seasonal trends.17 Day of the week was included as a dummy variable in the basic models. Partial autocorrelation function (PACF) was used to guide the selection of degrees of freedom (df) for the time trend until the absolute values of the sum of PACF of the residuals for lags up to 30 reached a minimal.18–20 Residuals of the basic model were examined to check whether there were discernable patterns and autocorrelation by means of residual plots and PACF plots.

After establishing the basic model, we introduced the Index change and covariates into the model. We then used the smoothing spline, with 3 df for the Index change, to graphically describe their relationships with CHD mortality. The results are presented as the percent change in daily CHD death for each 100-point or 1% Index change. The point and percent changes of the Index correspond, respectively, to the absolute and relative magnitudes of daily Index change of the SSE stock market. We presented data in both ways to facilitate future comparison of our study results with those from other stock markets that may have different overall stock values.

To further examine the temporal relationship between Index changes and CHD deaths, we fitted the model with different lag structures, including both single-day lag (from lag0 to lag4) and multi-day lag (lag01 and lag04). In single-day lag models, a lag of Day 0 (lag0) corresponds to the current-day Index change, and a lag of Day 1 (lag1) refers to the previous-day Index change; in multi-day lag models, lag04 corresponds to 5-day moving average of Index change of the current and previous 4 days.

If acute financial stress induces CHD death among susceptible individuals, one would expect that daily stock volatility is more strongly associated with sudden CHD deaths than with non-sudden deaths. Although we were not able to differentiate sudden from non-sudden CHD death based on the death certificate, we further examined the association of Index changes with CHD deaths by the location of death, assuming most sudden deaths occurred outside the hospital than in hospital. Finally, to examine the robustness of our choice on the optimal values of df for the time trend in the basic model, we performed a sensitivity analysis to test the impact of df selection on the regression results. All analyses were conducted using R 2.10.1 with the MGCV package.22

Results

Between 1 January 2006 and 31 December 2008, we documented a total of 22,272 CHD deaths or, on average, ~20.3 deaths per day (Table 1). During the mean time, the Index surged more than five-fold from 1164 in January 2006 to 6124 in October 2007, and then rapidly declined to 1,708 in November 2008 before stabilizing in 2009 (Figure 1). The minimal, mean, and maximal daily Index changes in absolute values were 0.02 (0.00%), 51.43 (1.64%), and 354.68 (9.46%) points, respectively.

We observed U-shaped relationships between Index change, either as point change or percent change, and CHD mortality.
both rising and falling of the stock market were associated with more deaths and the fewest deaths coincided with little to no change of the Index.

When we used the absolute rather than bidirectional change of the Index, the effect estimates seemed to vary by lag structure. For absolute point changes, statistically significant associations were observed for single-day lag 1 and multi-day lag 0; for absolute changes in percentage, statistically significant associations were observed for single-day lag 1, 3, and 4, and multi-day lag 0 (Figure 3). Each 100-point 1-day lagged Index change corresponded to 5.17% [95% confidence interval (CI): 1.71, 8.63%; \( P < 0.01 \)] increase in CHD deaths, and each 1% change of the Index corresponded to 1.87% (95%CI: 0.66, 3.09%; \( P < 0.01 \)) increase in CHD deaths.

During the study period, out-of-hospital CHD deaths account for approximately half of all CHD deaths. We found a significant association between absolute Index change and out-of-hospital CHD death (Table 2): for example, each 100-point 1-day lagged Index change corresponded to 6.09% (95%CI: 1.24, 10.94%; \( P < 0.05 \)) more out-of-hospital CHD deaths. The association of daily Index change with in-hospital CHD deaths seems to be in the same direction; however, it did not reach statistical significance (\( P > 0.05 \); Table 2).

Within the range of 1–15 \( df \), the change of \( df \) per year for time trend did not substantially change the regression results (data not shown), suggesting that our findings with regard to the effect of Index change on CHD mortality are robust.

### Table 1  Daily deaths of coronary heart disease (CHD), the changes of the Shanghai Stock Exchange (SSE) Composite Index and covariates (2006–2008)

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Min</th>
<th>P(25)*</th>
<th>Median</th>
<th>P(75)*</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily CHD deaths</td>
<td>20.3 ± 6.2</td>
<td>6.0</td>
<td>16.0</td>
<td>20.0</td>
<td>24.0</td>
<td>48.0</td>
</tr>
<tr>
<td>Out-of-hospital</td>
<td>10.2 ± 4.0</td>
<td>1.0</td>
<td>7.0</td>
<td>10.0</td>
<td>13.0</td>
<td>25.0</td>
</tr>
<tr>
<td>In-hospital</td>
<td>10.1 ± 3.6</td>
<td>2.0</td>
<td>8.0</td>
<td>10.0</td>
<td>12.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Daily change of SSE Composite Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bidirectional change</td>
<td>0.9 ± 76.3</td>
<td>–354.7</td>
<td>–22.7</td>
<td>5.3</td>
<td>37.0</td>
<td>351.4</td>
</tr>
<tr>
<td>Absolute change</td>
<td>51.4 ± 56.4</td>
<td>0.0</td>
<td>11.9</td>
<td>31.2</td>
<td>72.5</td>
<td>354.7</td>
</tr>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index closing value</td>
<td>2968.7 ± 1357.6</td>
<td>1181.0</td>
<td>1740.0</td>
<td>2770.1</td>
<td>4000.7</td>
<td>6092.1</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>17.8 ± 8.9</td>
<td>–1.8</td>
<td>10.3</td>
<td>18.7</td>
<td>25.1</td>
<td>33.8</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>70.0 ± 11.7</td>
<td>31</td>
<td>63.0</td>
<td>70.0</td>
<td>78.0</td>
<td>95.0</td>
</tr>
<tr>
<td>PM10 (μg/m³)</td>
<td>92.0 ± 55.2</td>
<td>11.5</td>
<td>52.4</td>
<td>79.8</td>
<td>116.7</td>
<td>643.0</td>
</tr>
<tr>
<td>O₃ (μg/m³)</td>
<td>64.8 ± 40.0</td>
<td>4.7</td>
<td>34.6</td>
<td>56.8</td>
<td>86.3</td>
<td>224.9</td>
</tr>
</tbody>
</table>


(Figure 2): both rising and falling of the stock market were associated with more deaths and the fewest deaths coincided with little to no change of the Index.

### Figure 1  Performance of the Shanghai Stock Exchange (SSE) Composite Index from January 2006 to December 2008.
Discussion

This study showed that CHD deaths fluctuated with daily stock changes in Shanghai during 2006–2008. Interestingly, the upward market seems to equally affect CHD death as the downward market and the associations appear to be linear in both directions (Figure 2). To the best of our knowledge, there was only one published abstract that examined stock performance in relation to cardiovascular health. In a study with data from the Duke healthcare system, acute myocardial infarction with cardiac catheterization in 2008–2009 was inversely related to the opening value of NASDAQ Index. Therefore, these two independent analyses, while preliminary, suggest a possible link between stock performance and cardiovascular health.

With the booming economy in late 1990s and early 2000s, many individuals began to invest in stocks in many areas worldwide. For example, US families with direct or indirect stock investments increased from 40.4 to 48.6% between 1995 and 2004. In China, the number of stock trading accounts jumped from 8.4 million in 1993 to 129.4 million in 2008, a 15-fold increase in 16 years. After years of slow growth, the Chinese stock market performed extremely well in 2006 and 2007. The booming stock market in China attracted many new investors. Unfortunately, most of these new individual investors had little financial knowledge about investing and often had unrealistic expectations. Further, many of them were elderly retirees who spent much of their day sitting at the Stock Exchange hall to monitor the real-time performance of the stock.

Although we do not know exactly how fluctuations of stock market affect cardiovascular health, however it is reasonable to speculate that emotional and physical stress may play an important role. Both rising and falling of the stock markets may represent substantial emotional, psychological, and physical stress that may adversely affect cardiovascular health. The relationship of psychological stress to coronary diseases has already been well established. For example, episode of anger and marital stress have been associated with the increased risk of myocardial infarction. Also, the coronary microcirculation may fail to dilate under mental stress. Further, psychological stress blunts the augmentation of myocardial blood flow in regions without significant epicardial stenosis. Moreover, patients with pre-existing cardiovascular diseases may have exaggerated systemic responses to stress, including abnormal elevations of blood pressure, heart rate, and rate of ventricular contraction. In patients with coronary occlusion and myocardial ischaemia, mental stress may further decrease the threshold for ventricular fibrillation. Therefore, chronic stress may increase the risk of cardiovascular disease, and lead to unexpected deaths among patients with poor cardiovascular health.

Our additional analyses on the location of death further support the hypothesis that acute financial stress may adversely affect cardiovascular health. Out-of-hospital CHD death is often used as a surrogate for sudden cardiac death. Our analysis revealed a stronger association of daily Index change with out-of-hospital CHD death than with in-hospital death.

Compared with populations in developed countries, our study population is particularly suitable for the research on the health implications of stock volatility. Shanghai is the financial capital of China with 8.9 millions locally registered SSE accounts at the end of 2008, approximately 10 times higher than the national average. Further, the stock market in China was extremely volatile between 2006 and 2008. Finally, as mentioned earlier, many of the stock holders might be financially unprepared elderly investors who were more susceptible to adverse effects of emotional or physical stresses.

Our study also has several limitations. First, our analysis is ecological in nature which did not allow us to analyse individual-based data and had limited capacity for causal inference. Also due to the lack of individual data and detailed clinical information, we were unable to further characterize the outcome and examine in details how the circumstances of deaths affect our analysis. Second, our analysis is preliminary and exploratory; therefore, we could not exclude the possibility of a spurious finding or confounding due to unmeasured factors that are associated with both stock volatility and cardiovascular health. Further, this study was conducted within a unique susceptible population; therefore, the generalizability of our finding to other areas of the world is limited.
unclear. Nevertheless, preliminary observation in the USA seems to support our results. Third, the current analysis focused on CHD death, probably from patients with existing cardiovascular diseases. It is plausible that chronic financial stress may also lead to incident cardiovascular diseases among otherwise healthy individuals, which should be examined in future studies.

In summary, our analysis suggests that stock volatility may adversely affect cardiovascular health. This may represent a new and significant public health threat, particularly in booming economies such as China. Further research will, therefore, be needed to understand the public health implications of stock market fluctuation.

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**Conflict of interest:** none declared.

**References**
5. Goldberg BJ, Spencer F, Lessard D, Yarzebski J, Lareau C, Gore JM. Occurrence of acute myocardial infarction in Worcester, Massachusetts, before, during, and

![Figure 3](https://example.com/figure3.png)

**Figure 3** Percent increase in death due to coronary heart diseases for each 100-point (A) and 1% (B) change of the Shanghai Stock Exchange Composite Index, classified by different lag days.

<table>
<thead>
<tr>
<th>Location of death</th>
<th>Mean daily deaths (n)</th>
<th>100-point change</th>
<th>1% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>20.3</td>
<td>5.17 (1.71, 8.63)</td>
<td>1.87 (0.66, 3.09)</td>
</tr>
<tr>
<td>Out-of-hospital</td>
<td>10.2</td>
<td>6.09 (1.24, 10.94)</td>
<td>2.10 (0.38, 3.81)</td>
</tr>
<tr>
<td>In-hospital</td>
<td>10.1</td>
<td>4.15 (−0.79, 9.08)</td>
<td>1.63 (−0.09, 3.35)</td>
</tr>
</tbody>
</table>

*One-day lagged Absolute Index change was used.

Including deaths occurring in emergency departments, private homes, public places, nursing homes and infirmaries, as well as deaths among persons declared dead on arrival at a hospital.


