

# Differences of maternal mortality rate between Shanghai and New York city from the perspective of regulatory policy

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## Abstract

**Background:** Regulatory policy (RP) is known as a major factor to improve health care system performance. A significant difference in maternal mortality rates (MMRs) was observed between New York city (NYC) and Shanghai (SH), both first-class international metropolises. This study aims to adopt a quantitative evaluation model to analyze whether RP differences contribute to the different MMRs of the two cities.

**Methods:** Based on collection of all publicly released policy documents regarding maternal health in the two cities, we assessed and compared the status of their maternal health care RPs from 2006 to 2017 through a series of quantitative indicators as regulatory elements coverage rate (RECR), departmental responsibility clarity rate (DRCR), and accountability mechanism clarity rate (AMCR), based on two characteristics of comprehensiveness and effectiveness of RPs. Pearson correlation analysis, principal component analysis, and linear regression analysis were used to test the relationships between the indicators and MMR in SH and NYC.

**Results:** By 2017, disparities of maternal health care RP are found between SH and NYC, from the indicators of RECR (100% vs. 77.0%), DRCR (38.9% vs. 45.1%), and AMCR (29.2% vs. 22.5%). From 2006 to 2017, RECR, DRCR, and AMCR in SH have shown a higher growth of 8.7%, 53.2%, and 45.2%, compared with growth of 25.0%, 12.5%, and 2.9% in NYC. The three indicators were found all negatively correlated with MMR in SH (Coefficients = -0.831, -0.833, and -0.909, and  $P < 0.01$ ), while only RECR and DRCR had negative correlation with MMR in NYC (Coefficients = -0.736 and -0.683, and  $P < 0.05$ ). Linear regression showed that the principal components of the three indicators were found with significant impact on MMRs both in SH ( $R = 0.914$ ,  $R^2 = 0.836$ ,  $P < 0.001$ ) and NYC ( $R = 0.854$ ,  $R^2 = 0.357$ ,  $P = 0.04$ ).

**Conclusion:** Compared with NYC, the more comprehensive and effective maternal health care RPs in SH had a stronger impact on MMR control, which contributed to the differences between the two cities' MMRs to some extent. The methods and indicators we adopted for assessment are reasonable and comparable.

**Keywords:** Maternal mortality; Regulatory policy; Maternal health; Shanghai; New York

## Introduction

Maternal death, defined by the World Health Organization (WHO) as the death of a woman while pregnant or within 42 days of termination of pregnancy, is a great burden on the family and society<sup>[1]</sup> and has received worldwide attention. Given that a significant number of maternal deaths are preventable,<sup>[2,3]</sup> and obstetric complications are sensitive to the quality of care provided at

delivery,<sup>[4,5]</sup> the performance of a city's maternity health care system (MHCS) is a critical means for reducing maternal mortality rates (MMRs). Regulation, the use of the coercive power of the government to change the behavior of individuals and organizations in the health sector, is a major control knob to improve health care system performance.<sup>[6]</sup> A well-functioning regulatory policy (RP) is recognized as helpful for improving the performance of a health system.<sup>[7,8]</sup>

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There are a few published researches of health care RPs. Kabir *et al* employing qualitative research methods and a framework of basic regulatory functions for health care, identified gaps in the design and implementation of policies for health care regulation in two Indian states and explained these regulatory failures.<sup>[9]</sup> Charles *et al* explored the effectiveness of regulations directed at the private-for-profit sector (general practitioners, private clinics, and hospitals) in Zimbabwe through the use of stakeholder interviews, and identified some potential strategies for improving the regulatory environment.<sup>[10]</sup> However, the architecture of health care RPs received limited research, especially regarding maternal health care, and most studies are qualitative analyses.

Generally, more developed cities have lower MMRs. Shanghai (SH) in China and New York city (NYC) in the United States are both first-class international metropolises. In 2006, MMRs in SH and NYC were respectively  $26.2/10^5$ <sup>[11]</sup> and  $23.1/10^5$ <sup>[12]</sup> at the same level. But in 2017, MMR in SH ( $3.0/10^5$ )<sup>[13]</sup> showed significantly lower than that in NYC ( $21.5/10^5$ )<sup>[14]</sup>. Many studies have attributed the high MMR in NYC to racial disparity.<sup>[1,15,16]</sup> Considering that SH, a multi-ethnic settlement in China, also has health disparities between native and migrant populations,<sup>[17]</sup> there might be other factors in addition to racial disparities contributing to the different MMRs between SH and NYC. We wondered whether there were disparities in RPs that contributed to the difference between the MMRs in SH and NYC.

In this study, for a better evaluation of RPs of MCHS, the research team exploratively developed a quantitative evaluation model, including three indicators based on comprehensiveness and effectiveness of RPs. Through this evaluation model, we measured and compared the maternal health care RPs in SH and NYC from 2006 to 2017, to find the differences between them and analyze the influence of these differences on MMRs of the two cities.

## Methods

### Ethical approval

This study is a third-party evaluation on RPs which does not involve human biological experiments, and the data of MMRs were from publicly official reports. Ethical approval should be exempted.

### Design

In this evaluation, we selected SH and NYC as comparison objects for the following reasons. First, in 2006 to 2017, SH and NYC showed significant differences in MMR trends, helping to analyze the impact of different RPs on MMR. Second, according to The World According to GaWC 2018 compiled by Globalization and World Cities Study Group and Network, SH and NYC, respectively belong to alpha + and alpha ++ global cities. There are only eight cities in the world with rating above alpha +, of which NYC ranks second and SH ranks sixth. This indicates that SH and NYC have similarities in multiple dimensions of urban development, which could be helpful in

controlling the confounding factors as population size, income, obstetric technology, health workforce, and so on.

For quantitatively evaluating the RPs of MHCS, first, we identified four high-priority maternal health issues as representative objects, around which the evaluation would be carried out. Second, we developed an evaluating model derived from two characteristics for RPs, including three qualitative standards for well-performing RPs and three accordingly quantitative indicators. Third, we systematically collected data from SH and NYC, and used the evaluating model to analyze the differences of RPs between the two cities. At last, we statistically analyzed the influence of RPs on MMRs in SH and NYC.

### High-priority maternal health issues

Based on a systematic review,<sup>[18]</sup> four high-priority maternal health issues were identified to assess maternal health care in this study. The first is the screening and management of high-risk pregnant women who may have conditions such as gestational hypertension, gestational diabetes, ectopic pregnancy, preterm birth, and spontaneous abortion. The second is prenatal health care, including maternal and child disease, birth defect screening, management of maternal nutritional disease (including night blindness, anemia), reproductive tract infection, and maternal diarrhea. The third is intrapartum safety, including infection, hemorrhage, and neonatal asphyxia. The fourth is postpartum care, including postpartum sepsis and depression. In this study, we assessed the MHCS mainly considering these four issues.

### Evaluating model for regulation policies

In this study, two characteristics were raised for evaluating RPs. One is "Comprehensiveness" representing the scope of the policy content, and the other is "Effectiveness" reflecting whether the policy can be effectively implemented. From Comprehensiveness and Effectiveness, three qualitative standards and three quantitative indicators were proposed. These characteristics, standards, and indicators together make up the evaluating model for RPs [Table 1].

### Comprehensiveness of regulation policies

The running of MHCS involves many elements,<sup>[9,19]</sup> including intangible elements like objectives, tasks, responsibilities, planning, assessment, evaluation, incentives, and so on, as well as tangible elements such as organization, human resource, finance, material, and so on. Generally, RPs should cover these elements to regulate the running of MHCS. Therefore, we developed the first qualitative standards [Table 1]: well-functioning RPs should have comprehensive coverage of essential regulatory elements.

Aiming to quantitatively assess the coverage of essential regulatory elements for RPs in MHCS, we developed 25 elements that RPs of a well-functioning health system should cover, including long-term and short-term objectives, measures and services, agencies, staffing, funding, material supplies, information system, surveillance, responsibilities,

**Table 1: Evaluation model for regulation policies.**

Characteristics	Qualitative standards	Quantitative indicators	Definition of indicators
Comprehensiveness	Comprehensive coverage of essential regulatory elements	Regulatory elements coverage rate (RECR) (%)	Average number of regulatory elements covered in a city’s maternal health policy file collection out of 25 regulatory elements that should be covered concerning each of the four maternal health issues.
Effectiveness	Well-defined responsibility of stakeholders involved in MHCS	Departmental responsibilities clarity rate (DRCR) (%)	Average number of departments with clear and measurable responsibility out of the 15 departments that should be included in MHCS concerning the four maternal health issues.
	Well-defined regulator and accountability mechanism	Accountability mechanism clarity rate (AMCR) (%)	Average number of departments with clearly defined monitoring agencies and accountability out of the 15 departments that should be included in MHCS concerning the four maternal health issues.

monitoring, assessment indicators, coordination and incentives, and so on [Supplementary Table S1, <http://links.lww.com/CM9/A201>]. A 30-member expert panel, which included policy makers, practitioners, and researchers who were experts engaging in maternal health practice or performance evaluation, all agreed on and confirmed the 25 essential regulatory elements which need be covered by health policies. On this basis, a quantitative indicator was developed namely regulatory elements coverage rate (RECR), whose definition was detailed in Table 1.

**Effectiveness of regulation policies**

Promoting maternal health requires multi-sectoral involvement.<sup>[20]</sup> The clear responsibilities of stakeholders are considered to be the key factors for the effective implementation of health policy and an important aspect of the RP. Therefore, we propose the second qualitative standards: a well-functioning RP should well-defined responsibilities of stakeholders involved in MHCS.

In addition, establishing an effective accountability mechanism is the important measure to guarantee effectively implementation of responsibilities. To strengthen accountability in maternal health has become an important agenda item for actors such as the United Nations and the international community since the millennium development goals (MDGs) were signed by 189 countries in 2001.<sup>[21]</sup> In light of this, we raised the third qualitative standards: a well-functioning RP should have well-defined accountability mechanism.

For quantitatively evaluating whether the responsibilities and accountability were well-defined in RPs, the scope of stakeholders involved in MHCS should be identified primarily. According to policy documents from the WHO,<sup>[20]</sup> the United States<sup>[22]</sup> and China,<sup>[23]</sup> we identified at least 15 stakeholders that should be included in a well-performing city MHCS, including governments at all levels, four actors in the health sector (department of health [DOH] and three types of health providers: public health agencies/ hospitals/primary health care providers), four key support departments (policy/finance/human

resources/insurance), five other support departments (sectors of education/welfare/agriculture/construction/water) and non-governmental organizations (such as associations, foundations, and universities).

On this basis, two quantitative indicators were adopted, respectively named departmental responsibility clarity rate (DRCR) and accountability mechanism clarity rate (AMCR), whose definition was detailed in Table 1.

**Data collection**

**Maternal health-related policy documents collection**

In this study, we assessed the RPs of the MHCSs in SH and NYC by analyzing the publicly released maternal health-related policy documents, including bills, laws, regulations, strategies, norms, rules, plans, budgets, guidelines, and standards. Relying mainly on the websites of legislature, government, health departments, and public health agencies and, in complement, on search engines (google.com, baidu.com., etc) and legal databases (govt.westlaw.com, law-lib.com), we collected all policy documents as of the year 2017 in SH and NYC, under the principle of “as much as possible” and “publicly released.” In total, we collected 417 policy documents in SH and 301 in NYC.

**Assessing information collection and reliability test**

The maternal health policy documents collected from SH and NYC were compiled as a city-consolidated maternal health policy collection. We collected information on aspects including “document release year,” “regulatory elements,” “departmental responsibilities,” “regulatory agencies,” and “penalties” concerning the four high-priority issues from each document in the policy collection. We took the “regulatory elements” as an example. For each document, corresponding to the list of elements in the Supplementary Table S1, <http://links.lww.com/CM9/A201>, we collected the regulatory elements involved regarding each issue. Summarizing all document excerpt results, the number of regulatory elements involved in the policy collection could be calculated.

In this study, the test-retest reliability method with the intra-group correlation coefficient (ICC) as a reliability coefficient was adopted to analyze the credibility of the data collection. After retesting by two experienced researchers, the ICC was 0.943, greater than 0.75, which suggested high credibility of the data collection.

**MMRs collection**

It is until 2006 that the MMR data of whole population began to be public released in SH, while only MMR data of household population could be found in SH before 2006. In light of this, for comparability we collected MMR data of SH and NYC in the period of 2006 to 2017 to analyze the disparity of MMR in the two cities. MMR data from 2006 to 2017 were collected from the vital statistics in NYC<sup>[14]</sup> and the health statistics bulletin in SH.<sup>[13]</sup>

**Data analysis**

We used Microsoft Excel 2016 (Microsoft, Redmond, WA, USA) to create a database for data processing. We performed statistical analyses using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA).

To study the trends of MMR and RM indicators in the two cities and to reduce the impact of outliers, we divided the study period into a 3-year moving time window (2006–2008, 2007–2009, . . . , 2015–2017), totally including ten-time windows. In each time window, the MMR is maternal deaths per 10,000 live births in the 3 years, and the results of the three indicators in model are the values of the first year, in light of the lag in full implementation and impact of policies. The examples of calculation formula are as follows:

$$MMR_{3\text{ years}} = \frac{\text{Maternal Death Cases}_{3\text{years}}}{\text{Live Birth Cases}_{3\text{years}}} \times 100,000$$

$$\text{Indicator}_{2007-2009} = \text{Indicator}_{2007}$$

We adopted the Pearson Correlation test to respectively examine the relationship between three indicators and MMR in the two cities, and combinedly used principal component analysis and linear regression analysis to synthetically analyze the influence of RPs on MMR. All *P* values were double sided, and confidence interval is 95%.

**Results**

**Comparison of RP indicators and MMRs of NYC and SH in 2017**

In terms of comprehensiveness of RPs, RECR had reached 100% in SH and 77.0% in NYC by 2017, which showed 29.9% higher in SH than in NYC [Table 2]. The RPs for the four priority issues in SH were found covering all 25 regulatory elements, while in New York the RPs still not covered the terms of workflow, coordination and accountability mechanisms, and so on [Supplementary Table S1, <http://links.lww.com/CM9/A201>].

**Table 2: The comparison of indicators in NYC and SH by the year 2017.**

Indicators	NYC	SH	Disparity (%)*
RECR (%)	77.0	100.0	29.9
DRCR (%)	45.1	38.9	-13.7
AMCR (%)	22.5	29.2	29.5
MMR (1/10 <sup>5</sup> live birth)	21.4	3.0	-85.9

\*Disparity (%) = (Value of SH – value of NYC)/Value of NYC×100%. NYC: New York city; SH: Shanghai; RECR: Regulatory elements coverage rate; DRCR: Departmental responsibilities clarity rate; AMCR: Accountability mechanism clarity rate; MMR: Maternal mortality rate.

In terms of the effectiveness of RPs, DRCR in SH (38.9%) was 13.7% lower than that in NYC (45.1%), and AMCR in SH (29.2%) showed 29.5% higher than that in NYC (22.5%). Although the departmental responsibilities were more clearly defined in NYC than in SH, the accountability mechanism on maternal death-related issues was not well defined in NYC.

**Trends analysis of RP indicators and MMR in NYC and SH from 2006-2017**

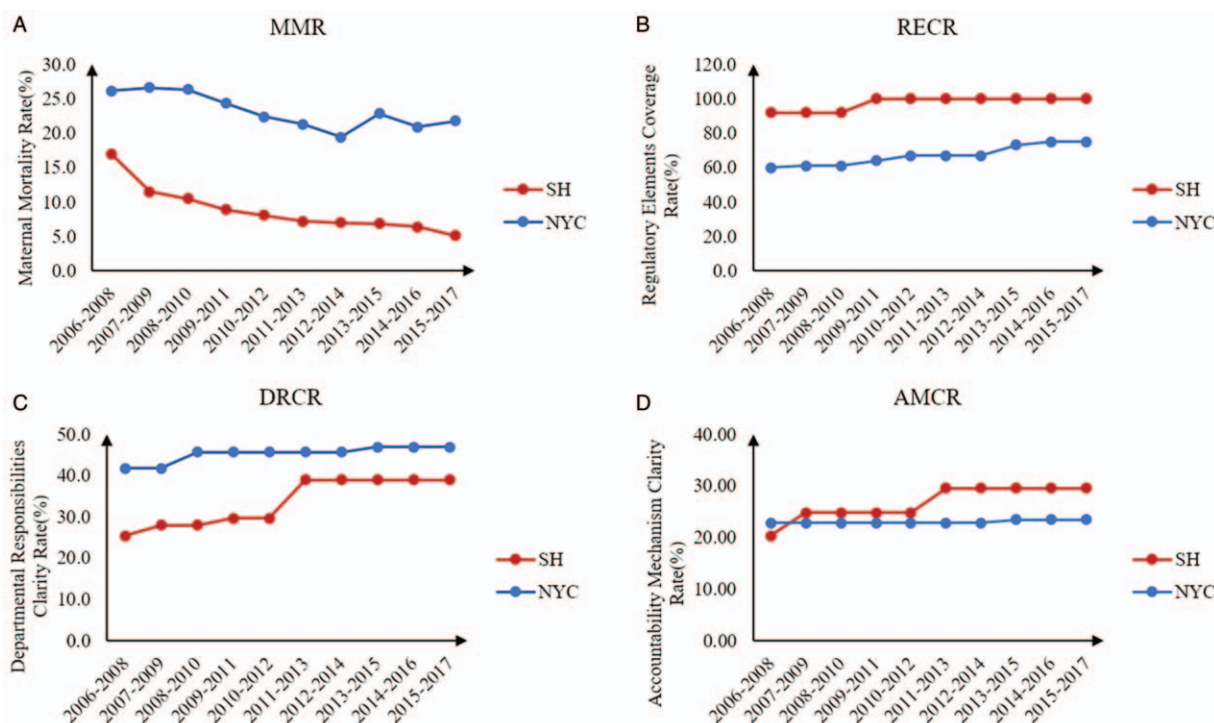
The three RP indicators of the MHCS in SH and NYC showed gradual growth trend from 2006 to 2017 [Figure 1B–D]. Shown as Table 3, RECR in SH grew from 92% (2006–2008) to 100% (2009–2011), and the growth was 8.7%, compared with a higher growth of 25.2% in NYC from 2006 to 2017. The DRCR and AMCR in SH showed higher growth of 53.2% and 45.2% from 2006 to 2017 [Table 3], compared with growth of 12.5% and 2.9% in NYC.

In the year of 2006, RECR showed higher in SH than NYC, while DRCR and AMCR were lower in SH than NYC, which suggests that the departmental responsibilities and accountability were defined worse compared with NYC at that time. However, up to the year of 2017, DRCR and AMCR had grown more apparently in SH than in NYC, and AMCR in SH had exceeded that in NYC. The trends suggest that the government of SH has attached importance to improving the effectiveness of RPs regarding MHC, while NYC seems to take less action to improve its RP.

**Correlation analysis between RP indicators and MMR in SH and NYC**

With the growth of three RP indicators in the two cities, the MMRs of SH and NYC presented a gradually declining trend [Figure 1A–D], suggesting that trends between them in SH and NYC might be correlated to some extent. Through the Pearson correlation test [Table 2], RECR, DRCR, and AMCR were found all negatively correlated with MMR SH (Coefficients = -0.831, -0.833, and -0.909, and *P* < 0.01). In NYC, RECR, and DRCR had negative correlation with MMR (Coefficients = -0.736 and -0.683, and *P* < 0.05), while AMCR was not significantly correlated with MMR (*P* = 0.282).

To analyze the comprehensive impact of RPs on MMR in two cities, we respectively extracted the principal



**Figure 1:** Trends of RP indicators and MMRs in NYC and SH from 2006 to 2017. (A) Trends of MMR (1/10<sup>5</sup> live birth) in SH and NYC from 2006 to 2017; (B) Trends of RECR (%) in SH and NYC from 2006 to 2017; (C) Trends of DRCR (%) in SH and NYC from 2006 to 2017; (D) Trends of AMCR (%) in SH and NYC from 2006 to 2017. AMCR: Accountability mechanism clarity rate; DRCR: Departmental responsibilities clarity rate; MMRs: Maternal mortality rates; NYC: New York city; RECR: Regulatory elements coverage rate; SH: Shanghai.

**Table 3: The trends of RP indicators and MMR in NYC and SH from 2007 to 2016.**

Indicators	2006–2008	2007–2009	2008–2010	2009–2011	2010–2012	2011–2013	2012–2014	2013–2015	2014–2016	2015–2017	Pre-post change (%)	Pearson correlation coefficient (with MMR)	P-value
<b>NYC</b>													
RECR (%)	60.0	61.0	61.0	64.0	67.0	67.0	67.0	73.0	75.0	75.0	25.0	-0.736	0.015
DRCR (%)	41.7	41.7	45.6	45.6	45.6	45.6	45.6	46.9	46.9	46.9	12.5	-0.683	0.029
AMCR (%)	22.8	22.8	22.8	22.8	22.8	22.8	22.8	23.4	23.4	23.4	2.9	-0.378	0.282
MMR (1/10,000 live birth)	26.1	26.6	26.3	24.3	22.4	21.3	19.4	22.8	20.9	21.7	-16.8	-	-
<b>SH</b>													
RECR (%)	92.0	92.0	92.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	8.7	-0.831	0.003
DRCR (%)	25.4	27.9	27.9	29.6	29.6	38.9	38.9	38.9	38.9	38.9	53.2	-0.833	<0.001
AMCR (%)	20.3	24.7	24.7	24.7	24.7	29.5	29.5	29.5	29.5	29.5	45.2	-0.909	<0.001
MMR (1/10,000 live birth)	17.0	11.5	10.5	8.9	8.0	7.2	7.0	6.8	6.3	5.1	-69.9	-	-

\*Pre-post change (%) = (value in 2014–2016 – value in 2007–2009)/value in 2007 to 2009 × 100%. NYC: New York city; SH: Shanghai; RECR: Regulatory elements coverage rate; DRCR: Departmental responsibilities clarity rate; AMCR: Accountability mechanism clarity rate; MMR: Maternal mortality rate.

components (PC<sub>SH</sub> and PC<sub>NYC</sub>) of the three indicators through principal component analysis, and we used Linear Regression to test the relation between PCs and MMRs. As shown in Table 4, in NYC, Kaiser-Meyer-Olkin value (KMO) = -0.571, *P* < 0.001, contribution = 84.18%; in SH, KMO = -0.673, *P* < 0.001, contribution = 87.96%. The linear regression model [Table 4] showed PC<sub>SH</sub> and PC<sub>NYC</sub> with significant impact on MMRs (*P* < 0.05), and the impact seemed stronger in SH (*R* = 0.914, *R*<sup>2</sup> = 0.836, *P* < 0.001) than in NYC (*R* = 0.854, *R*<sup>2</sup> = 0.357, *P* = 0.04).

This suggested that the difference of maternal health care RPs in the two cities might be a factor promoting the difference between the MMRs in SH and NYC.

**Discussion**

In a MHCS, RPs play an important role, relating in various ways to perfecting or correcting the results produced by economic markets. Any society relying on market

**Table 4: Statistical analysis between RP indicators and MMR 2006 to 2017.**

Cities	Principal component analysis (PCA)				Linear regression analysis*			
	KMO	P-value	Component	Contribution	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	P-value
NYC	0.571	<0.001	1	84.18%	0.654	0.428	0.357	0.04
SH	0.673	<0.001	1	87.96%	0.914	0.836	0.815	<0.001

\* MMR as dependent variable; PCs as independent variable. KMO: Kaiser-Meyer-Olkin value; NYC: New York city; SH: Shanghai.

exchange mechanisms must ensure that exchanges and transactions are done honestly and openly.<sup>[24,25]</sup> In particular, markets cannot deal with unequal distribution of income and varying health needs, and health-sector markets often do not possess the requisite conditions for reasonably effective competition.<sup>[26-28]</sup> Therefore, there is a need for a basic set of rules that define power, responsibility, and accountability of the various players in maternal health market transactions.

Structure-process-result conceptual framework<sup>[29,30]</sup> is a recognized tool for studying health systems. RP, as a structural factor, regulates and binds the behavior of the MHCS. By its regulatory role, RP could influence resource supply and organization coordination at structure level, promote the quality of maternal health care services at process level, and then improve the MMR at result level through the influence logic of structure-process-results. As our results indicated, from 2006 to 2017, there was a significantly negative correlation between the change trends of maternal health RP indicators and MMR in SH and NYC, which supported the positive effects of RP on improving the MMR. Therefore, the differences of maternal health care RPs between SH and NYC did contribute to the differences of their MMR to some extents.

From a comprehensive perspective, the RP in SH covered more regulatory elements in its maternal health policy collection than RP in NYC by 2017. Approximately 26% of the elements, on average, were not found in NYC's policy collection [Table 1]; missing elements included procedures for maternal health care service, department coordination and standards for assessment indicators. The lack of comprehensiveness of RP means that these aspects have not formed a clear working mechanism, which may reduce the operational effect of MHCS in NYC.

Taking the service procedure as an example, while prenatal, intrapartum, and postpartum care are often provided by different agencies based on their abilities to ensure the most appropriate level of care at delivery, it is essential to develop a procedure to connect and integrate these services. Our results revealed no clear process depiction in NYC's maternal health policy collection, which would be obstructive to the performance of the MHCS. Researchers from NYC also recognized this point and proposed "Fragmentation in maternal health care" as a focus areas for the 2018 New York Maternal Mortality Summit.<sup>[31]</sup> Compared with NYC, an integrated process of pregnancy risk warning assessment management was clearly depicted in the policy documents of SH in 2012, which greatly promoted the combination of prevention

and treatment. An evaluation study on the effect of pregnancy risk warning assessment in Shanghai showed that it effectively reduced the risk of maternal mortality.<sup>[32]</sup>

Taking coordination as another example, maternal health care requires the participation of multiple departments. There is in need of regulation of coordination to integrate these sectors for cooperating around maternal health. Shanghai sets up a joint conference of public health with 34 departments involved, in which maternal health is an important topic. As the work points of joint conference in the 2017, municipal departments of health, public security, propaganda, industry, commerce, and so on were required to cooperate and strengthen maternal risk warning, maternity emergency aid, and puerperal health care. Moreover, for the timely difficulty of consultation and referral, relying on the advanced general hospitals five centers for maternal emergency aid were established in SH, and each one was appointed to be responsible for definite areas, forming an effective and timely responding maternal safety network.<sup>[33]</sup> The network has fully utilized the role of high-quality medical resources to achieve the effective coordination on maternity emergency aid, and effectively promote the rescue success rate.<sup>[33]</sup> Since the establishment of the network to 2017, more than 3760 critically ill pregnant women have been treated, with a success rate of 98%.

From an effective perspective, compared with SH, the accountability mechanism on maternal death-related issues was not well defined in NYC by 2017. Accountability mechanisms were included in international declarations as a means to ensure accomplishment of the MDGs.<sup>[34]</sup> In SH, the DOH was well defined as an external accountability agency for the three types of maternal health care providers (maternal & child health care center, hospitals, and community health care centers).<sup>[35,36]</sup> Taking hospitals as an example, according to the regulations from the SH government, maternal deaths, especially preventable cases, would downgrade the performance evaluation of the hospital and its dean, which might influence government funding and the position of the dean. As a result, pregnant women with a risk of death always receive the highest quality of intrapartum care, for example, regional expert consultation and high priority of blood supply. In NYC, the DOH and mental hygiene was authorized by the NYC Chapter to review and supervise the performance of health providers.<sup>[37,38]</sup> However, no clear accountability mechanisms regarding maternal health care from providers could be found in the NYC policy collection. It appeared that providers would receive no penalty.

Although SH has a better performance concerning MMR and maternal health care RP than NYC, there are still deficiencies in SH's maternal health care RP. As shown in our results, the clarity of the departmental responsibilities in the MHCS of SH was still at a low level; only four health stakeholders (DOH, maternal & child health care centers, hospitals, and community health care centers) had clear and measurable departmental responsibilities listed in the maternal health policy collection, while no well-defined departmental responsibilities related to maternal health were found concerning key support departments (policy/finance/human resources/insurance) and other support departments (sectors of education/welfare/agriculture/construction/water). In light of the opinion of the WHO that approximately half of the achievements in the field of maternal health come from inputs outside the health sector,<sup>[20]</sup> SH still needs to well define the responsibilities of the key and other support departments regarding maternal health.

In addition to the differences of RPs in the cross-sectional perspective, there was also disparity in the improving trends of the RPs in SH and NYC. Our results indicated that the maternal health RP significantly improved from 2006 to 2017 in SH, while the RP only slightly improved in NYC [Figure 1B–D]. The trends showed that, SH had put high importance to the regulating its MHCS. Beginning in 2007, Shanghai launched a second round of Three-Year Action Plan of Strengthens Public Health System Construction on the theme of maternal health, lots of maternal health care RPs were launched. A number of studies have confirmed the positive impact of these policies on maternal mortality reduction.<sup>[32,33]</sup> Compared with SH, NYC did not seem to attach enough importance to the RP regarding maternal death in this period. This could have undesirable effects, as summarized by the 2018 New York Maternal Mortality Summit: “*With some notable exceptions, much of the historical work of MCH places an emphasis on infant and child health, with a lack of focus on the mother.*”<sup>[31]</sup> The results of PCA and linear regression in this study show that the impact of RP on MMR in NYC is not as significant as that in Shanghai, which indicates that the maternal health care RP in NYC has not played a strong improving effect on maternal mortality reduction.

However, currently, there are efforts to increase the emphasis on maternal health in NYC. In 2017, the NYS DOH convened a multidisciplinary Perinatal Standards Expert Panel to review and update the standards and requirements for hospital-level designations,<sup>[39]</sup> which will ensure that an increased emphasis on maternal health is a priority for the future designation of perinatal care services within hospitals.<sup>[31]</sup>

Though the exploratory quantitative evaluation method, we evaluated RPs of MHCS in SH and NYC. Showing as the results, the historical evolution of RPs can explain the changes of MMRs in SH and NYC to a certain extent, which was consistent with theoretical analysis. And the differences of maternal health RPs between the two cities were achieved by our evaluation. These results indicated that the exploratory evaluation we conducted could truly reflect the state of RPs of MHCS to some extent and suited

for inter-regional comparisons, which showed the value of this evaluation method in practice. Moreover, the data in this evaluation, not provided from local government, was collected from publicly released policy documents, which improved the operability and objectivity for evaluation by third parties. In summary, this exploration of quantitative evaluation for RPs in this study is scientific and reasonable, and with feasibility to evaluate the status of MHCS.

Our study innovatively analyzed the structure of the MHCSs in SH and NYC through the assessment of RPs. The exploration of quantitative evaluation for RPs in this study is scientific and reasonable, which could be a new method for assessing the structure of health systems. However, limitations also existed in our study. MHCS performance may be affected by many factors in addition to RP, such as the health literacy of the population, financial and human resources, political and economic environment and organizational structure, which would also contribute to the differences of MMR between SH and NYC. Such factors are inter-connected and interact in a health system. Further studies are needed to verify these relationships and their contributions to the disparity of MMR between SH and NYC.

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### Conflicts of interests

None.

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