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The burden of travel for care and its influencing factors in China: An inpatient-based study of travel time

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ABSTRACT

Introduction: Travel burden is a key dimension in conceptualizing geographic access to health care. Travel time measured from the perspective of actual utilization provides practical evidence on healthcare-related travel burden, while studies in this aspect remain limited, especially under the context of China's healthcare system. This study aimed to bridge the research gap by describing the current situation of travel burden as well as its related influencing factors in China.
Methods: Hospital discharge data which involved over 300 million inpatients from Sichuan province, China, was used. Travel burden was measured by the modeled utilization travel time spent on road trips from patients' residential locations to hospitals they were admitted. Quantile regression and mutilevel linear model were adopted to examine different effects posed by various determinants on travel time across the travel burden spectrum.
Results: The average modeled utilization travel time was 23.14 min in Sichuan China, while 236,988 patients had to spend over 1 h driving to obtain medical services. The regressions indicated that inpatient's travel time spent across the travel burden spectrums was positively affected by multiple factors including urban employment basic medical insurance insured, being admitted through the emergency department, being in general condition when getting admitted, having more complications, travel time to the nearest hospital. Moreover, travel time spent by inpatients among groups with heavy travel burdens could be dramatically decreased by enhanced availability of high-quality health care or improved transport infrastructure.
Conclusion: Healthcare-related travel burden was found to be generally acceptable in Sichuan province, China, while travel burden demonstrated large disparities among different regions. These regression findings provided evidence-based implications to inform future policy-making procedures in terms of alleviating healthcare-related travel burden via the optimization of health resources or improving road constructions, especially for residents under heavy travel burdens.

1. Introduction

Travel burden for care, which is an important component of healthcare-induced burden posed on worldwide residents who attempt

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to seek medical services, is also considered as a key dimension in conceptualizing geographic access to health care (Luo and Wang, 2003; Neutens, 2015; Penchansky and Thomas, 1981). Accurately describing travel time and distance needed by individuals seeking health care while identifying the related factors are very much likely to contribute to improved accessibility of health care via the provision of practical evidences needed for optimizing medical resource allocations, thus further facilitating the promotion of population health (Probst et al., 2007; Wang et al., 2021; Weiss et al., 2020). Increased travel time spent on attending medical visits would not only disrupt patients' normal life patterns, but also result in increased time and cost burden posed on both patients and their caregivers (Canupp et al., 1997; Sechrist et al., 2018; Zucca et al., 2011). For example, Zucca et al. discovered that cancer patients who had heavy travel burden over the first year after diagnosis reported significantly heavier travel-related financial burden than those who reported the absence of heavy travel burden during the corresponding post-diagnosis period (Zucca et al., 2011). According to previous literature in this field, quite a number of studies have examined the negative association of increased travel time with patients' treatment outcomes (Goodman et al., 1997; Hu et al., 2013; Kai et al., 2020; Kelly et al., 2016; Lawson et al., 2013; Learmonth, 1985). For example, in a cross-national, multicenter cohort study, Chen and colleagues identified positive association between increased travel time and the odds of poor functional status (severe disability in daily life) based on the Modified Rankin Scale designed for assessing trauma patients (Chen et al., 2020). In another study, Konerding et al. suggested that health-related quality of life among patients with type 2 diabetes might be improved by reduced travel time needed for accessing medical services (Konerding et al., 2017).

Raising sufficient awareness of travel burden posed on patients in a particular region as well as identifying its related region-specific influencing factors has great potential to facilitate the promotion of population health and the reduction of financial burden posed on disease treatments, especially for developing countries where both public and private transportation systems remain relatively underdeveloped. In China, striving to achieve the goal of "Health for All", the Chinese government has launched the national healthcare reform since 2009 via the implementation of a series of policies as well as considerable financial investments made for building the infrastructure of nationwide medical institutions and improving the quality of medical services delivered (Yip et al., 2019; Yip and Hsiao, 2009). As the result, a significant increase in the number of nationwide hospitals as well as greatly improved medical service delivery capacity among medical institutions was witnessed in China after the initiation of the healthcare reform in 2009 (Jiang and Pan, 2020). Despite such remarkable achievements made through the nationwide healthcare reform, China still has a long way to go before the ultimate goal of "Health for All" is universally achieved. As indicated by a national survey conducted by China's National Bureau of Statistics on populations residing in rural impoverished counties (representing over 300 million people), in the year of 2018, 80.3% of the sample population failed to seek health care as they lived "too far from medical institutions" (*China rural poverty monitoring report. 2018, 2019*). According to this survey, poor geographic accessibility of health care was considered as the primary reason for not acquiring health care in a timely manner (*China rural poverty monitoring report. 2018., 2019*), which therefore highlighted the necessity of reducing travel burden posed on patients as well as improving the geographical accessibility of medical services as urgent issues to be addressed under the context of China's healthcare system.

Previous studies focused on investigating travel burden for health care in China were mainly conducted from the perspective of potential geographic access (Chen and Pan, 2020; Pan et al., 2016; Wang et al., 2018), while evidence collected from the perspective of actual medical service utilization remain extremely limited. Unlike the actual travel burden (the distance covered, or time spent from the place of residence to the hospital patients were admitted), the potential geographic access mainly reflects the shortest distance or time that would take for patients to reach the nearest medical institution. In practical, the latter indicator has great limitations as it is based on the assumption that patients would always choose to visit the nearest medical institution when health care is needed, which, however, is usually not the case in the reality. Firstly, the distance covered or time needed for accessing the nearest medical service spot available fails to take into account the varied medical service capacity of different medical institutions, since not all medical institutions have the capacity to treat all kinds of diseases (Guagliardo, 2004; Kaufman et al., 2016; Mohr et al., 2017). Secondly, the shortest distance or time calculated based on this assumption ignores patients' subjective choosing behaviors among different medical institutions. Specifically, as the quality of a particular type of health service item typically demonstrates large disparities among different medical institutions may be of different quality for patients, it is not uncommonly found in the reality that patients would skip their nearest medical service spot due to service quality concerns (Alford-Teaster et al., 2016; Liu et al., 2008; Sanders et al., 2015). Given such flaws embedded in the assumption as discussed above, quite a number of scholars highly recommended that the analysis of travel burden be conducted by policy-makers from the perspective of actual medical service utilization instead of merely using potential travel burden as an indicator reflective of patients' accessibility of medical services (Hawthorne and Kwan, 2012, 2013; Lin et al., 2005).

As a response to improved awareness of addressing travel burden posed on patients as a critical issue, increased public attention has been paid to the identification of key factors associated with travel burden that would pose huge hinderance on patients obtaining medical services in a timely manner, based on which evidence-based implications would be provided to assist policy-making procedures. Existing empirical studies have been mainly focused on investigating travel burden posed on certain groups of people, such as the user of mammogram services (Probst et al., 2007), and those who came from developed countries. As the result, there has been a paucity of empirical research aimed at exploring the determinants of travel burden under the particular context of the general population in China. Based on inpatient discharge data which contains health-related information of more than 300 million residents, this study aimed to quantify residents' travel time needed for obtaining health care as a commonly adopted indicator in this field of study to evaluate travel burden posed on patients as well as to explore its related influencing factors. Our findings are expected to bridge the research gap in China, to inform future policy-making procedures related to healthcare resource allocation and health program planning, as well as to provide evidence-based implications to other countries confronted with similar challenges.

2. Study area and data

2.1. Study area

Based on data collected from Sichuan province, China, the findings produced by this study had the capacity to reflect the nationwide situation to a certain extent from a holistic perspective. Specifically, Sichuan province is located in southwest China (Fig. 1 (a)), with a landscape of 486,052 km^2 and 83.47 million residents as reported in 2019 (Statistics Bureau of Sichuan, 2018). It is the fifth-largest province in land size and the fourth largest by population in China. Sichuan can be categorized into two geographic zones, namely western Sichuan with comparatively less developed road network and economy, and eastern Sichuan, with well-developed transportation and economy (Fig. 1 (b) and 1 (c)). In China, all hospitals could be classified into three levels as primary, secondary, and tertiary hospitals based on their responsibilities, hospital capacity, and the quality of medical services. Higher hospital levels are typically associated with better quality of medical services delivered to patients (Peng et al., 2014). Fig. 1 (d) indicates the unevenly distributed health resources across the province, where the western area has sparsely distributed hospitals while the eastern area has relatively densely distributed hospitals at higher levels. There are distinctively large disparities embedded in the distribution of road networks, regional economic development status as well as the development of health services among different regions in Sichuan Province, which presents to be similar with the nationwide situation of China from a holistic perspective, thus having the potential to improve the generalization of the findings of our study.

2.2. Data

Hospital discharge data collected across Sichuan province, China, during the fourth quarter of 2017 (from September to December) was adopted for analysis in this study which was offered by the Health Information Centre of Sichuan Province. The patient-level information contained by the datasets included age, gender, address, marital status, diagnoses, health insurance, disease status and sources of hospital admission. The hospital-level-related information included the hospital ID, institutional address, and hospital level which comes from the hospital administrative data annually reported by the hospital at the end of each year. The city-level and county-level (where the patient lives) information used in this study included GDP per capita, hospital beds per thousand, while the length of highway per square was extracted from Sichuan statistical yearbook of 2018. After excluding inpatients with missing values, 3,001,237 inpatients (97.8% of the total) remained for analysis in this study. Table 1 presents the details of data cleaning process.

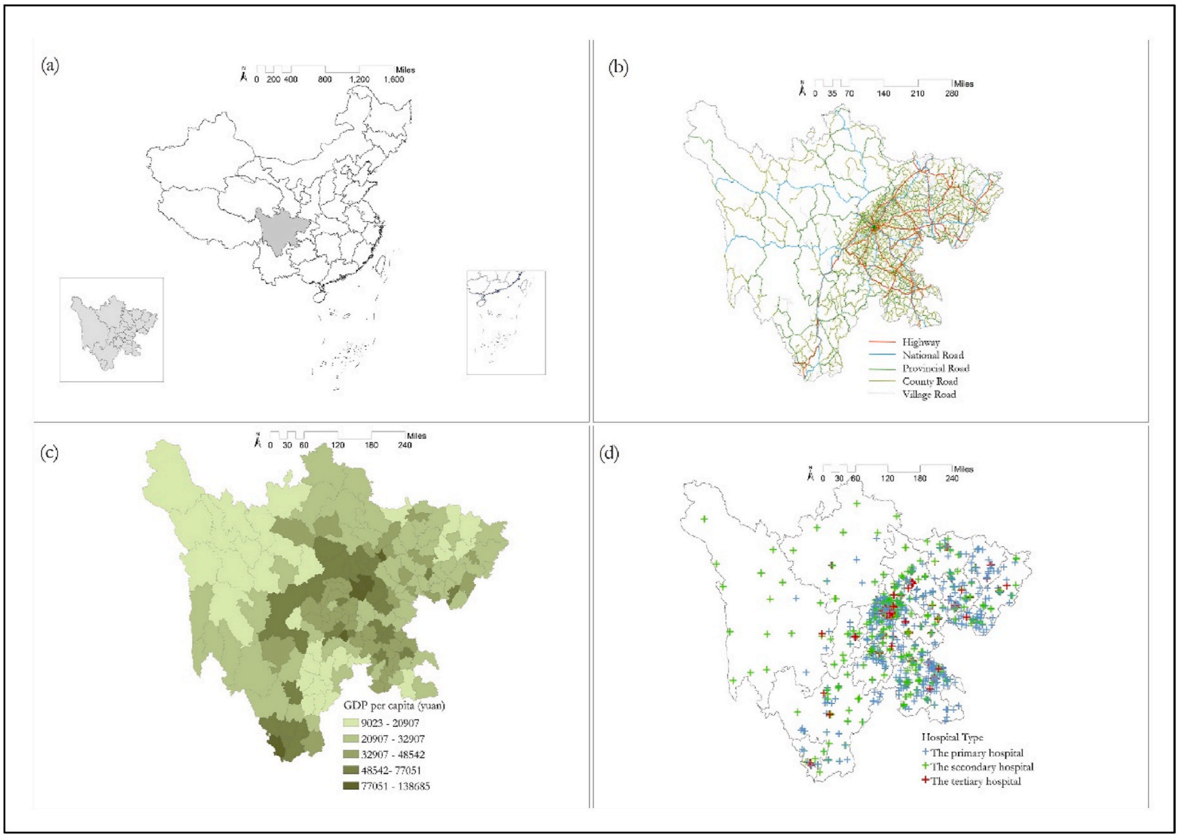

Fig. 1. Geographic location (a), transportation (b), GDP per capita (c), and hospital distribution (d) in Sichuan Province, China, in 2017.

3. Methods

3.1. Travel burden for health care

Based on Baidu Map Application Program Interface, travel burden was measured by the travel time needed by patients to drive from their location of residence to the hospital they were admitted to without considering road congestion. For further analysis, we divided the modeled utilization travel time into five categories, namely 0–10 min, 10–30 min, 30–60 min, 60–120 min, and over 120 min, and calculated the ratio of patients under each category. As it is widely known and accepted that the mortality rate will be sharply reduced if appropriate medical interventions are given within 60 min (Golden Hour), especially within 10 min (Platinum Ten Minutes) after traumatic injury, 10 and 60 min were used as thresholds in this study. The 30-min threshold was also added to indicate the amount of individuals who managed to achieve China's goal of 30-min access to health care (State Council, 2016). In addition, we added a 120 min threshold to reflect the heavy travel burden posed by the group of people who had to spend exceptionally long time on the road in seeking hospital's services.

3.2. Influencing factors analysis of travel burden for health care

Influencing factors of health services utilization is multidimensional. According to the Behavioral Model of Health Services Use proposed by Andersen, there are four dimensions: 1) individual characteristics, 2) contextual characteristics, 3) health behaviors, 4) outcomes (Andersen et al., 2014). Considering the availability of data, this study selected two dimensions including individual and contextual characteristics. Table 2 shows the variables included in our study. Individual characteristics include demography (age, gender) (Hulka and Wheat, 1985), social (marriage, occupation) (Wandera et al., 2015), organization (the shortest travel time) (Andersen et al., 2014), finance (medical insurance) (Faith et al., 2013), and disease status (comorbidity index, admission source, urgency when admission) (Broyles et al., 1999). Contextual characteristics refer to environmental factors that would affect individuals' behaviors in seeking medical services, such as finance (GDP per capita), organization (hospital beds per thousand people and the availability of high-quality local medical services), environment (length of highway per square) (Andersen et al., 2014). In China, tertiary hospitals provide the best quality of healthcare services (Peng et al., 2014). Therefore, the existence of a tertiary hospital located in the patient's residential district or county was considered as an indicator reflective of the availability of high-quality medical services within that region.

Standard linear regressions are of the form

$$y_i = x_i^{'}\boldsymbol{\beta} + \varepsilon_i \ , \ i = 1, \dots, n$$

where ε_i are independent and identically distributed errors with mean 0, $\boldsymbol{\beta}$ is a vector of regression coefficients, and $x_i^{'}$ is a row vector of covariates for the ith individual. Quantile regression uses the same basic model as Standard linear regressions but assumes that ε_i are independent errors whose τ th quantile is equal to zero, ie, $Pr(\varepsilon_i \leq 0) = \tau$. Thus, $x_i^{'}\boldsymbol{\beta}$ is interpreted as the conditional τ th quantile of y given x_i (Koenker and Bassett, 1978). The coefficients are estimated by minimizing the empirical loss function

$$L(\beta) = \sum_{i=1}^{n} \rho_\tau \left(y_i - x_i^{'}\boldsymbol{\beta} \right),$$

where $\rho_\tau(a) = \tau\, max(a,0) + (1 - \tau) min(-a,0)$. The linear regression model implies that the distribution of y shifts in its mean but not in its shape for different x_i. Quantile regression allows for both the mean and shape of the distribution of y to change with x, without assuming a particular error distribution and homoscedasticity (Burgette et al., 2011; Das et al., 2019; Koenker and Hallock, 2001). The quantile regression parameter estimates the change in a specified quantile of the dependent variable (the modeled utilization travel time) produced by one unit change in the independent variable. Regarding the travel burden, different influencing factors might have varied effects across the travel burden spectrum, for which quantile regression can be used to answer the question of how the effects of different influencing factors might vary across the dependent variable spectrum (Koenker and Bassett, 1978). And This allows the comparison of how some quantiles inherent in the travel time may be more affected by a certain factor than other quantiles (Peng et al., 2019). In other words, quantile regression allows the examination of the impact of the predictors posed on different quantiles inherent in the travel time and provides a comprehensive picture of the relationship between the influencing factors and the travel burden posed on patients. To explain variations in travel time needed by different individuals and to determine factors that might interfere with travel time, especially among residents with heavier travel burdens, quantile regression was conducted. Following this step, we

Table 1
The process of data cleaning.

Criteria	Number of included or excluded	Number of remained
Including all inpatients admitting to hospitals in Sichuan province in the fourth quarter of 2017	Of 3,068,629 inpatients are included	–
Excluding those individuals with missing addresses	Of 66,386 inpatients are excluded	3,002,243
Excluding those individuals with missing gender	Of 402 inpatients are excluded	3,001,841
Excluding those individuals with missing age	Of 590 inpatients are excluded	3,001,251
Excluding those individuals with missing admission characteristics	Of 14 inpatients are excluded	3,001,237

Table 2
Variable definition.

Variables	Definition
Dependent variable	
Travel times	The actual travel time it took patients to drive from their residence to the hospital they were admitted
Independent variables	
Gender	0 = Female, 1 = Male
Age	0 = Age 0–20, 1 = Age 20–40, 2 = Age 40–60, 3 = Age 60–80, 4 = Age 80 and above
Marital status	0 = Single, 1 = Married, 2 = Other
Occupation	0 = Civil service, 1 = Professionals, 2 = Staff, 3 = Business managers, 4 = Worker, 5 = Farmer, 6 = Soldier, 7 = Freelancers, 8 = Self-employed, 9 = Unemployed, 10 = Retired, 11 = Others
Health insurance program	0 = New cooperative medical scheme (NCMS), 1 = Urban resident basic medical insurance (URBMI), 2 = Urban employment basic medical insurance (UEBMI), 3 = Full self-expenses, 4 = Others
The shortest travel time	The shortest time it would take for patients to get to the nearest medical institution
Admission source	0 = Transferred from the emergency department within the hospital, 1 = Transferred from the outpatient department within the hospital, 2 = Transferred from other hospitals, 3 = Others
Urgency when admission	0 = General, 1 = Urgent, 2 = Critical urgent
Classification of diseases	Classification of diseases which was grouped by the first three code of the 10th version of the International Classification of Diseases (ICD-10)
Charlson Comorbidity Index	Charlson score
GDP per capita	Per capita gross regional product (ten thousand yuan)
Population-to-provider ratio	Hospital beds per thousand people
Availability of high-quality	0 = No; 1 = Yes
Transport infrastructure	Length of highway per square

Table 3
Travel time for different people in full sample.

Variables	Travel time (min) [median (IQR)]
All	7.53 (2.37,21.38)
Gender	
Female	7.12 (2.28,20.90)
Male	7.83 (2.45,21.92)
Age	
0-20	5.88 (2.13,19.58)
20-40	8.85 (2.58,26.53)
40-60	8.70 (2.60,23.98)
60-80	7.45 (2.38,19.78)
80+	4.73 (1.85,13.87)
Marital status	
Single	6.17 (2.20,19.53)
Married	7.82 (2.43,7.82)
Others	6.93 (2.20,21.53)
Health insurance program	
NCMS	10.02 (2.90,22.63)
UEBMI	3.72 (1.75,13.53)
URBMI	7.47 (2.53,19.22)
Full self-expenses	10.07 (2.80,40.08)
Others	10.97 (3.07,29.98)
Admission source	
From the emergency department	7.62 (2.47,23.38)
From the outpatient department	7.42 (2.33,20.82)
From other hospitals	17.86 (5.88,37.55)
Others	6.08 (1.72,27.47)
Urgency when admission	
General	7.65 (2.42,21.90)
Urgent	6.85 (2.25,19.55)
Critical urgent	6.85 (1.92,20.72)
Hospital level	
Primary	6.33 (2.15,17.33)
Secondary	7.17 (2.13,17.98)
Tertiary	8.53 (2.67,27.03)
Type of residence	
Urban	5.38 (2.07,17.15)
Rural	10.02 (2.90,22.63)

Notes: IQR interquartile range.

checked the collinearity of the variables (testing by variance inflation factor, VIF) before confirming the final model. Four quantile regressions were estimated at the 0.562 quantile (when travel time = 10), 0.831 quantile (when travel time = 30), 0.921 quantile (when travel time = 60) and 0.964 quantile (when travel time = 120). The regression model for quantile level τ of the response is:

In this model, $Time_i$ is the explained variable, which denotes inpatient's modeled utilization time burden of travel for individual i.

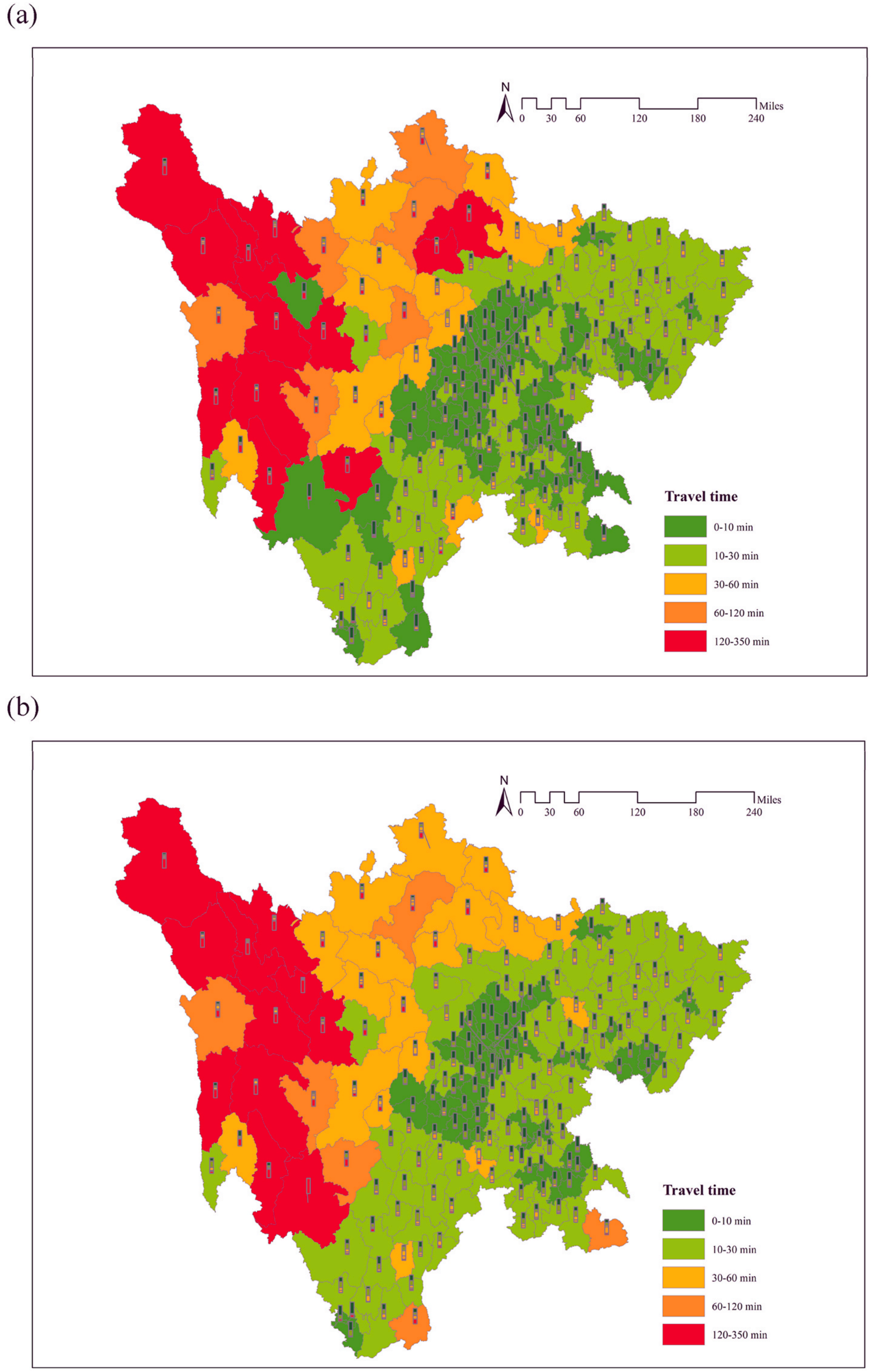

Fig. 2. The percentage of inpatient with different travel time and median travel time among regions in Sichuan province, China. Note: (a) included 3,001,237 inpatients; (b) removed patients whose street addresses are missed, and finally included 2,257,712 inpatients. The bars shows the percentage of inpatient with different travel time.

$Individual_i$ is a vector of individual characteristics, $Contextual_i$ is a vector of contextual characteristics, μ_i is the error term. In order to simplify the interpretation of the outcomes the level of travel burden posed on individuals were defined as "slight ", "moderate ", "heavy", and "exceptionally heavy" based on the length of the modeled utilization travel time, namely 10, 30, 60 and 120 min. Also, we do fit a multilevel linear regression model to estimate the mean value of the dependent variable for given levels of the independent variables to complement our analysis. This model was constructed with individual and county level variables, considering the nested structure of the data: inpatients are clustered within counties.

All data management and statistical analyses were performed via Rstudio (Version1.3.1056).

4. Results

4.1. Travel burden for health care

In Sichuan Province, the mean travel time was found to be 23.14 min (SD: 61.51min), with a median of 7.53 min (IQR: 2.37–21.38 min). More than 83% of inpatients' travel time achieved China's goal of 30-min access to health care, while 236,988 inpatients had to spend 60 min or longer time on the way to the hospitals they were admitted to, which exceeded the Golden Hour, which might lead to unsatisfactory treatment outcomes. Meanwhile, it was observed that travel time increased as the hospital level improved. The median travel time was 10.02 min (IQR: 2.90–22.63 min) in rural areas, while it was 5.38 min (IQR: 2.07–17.15 min) in urban areas, thus showing the disparity between rural and urban regions in travel burden posed on residents seeking medical services (see Table 3). Moreover, travel burden demonstrated large disparities among different regions (see Fig. 2 (a)). Inpatients living in western Sichuan were typically posed by heavier travel burden compared with those who lived in the rest parts of the province.

4.2. The influencing factors of travel burden for health care

Table 4 shows the descriptive statistics of the variables in the analyses. A total of 1,550,173 (51.65%) inpatients were women and 1,451,063 (48.35%) were men. A total of 42.34% of inpatient were aged over 60, indicating that the aged group were most likely to receive inpatient services. Among the sample population, 62.97% of inpatients were able to access high-quality health services in their

Table 4
Descriptive statistics for the full sample.

Variables	No. (%)
Gender	
Female	1,550,174 (51.65)
Male	1,451,063 (48.35)
Age	
0-20	421,814 (14.05)
20-40	466,510 (15.54)
40-60	842,304 (28.07)
60-80	1,061,076 (35.35)
80+	209,533 (6.98)
Marital status	
Single	645,935 (21.52)
Married	2,274,948 (75.8)
Others	80,354 (2.68)
Health insurance program	
NCMS	892,875 (29.75)
UEBMI	642,624 (21.41)
URBMI	883,454 (29.44)
Full self-expenses	303,188 (10.1)
Others	279,096 (9.30)
The shortest travel time [mean (SD)]	7.33 (31.94)
Admission source	
From the emergency department	620,025 (20.66)
From the outpatient department	2,340,628 (77.99)
From other hospitals	14,138 (0.47)
Others	26,446 (0.88)
Urgency when admission	
General	2,307,384 (76.88)
Urgent	564,873 (18.82)
Critical urgent	128,980 (4.30)
Charlson Comorbidity Index [mean (SD)]	0.85 (1.32)
GDP per capita [mean (SD)]	4.85 (2.77)
Hospital beds per thousand people [mean (SD)]	5.38 (3.16)
Availability of high-quality health care	
Yes	1,889,918 (62.97)
No	1,111,319 (37.03)
Transport infrastructure [mean (SD)	1.54 (0.73)

counties. Other information was not reported in the text due to space limitations but could be found in Table 4.

The results of multilevel regression and quantile regression delineated the associations between different influencing factors and travel time at the mean and different quantile spectrum (see Table 5). In terms of demographic characteristics, the male was found to be significantly positively associated with travel time at the mean and different quantile. As to marital status, being married was found to be associated with shorter travel time at the mean and different quantile. Compared with inpatients aged 0–20, those aged 20–40, 40–60, and 60–80 spent significantly longer travel time at the mean and different quantile, and the association increased monotonically as one moves up the distribution of the travel burden. Those aged over 80 spent significantly longer travel time than those aged 0–20, while such relationship was only found at the mean and among residents posed by slight travel burden.

In terms of individual finance, compared with those under the coverage of the new cooperative medical scheme (NCMS), residents with the insurance status of being reimbursed by the urban employment basic medical insurance (UEBMI) system was found to be positively associated with longer travel time at the mean and different quantile, while the magnitude of such association increased substantially as one moves up the distribution of travel time. Among the three basic health insurance schemes, the UEBMI provides the most comprehensive medical coverage and the highest reimbursement (K. Liu et al., 2017). Inpatients covered by UEBMI which is insurance for employees typically have high income thus are more likely to seek higher quality health services regardless of the inconvenience of long road trips for obtaining high-quality medical services. In the lowest end of the travel burden spectrum (travel time = 10 min, quantile = 0.562), inpatients covered by urban resident basic medical insurance (URBMI) presented to spend the longest travel time, while such population group tended to spend shorter travel time in other spectrums. URBMI is a medical insurance system that mainly covers urban residents who are not covered by UEBMI, while the NCMS is a mutual medical assistance system for rural residents (G. G. Liu et al., 2017). Compared with rural residents, urban residents tended to spend a shorter travel time for obtaining health care among multiple inpatient groups posed by moderate, heavy, or exceptionally heavy travel burden, showing the inequality of travel burden posed on urban and rural residents. In terms of the individual organization, the shortest travel time was found to be positively associated with modeled utilization travel time at the mean and different quantile, while the magnitude of such association became larger as one moved up the distribution of travel time, which hardly had variations across the travel burden spectrum.

Like previous studies, disease status was demonstrated to have an association with health-seeking behaviors which further affected

Table 5
Results of quantile regression and multilevel regression on the determinants of travel time in the full sample.

Variable	Travel time = 10 (0.56q)	Travel time = 30 (0.83q)	Travel time = 60 (0.92q)	Travel time = 120 (0.96q)	Multilevel regression
Gender (vs Female)					
Male	0.18(0.01)***	0.82(0.04)***	0.79(0.08)***	0.90(0.17)***	0.69(0.05) ***
Age (vs Aged 0–20)					
20-40	1.11(0.02)***	8.48(0.15)***	19.42(0.34)***	34.36(0.74)***	9.80(0.12) ***
40-60	1.04(0.02)***	4.93(0.11)***	7.81(0.24)***	13.27(0.5)***	8.65(0.12) ***
60-80	0.61(0.02)***	1.84(0.10) ***	2.56(0.23) ***	4.73(0.47) ***	5.76(0.12) ***
80+	0.22(0.02)***	−0.06(0.10)	−0.19(0.24)	0.58(0.49)	3.87(0.14) ***
Marital status (vs Single)					
Married	−0.26(0.01)***	−0.04(0.07)	−0.37(0.13)***	−2.27(0.29)***	−0.93(0.08) ***
Others	−0.60(0.02)***	−1.13(0.18)***	1.09(0.40)***	6.25(1.11)***	−2.23(0.17) ***
Occupation [P]	<0.01	<0.01	<0.01	<0.01	<0.01
Health insurance program (vs NCMS)					
UEBMI	0.57(0.01)***	4.41(0.07)***	11.38(0.18)***	30.96(0.64)***	9.29(0.09) ***
URBMI	0.38(0.01)***	−0.22(0.05)***	−2.08(0.09)***	−4.82(0.17)***	1.31(0.07) ***
Full self-expenses	3.21(0.04)***	38.89(0.37)***	87.52(0.73)***	120.42(0.99)***	24.28(0.10) ***
Others	1.55(0.02)***	16.16(0.23)***	56.73(0.73)***	93.46(1.05)***	16.13(0.10) ***
The shortest travel time	1.24(0.01)***	1.41(0.01)***	1.69(0.02)***	2.10(0.04)***	1.23(<0.01) ***
Admission source (vs From the emergency department)					
From the outpatient department	−0.55(0.01)***	−2.95(0.07)***	−5.36(0.15)***	−8.29(0.33)***	−4.22(0.06) ***
From other hospital	4.38(0.26)***	7.29(0.55)***	0.19(0.59)	−9.64(0.79)***	0.14(0.35)
Others	−1.16(0.03)***	−3.64(0.18)***	−10.46(0.40)***	−18.25(1.30)***	−11.15(0.28) ***
Urgency when admission (vs General)					
Urgent	−0.22(0.01)***	−1.23(0.05)***	−2.60(0.10)***	−5.78(0.19)***	−2.09(0.07) ***
Critical urgent	−0.06(0.02)***	−0.18(0.11)	−0.13(0.21)	−1.56(0.43)***	−1.31(0.13) ***
Classification of diseases[P]	<0.01	<0.01	<0.01	<0.01	<0.01
Charlson Comorbidity Index	0.23(<0.01)***	1.29(0.02)***	2.37(0.05)***	3.65(0.10)***	1.63(0.02) ***
GDP per capita	−0.01(<0.01)***	−1.24(<0.01)***	−2.53(<0.01)***	−4.12(<0.01)***	−2.91(1.33) **
Hospital beds per thousand people	−0.10(<0.01)***	−0.39(0.01)***	−0.13(0.02)***	0.25(0.04)***	−1.61(1.26)
Availability of high-quality health care (vs No)					
Yes	0.12(0.01)***	−7.17(0.07)***	−14.92(0.15)***	−25.35(0.37)***	−9.63(6.33)
Transport infrastructure	0.14(0.01)***	−1.70(0.03)***	−4.94(0.06)***	−10.39(0.11)***	−19.23(3.71) ***

Notes: Due to the space limitation, we use the likelihood ratio test to explore the relationship between occupation and disease classification and the actual travel time.
**p*<.05; ***p*<.01; ****p*<.001.

the utilization of health care (Wariri et al., 2021; Widayanti et al., 2020). For individual need, it was discovered that the travel time spent by inpatients in urgent or critical urgent conditions on admission was generally shorter at the mean and different quantile, while the magnitude of such association became larger as one moved up the distribution of travel time. It is not difficult to imagine that patients in urgent conditions tended to choose the nearest medical institutions in order to receive medical treatments in a timely manner. Compared to those from the outpatient department, inpatients who were admitted through the emergency department tended to spend longer travel time. This might seem counter-intuitive at the first sight, while it should not be unreasonable if you think about the varied service capacity of medical institutions for providing emergency services. As such, it is not uncommon that lots of patients would have to spend long travel time on the ambulance cars for obtaining emergent admission services.

Concerning contextual finance, GDP per capita was found to be negatively associated with travel time at the mean and different quantile, and the magnitude of such association across the travel burden spectrum ranged from −0.01 to −4.12. For contextual organization, the coefficient of hospital beds per thousand people presented to be relatively small, ranging from −1.61 to 0.25 in this study. Among those posed by moderate, heavy, and exceptionally heavy medical travel burden, availability of high-quality health care was found to be negatively associated with travel time, while such association became stronger as one moved up the distribution of travel time, ranging from −7.17 to −25.35.

For contextual environment, length of highway per square was found to be positively associated with travel time in the lowest end of the travel burden spectrum, while negatively associated with travel time in other spectrums. For inpatients with moderate, heavy, and exceptionally heavy medical travel burdens, the magnitude of coefficient reached the highest value in the exceptionally heavy travel burden group. This suggested that transport infrastructure conditions posed varied degrees of impact on different travel burden spectrums.

In our study, we included 3,001,237 inpatients, for which 743,525 inpatients' addresses could only be pinpointed to particular districts or counties thus could only be located at district or county levels. To test the robustness of our results, we repeated our analysis using the sample after excluding inpatients with their street addresses missing. The description of model utilization travel time and the variables and the results of the regressions are presented in Table 6, Table 7, Fig. 2 (b), and Table 8. The results listed demonstrated to be generally consistent with the statistical outcomes produced by the whole sample. In terms of influencing factors, except for those aged over 80 and whether in critical urgent condition when getting admitted, the outcomes and statistical significance of the

Table 6
Travel time for different people for robustness test.

Variables	Travel time (min) [median (IQR)]
All	9.82 (3.25,23.05)
Gender	
Female	9.42 (3.15,22.73)
Male	10.27 (3.38,23.37)
Age	
0-20	8.83 (2.97,22.42)
20-40	11.70 (3.85,28.90)
40-60	10.88 (3.62,25.23)
60-80	9.55 (3.20,21.48)
80+	6.18 (2.17,15.45)
Marital status	
Single	9.30 (3.12,22.33)
Married	9.92 (3.27,23.2)
Others	11.20 (3.97,24.47)
Health insurance program	
NCMS	12.90 (5.73,24.83)
UEBMI	4.42 (1.83,15.37)
URBMI	9.37 (3.23,20.98)
Full self-expenses	13.02 (3.70,43.50)
Others	12.02 (4.10,26.10)
Admission source	
From the emergency department	9.82 (3.25,23.45)
From the outpatient department	9.75 (3.25,22.80)
From other hospitals	19.7 (9.25,38.23)
Others	12.03 (3.18,31.61)
Urgency when admission	
General	9.97 (3.30,23.42)
Urgent	9.18 (3.02,21.73)
Critical urgent	10.08 (3.37,22.47)
Hospital level	
Primary	7.75 (2.82,18.48)
Secondary	9.22 (3.20,19.98)
Tertiary	12.07 (3.53,28.95)
Type of residence	
Urban	7.15 (2.42,19.38)
Rural	12.90 (5.73,24.83)

Notes: IQR interquartile range.

coefficient estimates presented to be generally consistent.

5. Discussions

Modeled utilization travel time reflects the travel burden without assuming that patients would always choose to go to the nearest hospital when necessary. According to some researchers, travel time simulated via the adoption of real-world medical serivce information was also called actual or revealed travel time. (Casas, 2017; Perucca et al., 2019). Using discharge data from all the hospitals providing inpatient services across Sichuan province during the fourth quarter of 2017, this study described the current situation of revealed travel burden posed on inpatients over the study area with a list of influencing factors identified.

Our results showed that the mean modeled utilization travel time was 23.14 min, with a median of 7.53 min, suggesting that the average travel burden was not heavy in Sichuan province. However, travel burden demonstrated large variations among different regions across the study area. Inpatients who were posed by lower degrees of travel burden mainly resided in the eastern Sichuan. In contrast, those who lived in the western area were generally posed by heavy travel burdens. Combining the outcomes presented in both Figs. 1 and 2, it can be concluded that varied travel burdens among different regions across the province are also presented to be consistent with varied distributions of health resources, economy, and road network constructions. For example, the healthcare system development in the western region of Sichuan Province lagged the eastern regions, only a small number of hospitals were located in western Sichuan which were mainly primary hospitals (Fig. 1). Based on such findings, it is not unreasonable to predict that in the rest part of China, regions with less developed economic levels, poorer health services and worse geographical environments are confronted with similar situations of having heavy travel burdens. Therefore, the optimization of medical resources among different regions should be addressed at government levels to serve the holistic goal of providing equal and sustainable health services in a nationwide range as proposed by the Chinese government.

Based on the statistical outcomes, the shortest travel time of inpatients in Sichuan province was found to be 7.33 min with only 11.97% of inpatients hospitalized in medical institutions which were closest to their residential locations. Such a large discrepancy

Table 7
Descriptive statistics for robustness test.

Variable	No. (%)
Travel time [mean(SD)]	23.76 (54.88)
Gender	
Female	1,170,719 (51.85)
Male	1,086,993 (48.15)
Age	
0-20	292,161 (12.94)
20-40	345,312 (15.29)
40-60	637,013 (28.21)
60-80	822,423 (36.43)
80+	160,803(7.12)
Marital status	
Single	448,677 (19.87)
Married	1,755,246 (77.74)
Others	53,789 (2.38)
Health insurance program	
NCMS	677,596 (30.01)
UEBMI	477,635 (21.16)
URBMI	693,359 (30.71)
Full self-expenses	221,882 (9.83)
Others	187,240 (8.29)
The shortest travel time [mean (SD)]	8.88 (25.74)
Admission source	
From the emergency department	434,683 (19.25)
From the outpatient department	1,794,763 (79.49)
From other hospitals	11,315 (0.50)
Others	16,951(0.75)
Urgency when admission	
General	1,741,029 (77.11)
Urgent	427,525 (18.94)
Critical urgent	89,158 (3.95)
Charlson Comorbidity Index [mean (SD)]	0.86 (1.31)
GDP per capita [mean (SD)]	4.72 (2.76)
Hospital beds per thousand people [mean (SD)]	5.21 (3.01)
Availability of high-quality health care	
Yes	1,398,757 (61.95)
No	858,955 (38.05)
Transport infrastructure [mean (SD)]	1.55 (0.72)

Note: Removed patients whose street addresses are missed, and finally included 2,257,712 inpatients.

Table 8
Results of quantile regression and multilevel regression for robustness test.

Variable	Travel time = 10 (0.56q)	Travel time = 30 (0.83q)	Travel time = 60 (0.92q)	Travel time = 120 (0.96q)	Multilevel regression
Gender (vs Female)					
Male	0.19(0.01)***	0.72(0.04)***	0.70(0.09)***	0.77(0.18)***	0.67(0.05) ***
Age (vs Aged 0–20)					
20-40	1.39(0.03)***	8.10(0.16)***	18.35(0.38)***	32.90(0.91)***	9.72(0.14) ***
40-60	1.26(0.03)***	4.51(0.12)***	7.80(0.27)***	12.58(0.53)***	8.35(0.14) ***
60-80	0.82(0.02)***	2.07(0.11)***	3.30(0.27)***	6.23(0.50)***	6.05(0.14) ***
80+	0.42(0.03)***	0.59(0.12)***	0.77(0.27)***	2.72(0.53)***	4.37(0.16) ***
Marital status (vs Single)					
Married	−0.50(0.02)***	−1.36(0.08)***	−2.15(0.16)***	−3.69(0.29)***	−1.60(0.10) ***
Others	−0.58(0.03)***	−1.19(0.19)***	−0.58(0.37)	−3.69(0.65)***	−2.17(0.20) ***
Occupation [P]	<0.01	<0.01	<0.01	<0.01	<0.01
Health insurance program (vs NCMS)					
UEBMI	0.56(0.02)***	5.05(0.08)***	14.87(0.22)***	46.37(1.02)***	9.47(0.09) ***
URBMI	0.24(0.01)***	−0.24(0.05)***	−1.42(0.09)***	−3.33(0.17)***	0.58(0.08) ***
Full self-expenses	4.02(0.05)***	39.55(0.46)***	91.64(0.83)***	128.59(1.04)***	23.62(0.11) ***
Others	0.78(0.02)***	4.94(0.11)***	20.92(0.52)***	61.05(1.38)***	8.63(0.11) ***
The shortest travel time	1.18(<0.01)***	1.56(0.01)***	2.05(0.03)***	2.33(0.05)***	1.15(<0.01) ***
Admission source (vs From the emergency department)					
From the outpatient department	−0.41(0.01)***	−1.03(0.06)***	−1.16(0.14)***	−1.80(0.29)***	−1.15(0.07) ***
From other hospital	5.72(0.26)***	8.91(0.45)***	3.03(0.59)***	−3.00(1.00)***	3.43(0.38) ***
Others	−0.24(0.07)***	−0.20(0.30)	−3.63(0.53)***	−3.21(1.43)***	−7.64(0.34) ***
Urgency when admission (vs General)					
Urgent	−0.17(0.01)***	−0.76(0.05)***	−1.17(0.11)***	−3.56(0.22)***	−1.28(0.07) ***
Critical urgent	0.18(0.03)***	−0.23(0.12)	−0.15(0.23)	−0.67(0.44)	−0.96(0.15) ***
Classification of diseases[P]	<0.01	<0.01	<0.01	<0.01	<0.01
Charlson Comorbidity Index	0.25(0.01)***	1.01(0.02)***	1.76(0.05)***	2.58(0.10)***	1.30(0.02) ***
GDP per capita	−0.10(<0.01)***	−1.20(<0.01)***	−2.50(<0.01)***	−4.10(0.10)***	2.83(1.46) *
Hospital beds per thousand people	−0.12(<0.01)***	−0.46(0.01)***	−0.28(0.02)***	0.33(0.05)***	−1.39(1.39)
Availability of high-quality health care (vs No)					
Yes	0.23(0.01)***	−3.98(0.06)***	−9.01(0.15)***	−17.28(0.35)***	−10.00(6.98)
Transport infrastructure	0.23(0.01)***	−1.32(0.03)***	−4.39(0.06)***	−9.09(0.12)***	−19.28(4.09) ***

Notes: Due to the space limitation, we use the likelihood ratio test to explore the relationship between occupation and disease classification and the actual travel time.
*p<.05; **p<.01; ***p<.001.

between the modeled utilization travel time (23.14 min) and the shortest travel time makes it necessary to look at the travel burden from a practical perspective. Similarly, in a previous study conducted by Alford et al., only 35% of women participating in the US based Breast Cancer Surveillance Consortium for years 2005–2012 chose to seek medical services from their closest medical facility, which indicated that travel time to the closest facility might not be reflective enough as an indicator for evaluating the travel burden to health care, particularly in areas with unevenly distributed medical resources (Alford-Teaster et al., 2016). Such discrepancy between the modeled utilization travel time and the shortest travel time is very much likely to be exacerbated in China where unevenly distributed health resources, especially high-quality health resources were found across the nation (Zhao et al., 2020). For example, most tertiary hospitals are located in large urban cities, especially provincial-capitals (e.g., Chengdu) and municipalities cities (e.g., Beijing) (Li et al., 2021a). This, therefore, necessitates the investigation of the healthcare-related travel burden issue via a more practical and reliable approach under the context of China's situation.

This paper also investigated the determinants of travel burden for health care in Sichuan province. A comprehensive list of individual and region-specific characteristics was added to the analysis. The identification of the determinant factors associated with healthcare-related travel burden is expected to provide evidence-based implications to inform policy-making procedures aimed at improving residents' accessibility of health care via the alleviation of travel burden posed on the process of seeking medical services.

Based on the data available for analysis, we were not able to conclude whether travel time discrepancies identified at individual levels had been induced by a list of demographic attributes related to patients' choosing behaviors. In this study, we were mainly focused on investigating the travel burden posed on population groups that are vulnerable to health problems, as well as exploring influencing factors that might add to unwarranted travel burden discrepancies identified at individual levels. It is noteworthy that the aged population groups are typically more vulnerable to health problems, who tend to seek easily accessible health services close to their residential locations via walking or using public transit systems. However, based on our findings patients aged over 60 tend to take relatively long road trips for accessing medical services across the travel burden spectrum. As in our study individuals' travel time spent on the road before reaching healthcare providers were merely calculated by the time needed for driving, it is not unreasonable to predict that the actual travel burden posed on the aged population groups should be heavier than what was reported by the statistical outcomes. By 2050, the total number of people aged 65 or above is estimated to exceed 336 million, accounting for approximately 24% of China's total population (Zhong et al., 2018). This study contained a study sample of 3,001,237 patients, which, however, had 42%

of the patients being more than 60 years old. Under such circumstances, effective strategies should be adopted at governmental levels to reduce the healthcare-related travel burden posed on the aged population groups via improving the nationwide healthcare system tailored for the specific needs of the aged residents.

Among people with moderate, heavy and exceptionally heavy medical travel burdens, the travel time spent by rural residents for obtaining medical treatments presented to be longer than that of urban residents across the travel burden spectrum, which was consistent with the findings reported by both domestic and foreign studies (Li et al., 2021b; Shen et al., 2020; Wang and Luo, 2005). This suggests that the optimization of medical resource allocations should be addressed at governmental levels in order to achieve a well-balanced travel burden posed on both urban and rural residents.

For contextual characteristics, among those with moderate, heavy, and exceptionally heavy travel burdens, the availability of high-quality health care was found to be negatively associated with travel time. Moreover, the quantile regression showed that those posed by the heaviest time burden for travel tended to be more affected by the availability of high-quality than the others, which indicated that the provision of high-quality medical support to those who had to spend exceptionally long time accessing medical services should be highlighted as a critical issue. Ever since the initiation of China's new health care reform in 2009, both quantity and quality of China's health care resources have been dramatically improved, while the provision of high-quality health care resources remains insufficient from a holistic perspective which is mainly concentrated in wealthy areas (Cheng et al., 2020; Yip et al., 2019). In our study, among inpatients with varied levels of travel burden, small coefficients were detected in the number of beds per thousand people as well as individuals' potential accessibility-the shortest travel time to health care. These might serve as indications that such healthcare-related travel burden posed on China's residents has been alleviated after the new health care reform launched in 2009, while residents' overall demand for obtaining high-quality medical services has increased. At the governmental level, it is rather essential to building a well-balanced nationwide healthcare system tailored for the needs of both disadvantaged population groups and underdeveloped regions.

It is discovered that well-established transportation infrastructure is significantly positively associated with geographic access (Khan, 1992; Pan et al., 2015). Travel barriers can impede the progression from potential to realized access to health care. The disparity in transportation infrastructure may exacerbate the inequities embedded in health-related travel burden posed on the process of obtaining access to medical services. As part of our statistical outcomes, western Sichuan with less developed geographical environments are confronted with similar situations of having heavy travel burden. The quantile regression also showed that the negative effect of the developed road network posed on travel time demonstrated to be greater in the population with heavier travel burdens. This provided significant implication for the governments to inform that the enhancement of regional transportation infrastructure serves as a meaningful strategy to reduce the travel burden posed on the process of seeking medical services, especially for residents posed by exceptionally heavy healthcare-related travel burdens.

There are several limitations to this study. First, the travel burden was measured by the travel time spent from the patient's residential location to the hospital for admission, which was based on the assumption that patients would always depart directly from their residential addresses to the hospitals. However, in the reality, it is not uncommonly seen that patients might also travel to the hospitals from other places, such as their workplaces, scenic spots, etc. Second, our measure of travel time, using hospitalization data in 2017 and real-time Baidu map in 2020, failed to take into account potential factors that might exacerbate travel burdens such as road congestion and road reconstruction over the study period. As such, the travel time produced by our measurements might be underestimated compared with the actual situation. Third, the residential addresses of some patients engaged in this study lacked accuracy in that they could only provide patients' residential districts or counties instead of indicating the street locations. In an attempt to eliminate biased outcomes induced by data inaccuracy, a robustness test was conducted by excluding patients with inaccurate residential location information. The results of the robustness test were found to be consistent with outcomes produced by the full data set, thus indicating the reliability of the study. Fourth, the quantile regression may ignore some heterogeneity and dependence, such as the nested structure of the data: inpatients are clustered within counties.

Despite these limitations above, to the best of our knowledge, this is the first attempt to use advanced transportation science and technology to estimate the health-related travel burden in China based on hospital discharge data. With both individual and contextual characteristics added into analysis, the adoption of quantile regression and multilevel linear regression proved to be meaningful approaches to investigate the varied impacts of influencing factors posed on travel burden in the process of seeking medical services. These methods provided a comprehensive picture of the relationship between the influencing factors and the travel burden posed on patients.

6. Conclusion

As far as we know, seldom studies have explored the travel burden posed on the process of seeking medical services in China. Despite that the travel burden posed on inpatients was found to be acceptable in Sichuan province, China, such travel burden demonstrated large disparities across the study area. Moreover, both individual and contextual characteristics were found to be influential on the travel burden posed on patients via interfering with individuals' healthcare-seeking behaviors. It should be noted that some of these influencing factors are highly associated with unwarranted inequality of healthcare accessibility among different regions, such as the availability of high-quality healthcare in a particular region and the construction of regional transportation infrastructure. Under such circumstances, policies and strategies should be proposed and implemented at the governmental level to mitigate the negative impacts posed by influencing factors associated with unwarranted healthcare outcomes. The establishment of regional medical centers with sufficient capacity of delivering high-quality medical services might be adopted as an effective solution to alleviated the healthcare-related travel burden posed on residents living in impoverished regions.

Author contributions

Qingyu Wang: Data curation, Methodology, Writing - Original draft preparation. Qingling Jiang: Methodology, Visualization, Investigation. Jay Pan: Methodology, Conceptualization, Supervision. Yili Yang: Writing- Reviewing and Editing.

Declaration of competing interest

The authors declared no conflicts of interest for the submission of this manuscript, which has gained approval from all authors for its publication. The manuscript represents original research that has never been published, or been under consideration for publication elsewhere, in whole or in part by any of the authors. All the authors listed above have approved the manuscript enclosed.

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