

Country Characteristics and Variation in Diabetes Prevalence among Asian Countries – an Ecological Study

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Abstract

Objectives. To determine the variation in diabetes prevalence across Asian countries and its relationship with the quality of health system and socioeconomic characteristics of the country.

Methodology. An ecological analysis was conducted using publicly available data from the World Bank, the World Health Organization and the International Diabetes Federation. Geographical variation in diabetes prevalence across countries was examined using control charts while the relationships between country-level determinants and diabetes prevalence were investigated using linear regression analysis.

Results. The control chart shows special-cause variation in diabetes prevalence in 21 (58%) of the Asian countries; nine countries were below the 99.8% control limits while twelve were above it.

Fifteen (42%) countries suggest common-cause variation. Three country characteristics independently associated with diabetes prevalence were hypertension prevalence (OR 0.39, 95% CI 0.22 to 0.55; p -value<0.001), obesity prevalence (OR 0.15, 95% CI 0.13 to 0.18; p -value<0.001), and quality of health care governance (OR 0.18, 95% CI 0.04 to 0.34; p -value=0.02).

Conclusions. There is a considerable geographical variation in diabetes prevalence across Asian countries. A substantial part of this variation could be explained by differences in the quality of health care governance, hypertension prevalence and obesity prevalence.

Key words: Asia, diabetes, prevalence, health system

INTRODUCTION

The increasing number of people with diabetes worldwide, and the grim consequences of the disease with close to five million deaths each year, makes it one of the largest epidemics in human history.¹ Without effective prevention and management, the burden will continue to increase globally. Type 2 diabetes accounts for 85% to 95% of all cases of diabetes in high-income countries and this estimate may even be higher in low- and middle-income countries.²

Asia accounts for more than half of the diabetes prevalence worldwide. Six of the ten top countries with the highest numbers of people with diabetes are Asian countries and this is expected to increase to seven by 2030.³ The rise in diabetes prevalence among Asian countries is consistently observed although the prevalence vary between country to country.⁴ Understanding the variation in health

outcomes is key in epidemiological research. According to Deming, variation in an outcome can be due to common cause variation (i.e., variation that is within what is expected) and special cause variation (i.e., variation that is outside what is expected).^{5,6} The differences in prevalence of diabetes across Asian countries have not been well addressed. Addressing this gap in knowledge may help improve public health efforts in reducing the disease progress.

Since the prevalence of a chronic disease like diabetes is determined by its occurrence and survival rate, we aim to explain variation in diabetes prevalence among Asian countries by considering health system characteristics (health workforce, health financing, and health governance) and typical diabetes-associated factors (such as affluent lifestyle, hypertension and obesity) within the countries.

METHODOLOGY

Setting

In total, there are 36 countries in Asia. This continent is subdivided in regions namely East Asia (China, Japan, Mongolia, North Korea and South Korea), South East Asia (Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam and Timor Leste), South Asia (Bangladesh, Bhutan, India, Maldives, Nepal and Sri Lanka), and West Asia or East Mediterranean (Afghanistan, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Pakistan, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen).

Study design and data acquisition

An ecological study was conducted using publicly available data and reports released by the World Health Organization (WHO)⁷, the International Diabetes Federation (IDF)⁸ and the World Bank⁹. We extracted data at country level on the determinants and outcome of the 36 Asian countries. Determinants were the factors typically associated with diabetes (affluent lifestyle, hypertension and obesity prevalence) and components of the WHO's building blocks of the health system, e.g., health human resource, healthcare financing and quality of healthcare governance.^{10 11}

Health human resources were represented by the ratio of physicians (any specialties) in the country per 1000 population.⁷ Healthcare financing was measured by the mean diabetes related expenditure per person per year in US\$.¹² Leadership and governance in health was measured using the Worldwide Governance Indicators (WGI); a research dataset by the World Bank built on a survey on the experts' views on political stability, government effectiveness, voice and accountability, rule of law, regulatory quality, political stability and control of corruption of a country. The experts came from various enterprises, regular citizen and experts in industrial and developing countries. The WGI data were gathered from a number of surveys of households and firms, commercial business information providers, non-governmental organizations, and public sector organizations. It is currently used by the World Bank and several other donor agencies to measure the quality of governance of a country.¹³ Each of the six parameters in the survey was ranked from -2.5 to +2.5. The ranks were summed up to a total score for the quality of healthcare governance of a country, which ranges from -15 (worst) to +15 (best).¹⁴

In addition, we considered other factors for each country, such as number of motor vehicles (per 1000 population) which represents affluent lifestyle, prevalence of hypertension above 18 years of age (defined as Systolic Blood Pressure ≥ 140 OR Diastolic Blood Pressure ≥ 90 mmHg; age-standardized estimate) and prevalence of obesity above 18 years of age (Body Mass Index ≥ 25 ; age-standardized estimate).

As the outcome of interest in this study, we took diabetes prevalence above 18 years of age which was defined as a fasting blood glucose ≥ 7.0 mmol/L or on medication (age-standardized estimate).⁷

Statistical analysis

We determined the range, mean and standard deviation of diabetes prevalence and the potential determinants. The weighted average of diabetes prevalence was estimated using mixed model analysis.

A Shewhart control chart was used to explore variation of diabetes prevalence across Asian countries to differentiate common cause variation from special cause variation graphically.^{5 6}

The control chart depicts the plotting weighted mean of diabetes prevalence on the y-axis against a measure of their precision, i.e., standard deviation on the x-axis. The chart consists of five horizontal lines, one central line with two lines below and above it. The central line represents the weighted mean of diabetes prevalence, while the other two lines above and below the central line indicate 95% limits (2 standard deviations) and 99.8% limits (3 standard deviations) of the weighted mean of diabetes prevalence. We used three standard deviations as the control limits in accordance with the methodological criteria of Shewhart control chart applied in a systematic review by Kotsier et al.¹⁵ Countries with a diabetes prevalence within the control limits (3 standard deviation) are regarded to show common-cause variation while those outside the control limits are considered to show special-cause variation.

Associations between diabetes prevalence and country-level determinants were examined descriptively using bar charts. The pooled country-level of number of physicians per 1000 people, mean diabetes-related health expenditure, quality of healthcare governance, number of motor vehicles per 1000 people, hypertension prevalence and obesity prevalence were plotted using multiple double-bar charts against the average diabetes prevalence of countries located below, within and above the control limits in the control chart.

Relationships between country-level determinants and diabetes prevalence were examined using linear regression analysis in both univariable and multivariable analysis. Two-tailed Wald test at significance level of alpha equal to 5% was used to determine the statistical significance of the association. Stata statistical package version 12 was used to perform statistical analysis.¹⁶

Ethical approval

We used publicly available data, thus no ethical approval was required.

RESULTS

The prevalence of diabetes varies considerably across Asia, ranging from 5.6% in North Korea to 23% in Qatar, with an average prevalence of 11.6% (SD 4.3%). The countries also showed marked variation in all determinants as shown in Table 1. The ratio of physicians per 1000 population was lowest in Timor Leste (0.07) and highest in Qatar (7.7). The average diabetes-related expenditure per person was 804 US dollars, ranging from 31 to 4,308 US dollars. Ten countries (Japan, Singapore, Qatar, South Korea, United Arab Emirates, Kuwait, Brunei Darussalam, Oman, Saudi

Table 1. Characteristics of the Asian countries (n=36)

Country characteristics	Mean (SD)	Range
Diabetes prevalence (Fasting blood glucose ≥ 7.0 mmol/L or on medication; age-standardized estimate), %	11.6 (4.25)	5.6; 23.0
Number of physicians (per 1000 population), n	1.4 (1.4)	0.07; 7.7
Mean diabetes related health expenditure per person, USD †	804 (1065)	31; 4308
Quality of healthcare governance‡	-2.3 (4.8)	-9.5; 9.4
Number of motor vehicles (per 1000 population), n †	180 (194)	3; 588
Raised blood pressure prevalence (SBP ≥ 140 OR DBP ≥ 90 ; age-standardized estimate), %	23.8 (4.2)	10.8; 31.4
Obesity prevalence (BMI ≥ 25 ; age-standardized estimate), %	39.6 (21.3)	14.5; 78.1

† no data available for North Korea
 ‡ Measured using Worldwide Governance Indicators which capture six key dimensions of governance (Voice & Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption).

Arabia and Bahrain) spent more than 1000 US\$ on diabetes health-related care per person per year while seven other countries (Myanmar, Bangladesh, Pakistan, Nepal, Laos, Cambodia and India) spent less than 100 US\$. The average quality of healthcare governance was generally low with a mean score of -2.3 and only nine countries (Singapore, Japan, South Korea, Qatar, Brunei Darussalam, United Arab Emirates, Malaysia, Oman, and Bhutan) had a positive score indicating good quality healthcare governance. The average number of motor vehicles per 1000 population was 180; ranging from 3 in Bangladesh to 588 motor vehicles per 1000 population in Japan.

Special- and common-cause variations in diabetes prevalence

Figure 1 shows the results of the control chart that explored variation in diabetes prevalence across 36 Asian countries. The weighted mean of diabetes prevalence was 10.5 (99.8% CI 8.8; 12.2). The diabetes prevalence in fifteen (42%) Asian countries was within the 99.8 percent control limits which suggests common-cause variation. The diabetes prevalence in nine (25%) Asian countries was below the control limits while in twelve (33%) Asian countries the diabetes prevalence was higher. Thus, special-cause variation appeared present for twenty-one (58%) Asian countries.

The map in Figure 2 shows the variation in diabetes prevalence across Asian countries. We observed that countries located above the control limit in the control chart (diabetes prevalence $>12.2\%$) are mostly located in the Western part of the continent (the Middle East region) while countries below the control limit (diabetes prevalence $<8.8\%$) like North Korea, Vietnam, Myanmar, Philippines, Timor Leste and Japan are located in the eastern part of the continent.

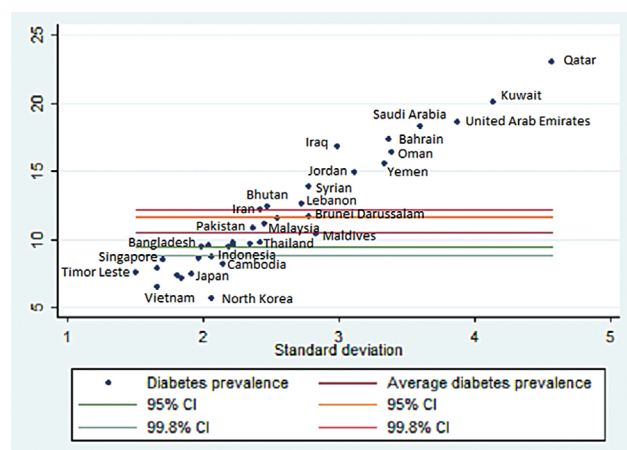


Figure 1. Control chart of diabetes prevalence across Asian countries.

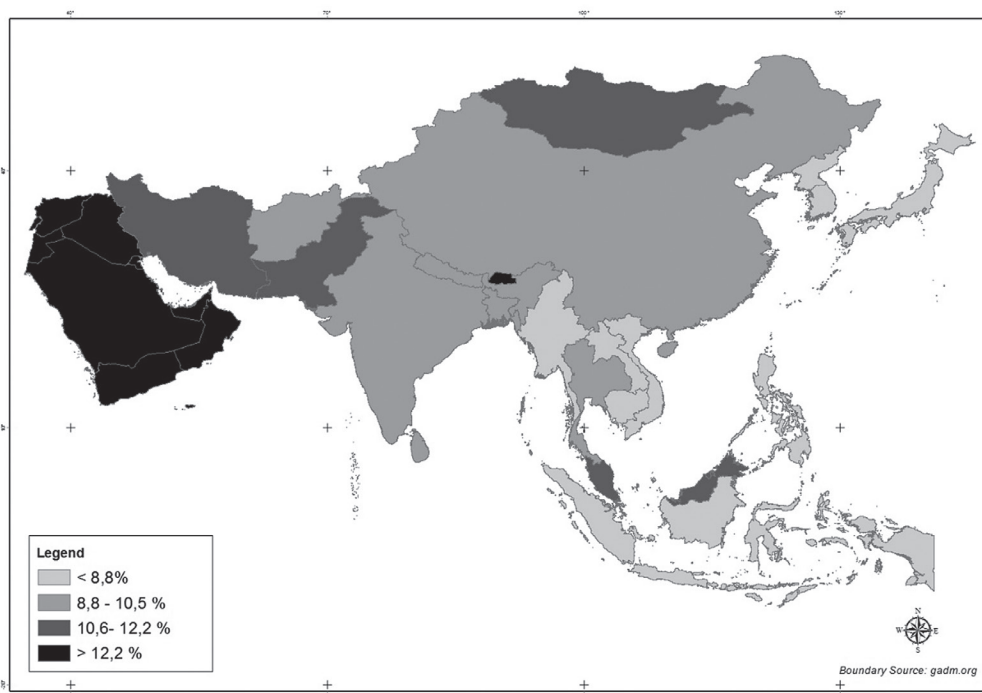


Figure 2. Prevalence of diabetes in Asian countries.

Relationships between country-level determinants and diabetes prevalence

The relationships between country-level determinants and diabetes prevalence are shown in Figure 3 using multiple double-bar charts. The charts show that the diabetes prevalence increases in the same direction as the prevalence of hypertension or obesity. The number of physicians, mean diabetes-related expenditure per person, quality of healthcare governance, and number of motor vehicles showed no linear relationships to diabetes prevalence.

The comparison of characteristics of the countries with the average diabetes prevalence below, within and above the control limits shows positive linear relationships with the country's hypertension and obesity prevalence (Figure 4).

Crude and Adjusted associations

The results of the univariable and multivariable linear regression analyses to examine the association between country characteristics and diabetes prevalence are shown in Table 2. In the final model, three determinants showed

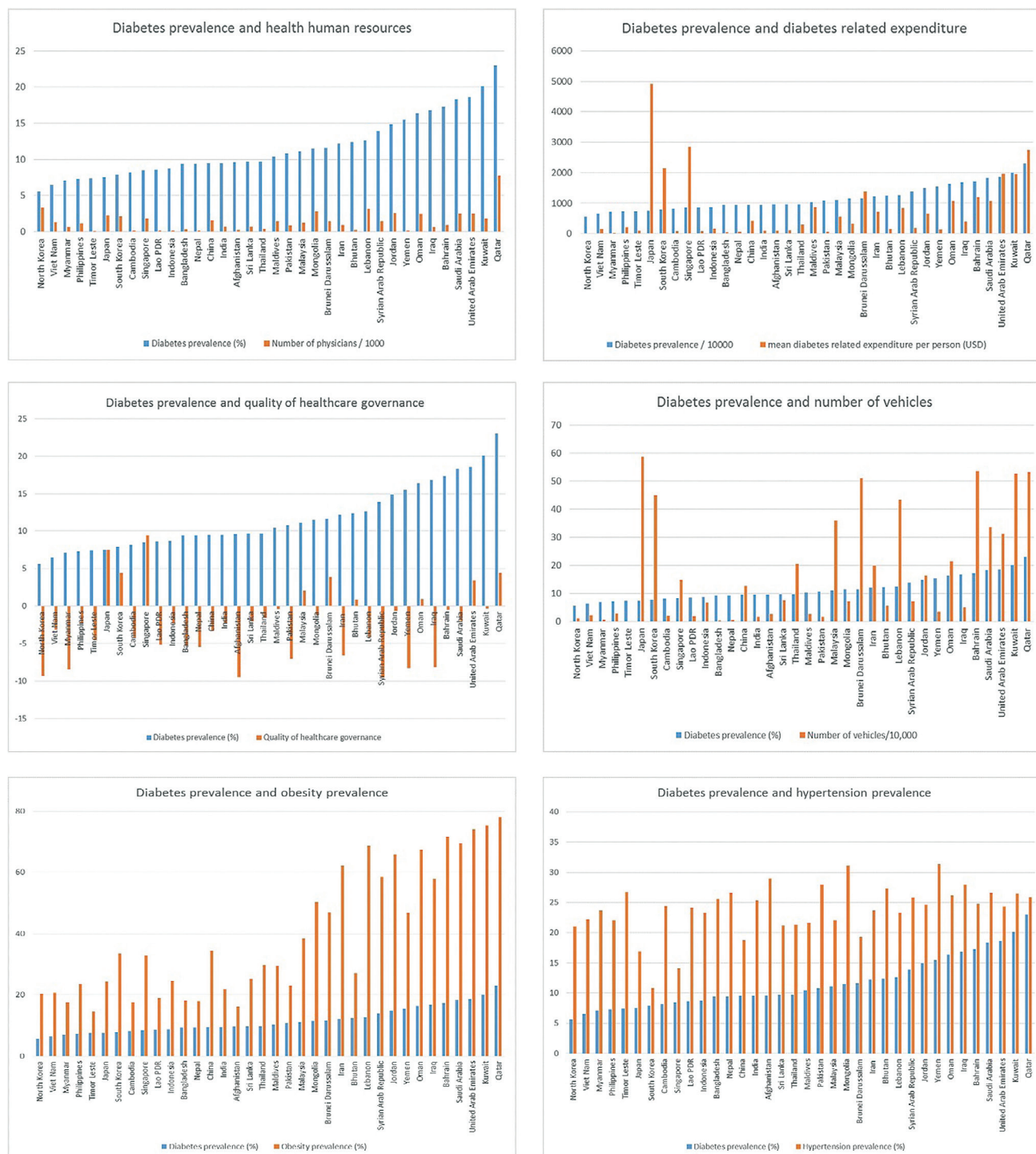


Figure 3. Relationship between country level characteristics and diabetes prevalence in Asia.

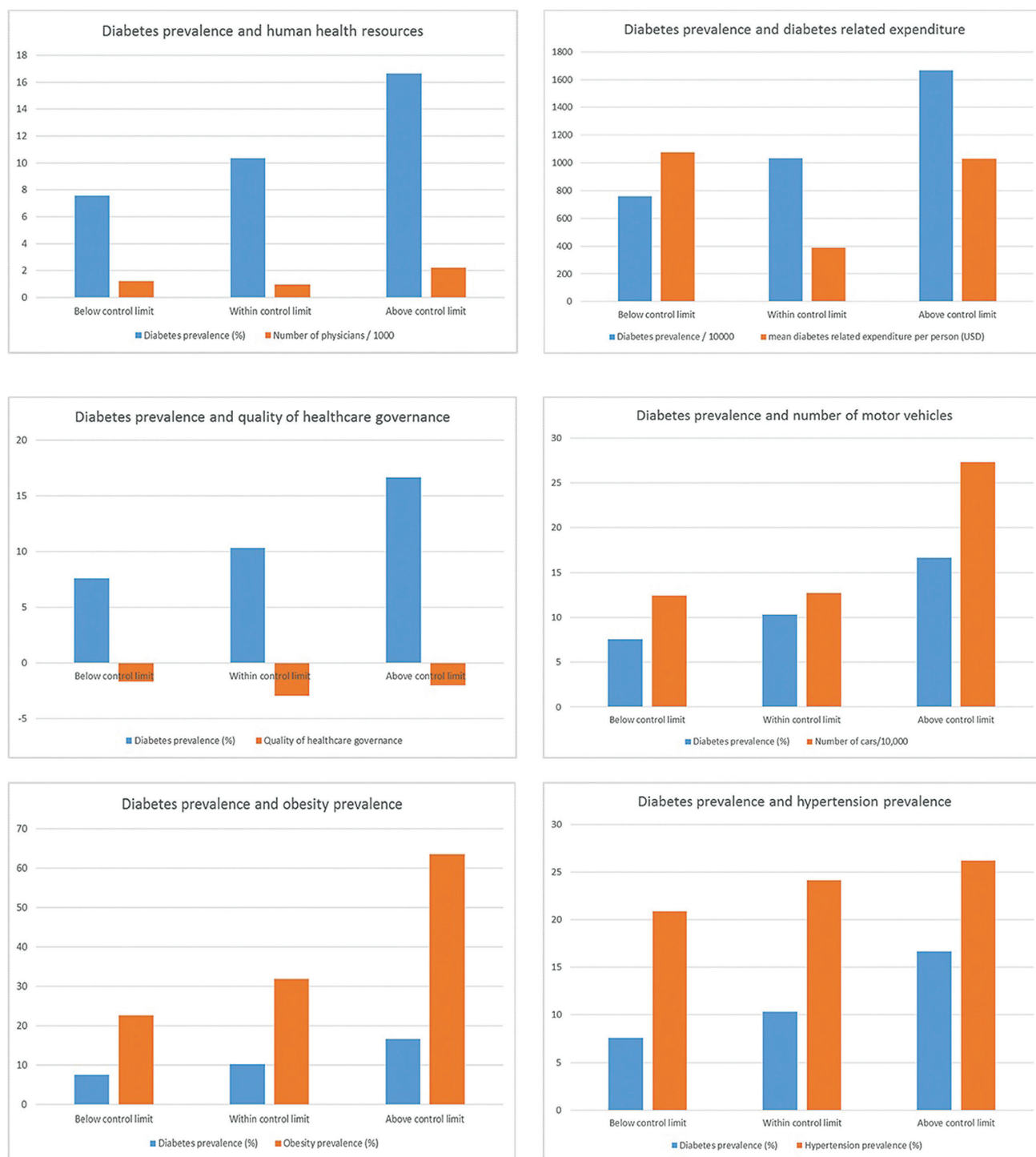


Figure 4. Relationships between country level characteristics and grouped diabetes prevalence (i.e., below control limit, within control limit and above control limit).

Table 2. Associations between Asian country characteristics and diabetes prevalence (n=36)

Country characteristics	Crude OR (95% CI)	Adjusted OR (95% CI) [§]
Number of physicians (in 1000 population)	1.43 (0.53-2.33)*	###
Mean diabetes related health expenditure per person (USD) [†]	0.001 (-0.0003; 0.002)	###
Quality of healthcare governance [‡]	0.15 (-0.16; 0.46)	0.18 (0.04; 0.33)*
Motor vehicles (in 1000 population)	0.01 (0.004; 0.02)*	###
Hypertension prevalence	0.43 (0.11; 0.74)*	0.39 (0.23; 0.55)*
Obesity prevalence	0.18 (0.15; 0.21)*	0.15 (0.13; 0.18)*

[†] no data available for North Korea

[‡] Measured using Worldwide Governance Indicators which capture six key dimensions of governance (Voice & Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption).

[§] Analyzed using multivariable linear regression. Adjusted R-squared= 0.88

* p<0.05

not included in the final model

a significant independent association with diabetes prevalence. Hypertension was the most strongly related to diabetes prevalence. For every percent increase in hypertension prevalence, diabetes prevalence increased by 0.39 percent (95% CI 0.23 to 0.55; $p < 0.001$). For every percent increase in obesity prevalence, diabetes prevalence increased by 0.15 percent (95% CI 0.13 to 0.18; $p < 0.001$). For every unit increase in the country's quality of healthcare governance, diabetes prevalence increased by 0.18 percent (95% CI 0.04 to 0.32; $p = 0.02$). The adjusted R-squared of this model was 0.88, meaning approximately 88% of the variability of diabetes prevalence could be explained by these three determinants.

DISCUSSION

The results of this study show a considerable geographical variation in diabetes prevalence across 36 Asian countries. Countries with the highest diabetes prevalence in Asia are located in the western part of the continent (the Middle East region). Differences in the quality of healthcare governance, hypertension prevalence and obesity prevalence across these countries explain a substantial part of the variation in diabetes prevalence that is observed across Asian countries.

The finding that obesity and hypertension are strongly related to the occurrence of diabetes is in line with associated factors (particularly physical activity, overweight and obesity) that are driving the prevalence of diabetes globally. Across Asian countries, obesity is most common in the Eastern Mediterranean region and lowest in the South-East and East Asia region.¹⁷ Favorable determinants in the eastern part of Asia which might have succeeded in stalling the prevalence of diabetes should be identified. Several studies have reported that sedentary lifestyle and westernized diet,¹⁸ fish and seafood consumption¹⁹, urban exposure^{20,21} and over-dependence on motorized transportation²² may contribute to the global rise in obesity and diabetes prevalence.

A large population-based cohort study has shown that high normal blood pressure as well as established hypertension are strongly and independently related to the development of type 2 diabetes.²³ Possible underlying mechanisms include endothelial dysfunction which is associated with both elevated blood pressure and insulin resistance which forms the substrate for the development of type 2 diabetes. Second, inflammatory mechanisms associated with hypertension could promote the development of type 2 diabetes.²⁴ In addition, use of certain blood pressure lowering drugs has been suggested to be related to the occurrence of type 2 diabetes.²⁵

With the 4.1 billion people residing in Asia, a single percent increase in hypertension or obesity prevalence may increase the number of people with diabetes in the region by 16 or 6.1 million respectively.

The multivariable analysis suggests that stronger healthcare governance is associated with increased rates of diabetes. A strong health governance at all levels is necessary to ensure that healthcare resources are utilized appropriately to achieve affordable, accessible quality healthcare for all.¹¹ Typically, when the quality of

healthcare governance is good, it is expected to increase the performance of the healthcare system which allows to provide adequate health promotion and prevention of NCDs' risk factors including obesity and hypertension. On the other hand, in the case of chronic diseases such as diabetes, good quality of the healthcare system may lead to earlier and more complete detection of diabetic patients. This may paradoxically even increase the prevalence of diabetes.

Ecologic studies may suffer from what is known as the ecological fallacy.²⁶ Ecological studies are increasingly rediscovered as powerful tools in the investigation of the population determinants of health, but observations in ecological studies should be interpreted with caution. It should be realized that much of the data utilized in this study were estimated by modeling local data. However, in countries without available local data, estimates were based on modeling using pooled data from countries that were considered similar in geography, ethnicity, and economic development.¹⁷ However, the data have face validity as for example the relationship between obesity and hypertension with diabetes has been well-established. Another limitation of our study is that we only included three of six WHO health systems building blocks as information on other components of the health systems. Other aspects of the management of NCDs such as healthcare delivery, information system, and availability of medical products and technologies may also be relevant but the data are not easily or openly accessible. Diabetes like most NCDs is a chronic disease associated with lifestyle factors. A health system within which each component functions well is necessary for successful detection and management of diabetes.

CONCLUSIONS

This study shows considerable geographical variation in diabetes prevalence across Asian countries. Countries with the highest diabetes prevalence in Asia are located at the western part of the continent (the Middle East region). A substantial part of this variation can be explained by differences in quality of healthcare governance, the prevalence of hypertension and obesity rates. These observations support the view that investments and improvements in healthcare systems provide important opportunities to affect the burden of chronic disease in low and middle income countries, notably by their impact on the occurrence and management of diabetes.

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Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

The authors declare no conflict of interest.

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