# PREVALENCE AND INFLUENCE FACTORS FOR MYOPIA AND HIGH MYOPIA IN SCHOOLCHILDREN IN SHANDONG, CHINA

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**SUMMARY**

*Objectives:* The aim of the study was to identify the prevalence and risk factors of myopia and high myopia in students from primary school and junior high school in Shandong.

*Methods:* A total of 35,614 subjects completed the visual acuity test, refraction error measurement, and questionnaire in 2019. The visual acuity test was performed using the standard logarithmic visual acuity chart and the refractive error was measured by an automatic refractometer without cycloplegia.

*Results:* The average age was 12.38 ± 1.78 years, with 18,501 boys and 17,113 girls. The overall prevalence of myopia and high myopia was 68.02% and 5.90%, respectively, and reached up to 85.54% and 13.13% for the grade 9 students. The risk factors included girls, parental myopic history, time spent doing homework, and less sleep time. Performing eye exercise was significantly associated with a lower risk of myopia. Use of mobile devices and reading while lying down were only related to myopia, not high myopia.

*Conclusion:* The prevalence of myopia and high myopia is at a high level. In addition to genetic factors, continuous close work and a lack of sleep was an important factor associated with children myopia and high myopia.

*Key words:* myopia, high myopia, prevalence, influence factors, primary school, junior high school

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## INTRODUCTION

With the popularity of electronic products and changes in the way people live and learn, the prevalence of myopia continues to rise around the world, and shows a trend of younger onset, deeper myopia, and higher incidence of high myopia. It has become a global public health problem. Holden et al. predicted that by 2050 there will be 4,758 million people with myopia, which is about half of the world population (1), and this means myopia has become an epidemic. Myopia, especially high myopia, can cause a series of serious complications such as retinal detachment, subretinal neovascularization, cataracts, and glaucoma. In addition, the impact of myopia on the physical and mental health, learning and life of children and adolescents should not be underestimated.

The prevalence of myopia has been shown to vary widely with geographic location according to previous studies. The prevalence of myopia was 6.0% in 6–8 years old children and 28.9% in 11–13 years old children in Canada (2), 14.8% and 59.0% in 5–7 and 17–19 years old children, respectively, in USA (3), and 13.3% in 3–17 years old children in Germany (4). The prevalence of myopia in children was 20% in Spain (5), 13% in Norwegian adolescents (6), and 21.1% in North India (7). Compared with other countries in the world, East Asia has significantly higher prevalence of myopia, reaching 81.2% in age group 16–18 years in China (8), 76.5% among the elementary school students and 94.9% among the junior high school students in Japan (9), and 64.6% in Korea (10).

Within China, the myopia prevalence also varies from province to province. Prevalence of myopia was 80.7% in Beijing (11). In Guangzhou, the overall prevalence of myopia among primary and middle school students was 47.4%. The prevalence of myopia was 0.2% in students in grade 1, 38.8% in grade 3, and 68.4% in grade 9 (12). The prevalence of myopia in the second-grade primary school children was 36.4% in Taipei (13). The results of a study conducted in 6 provinces of China showed that the myopia prevalence was 35.8% in age group 6–8 years, 58.9% in age group 10–12 years, 73.4% in age group 13–15 years, and 81.2% in age group 16–18 years (8).

As a populous province and strong province of education, Shandong province has more than 13 million primary and secondary school students. The number of students with myopia is huge and only some cross-sectional studies had been conducted in local areas or schools, such as Shandong children eye study, which study areas are limited to Guanxian and Weihai. Detailed research has not been conducted in history. Our study covered all 16 cities in Shandong province and the study participants were

over 35,000. The aim of this study was to identify the prevalence of myopia in Shandong province and the factors associated with myopia.

## MATERIALS AND METHODS

### Study Population

All 16 cities were covered, and one urban area and one county were chosen from each city, then 4 schools were chosen from the urban and county area (2 primary schools, 2 junior high schools).

The health monitoring and questionnaire survey was conducted in the fourth to sixth grades of primary school and all grades of junior high school. An entire class of each grade was selected. Eventually, 35,614 subjects completed the survey including 18,501 boys and 17,113 girls with the average age 12.38 ± 1.78 years. For the fourth to sixth grades of primary school, the average age was 10.85 ± 0.94 years with 9,209 boys and 8,379 girls. For junior high school, the average age was 13.86 ± 0.96 years with 9,292 boys and 8,734 girls. Informed consent was obtained from their parents. The study adhered to the tenets of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Review Board of Shandong Centre for Disease Control and Prevention (approval number 201903016).

### Distance Visual Acuity Examination

The visual acuity was measured by two qualified optometrists from hospital at 5m distance using a standard logarithmic visual acuity chart in a room with sufficient lighting to illuminate the chart. The height of 1.0 line of the visual chart is as high as the eyes of the subjects. The right eye was checked first, then the left eye. Students with glasses removed their glasses first, used a black eye shield to fully cover the non-examination eye and to avoid oppressing the eye. The optometrists started with the big letter. If no letter for 4.0 to 4.5 line, less than 2 letters for 4.6 to 5.0 line, or less than 3 letters for 5.1 to 5.3 line failed to be recognized, the corresponding line is considered to pass.

### Refraction Error Measurement

A refractive error of each subject was measured by an automatic refractometer (AR-600; Nidek Ltd., Tokyo, Japan) without cycloplegia. The optometrists adjusted the height of the lifting platform and the subject's head position so that the subject's lateral canthus was horizontally aligned with the marked line. The subject opened his eyes wide, gazed at the pattern in the visual field, and minimized the blinking frequency. The inspector controlled the joystick to align the cross mark on the screen with the centre of the cornea and pushed the joystick back and forth to focus. When the bright spot in the focus frame was the clearest, the refractometer automatically measured the dioptre. The mean of three consecutive measurements was recorded for each eye. The spherical equivalent refraction (SE) was used to represent the dioptre, which is the sum of the spherical value plus half the cylindrical value. Myopia was defined as having an uncorrected distance visual acuity < 5.0 and SE ≤ −0.5D in at least one eye. High myopia was defined as having SE ≤ −6.0D in at least one eye.

### Data Collection

Demographic data and myopia risk factors were collected for each student through a detailed questionnaire including gender, area of residence, parental myopia status, eye use in and after school, near work habits, outdoor activities, and sleep duration. Eye use in and after school included the frequency of eye exercises, time spent on homework, participation in the afterschool tutorial programme. Near work habits included the use of mobile devices, time spent watching TV/computer each day, reading books, or watching electronic screens in the sun/lying down.

### Statistical Analysis

The overall prevalence of myopia and the prevalence of myopia stratified by age and gender were estimated. Multiple logistic regression models were applied to investigate the association between myopia status and potential influence factors. Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. Statistical analysis was performed using SAS 9.13 (SAS Institute, Cary, NC, USA), $p < 0.05$ was considered statistically significant.

## RESULTS

### Participant Characteristics

The characteristics of the participants are shown in Table 1. In this population 51.95% were boys and 48.05% were girls, 49.39% were primary school students and 50.61% were junior high school student, 14.27% had two myopic parents and 33.74% had one myopic parent, 62.18% spent more than 2h/d on outdoor activities, 64.45% slept 8–10 h every day, 35.54% spent more than 2 h/d on homework, and 53.71% participated in after-school tutorial programmes. Less than half of the participants read books or watched electronic screens in the sun or lying down.

### Prevalence of Myopia and High Myopia

The prevalence of myopia and high myopia was 68.02% and 5.90% in this study population, 63.83% and 5.39% for boys, 72.54% and 6.46% for girls, respectively. The distribution of the prevalence between different genders and ages is shown in Table 2.

### Univariate Analysis of Influence Factors Associated with Myopia and High Myopia

The results of logistic analyses for myopia and high myopia are shown in Table 3. After adjustment for age, girls and parental myopia history had significantly higher risk of myopia. Students with two myopic parents had the highest risk of myopia followed by those with one myopic parent. Subjects who slept more than 8 hours per day had a significantly lower risk of myopia. In terms of near work habits, those who did homework more than 2 hours per day, used mobile devices, read books or watched electronic screens while lying down, and did not perform eye exercises were significantly associated with a higher risk of myopia. When the analyses performed were stratified by gender, the statistically significant influencing factors have not changed.

***Table 1.*** *Prevalence of myopia and high myopia and its influence (N = 35,614)*

| Variables | Total | Myopia | | High myopia | |
|---|---|---|---|---|---|
| | n | n | % | n | % |
| Gender | | | | | |
| Male | 18,501 | 11,809 | 63.83 | 997 | 5.39 |
| Female | 17,113 | 12,414 | 72.54 | 1,105 | 6.46 |
| School | | | | | |
| Primary school | 17,588 | 9,698 | 55.14 | 409 | 2.33 |
| Junior high school | 18,026 | 14,525 | 80.58 | 1,693 | 9.39 |
| Parental myopia | | | | | |
| Neither | 18,444 | 11,463 | 62.15 | 763 | 4.14 |
| Either | 11,973 | 8,701 | 72.67 | 794 | 6.63 |
| Both | 5,065 | 3,971 | 78.40 | 540 | 10.66 |
| Outdoor activity (h/d) | | | | | |
| < 2 | 12,802 | 8,606 | 67.22 | 715 | 5.59 |
| > 2 | 21,046 | 14,453 | 68.67 | 1,286 | 6.11 |
| Sleep (h/d) | | | | | |
| < 8 | 7,190 | 5,594 | 77.80 | 626 | 8.71 |
| 8–10 | 22,692 | 15,386 | 67.80 | 1,311 | 5.78 |
| > 10 | 5,328 | 2,978 | 55.89 | 145 | 2.72 |
| Perform eye exercises | | | | | |
| Yes | 29,954 | 19,844 | 66.25 | 1,674 | 5.59 |
| No | 5,550 | 4,302 | 77.51 | 423 | 7.62 |
| Time spent doing homework (h/d) | | | | | |
| < 1 | 8,614 | 4,930 | 57.23 | 302 | 3.51 |
| 1–2 | 13,643 | 9,344 | 68.49 | 816 | 5.98 |
| > 2 | 12,269 | 9,229 | 75.22 | 924 | 7.53 |
| After-school tutorial programme | | | | | |
| No | 15,971 | 10,733 | 67.20 | 946 | 5.92 |
| Yes | 18,528 | 12,762 | 68.88 | 1,099 | 5.93 |
| Watch TV | | | | | |
| No | 7,240 | 5,124 | 70.77 | 503 | 6.95 |
| Yes | 28,271 | 19,024 | 67.29 | 1,595 | 5.64 |
| Use computer | | | | | |
| No | 17,254 | 11,369 | 65.89 | 917 | 5.31 |
| Yes | 18,250 | 12,774 | 69.99 | 1,181 | 6.47 |
| Use mobile devices | | | | | |
| No | 11,122 | 7,152 | 64.30 | 604 | 5.43 |
| Yes | 24,286 | 16,922 | 69.68 | 1,486 | 6.12 |
| Read in the sun | | | | | |
| No | 23,859 | 15,754 | 66.03 | 1,356 | 5.68 |
| Yes | 11,638 | 8,387 | 72.07 | 742 | 6.38 |
| Read while lying down | | | | | |
| No | 18,478 | 11,838 | 64.07 | 982 | 5.31 |
| Yes | 16,993 | 12,286 | 72.30 | 1,114 | 6.56 |

For high myopia, subjects who sleep more than 8 hours per day had a significantly lower risk of myopia. Girls and parental myopia history were significantly associated with a higher risk of myopia. No eye exercises, more time spent on homework were also significantly associated with a higher risk of myopia.

***Table 2.*** *Prevalence of myopia and high myopia in schoolchildren by age and gender (N = 35,614)*

| | | Total | Myopia | | | p-value | High myopia | | | p-value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | n | n | % | 95% CI | | n | % | 95% CI | |
| Boys | Grade 4 | 3,178 | 1,330 | 41.85 | 40.15–43.57 | <0.001 | 39 | 1.23 | 0.90–1.68 | <0.001 |
| | Grade 5 | 3,035 | 1,564 | 51.53 | 49.75–53.30 | | 52 | 1.71 | 1.31–2.24 | |
| | Grade 6 | 2,996 | 1,832 | 61.15 | 59.39–62.88 | | 77 | 2.57 | 2.06–3.20 | |
| | Grade 7 | 3,060 | 2,098 | 68.56 | 66.89–70.18 | | 174 | 5.69 | 4.92–6.57 | |
| | Grade 8 | 3,143 | 2,456 | 78.14 | 76.66–79.55 | | 266 | 8.46 | 7.54–9.48 | |
| | Grade 9 | 3,089 | 2,529 | 81.87 | 80.47–83.19 | | 389 | 12.59 | 11.47–13.81 | |
| | Total | 18,501 | 11,809 | 63.83 | 63.13–64.52 | | 997 | 5.39 | 5.07–5.72 | |
| Girls | Grade 4 | 2,816 | 1,348 | 47.87 | 46.03–49.72 | <0.001 | 59 | 2.10 | 1.63–2.70 | <0.001 |
| | Grade 5 | 2,788 | 1,655 | 59.36 | 57.53–61.17 | | 68 | 2.44 | 1.93–3.08 | |
| | Grade 6 | 2,775 | 1,969 | 70.95 | 69.23–72.61 | | 114 | 4.11 | 3.43–4.91 | |
| | Grade 7 | 2,919 | 2,310 | 79.14 | 77.63–80.58 | | 182 | 6.24 | 5.42–7.18 | |
| | Grade 8 | 2,893 | 2,519 | 87.07 | 85.80–88.24 | | 282 | 9.75 | 8.72–10.88 | |
| | Grade 9 | 2,922 | 2,613 | 89.43 | 88.26–90.49 | | 400 | 13.69 | 12.49–14.98 | |
| | Total | 17,113 | 12,414 | 72.54 | 71.87–73.20 | | 1,105 | 6.46 | 6.10–6.84 | |
| All | Grade 4 | 5,994 | 2,678 | 44.68 | 43.43–45.94 | <0.001 | 98 | 1.63 | 1.34–1.98 | <0.001 |
| | Grade 5 | 5,823 | 3,219 | 55.28 | 54.00–56.55 | | 120 | 2.06 | 1.73–2.46 | |
| | Grade 6 | 5,771 | 3,801 | 65.86 | 64.63–67.07 | | 191 | 3.31 | 2.88–3.80 | |
| | Grade 7 | 5,979 | 4,408 | 73.72 | 72.59–74.82 | | 356 | 5.95 | 5.38–6.58 | |
| | Grade 8 | 6,036 | 4,975 | 82.42 | 81.44–83.36 | | 548 | 9.08 | 8.38–9.83 | |
| | Grade 9 | 6,011 | 5,142 | 85.54 | 84.63–86.41 | | 789 | 13.13 | 12.30–14.01 | |
| | Total | 35,614 | 24,223 | 68.02 | 67.53–68.50 | | 2,102 | 5.90 | 5.66–6.15 | |

## DISCUSSION

In this study, the prevalence of myopia was 68.02% (63.83% for boys and 72.54% for girls). The prevalence of high myopia was 5.90% (5.39% for boys and 6.46% for girls). The prevalence of myopia and high myopia in grade 9 students was 85.54% and 13.13% (81.87% and 12.59% for boys, 89.43% and 13.69% for girls, respectively), which is significantly higher than in European and American countries. The myopia prevalence of students in Shandong is also at a relatively high level even compared with other provinces in China and the high prevalence of myopia indicates that special efforts are needed to stop its rapid development.

The results of multivariate logistic regression indicated that parental history of myopia, spending more time on homework, not performing eye exercises, and less sleep were all associated with a higher risk for myopia or high myopia, and watching screens while lying down and use of mobile devices were associated with a higher risk for myopia only. Some of the results of this study are consistent with previous studies and some are not.

Parental history was found to be associated with the formation of myopia already in 1989 (14). Studies in different countries have reached a common conclusion that parental history is the most important factor associated with myopia (15, 16) and children with myopic parents have a higher risk of myopia. The highest OR was found in Nigeria, where people with one myopic parent had 5.80% (95% CI: 2.76–16.74) higher risk of developing myopia than those with none myopic parent, and risk for those with two myopic parents was 8.47% (95% CI: 3.88–23.13) higher (17). Parental myopia was also significantly associated with high myopia (18). Results of the Guangzhou Twin Eye Study showed that children with highly myopic parents were at a higher risks of developing high myopia (OR = 25.71) (19).

The relationship between heredity and myopia is strong, but genes cannot explain the rapid increase in myopia prevalence in recent years and the main reason may be the environment and behaviour, especially the increase in the continuous use of the eye at close range. One of the most typical studies was conducted in Israel. Boys attending Orthodox schools had very high prevalence of myopia compared with girls attending Orthodox schools and students attending Israeli secular schools (20). Among the factors related to education, the time and distance of near work are extensively studied and significantly associated with myopia (11, 21, 22). Hsu et al. (13) found that longer time spent on near work activity and shorter visual distance when doing near work activity were significantly associated with a higher risk of myopia. One year later, they surveyed the same subjects and found that a shorter eye-object distance when doing near work (OR: 1.45, 95% CI: 1.18–1.78) was associated with fast myopia progression (23). The twin study also demonstrated near work difference was a risk factor of myopia (24). Our results showed that compared with students whose homework time was less than 2 hours, those who spend more than 2 hours on homework had a significantly higher risk of myopia. Although we did not investigate the study

***Table 3.*** *Factors associated with myopia and high myopia based on multiple logistic regression analysis (N = 35,614)*

| Variables | Myopia | | | High Myopia | | |
|---|---|---|---|---|---|---|
| | Total (Model 1) | Boys (Model 2) | Girls (Model 3) | Total (Model 1) | Boys (Model 2) | Girls (Model 3) |
| Gender | | | | | | |
| Female | Ref. | – | – | | – | – |
| Male | 0.701 (0.67–0.74) | – | – | 0.883 (0.8–0.97) | – | – |
| Parental myopia | | | | | | |
| Neither | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| Either | 1.633 (1.55–1.72) | 1.707 (1.59–1.84) | 1.55 (1.59–1.84) | 1.662 (1.49–1.85) | 1.78 (1.53–2.08) | 1.575 (1.35–1.83) |
| Both | 2.274 (2.1–2.46) | 2.347 (2.11–2.61) | 2.19 (2.11–2.61) | 2.801 (2.48–3.16) | 2.63 (2.2–3.15) | 2.956 (2.51–3.49) |
| Sleep (h/d) | | | | | | |
| < 8 | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| 8–10 | 0.75 (0.7–0.8) | 0.83 (0.76–0.91) | 0.67 (0.76–0.91) | 0.722 (0.65–0.81) | 0.666 (0.57–0.78) | 0.741 (0.64–0.86) |
| > 10 | 0.504 (0.46–0.55) | 0.555 (0.49–0.62) | 0.453 (0.49–0.62) | 0.354 (0.29–0.43) | 0.249 (0.18–0.34) | 0.445 (0.34–0.58) |
| Perform eye exercises | | | | | | |
| Yes | Ref. | Ref. | Ref. | Ref. | – | – |
| No | 1.495 (1.38–1.62) | 1.538 (1.39–1.71) | 1.433 (1.39–1.71) | 1.145 (1.01–1.3) | – | – |
| Time spent doing homework (h/d) | | | | | | |
| < 1 | Ref. | Ref. | Ref. | Ref. | Ref. | Ref. |
| 1–2 | 1.478 (1.39–1.57) | 1.409 (1.3–1.53) | 1.564 (1.3–1.53) | 1.554 (1.35–1.79) | 1.674 (1.37–2.05) | 1.469 (1.21–1.78) |
| > 2 | 1.782 (1.67–1.91) | 1.742 (1.59–1.9) | 1.813 (1.59–1.9) | 1.76 (1.53–2.03) | 1.895 (1.54–2.33) | 1.733 (1.42–2.11) |
| Use mobile devices | | | | | | |
| No | Ref. | Ref. | Ref. | – | – | – |
| Yes | 1.094 (1.04–1.15) | 1.074 (1–1.15) | 1.112 (1–1.15) | – | – | – |
| Read while lying down | | | | | | |
| No | Ref. | Ref. | Ref. | – | – | – |
| Yes | 1.18 (1.12–1.24) | 1.083 (1.01–1.16) | 1.314 (1.01–1.16) | – | – | – |

Descript as OR (95% CI).
Model 1 included age, gender, family history, sleep duration, eye exercise, outdoor play hours, study hours for school assignments or after-school tutorial programme, use of mobile devices, daily hours of watching television, daily hours of using computer, read in the sun, read while lying down, and adjusted for age.
Model 2 and model 3 included age, family history, sleep duration, eye exercise, outdoor play hours, study hours for school assignments or after-school tutorial programme, use of mobile devices, daily hours of watching television, daily hours of using computer, read in the sun, read while lying down, and adjusted for age.

time and rest time of students at school, we believe that education intensity is an important cause of myopia. Most students study as much as possible at school and do not have much rest time, due to the strong pressure of entering higher education.

The most effective way to reduce the impact of near work on eyes might be to reduce the time of continuous near work, that is, increase the time of outdoor activities. The relationship between outdoor activities and myopia is a current research hotspot and outdoor activities may be the most effective way to prevent and control myopia. The epidemiological surveys have shown that increased amounts of time spent outdoors protect against the development of myopia (16, 25). Although the exact mechanism for the protective effect of outdoor activities on myopia is unknown, Rose et al. (25) proposed a hypothesis that the increased light intensity outdoors can increase the release of dopamine and the increased dopamine protects eyes from myopia. The protective effect has been replicated in experiments (26) and can be blocked by a dopamine antagonist (27). However, our results show that there is no relationship between outdoor activities and myopia. The possible reason is that although the time of outdoor activities was investigated, the sun conditions during outdoor activities were not investigated in this study. According to Rose et al. theory, there must be enough light intensity to prevent myopia. Therefore, the follow-up research should not only investigate the outdoor activity time, but also the outdoor light intensity.

In terms of the association between near-work habits (including watching TV/computer, reading in the sun/lying down, and eye exercise) and myopia, most studies indicated watching TV/computer was a risk factor for myopia (8). However, our results find that use of mobile devices and watching screens while lying down were associated with myopia rather than watching TV/computer. The reason might be that mobile devices have become more and more popular, and the students spent much more time on mobile devices than on TV/computer. There is no definite conclusion about eye exercises and decrease of myopia risk. Our results show that eye exercises can reduce the risk of myopia, but some other studies show only a modest protective effect on myopia or no effect (28, 29). The relationship between eye exercises and myopia should be studied in depth, not only the epidemiology, but also mechanism.

In this study, longer sleep time was associated with a lower risk of myopia. A study of 8,030 primary and secondary school students showed that the OR of students with longer sleep time

in the age groups 13–15 and 16–18 years were 0.73 and 0.38, respectively (21). In Korea, the result also showed that > 9 hour sleep (OR: 0.59, 95% CI: 0.38–0.93) was associated with a lower risk of myopia (30). One possible reason is a child's activity pattern, which is characterized by high amounts of close work and little outdoor time. Therefore, children who sleep more have less time for close work. In this case, the cause of myopia may be close work and outdoor time, and sleep may only be a covariate (30).

There are some limitations in this study. First, the refractive error of students was measured without cycloplegia, which may lead to an overestimation of the prevalence of myopia. Secondly, there is no detailed investigation of students' education intensity at school, such as total learning time, rest time, physical education time, etc., which should be targeted in the future research.

## CONCLUSIONS

The overall prevalence of myopia and high myopia was 58.68% and 7.17, respectively, in this study population and reached up to 89.34% and 21.48% for the age group of 17 years, indicating a high prevalence of myopia in schoolchildren in Shandong. The risk factors associated with myopia and high myopia included parental myopic history, education intensity, unhealthy near-work habits, less sleep time, and outdoor activities. Recently, the Chinese government has realized the dangers of myopia and is promulgating a series of policies to curb the rapid growth of myopia, including not assigning after-school homework for grades 1 and 2, increasing the time between classes, ensuring students' sleep time, and prohibiting off-campus training institutions from occupying students' time with tuition during holidays and weekends. With the successive implementation of these policies, we believe that the myopia rate of Chinese students is expected to show a downward trend in the next few years.

**Conflict of Interests**

None declared

**Authors' Contribution**

ZC and JZ discussed the idea of the study and together outlined the study design; MZ and SL determined the methodology; HX, YZ, PX, YJ and HZ performed the query in databases and drafted the paper; MZ and ZC together agreed on the main conclusions and MZ prepared the final version of paper.

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