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Research Article

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Effect of the COVID-19 pandemic on the status of overweight and obesity among children and adolescents: a retrospective study in Chengdu, China

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Background: The prevalence of overweight and obesity among children and adolescents is steadily increasing and has become a public health concern. Lifestyle changes due to the COVID-19 pandemic may have an impact on the status of overweight and obesity among children and adolescents. This study aimed to analyze the effect of the COVID-19 pandemic on the status of overweight and obesity among children and adolescents.

Methods: We retrospectively analyzed the children and adolescents who visited the West China Second University Hospital, Sichuan University from January 1st, 2018 to June 30st, 2020. We included obese children who met the criteria and divided them into 5 groups with 6 months as the unit according to the time of their visit. The national lockdown time was used as a segmentation point to study the changes of obesity status in the same children before and after lockdown.

Results: A total of 140,526 children and adolescents visited the outpatient department from January 1st, 2018 to June 30st, 2020, and 1,740 of them were diagnosed as overweight or obese at the time of their first visit. The study found that there was a significant difference in the obesity rate among the groups (P < 0.01). However, there was no difference between January to June, 2020 and the previous period. Except for the increased incidence of VD deficiency (P < 0.01), the severity of obesity, insulin resistance and dyslipidemia of obese children did not change before and after COVID-19 (P=0.303, 0.663, 0.106, respectively). A total of 65 obese children were followed up in the outpatient department before and after COVID-19 lockdown. There were no significant differences in BMI-SDS, HOMA-IR and 25(OH)VD among obese children before and after lockdown (p = 0.626, 0.386, 0.251, respectively).

Conclusions: The available evidence cannot prove that the COVID-19 pandemic affects the status of overweight and obesity among children and adolescents who visited hospitals. It may be related to the multiple effects of the COVID-19 pandemic on children.

Keywords: COVID-19 pandemic, childhood obesity, Insulin resistance, VD deficiency, Dyslipidemia

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Introduction

Overweight and obesity have become a global public health concern (1), and this trend is also becoming more obvious in children (2). It was reported that in 2015, 12% of adults and 5% of children in the world met the diagnostic criteria for obesity. Although the obesity rate of children is lower than that of adults, it is rising faster than that of adults (3,4). From 1997 to 2015, the incidence of overweight, obesity and severe obesity of children in China increased from 4.6% to 21.1%, 1.4% to 10.1%, and 0.2% to 4.0%, respectively (5). And researches have shown that Obesity is associated with a variety of diseases, such as type 2 diabetes and cardiovascular disease (6-8) and obesity in childhood is associated with an increased risk of cardiovascular death in adulthood (9). And early detection of cardiovascular problems in obese children can help reduce long-term complications (10).

COVID-19 pandemic swept the world by the end of 2019 and the beginning of 2020. As of September 20st, 2020, there had been 30,675,675 confirmed cases of COVID-19 worldwide, including 954,417 deaths (11). In order to slow down the spread of COVID-19, most places of China implemented a comprehensive lockdown policy, and this lockdown policy changed people's lifestyle, especially in terms of physical activity and eating habits, which may have an impact on people's weight (12). Studies have reported that the implementation of lockdown measures during COVID-19 pandemic reduces physical activity in adults and leads to an increase in body mass index (BMI) (13). For children and adolescents, although some scholars believe that school closures during COVID-19 pandemic may result in reduced physical activity and increased unhealthy diets, resulting in weight gain (14), which is also found in clinical practice, others believe that the pandemic may reduce the risk of childhood obesity (15). The relevant research in this area has not been reported. Therefore, we retrospectively analyzed the children who visited the West China Second University Hospital, Sichuan University from January 1st, 2018 to June 30st, 2020, trying to find the effect of COVID-19 pandemic on the overweight and obesity of children and adolescents.

Materials and Methods

Study population: A total of 140,364 children and adolescents aged 2-18 years visited the West China Second University Hospital, Sichuan University from January 1st, 2018 to June 30st, 2020. We included children or adolescents who first visited the outpatient during the study period and were diagnosed as overweight or obese according to the diagnostic criteria. The exclusion criteria were obese children with conditions that may affect the BMI, such as central precocious puberty, growth hormone deficiency dwarfism, chronic kidney disease, Autoimmune and chronic kidney diseases requiring hormone therapy, etc. Further, we included obese children who were followed up at the outpatient during the study period and visited the outpatient before and after the COVID-19 pandemic national lockdown time (January 23st, 2020), respectively.

Data collection: We collected basic information about children and adolescents, such as sex, date of birth, date of diagnosis, age at diagnosis, height, weight, comorbidities through the hospital case system. We divided the study period into 5 groups with 6 months as the unit, and
Each obese child was divided into 5 groups according to the date of diagnosis. All measurements of children’s height and weight were carried out and recorded by specially-trained personnel in accordance with standards. BMI is a person’s weight in kilograms divided by the square of height in meters and the formula is weight (kg) / [height (m)]^2. BMI-SDS was calculated based on height and weight in kilograms/meter^2 and adjusted for sex and age according to Chinese growth curves(16). We collected the laboratory results of children and adolescents through the hospital laboratory system, such as fasting blood glucose(FBG), fasting insulin(INS), 25-hydroxyvitamin D(25 (OH) D), total cholesterol(TC), low-density lipoprotein cholesterol(LDL-C), high-density lipoprotein cholesterol(HDL-C) and triglyceride(TG). All laboratory results were obtained during normal clinical activities. FBG, INS, TC, LDL-C, HDL-C and TG were measured in the morning under fasting status. All laboratory tests were carried out by professional personnel. The study has been granted an exemption from requiring ethics approval and informed consent by the Ethics Committee of West China Second University Hospital of Sichuan University because of following factors. Firstly, the COVID-19 pandemic is a public health emergency that cannot be predicted in advance. Secondly, we collected patient’s anonymous data retrospectively and were unable to track the anonymous data. Thirdly, we only used data from normal clinical activity during the study and promised not to misuse it.

**Definitions:** Obesity: According to the Chinese textbook 《Pediatrics Children》， overweight in children (>2 years old) was defined as BMI between the 85th percentile and 95th percentile of the growth standard curve (P85-P95), obesity was BMI above the 95th percentile (>P95)(17). For severe obesity, we refer to the USCDC standard which was defined as BMI greater than 120% of the 95th percentile or BMI greater than 35 kg/m² (18). The growth standard curve refers to the growth curve of Chinese children aged 0-18 years in 2009 (16).

Insulin resistance: Whether children had insulin resistance was estimated using homeostasis model assessment of insulin resistance (HOMA-IR) (19). The calculation formula was HOMA-IR=FBG(mmol/L)×INS(mIU/L)/22.5. According to WHO recommendations, higher than the highest quartile of HOMA-IR in non-diabetic subjects was considered to be insulin resistance (20). For Chinese children, the threshold was HOMA-IR > 3 (21). Vitamin D (VD) deficiency: the status of vitamin D was graded according to the serum 25 (OH) D level: the serum 25 (OH) D > 250 nmol/L was toxicosis, 50-250 nmol/L sufficient. 30-50 nmol/L insufficient and < 30 nmol/L deficient (22). Dyslipidemia: dyslipidemia was assessed on the basis of TC, LDL-C, HDL-C and TG. Dyslipidemia was defined as abnormality of any of the four indicators. The abnormalities in the four indicators were TC ≥ 200 mg/dL, LDL-C ≥ 130 mg/dL, HDL-C < 40 mg/dL, TG: 2-9 years old ≥ 100 mg/dL and 10-18 years old ≥ 130 mg/dL (23).

**Statistics:** SPSS 21.0 was used for statistical analysis of the data obtained in the study. Categorical variables were expressed as frequencies (n) and percentages(%) and analyzed by the Chi-square test. Continuous variables were expressed as mean ± standard deviation (SD) and compared using one-way ANOVA. Chi-square test was used to analyze the changes of obese children in different time periods. The continuity variables of obese children who visited the outpatient before and after COVID-19 pandemic lockdown were tested for normality. Those with approximate normal distribution were analyzed by paired t test, and those without were analyzed by wilcoxon signed ranks sum test. A p-value < 0.05 was considered statistically
significant.

Results:

The incidence of childhood obesity at different time periods:
A total of 140,364 children and adolescents visited the outpatient department of the West China Second University Hospital, Sichuan University from January 1st, 2018 to June 30st, 2020. Among them, 1,740 children were diagnosed as overweight or obese at the time of their first visit. The obesity rates of the five time groups: January to June in 2018, July to December in 2018, January to June in 2019, July to December in 2019, January to June in 2020 were 1.1%, 1.5%, 1.1%, 1.4%, 1.2%, respectively. Among them, the incidence of obesity was significant lower in January to June in 2018 and 2019 than in July to December in 2018 and 2019 (p<0.01). However, there was no statistical difference between each group and January to June, 2020 (Table 1)

| Time | 1-6, 2018 (n=26534) | 7-12, 2018 (n=28433) | 1-6, 2019 (n=28926) | 7-12, 2019 (n=30343) | 1-6, 2020 (n=26128) | p |
|------|----------------|----------------|----------------|----------------|----------------|------|
| N (%) | N (%) | N (%) | N (%) | N (%) | N (%) | <0.01 |
| Normal | 28,254 (98.9) | 28,013 (98.5) | 28,619 (98.9) | 29,924 (98.6) | 25,814 (98.8) | <0.01 |
| Obesity | 280 (1.1) | 420 (1.5) | 307 (1.1) | 419 (1.4) | 314 (1.2) | <0.01 |

TABLE 1 | The obesity rate of outpatient visits of children in different time groups

Each superscript letter represents a subset of the column time categories, with column proportions not significantly different from each other at the 0.05 level.

1-6, 7-12 refers to the months of the year.

The characteristics of the study population:
A total of 1,740 children and adolescents diagnosed as overweight or obese were enrolled. The sex and age baselines for obese children were comparable across time periods (Table 2).

Among the obese children, 53.4% were male and 46.6% were female, with an average age of 9.32 ± 2.532 years. Most of them were diagnosed as obesity (60.4%), 42% had insulin resistance, 46.1% had VD insufficiency or deficiency and 42.8% had dyslipidemia. The relationship between the severity of obesity and sex, age, glycometabolism, VD level and lipid metabolism was significant (p<0.01, <0.01, <0.01, 0.016, <0.01, respectively) (Table 3).

| Variables | 1-6, 2018 (n=280) | 7-12, 2018 (n=420) | 1-6, 2019 (n=307) | 7-12, 2019 (n=419) | 1-6, 2020 (n=314) | p |
|-----------|----------------|----------------|----------------|----------------|----------------|------|
| N (%)     | N (%) | N (%) | N (%) | N (%) | N (%) | 0.829 |
| boy       | 158 (56.4) | 219 (52.1) | 162 (52.8) | 221 (52.7) | 170 (54.1) | 0.829 |
| girl      | 122 (43.6) | 201 (47.9) | 145 (47.2) | 198 (47.3) | 144 (45.9) | 0.078 |
| Age       | 9.26 ± 2.711 | 9.21 ± 2.443 | 9.33 ± 2.664 | 9.38 ± 2.576 | 9.29 ± 2.96 | 0.078 |

TABLE 2 | The basic characteristics of obese children in different time groups
The basic characteristics and metabolic status of children with different levels of obesity.

The n outside the brackets denotes the number of children with this characteristic at that level of obesity. % in parentheses indicates the percentage of children with this characteristic at this obesity level.

Counting data were tested by chi-square test, and measurement data were analyzed by one-way analysis of variance.

**The situation of obese children at different time periods:**

The VD deficiency rate of obese children was significant higher in January to June, 2020 than in 2018 and July to December, 2019 (p < 0.01)(Table 4). Further study found that this difference was only found in children diagnosed as obese and severely obese (p < 0.01, 0.037, respectively), while there was no significant change in VD deficiency rate in overweight children (p = 0.893)(Table 5). However, there were no significant differences in the severity of obesity, insulin resistance and dyslipidemia among obese children at different time periods (p = 0.303, 0.663, 0.106, respectively)(Table 4).

### TABLE 3

The basic characteristics and metabolic status of children with different levels of obesity.

The n outside the brackets denotes the number of children with this characteristic at that level of obesity, % in parentheses indicates the percentage of children with this characteristic at this obesity level.

Counting data were tested by chi-square test, and measurement data were analyzed by one-way analysis of variance.

| Variables      | Overweight N (%) | Obesity N (%) | Severe Obesity N (%) | p     |
|----------------|------------------|---------------|----------------------|-------|
| Sex            | N=295            | N=1051        | N=394                | <     |
|                |                  |               |                      | 0.01  |
| Boy            | 209 (70.8)       | 524 (49.9)    | 197 (50.0)           |       |
| Girl           | 86 (29.2)        | 527 (50.1)    | 197 (50.0)           |       |
| Glycometabolism| N=183            | N=700         | N=307                | <     |
|                |                  |               |                      | 0.01  |
| Non-IR         | 119 (65.0)       | 429 (61.3)    | 142 (46.3)           |       |
| IR             | 64 (35.0)        | 271 (38.7)    | 165 (53.7)           |       |
| VD status      | N=211            | N=759         | N=296                | 0.016 |
| sufficient     | 130 (61.6)       | 408 (53.8)    | 145 (49.0)           |       |
| insufficient   | 74 (35.1)        | 298 (39.3)    | 122 (41.2)           |       |
| deficient      | 7 (3.3)          | 53 (6.9)      | 29 (9.8)             |       |
| Lipid Metabolism| N=125            | N=578         | N=266                | 0.002 |
| Non-Dyslipidemia| 82 (65.6)       | 343 (59.3)    | 129 (48.5)           |       |
| Dyslipidemia   | 43 (34.4)        | 235 (40.7)    | 137 (51.5)           |       |
| Age            | 10.91±2.179      | 9.15±2.456    | 8.59±2.487           | <     |
|                |                  |               |                      | 0.01  |
The severity of obesity and metabolic status of obese children in different time groups

| Variables          | 1-6.2018 N(%) | 7-12.2018 N(%) | 1-6.2019 N(%) | 7-12.2019 N(%) | 1-6.2020 N(%) | p  |
|--------------------|---------------|----------------|---------------|----------------|---------------|----|
| Diagnosis          |               |                |               |                |               |    |
| Overweight         | 42 (15.0)     | 60 (14.3)      | 53 (17.3)     | 82 (19.6)      | 58 (18.5)     | 0.303 |
| Obesity            | 177 (63.2)    | 262 (62.4)     | 181 (59.0)    | 255 (60.8)     | 176 (56.1)    |    |
| Severe Obesity     | 61 (21.8)     | 98 (23.3)      | 73 (23.7)     | 82 (19.6)      | 80 (25.4)     |    |
| Glycometabolism    |               |                |               |                |               |    |
| Non-IR             | 128 (62.1)    | 159 (56.8)     | 117 (57.4)    | 173 (58.6)     | 113 (55.1)    | 0.663 |
| IR                 | 78 (37.9)     | 121 (43.2)     | 87 (42.6)     | 122 (41.4)     | 92 (44.9)     |    |
| VD status          |               |                |               |                |               |    |
| Sufficient         | 130 (61.6)    | 181 (60.3)     | 84 (40.9)     | 176 (57.0)     | 112 (47.5)    | < 0.01 |
| Insufficient       | 75 (35.5)     | 109 (36.3)     | 93 (43.3)     | 120 (38.8)     | 97 (41.1)     |    |
| Deficient          | 6 (2.8)       | 10 (3.3)       | 33 (15.7)     | 13 (4.2)       | 27 (11.4)     |    |
| Lipid Metabolism   |               |                |               |                |               |    |
| Non-Dyslipidemia   | 120 (64.2)    | 126 (52.9)     | 96 (60.4)     | 123 (53.2)     | 89 (57.8)     | 0.106 |
| Dyslipidemia       | 67 (35.8)     | 112 (47.1)     | 63 (39.6)     | 108 (46.8)     | 65 (42.2)     |    |

Each superscript letter represents a subset of the column time categories, with column proportions not significantly different from each other at the 0.05 level.

The n outside the brackets denotes the number of children with this characteristic in this time group, % in parentheses indicates the percentage of children with this characteristic at this time group.
Chi-square test was used.

### TABLE 5: The incidence of VD deficiency in children with different severity of obesity in different time groups

| Diagnosis | 1-6, 2018 N(%) | 7-12, 2018 N(%) | 1-6, 2019 N(%) | 7-12, 2019 N(%) | 1-6, 2020 N(%) | p  
|-----------|----------------|----------------|----------------|----------------|----------------|------  
| Overweight | N=31 | N=40 | N=35 | N=62 | N=43 |  0.893  
| Sufficient | 21 (67.7) | 25 (62.5) | 20 (57.1) | 38 (61.3) | 26 (60.5) |  <0.01  
| Insufficient | 10 (32.3) | 14 (35.0) | 14 (40.0) | 22 (35.5) | 14 (32.6) |  0.037  
| Deficient | 0 (0.0) | 1 (2.5) | 1 (2.9) | 2 (3.2) | 1 (2.3) |  <0.01  
| Obesity | N=126 | N=182 | N=128 | N=186 | N=137 |  0.017  
| Sufficient | 83 (65.9) | 110 (60.4) | 43 (33.6) | 108 (58.1) | 64 (46.7) |  <0.01  
| Insufficient | 39 (31.0) | 67 (36.8) | 63 (49.2) | 72 (38.7) | 57 (41.6) |  0.037  
| Deficient | 4 (3.1) | 5 (2.8) | 22 (17.2) | 6 (3.2) | 16 (11.7) |  <0.01  
| Severe obesity | N=54 | N=78 | N=47 | N=61 | N=56 |  <0.01  
| Sufficient | 26 (48.1) | 46 (59.0) | 21 (44.7) | 30 (49.2) | 22 (39.3) |  <0.01  
| Insufficient | 26 (48.1) | 28 (35.9) | 16 (34.0) | 26 (42.6) | 26 (46.4) |  <0.01  
| Deficient | 2 (3.8) | 4 (5.1) | 10 (21.3) | 5 (8.2) | 8 (14.3) |  <0.01  

*The expected count of 5 cells (33.3%) is less than 5. The minimum expectation count is 1.03.

The n outside the brackets denotes the number of children with this characteristic in this time group. % in parentheses indicates the percentage of children with this characteristic at this time group.

Chi-square test was used.

1 Obese children before and after lockdown:
2 A total of 65 obese children were followed up in the outpatient department of West China
3 Second University Hospital, Sichuan University before and after lockdown. Among them, 34
children had FBG and INS tested twice and 37 children were examined twice for serum 25 (OH)D. However, there were no significant differences in BMI-SDS, HOMA-IR and 25(OH)VD among obese children before and after lockdown (p = 0.626, 0.386, 0.251, respectively)(Table 6).

**TABLE 6** The changes of BMI SDS and metabolic status in children before and after lockdown.

The difference follows normally distributed and the paired t test is used.

The difference does not follow normal distribution and the Wilcoxon signed ranks sum test is used.

**Discussion**

We retrospectively analyzed the children and adolescents who visited the West China Second University Hospital, Sichuan University from January 1st, 2018 to June 30st, 2020, trying to find the impact of COVID-19 pandemic on overweight and obesity among children and adolescents. There was no significant change in the obesity rate of children visiting the hospital from January to June, 2020 compared with that in the previous period. In addition to the increased incidence of VD deficiency, the severity of obesity, insulin resistance and dyslipidemia in obese children did not change. Therefore, it has not been demonstrated that the pandemic affects the obesity status of children and adolescents visiting the hospitals.

Although there was a slight increase from January to June, 2020 in childhood obesity compared to that from January to June in 2018 and 2019, and a slight increase in severe obesity rate among obese children, which was consistent with what we saw in the outpatient department, these differences were not significant. This is contrary to the opinion of Andrew G et al(14). The lockdown during the COVID-19 pandemic caused the closure of schools, and studies have shown that out-of-school environment may increase the BMI of children (24-25). Studies have shown that the COVID-19 pandemic lockdown leads to changes in children’s behavior: increased sugar intake and sleep time, and decreased
exercise time, which may have a negative impact on children's obesity (26). But lockdown also
caused the closure of restaurants (27), reducing the rate of children eating outside, and
increasing the healthy diet at home (28-29), which could have a beneficial impact on childhood
obesity. The obesity rates were higher in the second half of 2018 and 2019 than in the first half,
with a slight increase in severe obesity rate among obese children. The possible reason is that
children have more physical activity and less sedentary in spring, and the opposite in winter
(30), which could lead to lower obesity rates in the spring and higher obesity rates in the winter.
For obese children who were followed-up in outpatient department and visited the outpatient
department before and after lockdown respectively, there was a slight decrease in BMI-SDS,
although this was not statistically significant. This was similar to the findings of Donald A et al,
which was that overweight children tended to lose weight and normal-weight children tended
to gain weight, which may be related to the measures taken by obese children to control their
weight (31).
Obesity may increase the incidence of VD deficiency in children (32-33), which may be due to
reduced expression of vitamin D25-hydroxylase CYP2R1 in the liver of obese children (34) and
excessive 25 (OH)D accumulation in adipose tissue (35). In addition, the lack of VD in children
may aggravate systemic inflammation, affect insulin sensitivity but also beta-cell function in
non-diabetic overweight and obese children and adolescents and may even affect COVID-19
infection (36-38). Therefore, we studied the changes of VD. The VD deficiency rate of obese
children in January to June, 2020 was increased compared with that in January to June, 2018
and July to December, 2018. This may be attributed to the implementation of social lockdown
measures reduces children’s time for outdoor activities which may have a beneficial impact on
VD level (39). However, This change in VD deficiency was seen only in children diagnosed as
obese and severely obese, but not in overweight children. This may be due to the negative
correlation between VD level and BMI, and the heavier the degree of obesity, the worse the VD
level (40), which was consistent with the relationship between obesity and VD levels seen in our
study. However, there was no significant reduction in 25 (OH)D in obese children who were
followed up in the outpatient department and visited the outpatient department before and
after the lockdown respectively, which may be related to the long-term vitamin D
supplementation in children who were followed up in the outpatient department.
Strengths: Till now, there is few report to analyze the impact of COVID-19 pandemic on
overweight and obesity among children and adolescents, which is the great strength of this
article. Moreover, the study population was from one of the largest pediatric hospitals in
southwest China, with a large and representative sample size. And we analyzed the obese
children with the long-term follow-up in the outpatient department, and found that there was
no significant change in the obesity status of these children, which may have implications for
the follow-up of obese children in the future.
Limits: There are some limitations in our study, which need further study to improve. Firstly, the
number of patients visited before and after the lockdown respectively is relatively small, which
may lead to false negative results. Moreover, due to the lack of clinical collection of obesity risk
factors (family history, bad behavior) and deal with factors (Dietary guidelines, drugs), we can
not explore the underlying causes, which may be a focus of future research. In addition, as the
observation date of this study is June 30st, 2020, we can only analyze one set of data after the
outbreak of COVID-19. COVID-19 pandemic affects people’s life far beyond this period, which should be integrated with longer term or even better longitudinal data.

Conclusion

When we focus on the impact of COVID-19 pandemic on lifestyle, we cannot ignore the impact of lifestyle changes on childhood obesity. Our study cannot prove that the COVID-19 pandemic affect the status of overweight and obesity among children and adolescents who visited hospitals, but provides a direction for future research, and suggests that it is necessary to prevent childhood obesity by implementing measures such as proper outdoor exercise and reasonable diet.

Abbreviations

- body mass index BMI
- fasting blood glucose FBG
- fasting insulin INS
- 25-hydroxyvitamin D 25 (OH) D
- total cholesterol TC
- low-density lipoprotein cholesterol LDL-C
- high-density lipoprotein cholesterol HDL-C
- Triglyceride TG
- United States Centers for Disease Control and Prevention standards USCDC
- homeostasis model assessment of insulin resistance HOMA-IR
- Vitamin D VD

Declarations

Ethics approval and consent to participate

The study has been granted an exemption from requiring ethics approval and informed consent by the Ethics Committee of West China Second University Hospital of Sichuan University because of following factors. Firstly, the COVID-19 pandemic is a public health emergency that cannot be predicted in advance. Secondly, we collected patient’s anonymous data retrospectively and were unable to track the anonymous data. Thirdly, we only used data from normal clinical activity during the study and promised not to misuse it.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
Competing interests

The authors declare that they have no competing interests

Funding

The authors declare that the research was conducted in the absence of any funding.

Authors’ contributions

ML and FY contributed to conception and design of the study. ML, LKL and XH organized the database. SFY and JHS performed the statistical analysis. ML wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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