

# The Correlation Between Rhabdomyolysis and the 24 Solar Terms: A Retrospective Study

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**Background:** Rhabdomyolysis(RMI) is a life-threatening clinical disease, and its onset is correlated with climate temperature changes. However, there is a lack of research on the onset time of this disease, making it impossible to predict its occurrence from a temporal perspective.

**Objective:** To explore the correlation between the 24 Solar Terms and the RMI.

**Methods:** A retrospective observational study was conducted on patients with creatine kinase (CK) levels  $\geq 1000$  U/L detected at the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine from February 4, 2022, to February 3, 2024. The data indicators observed included admission and discharge dates, length of hospital stay, underlying diseases, complications, relevant laboratory test indicators, and recovery status. The relationships between the fluctuations in the number of cases and the 24 solar terms were analyzed.

**Results:** A total of 1124 cases of RMI were identified, with 606 cases from February 4, 2022, to January 3, 2023, and 518 cases from January 4, 2023, to February 3, 2024. Among them, 816 were male, and 308 were female. The incidence of RMI showed periodic fluctuations with the solar terms, with the highest number of cases occurring during the Great Cold period and the lowest during the Vernal Equinox and Lesser Fullness periods. Among the 781 hospitalized patients, 266 (n=34.06%) had electrolyte disorders as complications. A total of 108 patients (n=13.83%) experienced varying degrees of renal impairment, and 45 patients (n=5.76%) developed acute kidney injury (AKI), accounting for 41.67% of those with renal impairment. Among the patients with AKI, 21 (n=46.67%) died eventually.

**Conclusion:** There is a correlation between the 24 Solar Terms and the RMI.

**Keywords:** rhabdomyolysis, 24 solar terms, creatine kinase, meteorology, viral infection

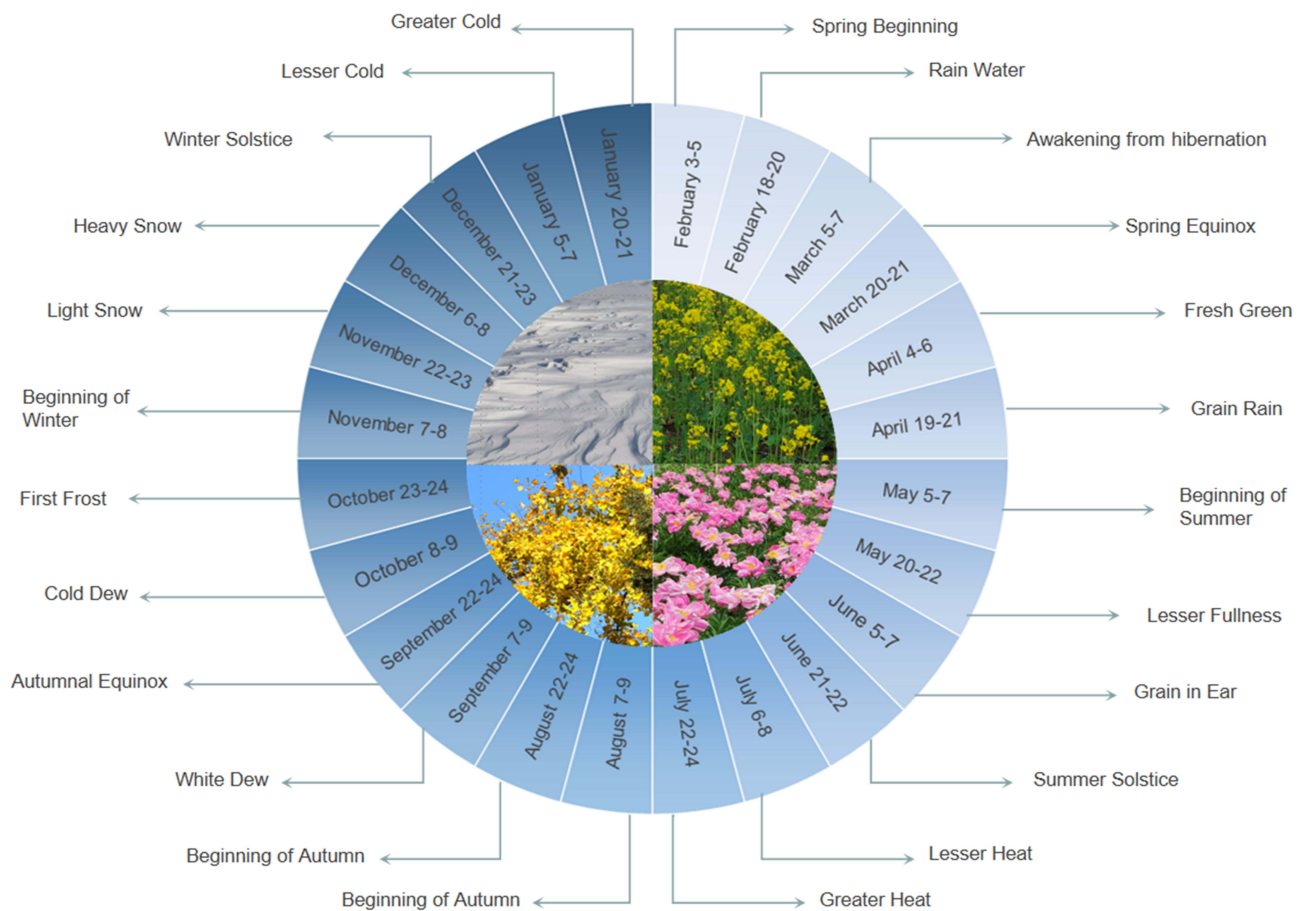
## Introduction

Rhabdomyolysis (RMI) is a life-threatening clinical condition characterized by muscle cell damage, leading to the release of cellular components such as myoglobin (MYO), serum creatine kinase (CK), and lactate dehydrogenase (LDH) into the bloodstream.<sup>1-4</sup> In modern medical research, various studies have explored the role of climatic temperature changes in the onset of the RMI. Common causes include exercise, infection, fever, and exposure to high or low temperatures, all of which involve multiple pathophysiological processes. In 2005, Koski et al first reported a case of RMI caused by hot air burns, confirming that high temperatures can directly damage the muscle cell membrane.<sup>5</sup> Other studies have experimentally demonstrated that low temperatures exacerbate muscle fiber damage and energy metabolism collapse, leading to the occurrence of the RMI.<sup>6</sup> The core mechanism lies in the disruption of the lipid composition of the cell membrane, calcium homeostasis, and ATP synthesis by extreme temperatures, thereby inducing RMI. High temperatures directly impair mitochondrial function, whereas low temperatures inhibit enzyme activity and trigger chemical-

reperfusion free radical bursts, both of which lead to autophagy impairment and muscle cell disintegration, subsequently causing systemic complications.<sup>7,8</sup> However, relatively few studies directly related to the onset time of RMI exist. Moreover, if RMI onset is explored by month or season, the time span is too broad to provide corresponding clinical guidance value. Therefore, we can adopt a new timing method to categorize it-the 24 solar terms.

The 24 Solar Terms are a cultural phenomenon that emerged from Chinese civilization, reflecting the unique Chinese worldview and natural view. They not only guide agricultural production in China but also contain knowledge related to health preservation.<sup>9</sup> Summarized by ancient people on the basis of the length of shadows and seasonal changes, the 24 Solar Terms integrate modern astronomy with the ancient Chinese calendar. Each solar term represents the time it takes for the sun's ecliptic longitude to move from 0° to 15°. Therefore, with a total of 360 degrees in a year, there are 24 solar terms, each typically lasting 15 days (although there may be variations of 14 or 16 days in some cases<sup>1</sup>). Thus, analyzing the RMI on the basis of the 24 solar terms is more precise than categorizing it by month or season. Therefore, the 24 Solar Terms can serve as a benchmark for predicting the onset of the RMI in China. The corresponding Gregorian calendar start times for the 24 Solar Terms in the lunar years of Renyin and Guimao are shown in Figure 1 and Table 1.

To better measure the onset of RMI from a perspective that aligns more closely with the physical conditions of the Chinese population, this study adopted a quantitative research method. We collected partial clinical information from all patients with CK levels ≥1000 U/L detected via laboratory tests at the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine from February 4, 2022 (the beginning of the Chinese lunar year Renyin, the year of the tiger), to February 3, 2024 (the end of the Chinese lunar year Guimao, the year of the rabbit), for a retrospective study. This was done with the expectation of obtaining clinical information on RMI during different solar terms, thereby providing a solid basis for the clinical treatment of this disease.



**Figure 1** Gregorian calendar start dates of the 24 solar terms in the Chinese year Renyin (Tiger, from February 4, 2022, to January 3, 2023) and Guimao (from January 4, 2023, to February 3, 2024).

**Table 1** Specific Dates of Each Solar Term in the Chinese Lunar Calendar

Season	Solar Terms and Corresponding Dates	
Spring	Beginning of Spring: February 4th	Beginning of Spring: February 4th
	Rain Water: February 19th	Rain Water: February 19th
	Awakening from hibernation: March 6th	Awakening from hibernation: March 5th
	Vernal Equinox: March 21st	Vernal Equinox: March 20th
	Fresh Green: April 5th	Fresh Green: April 5th
Summer	Grain Rain: April 20th	Grain Rain: April 20th
	Beginning of Summer: May 5th	Beginning of Summer: May 6th
	Lesser Fullness: May 21st	Lesser Fullness: May 21st
	Grain in Ear: June 6th	Grain in Ear: June 6th
	Summer Solstice: June 21st	Summer Solstice: June 21st
Autumn	Lesser Heat: July 7th	Lesser Heat: July 7th
	Greater Heat: July 23rd	Greater Heat: July 23rd
	Beginning of Autumn: August 7th	Beginning of Autumn: August 8th
	End of Heat: August 23rd	End of Heat: August 23rd
	White Dew: September 7th	White Dew: September 8th
Winter	Autumnal Equinox: September 23rd	Autumnal Equinox: September 23rd
	Cold Dew: October 8th	Cold Dew: October 8th
	First Frost: October 23rd	First Frost: October 24th
	Beginning of Winter: November 7th	Beginning of Winter: November 8th
	Light Snow: November 22nd	Light Snow: November 22nd
	Heavy Snow: December 7th	Heavy Snow: December 7th
	Winter Solstice: December 22nd	Winter Solstice: December 22nd
	Lesser Cold: January 5th	Lesser Cold: January 6th
	Greater Cold: January 20th	Greater Cold: January 20th

**Note:** Source of Information: <https://www.rili.com.cn/>.

## Methods

### Setting

#### Ethical Approval and Consent to Participate

The study strictly adhered to the principles of the Declaration of Helsinki, was approved by the ethics committee and was obtained from the Ethics Committee of the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine. The ethics review reference number is No. EfE-2024-003-01. Given that this study is retrospective and uses de-identified patient data, the requirement for informed consent was waived by the Institutional Review Board. Access to and analysis of the data strictly followed the patient information confidentiality and data security policies of the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine.

### Patients

This retrospective study included data from patients who had CK levels  $\geq 1000$  U/L detected at the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine between February 4, 2022, and February 3, 2024.

A CK level  $\geq 1000$  U/L was defined as an RMI.<sup>3</sup>

Patients with CK levels  $\geq 1000$  U/L were identified from both inpatient and outpatient records through the Neusoft Medical Systems Co, Ltd. The inclusion criteria were as follows: (1) patients who visited the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine between February 4, 2022, and February 3, 2024; and (2) patients with elevated CK levels  $\geq 1000$  U/L.

The exclusion criteria were as follows: (1) patients with missing basic information or incomplete diagnostic data and (2) duplicate data.

## Data Collection

Clinical data and laboratory results related to the RMI for all study subjects were collected from the hospital information system (Neusoft Medical Systems Co, Ltd). Duplicate and invalid data were removed via Excel. The data collected for each patient included the following:

Basic Information:

- Patient type (inpatient or outpatient).
- Patients' medical ID.
- Patient sex.
- Patient age.
- Department of visit.
- Preliminary diagnosis.

Data Information:

- Admission and discharge dates.
- Length of hospital stay.
- Underlying diseases.
- Complications.
- Recovery status of relevant laboratory indicators.

To ensure the reliability of data entry, two technicians independently entered the same data on the basis of the original medical records. The accuracy of the entered data was verified via cross-checking. After confirming that the data were correct, the specific solar term dates for the years Renyin and Guimao were consulted from the perpetual calendar. Patients whose test dates fell within the study period were selected for data analysis.

The duplicate removal function was used to delete duplicate data entries for the same patient within one day. Specifically, when a patient had two records from the same visit, only the first record was retained.

## Observation Indicators

This study investigated the onset and clinical outcomes of patients with CK levels  $\geq 1000$  U/L who visited the Second Affiliated Hospital of Tianjin University of Traditional Chinese Medicine for laboratory tests. The specific data indicators included admission and discharge dates, length of hospital stay, underlying diseases, complications, and the recovery status of relevant laboratory indicators.

Underlying diseases: According to research by Brian et al<sup>1</sup> diseases that may lead to CK levels  $\geq 1000$  U/L include infectious diseases, neurological disorders, cardiovascular diseases, psychiatric conditions, respiratory diseases, kidney diseases, liver dysfunction, diabetes, other metabolic diseases, rheumatic diseases, fractures, or trauma. In this study, patients diagnosed with any of the above diseases upon admission were considered to have underlying diseases.

The complications include the following:

- Electrolyte Abnormalities: These abnormalities occur due to abnormal ion transport of potassium, sodium, calcium, magnesium, etc., caused by muscle cell damage.<sup>10,11</sup>
- Subclinical kidney injury: This is defined as an increase in serum creatinine without reaching the threshold for acute kidney injury (AKI), accompanied by proteinuria or abnormal urine sediment.
- Acute kidney injury (AKI): AKI is defined on the basis of the clinical practice guidelines from the Kidney Disease: Improving Global Outcomes (KDIGO) Organization.<sup>12</sup> AKI is defined as an increase in serum creatinine (SCr) of  $\geq 0.3$  mg/dL ( $\geq 26.5$   $\mu\text{mol/L}$ ) within 48 hours or a SCr  $\geq 1.5$  times the baseline value, known or presumed to have occurred within the past 7 days, or a urine output  $< 0.5$  mL/(kg·h) for at least 6 hours.<sup>13</sup>

The relevant laboratory indicators included the following:

- Initial and final CK test results (the first CK value  $\geq 1000$  U/L after the visit was considered the initial value).
- Aspartate transaminase (AST).
- Lactate dehydrogenase (LDH).
- Creatinine (CR).
- Myoglobin (MYO).

For inpatients, all laboratory test data were considered valid if they were collected within seven days before or after the initial CK test date. Although CK-MB and CK-BB are not differentiated, CK, as a pragmatic biomarker, is in line with the requirements of guideline-directed initial management and can serve as a diagnostic criterion for RMI.<sup>14</sup>

MYO is one of the indicators of the severity of RMI.<sup>15</sup> MYO is believed to play a significant role in the development of acute kidney injury (AKI) from RMI, primarily through three mechanisms: renal vasoconstriction, the formation of tubular casts within the kidneys, and the direct toxicity of myoglobin to renal tubular cells, all of which contribute to renal dysfunction.<sup>16,17</sup> Under normal circumstances, MYO reaches its peak concentration within 12 hours after muscle injury, but due to rapid clearance by the kidneys, its concentration in the bloodstream decreases within 24 hours.<sup>13</sup> Therefore, early and effective reduction of MYO levels in the bloodstream can prevent the occurrence and progression of AKI or at least shorten the duration of renal injury.<sup>15</sup>

Serum transaminases are nonspecific markers of tissue damage, which can be caused by muscle injury or liver damage. One study revealed that 93% of patients with RMI and CK levels  $\geq 1000$  U/L had elevated AST.<sup>18</sup>

LDH is primarily found in animal tissues such as the myocardium, liver, kidneys, skeletal muscles, or lungs.<sup>19</sup> Research has shown that high levels of LDH are also associated with the occurrence of AKI.<sup>20</sup>

CR is a metabolic product of muscle metabolism in the human body and is the main indicator of renal function in clinical practice. Serum creatinine levels rise when renal function is impaired.<sup>21</sup>

Patients who visited during the years Renyin and Guimao were observed separately to discuss whether there were any patterns in the onset of the disease during different periods.

## Statistical Analysis

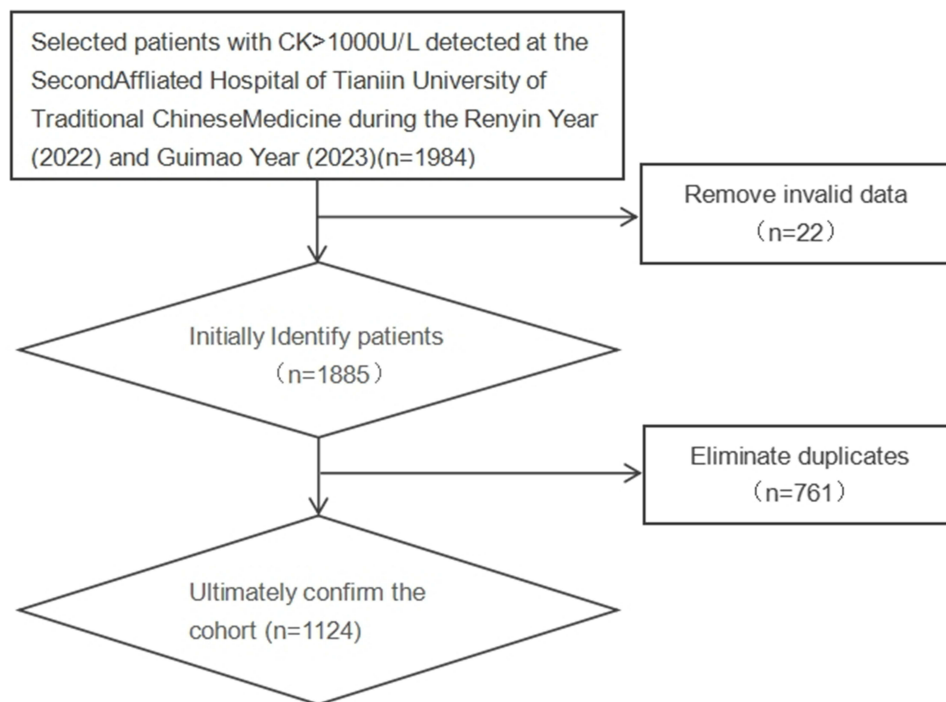
An Excel database was established for data collection, and statistical analyses were performed via Excel and IBM SPSS Statistics 27. All the statistical analyses were conducted as follows: Categorical variables were described using absolute frequencies (n) and percentages (%). Nonnormally distributed continuous data are presented as medians [Q1, Q3] (where Q1 is the first quartile and Q3 is the third quartile). The chi-square goodness-of-fit test was used to assess significant differences between groups. STL (seasonal and trend decomposition using Loess) time series decomposition was applied to evaluate the periodicity of disease onset across different solar terms. Histograms, radial bar charts, line charts, dual-line charts, and double-layer donut charts were used to visualize the variables, with Origin 2024 software employed for graphing. Specific numerical values are required for analyzing laboratory indicators, so all right-censored values were replaced with threshold values, and the results were rounded to two decimal places. A p value of less than 0.001 or less than 0.05 was considered statistically significant (\*:  $p < 0.05$ ; \*\*:  $p < 0.001$ ).

## Results

### Population

From January 1, 2022, to February 13, 2024, there were 1984 patients with CK levels  $\geq 1000$  U/L. After 77 patients and 22 invalid cases (those without a clear diagnosis) were excluded and 761 duplicate records were removed, a total of 1124 cases remained (Figure 2 and Table 2).

The study included 816 males ( $n=72.60\%$ ) and 308 females ( $n=27.40\%$ ), with a mean age of  $66.00 \pm 17.77$  years (range 2–96 years). The distribution of patients by age and sex is shown in Figure 3. The incidence rate in male patients was approximately 2.65 times greater than that in female patients.



**Figure 2** Flowchart of the data screening process.

### Annual, Monthly, and Weekly Incidence Rates

A statistical analysis of all the cases from Renyin and Guimao revealed that the number of RMI cases in Renyin was 606, and in Guimao, it was 518. The statistical results revealed that the highest number of cases occurred in December ( $p < 0.001$ , statistically significant), whereas the lowest number of cases occurred in April ( $p < 0.001$ , statistically significant). The specific distribution is shown in [Figure 4](#).

**Table 2** Baseline Characteristics of the Study Patients

Categories	No (%)
Age	66.00±17.77
Male	65.02±17.13
Female	68.62±19.18
Gender	
Male (%)	816 (72.60%)
Female (%)	318 (27.4%)
Primary Diseases	
Cardiovascular diseases (%)	376 (48.14%)
Neurological diseases (%)	404 (51.73%)
Cardiovascular diseases (%)	499 (63.89%)
Psychiatric disorders (%)	35 (4.48%)
Respiratory diseases (%)	386 (49.42%)
Renal diseases (%)	132 (16.9%)
Liver dysfunction (%)	45 (5.76%)
Diabetes mellitus (%)	267 (34.19%)
Other metabolic disorders (%)	119 (15.24%)
Rheumatic diseases (%)	21 (2.69%)
Fractures or trauma (%)	100 (12.8%)

(Continued)

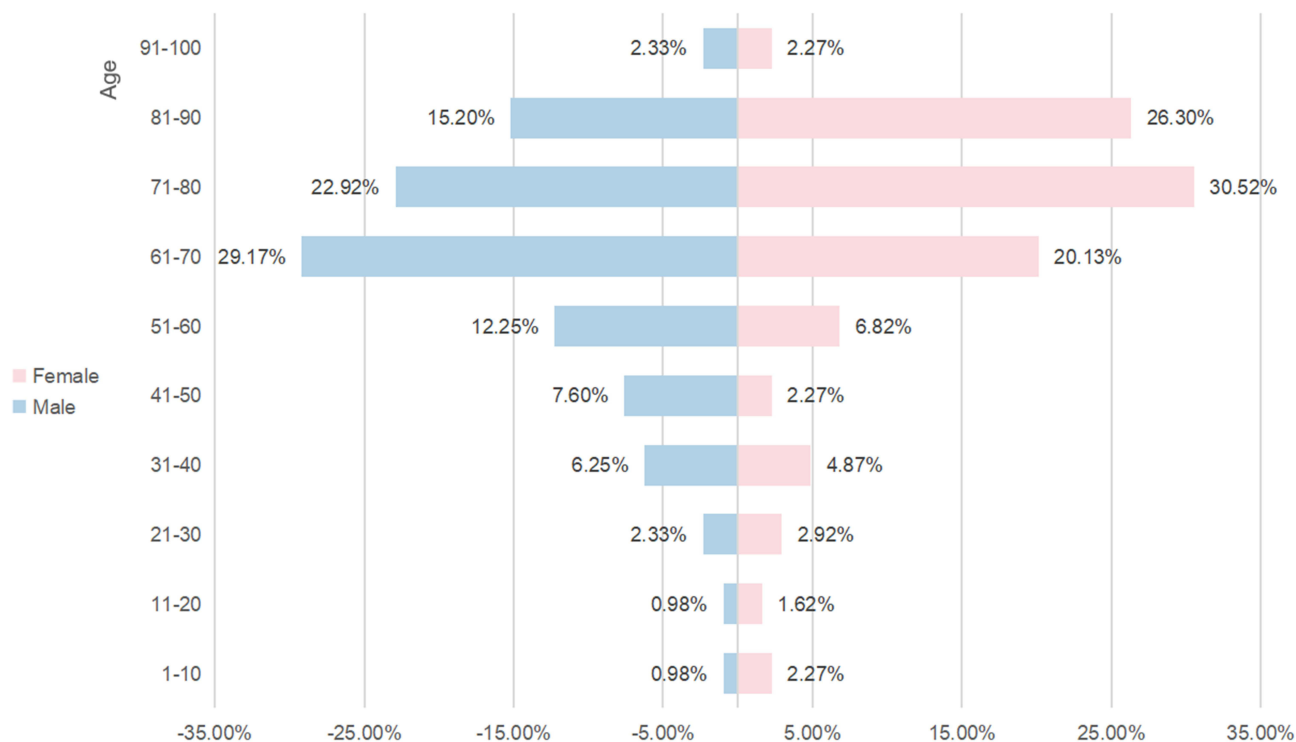
**Table 2** (Continued).

Categories	No (%)
<b>Complications</b>	
Electrolyte disturbances (%)	266 (34.06%)
Renal impairment (%)	108 (13.83%)
Acute renal failure (%)	45 (5.76%)
<b>Laboratory Indicators</b>	
Significant darkening of urine color (%)	20 (1.78%)
CK Median [QL, QU]	1695.50 (1238.00, 2689.50)
AST↑	935 (83.78%)
AST↑Median [QL, QU]	108.00 (63.00, 202.00)
LDH↑	944 (84.14%)
LDH↑Median [QL, QU]	418.50 (326.25, 655.75)
CR↑	513 (47.68%)
CR↑Median [QL, QU]	152.30 (111.90, 251.20)
MYO↑	844 (95.37%)
MYO↑Median [QL, QU]	897.00 (368.00, 2241.00)

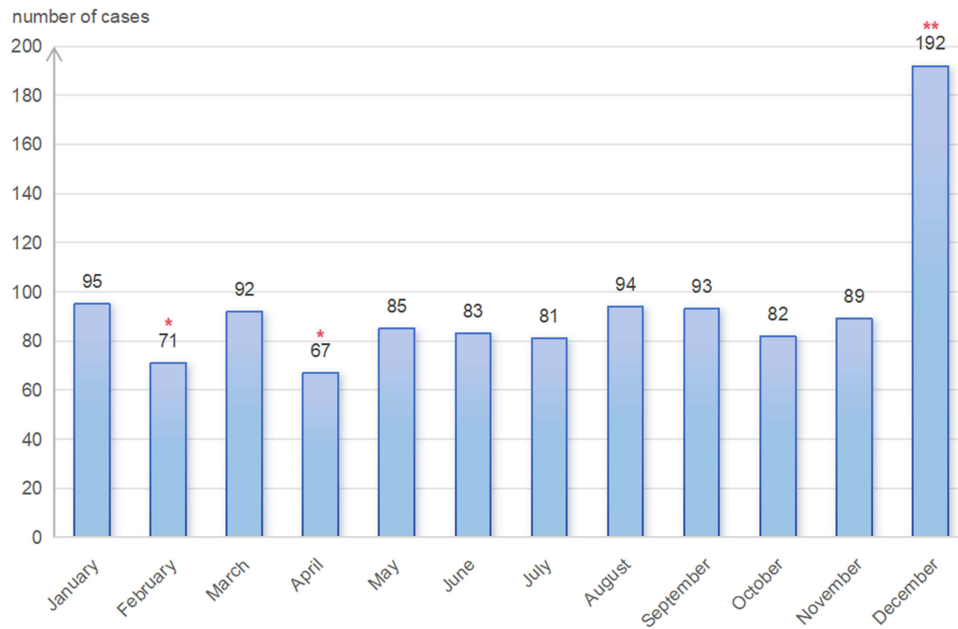
### Incidence Rates Across the 24 Solar Terms

From the perspective of the 24 Solar Terms, the incidence of RMI varies significantly (Figure 5). The highest number of cases occurred during the Heavy Snow period, with 115 cases. The lowest number of cases occurred during the Vernal Equinox and Lesser Fullness periods, with 32 cases each.

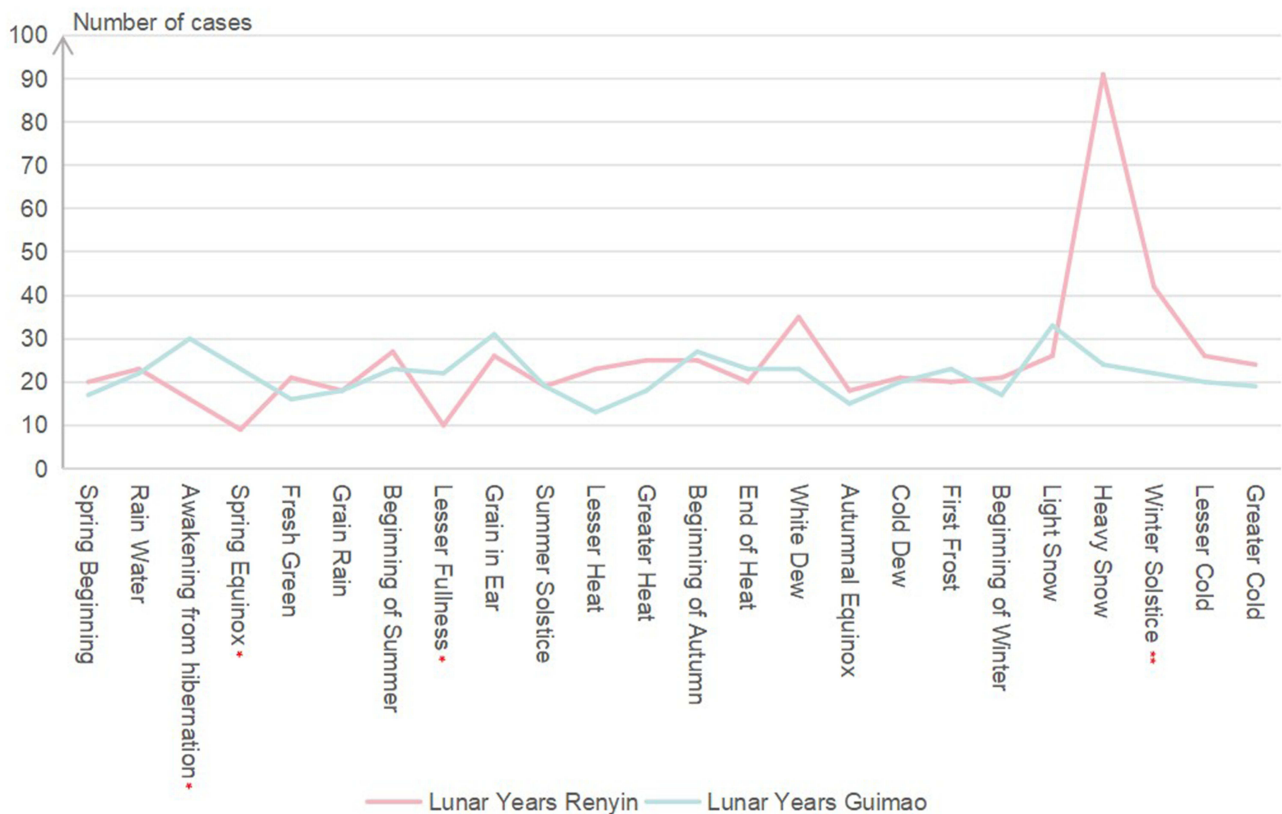
As shown in Figure 5, the incidence of the RMI varies significantly across the 24 solar terms. The highest number of cases occurred during the Heavy Snow period, with 115 cases, whereas the lowest number of cases occurred during the Vernal Equinox and Lesser Fullness periods, with 32 cases each.



**Figure 3** Distribution of age and sex in patients with RMI.



**Figure 4** Distribution of onset months in patients with RMI (\* $p < 0.05$ ; \*\* $p < 0.001$ ).



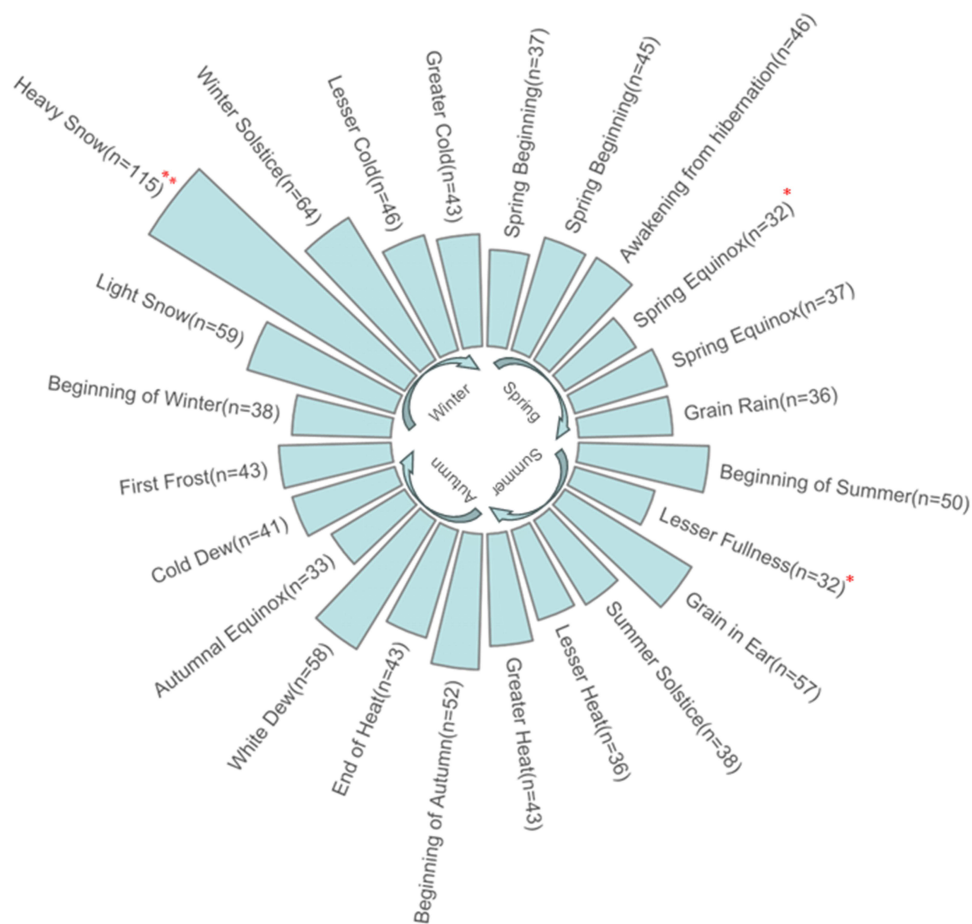
**Figure 5** Distribution of RMI cases across 24 solar terms (\* $p < 0.05$ ; \*\* $p < 0.001$ ).

The total number of cases in each solar term across the two years was summed, and a chi-square test revealed a highly significant nonuniform distribution of cases across the solar terms ( $p < 0.001$ ). This study employs time series decomposition to break down the disease incidence sequence into three core components: the long-term trend component ( $T_t$ , reflecting the baseline changes in incidence), the seasonal component ( $S_t$ , characterizing the periodic fluctuations of the solar terms), and the

residual component ( $R_t$ , random noise). An additive model is used:  $Y_t = T_t + S_t + R_t$ . Here,  $Y_t$  represents the original incidence number (time series according to the 24 solar terms), and  $t$  is the time index of the solar terms. The construction steps are as follows: ① Calculate the seasonal component: Extract the periodic fluctuation pattern of the 24 solar terms from the original sequence. ② Remove the seasonal effect: Obtain the deseasonalized sequence through  $Y_t - S_t$  and establish the long-term trend model  $T_t$  on the basis of the deseasonalized sequence. ③ Establish the trend prediction model: Fit the long-term trend change pattern via the deseasonalized sequence. ④ Generate the final prediction: Combine the trend component and the seasonal component as  $\hat{Y}_t = T_t + S_t$ , where the residual component  $R_t$ , as an unpredictable random fluctuation, is excluded, and  $\hat{Y}_t$  is the final predicted value. Further analysis via STL time series decomposition revealed that the seasonal component had an amplitude of  $\pm 20$  cases, accounting for 17.8% of the total variation. The residual component showed no significant pattern, indicating a stable periodic fluctuation driven by the solar terms.

Additionally, the number of cases in each solar term was separately analyzed for the lunar years Renyin and Guimao, resulting in the following line chart (Figure 6).

The chart shows that the incidence pattern of the disease remains largely consistent across different solar terms. However, there were notable differences in the number of cases during certain solar terms, such as Heavy Snow, Weakening from Hibernation, Verbal Equinox, and Lesser Fullness.



**Figure 6** Line Chart of RMI Cases by Solar Terms in Lunar Years Renyin and Guimao (\* $p < 0.05$ ; \*\* $p < 0.001$ ).

## Primary Diseases

In this study, the majority of patients had multiple underlying diseases that could lead to RMI. Among the 781 hospitalized patients, 13 patients (n=1.66%) had no underlying disease as defined in this study, 150 patients (n=19.21%) had a single underlying disease, and 618 patients (n=79.13%) had two or more possible underlying diseases.

## Complications

Among the 781 hospitalized patients, electrolyte disturbances were the most common complications, including hyperkalemia, hypokalemia, hyperphosphatemia, hyperuricemia, high anion gap metabolic acidosis, and hypermagnesemia, affecting a total of 266 patients (n=34.06%). A total of 108 patients (n=13.83%) experienced varying degrees of renal impairment, with 45 patients (n=5.76%) developing AKI, accounting for 41.67% of those with renal impairment. Among these, 21 patients (n=46.67%) eventually died.

Among the 155 deceased patients (n=19.85%), 84 patients (n=54.19%) had electrolyte disturbances, and 21 patients (n=13.55%) had AKI.

## Laboratory Tests

All patients in the database had their serum CK levels measured, with an average value of 2823.36 U/L, a maximum value of 121,211 U/L, and a minimum value of 1000 U/L.

Among patients with varying degrees of renal impairment, 98 patients (n=90.74%) had elevated CR levels.

In this study, following the occurrence of RMI, after excluding undetected data, the detection rate of elevated MYO was the highest at 844 patients (n=95.37%), higher than that of elevated AST (83.78%), elevated LDH (84.14%), and elevated CR (47.68%).

A total of 20 patients exhibited noticeable changes in urine color (gross hematuria, red, brown, or dark brown). Among the hospitalized patients, 17 patients (n=2.59%) experienced these changes, with a probability of renal impairment occurring in 23.53% of them.

## Discussion

The STL (seasonal-trend decomposition procedure based on Loess) is a time series decomposition method based on locally weighted regression (Loess). It decomposes a time series into three additive components: the trend component, the seasonal component, and the residual component. STL is suitable for decomposing seasonal patterns with arbitrary periods and can better observe the fluctuations in disease incidence across solar terms. STL has been widely validated as a standardized decomposition tool in fields such as epidemiology, meteorology, and economics. To further quantify the seasonal amplitude and trend attenuation, we chose to use STL time series decomposition for validation.<sup>22,23</sup>

An analysis of the incidence rate of the RMI from the perspective of the 24 Solar Terms, reveals observed that the incidence of this disease peaks during the Heavy Snow period and reaches its lowest points during the Vernal Equinox and Lesser Fullness periods. After separately tallying the cases in the years Renyin and Guimao, the incidence rate of the RMI essentially remains consistent across the same solar terms in different years. Therefore, it is possible to predict the occurrence of this disease on the basis of the time corresponding to the 24 Solar Terms. The Vernal Equinox marks the safest period for the RMI throughout the year, while vigilance against the occurrence of the RMI is necessary during the Heavy Snow solar terms.

Among all patients with underlying disease in this study, the most common was cardiovascular disease. *The 2023 ESC Guidelines for the Management of ST-segment Elevation Acute Myocardial Infarction* proposed that CK is a nonspecific marker of myocardial injury, as CK levels can increase in both myocardial and skeletal muscle injuries. When myocardial cells are damaged, the released isoenzyme is creatine kinase-MB (CK-MB), while skeletal muscle cell damage results in CK-MM release. If further detection of isoenzyme subtypes could be conducted, it would be possible to differentiate between myocardial infarction or RMI caused by CK levels  $\geq 1000$  U/L. However, most patients in this study did not undergo such tests, which might explain why cardiovascular disease was the most prevalent underlying disease. Acute myocardial infarction has a peak incidence during the solar periods of the End of Heat and Fresh Green,<sup>24</sup> whereas

coronary heart disease peaks at the Autumnal Equinox, with a high incidence concentrated in the autumn and winter.<sup>25</sup> The second most common category was neurological diseases. Cerebral creatine kinase CK-BB can reflect the degree of damage to neurons and glial cells and is a specific protein associated with cerebral infarction.<sup>26</sup> Like in cardiovascular diseases, CK-BB can also be detected when CK is measured, which may have caused corresponding errors. The incidence of cerebral infarction is highest at the Summer Solstice and lowest at the Lesser Cold, with a higher incidence in summer and autumn. The incidence of cerebral hemorrhage peaks at the autumnal equinox.

The traditional Chinese calendar, known as the “Chinese calendar”, is established on the basis of lunar phases, with reference to the solar tropical year as the length of a year. It incorporates the 24 solar terms and intercalary months to align the average calendar year with the solar year. Therefore, even in different years, the external environment can remain essentially consistent during the same solar terms. In traditional Chinese medicine (TCM), which is nurtured by traditional Chinese culture, the human body is closely related to the natural environment, and the strength or weakness of many human functions corresponds to natural changes. Thus, it is possible to infer the peak times for diseases on the basis of solar terms and to take corresponding preventive and therapeutic measures. Although there is no specific disease in TCM that directly corresponds to RMI, the typical symptoms of RMI, such as muscle pain and fatigue, are similar to the “Bi syndrome” and “Wei syndrome” described in TCM. Therefore, the onset of RMI can be explained from the perspective of TCM. In this study, RMI was found to occur more frequently in the Heavy Snow solar terms and less frequently in spring and summer.

The Heavy Snow solar term corresponds to December 7 to December 21, 2022, and December 7 to December 22, 2023. This period marks the deepening of winter, with increasingly colder weather and potentially increased snowfall. Researches show that disease incidence significantly clusters in the solar term dimension, with Heavy Snow being the main peak node. On December 7, 2022, the country began to fully optimize and adjust its COVID-19 prevention and control measures. The novel coronavirus is closely related to RMI—the virus binds to angiotensin-converting enzyme 2 (ACE2) on the surface of skeletal muscle cells, directly invades muscle cells, and causes rhabdomyolysis.<sup>27</sup> Therefore, an increase in COVID-19 cases inevitably leads to an increase in RMI incidence, resulting in a significant peak in cases during the Heavy Snow period of Renyin.

Awakening from the Hibernation solar term corresponds to March 5 to March 20, 2022, and March 6 to March 20, 2023. This term marks the deepening of spring, with gradually warming weather, the first spring thunder, and the awakening of hibernating animals. The Vernal Equinox corresponds to March 20 to April 4, 2022, and March 21 to April 4, 2023. On the day of the Vernal Equinox, the sun is directly over the equator, and day and night are almost equal in length worldwide. From the Vernal Equinox onward, temperatures gradually rise, precipitation increases, and the weather becomes warm and humid. During the Guimao year, the positivity rate of influenza virus increased during the Awakening from hibernation and Vernal Equinox.<sup>28</sup> After influenza virus infection, various enzymes in the body are activated, the internal environment is disturbed, many oxygen free radicals are formed, and mitochondrial dysfunction also leads to the occurrence of rhabdomyolysis.<sup>29</sup> Moreover, higher temperatures, unstable air humidity, air pressure, and complex environmental changes during Awakening from hibernation and Vernal Equinox in Guimao are conducive to the spread of pathogens.<sup>30</sup>

The Lesser Fullness solar term corresponds to May 20 to June 5, 2022, and May 21 to June 5, 2023. In southern China, this period marks the beginning of the flood season, with frequent rainfall and rising river levels. The weather gradually warms up, and the grains of summer crops such as wheat in the north begin to fill out, hence the name. During the Lesser Fullness period of the Guimao Year, the temperature was significantly lower than that of the same period in the Renyin Year (based on several network data sources), and the positivity rate of the novel coronavirus was high,<sup>28,31</sup> resulting in more cases than those in the Renyin Year.

Some studies have indicated that patients with CK levels below 5000 IU/L are not at risk for AKI.<sup>32</sup> In this study, the serum CK levels of all patients in the database were measured, with an average value of 2823.36 U/L, a maximum value of 121,211 U/L, and a minimum value of 1000 U/L. Among the 713 patients with CK levels less than 5000 IU/L who were analyzed for complications, 37 patients (n=5.19%) developed AKI, which is not significantly different from the findings of other studies. After muscle injury, CK levels typically peak within 1--3 days, with a half-life of approximately 1.5 days. This duration is longer than the period during which MYO levels remain elevated. Some studies have suggested

that MYO levels may not be a significant concern.<sup>4</sup> However, in this study, after excluding undetected data, MYO was found to be a better indicator of renal injury than other laboratory tests. The typical clinical triad of RMI includes muscle weakness, muscle pain, and a darkened urine color. However, in this study, the proportion of patients with MYO among those who underwent routine urinalysis was not high. Therefore, diagnosing RMIs on the basis solely of changes in urine color may not be accurate.

Aggressive fluid resuscitation is the cornerstone of RMI treatment.<sup>33</sup> Similar to the findings of Brown et al<sup>15</sup> this study revealed that patients treated with fluid resuscitation had a significantly lower probability of developing severe complications and mortality than did those treated with sodium bicarbonate solution. However, there was no significant difference in the probability of severe complications, the need for renal replacement therapy, or mortality between patients treated with a combination of fluid resuscitation and sodium bicarbonate solution and those treated with sodium bicarbonate solution alone. This may suggest that, compared with adequate fluid resuscitation, the use of sodium bicarbonate treatment for RMI may not be necessary. Nevertheless, this study included a relatively small sample size and is not suitable for evaluating clinical efficacy; therefore, it cannot provide guidance for clinical treatment.

This retrospective study reveals from an epidemiological perspective that there is a significant correlation between the incidence risk of the RMI and the 24 solar terms, with the highest incidence rate occurring during the Heavy Snow period and the lowest during the Vernal Equinox and Lesser Fullness periods. This temporal distribution pattern suggests that heavy snow may be an important environmental factor for the occurrence of RMI. The biological plausibility of this association lies in the fact that many relevant studies have demonstrated significant seasonal fluctuations in the triggers of RMI. However, as an observational study, the results may be affected by unmeasured or not fully controlled confounding factors (such as temperature or humidity changes accompanying the solar terms, differences in the intensity of holiday-related activities, and the prevalence trends of specific diseases during the same period) and cannot establish a causal relationship between the solar terms themselves and the RMI. Moreover, the results of this study also have potential public health value, providing a scientific basis for establishing a solar-term-sensitive standardized prevention mechanism. Against the backdrop of the transformation of primary health care into health management, health administrative departments can issue early warnings on the basis of the solar-term risk model and dynamically allocate medical resources (such as dialysis equipment). Medical institutions need to optimize the triage process during high-risk solar terms (eg, prioritizing the detection of MYO/CK for “dark urine”). Promote the introduction of portable detection technologies into communities; clinicians should strengthen education for high-risk groups on the basis of the characteristics of solar terms (eg, timely reminders to hydrate on hot days and control exercise intensity); patients can identify early symptoms (muscle pain, abnormal urine color) through solar-term health prompts and enhance their awareness of seeking medical attention proactively. Through multilevel collaboration, the regularity of solar terms can be transformed into prevention and intervention nodes, which is expected to significantly reduce the incidence of RMI-related acute kidney injury and achieve a transition from passive diagnosis and treatment to active health management.

Since this study is retrospective, it inevitably has certain limitations. First, the study included only patients from the past two years, resulting in a relatively small sample size. Second, Although the 24 Solar Terms represent a regular understanding of the climatic characteristics of different seasons throughout the year, there is indeed an inescapable element of unpredictability in climate change that we cannot avoid. Third, right-censored values were substituted with threshold values, which may introduce some discrepancy compared with the actual values. Future research will incorporate a larger dataset and delve deeper into the underlying mechanisms of RMI onset across different seasons. Efforts will also be made to address the limitations of the current study. By further leveraging our research findings, we aim to enhance the prediction and management of RMI, thereby improving the treatment level and patient outcomes.

This study analyzed the relationships between the incidence of the RMI and the 24 solar terms during the Renyin and Guimao years. The incidence of the RMI peaks during the Heavy Snow solar term and reaches its lowest point during the Vernal Equinox and Lesser Fullness terms. The incidence rate remains essentially consistent across different years during the same solar terms, thus confirming that the value of the solar term changes for disease prediction. From the perspective of traditional Chinese medicine, the incidence pattern of RMI is attributed to low winter temperatures, which suppress the

immune system and enhance metabolism in summer. Modern medical indicators (such as MYO) can be used to predict potential renal injury. However, due to the limited sample size, further validation is needed.

## Conclusion

The 24 Solar Terms provide a valuable reference for measuring the onset of RMI. In clinical practice, the specific solar terms of the Chinese lunar calendar can be utilized to predict the occurrence of the RMI, which transforms the patterns of solar terms into early warning nodes. Proactive health management can be realized through multilevel collaboration, thereby enabling earlier and more timely management of this serious disease, which poses a threat to human health. Additionally, abnormal climatic changes in nature and infections from external viruses or bacteria can significantly disrupt the body's equilibrium and are potential triggers for RMI that require vigilance.

## Disclosure

The authors report no conflicts of interest in this work.

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