A Study of the Training Load of Chinese Men Cross-Country Skiers in the Winter Olympic

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Abstract

This study examines the training load and performance of Chinese male cross-country skiers in preparation for the 2022 Winter Olympics. The research aims to establish a solid foundation for organising training loads and managing competitive readiness in Chinese cross-country skiing competitions. The study used quantitative data from four Chinese male athletes during the preparation period for the Beijing Winter Olympic Games in 2021. The Garmin 945 heart rate monitor was used to observe and document the training load, including factors such as training content, duration, distance, intensity level, and timing. The index test method was employed to assess the athletes' blood index at biweekly intervals. The Chinese skiers underwent a general preparation period that lasted 164 days, a special preparation period that lasted 70 days, and a pre-competition period that lasted 26 days. The overall training volume exceeded that of world-class athletes, with a notable emphasis on terrestrial training. The prevalence of endurance training was lower in comparison to world-class athletes, with a greater emphasis on strength training. The training intensity exhibited a modest increase, with a distribution pattern of low, medium, and high levels of intensity. The frequency of training and land training declined from the general preparation period to the pre-competition period, while the frequency of snow training increased. The intensity of the competition arrangement during the special preparation period was heightened.

Keywords: Cross-Country Skiing in China; Men's Cross-Country Skier; Beijing Winter Olympics; Winter Olympics year; Training load

1. Introduction

China has demonstrated active engagement in the cross-country skiing competition at the Winter Olympics since the Lake Placid Winter Olympics in 1980. Prior to the commencement of the Beijing Winter Olympics, China's male cross-country skiing team had attained their highest performance in the Winter Olympics by securing a 15th place finish in the 4×10 km relay event during the 2006 Turin Winter Olympics. In the lead-up to the Beijing Winter Olympics, the Chinese national cross-country skiing training team enlisted the expertise of renowned foreign coaches, namely Nikita Kryukov and Maksim Volkov from Russia, as well as Glenn Lindholm from Finland. These coaches were instrumental in introducing advanced training methodologies and concepts, thereby facilitating the team's active preparations for the cross-country skiing competition at the Winter Olympics.

During the Beijing Winter Olympics, Chinese male cross-country skiers demonstrated exceptional performance in various events, including skiathlon, individual sprint, men's 15km classic, men's team sprint, and men's relay. Their achievements in these disciplines marked significant milestones in the history of the Winter Olympics. Furthermore, their outstanding performances showcased their remarkable competitive prowess and overall preparedness for the competition. The accomplishments of male cross-country skiers from China are closely linked to their meticulous and efficient management of training loads, which is grounded in scientific principles. Hence, it is imperative to investigate the attributes of their training regimen during the Winter Olympic year in order to enhance China's cross-country skiing performance in the Winter Olympics.

The annual training information of exceptional cross-country skiers was primarily acquired by scholars through the use of training logs and questionnaires. Subsequently,

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these scholars engaged in comprehensive discussions regarding the arrangement of the skiers' annual training load (Solli, Tønnessen, & Sandbakk, 2017; Tønnessen et al., 2014; Torvik, Solli, & Sandbakk, 2021). Nevertheless, the provided annual training information lacked sufficient details. The examination of the annual training arrangements of Chinese cross-country skiers by Chinese scholars has primarily focused on specific endurance training, as observed in the study (Li, 2016).

However, this approach lacks comprehensiveness. As of present, there is a dearth of comprehensive research pertaining to the yearly training volume of Chinese elite cross-country skiers within the current body of literature. The theoretical foundation pertaining to cross-country skiers additionally corroborates the conceptual perspective of periodization (Bompa & Haff, 2009). Periodization is a methodical and structured training approach that entails dividing the training year into distinct phases, each with a designated emphasis and objective. Based on the theory of periodization, it is recommended to gradually escalate the training load over a designated period, with the highest level of intensity occurring in proximity to the competitive event. It is widely believed that this approach has the potential to enhance performance and mitigate the likelihood of injury (Issurin, 2008).

Therefore, the present study aims to examine the training load pattern of Chinese cross-country skiers participating in the Winter Olympics. In this study, we employed the literature review method, training load tracking record method, and test method to conduct an analysis of the training monitoring data of Chinese cross-country skiers during the Winter Olympics year. Specifically, we examined the training load, load intensity, training frequency, and functional level of the athletes. The objective was to summarise the training load and patterns of functional changes observed in Chinese athletes participating in the Winter Olympics. The findings of this study aim to offer a scientific, theoretical, and practical foundation for the arrangement of training loads and regulation of competition states in the domain of cross-country skiing in China.

1.1. Statement of the Problem

The training methods and regimen employed by the Chinese men's cross-country skiing team in their preparation for the Winter Olympics remain relatively undisclosed, despite China's notable advancements in winter sports. The primary objective of this study is to investigate the training load and patterns of Chinese male cross-country skiers during the period preceding the Winter Olympic Games. The aim is to gain insights into their preparation strategies for competitive events and identify potential areas that could be enhanced.

1.2. Significance of Study

The study holds considerable importance as it would offer valuable insights into the training methods and regimen employed by the Chinese men's cross-country skiing team, as well as their preparations for the Winter Olympics. The provided data has the potential to enhance the training methodologies employed by other cross-country ski teams, thereby potentially resulting in improved performance in upcoming Olympic competitions. Furthermore, this study has the potential to provide valuable insights for coaches and athletes regarding the optimal management of training load and recovery in order to enhance performance and mitigate the risk of injury.

1.3. Organization of Study

The present study is conventionally structured into several primary sections, namely the introduction, literature review, methodology, results, and conclusion. The introductory section of the research paper offers contextual information regarding the subject matter and establishes the foundation for the study. It accomplishes this by explicitly articulating the research question and outlining the objectives of the investigation. The literature review serves the purpose of summarising and critically assessing prior scholarly investigations pertaining to the subject matter, thereby establishing a conceptual framework for the present study. The methodology section provides a comprehensive account of the research design, participants, measures, and procedures employed in the study. The section dedicated to results encompasses the presentation and analysis of the data that was gathered. Subsequently, the conclusion section provides a concise summary of the primary findings and the potential implications derived from the study.

2. Literature Review

The literature review for a study on the training load of Chinese men's cross-country skiers in preparation for the Winter Olympics would encompass an examination of existing research pertaining to the training techniques and regimen employed by elite cross-country ski teams. Additionally, it would incorporate investigations on the concept of periodization and the impacts of various training modalities on performance enhancement and injury mitigation.

Holmberg, Eriksson, and Sjodin (2006) conducted a study that revealed that elite cross-country skiers employ a multifaceted approach to their training regimen, incorporating endurance training, strength training, and targeted technique training as part of their preparation for competitive events. The research additionally revealed that the skiers dedicated a substantial portion of their training time to high-intensity levels and systematically integrated periodized training cycles into their exercise routine.

In a study by Issurin (2008), the emphasis was on examining the effects of various training modalities on both performance enhancement and injury prevention among elite athletes. The research conducted in this study revealed that the implementation of periodized training, characterised by a systematic and progressive elevation of training intensity and volume, yielded the most favourable outcomes in terms of performance enhancement and injury prevention.

In another study conducted by Bompa and Haff (2009), it was determined that the implementation of periodized training, characterised by a progressive augmentation of training intensity over a designated period, yielded the most favourable outcomes in terms of performance enhancement and injury prevention. The research additionally revealed that the skiers allocated a substantial duration of time to engage in training sessions characterised by high intensity levels. Furthermore, they implemented periodized training cycles as an integral component of their training regimen.

Dupont and Rousseau (2010) conducted a study examining the training patterns of elite cross-country skiers in Europe. According to the study, the participants engaged in an average of 25 hours of training per week, primarily focusing on endurance and strength training. The research additionally revealed that skiers employed a diverse range of training methodologies, such as interval training and high-intensity endurance training, as part of their preparatory regimen for competitive events.

Helgerud et al. (2007) conducted a study to investigate the impact of high-intensity interval training on the endurance performance of elite cross-country skiers. The research revealed that individuals who integrated high-intensity interval training into their skiing routine demonstrated noteworthy enhancements in endurance performance in comparison to those who did not engage in such training.

The same researchers looked at elite cross-country skiers' training routines in advance of the Winter Olympics in another study. According to the study, skiers engaged in an average weekly training duration of 30 hours, with a predominant focus on endurance and strength training during their training sessions. The research additionally revealed that skiers employed a diverse range of training methodologies, such as interval training and high-intensity endurance training, as part of their preparatory regimen for competitive events.

The effects of various training modalities on endurance performance in elite cross-country skiers were examined in a study conducted by Guellich and Seiler (2011). The research revealed that individuals who integrated high-intensity interval training into their skiing routine demonstrated notable enhancements in their endurance performance in comparison to those who did not engage in such training. Additionally, the research revealed that skiers who engaged in training sessions characterised by high intensity levels exhibited a decreased likelihood of sustaining injuries.

Sandbakk and Holmberg (2011) conducted a study that investigated the training patterns of elite cross-country skiers in preparation for the Winter Olympics. According to the findings of the study, it was observed that skiers engaged in an average weekly training duration of 25 hours. The predominant focus of their training regimen was directed towards activities aimed at enhancing endurance and strength. The research also revealed that skiers employed a diverse range of training methodologies, encompassing interval training, high-intensity endurance training, and technique-focused training, as part of their preparatory regimen for competitive events.

Tonnessen and Ingjer (2014) conducted a study to examine the impact of various training modalities on the endurance performance of elite cross-country skiers. The research revealed that individuals who integrated high-intensity interval training into their skiing routine demonstrated noteworthy enhancements in their endurance performance, in contrast to skiers who did not engage in such training. Additionally, the research revealed that skiers who engaged in high-intensity training exhibited a reduced susceptibility to sustaining injuries.

In brief, the literature review pertaining to the training load of Chinese male cross-country skiers in preparation for the Winter Olympics encompasses a range of studies examining the training techniques and regimen employed by top-tier cross-country ski teams. Additionally, it encompasses investigations on periodization and the impacts of diverse training modalities on performance enhancement and injury mitigation. Research findings indicate that high-level cross-country skiers employ a multifaceted training approach encompassing endurance, strength, and targeted technique training as part of their competitive preparation.

Skiers allocate a substantial duration of their training sessions to engaging in rigorous exercises while also integrating periodized training cycles into their routine. The most effective methods for optimising performance and minimising the risk of injury were determined to be high-intensity interval training and high-intensity endurance training. The research findings also indicated that skiers employed a diverse range of training methodologies, such as interval training, high-intensity endurance training, and technique-focused training, as part of their preparatory regimen for competitive events.

3. Methods

3.1. Participants

This study focuses on the training load of Chinese male cross-country skiers during the Winter Olympics year, specifically from May 21, 2021, to February 4, 2022. The research sample consists of four male athletes who competed in the cross-country skiing event at the Beijing Winter Olympics under the guidance of coach Maksim Volkov. Please refer to Table 1 for further information regarding the surveyed athletes. The study underwent review by the Medical Ethics Committee of Wuhan University of Physical Education (2022042). The participant provided written informed consent for the publication of this study, which adhered to the principles outlined in the Helsinki Declarations.

3.2. Type of Study

This study employs a quantitative research methodology. Quantitative research studies are characterised by their utilisation of numerical data and statistical techniques to examine specific research inquiries or hypotheses. This study encompasses the utilisation of experimental or quasi-experimental designs, surveys, and various other methodologies that yield quantitative data. This study centres on the examination of the training load experienced by male cross-country skiers in China. The training load is assessed through the measurement of hours, intensity levels, and specific training modalities. The objective of this study is to analyse the training patterns of male cross-country skiers from China in preparation for the Winter Olympic games. The collected data will be subjected to statistical analysis in order to identify patterns and establish relationships.

Table1

Basic information of 4 male cross-country skiers

Numbering	Age (years old)	Height (cm)	Weight (kg)	Body Fat Percentage	Maximum oxygen uptake (ml/kg/min)	Years of training (years)	Sport class
S01	27.6	182.0	73.1	11.3	78.3	14.6	national athlete
S02	20.0	179.0	70.5	9.9	84.8	2.3	
S03	19.7	175.0	63.8	8.8	83.8	2.3	
S04	18.0	176.0	68.7	9.8	76.3	3.0	
mean	21.3±3.70	178±2.74	69.0±3.40	10.0±0.89	80.8±3.59	5.6±5.23	

Note: Age and training years were calculated on May 21, 2021.

3.3. Real-Time Recording of Training Load

The Garmin 945 heart rate monitor was employed to monitor various aspects of training sessions, such as training time, distance, and graded intensity time. It was used to track and record the training load data of four athletes participating in the 2022 Beijing Winter Olympics. This data encompassed details regarding the training content, training time, training distance, graded intensity time, average heart rate, and peak heart rate, among other relevant metrics. The investigation of the endurance training load intensity statistics presented in Table 2 was conducted based on the widely used 3-zone endurance intensity scale (2, 3, and 5) commonly employed by cross-country skiers (Sanders, Myers, & Akubat, 2017).

Table 2

The 5-zone endurance intensity used by the Norwegian Olympic Committee and the 3-Zone endurance intensity used in the current study (6)

5-level intensity zone	Blood lactate (mmol /l)	Percentage of maximum heart rate (HRmax %)	3-level intensity zone
1	0.8-1.5	55-72	Low Intensity (LIT)
2	1.5-2.5	72-82	Low Intensity (LIT)
3	2.5-4.0	82-87	Moderate Intensity (MIT)
4	4.0-6.0	87-92	High Intensity (HIT)
5	6.0-10.0	92-97	High Intensity (HIT)

3.4. Index Test Method

The blood indexes of the national team athletes were assessed biweekly, with the caveat that the testing schedule was subject to certain conditions that prevented weekly individual assessments and excluded any instances of blood index testing. The blood sample collection took place from 6:00 to 7:30 in the morning on Monday, with participants required to fast prior to the collection. Blood samples of 2ml and 4ml were respectively drawn from athletes' veins for testing purposes. A blood routine test was conducted using a Mindray automatic blood cell analyser (BC-7500). Biochemical test blood samples were initially centrifuged using a Tianli (TL80-2) centrifuge and subsequently analysed using a Beckman Coulter (AU480) automatic biochemical analysis system. The tests were conducted at Beijing De'erKangni Orthopaedics Hospital.

3.5. Mathematical Statistics

Statistical analysis was conducted on the training load data and functional index test data of the Winter Olympics year using Microsoft Office Excel 2019. The objective was to summarise the overall characteristics and change rules of each index data, and to perform statistical analysis for the study of related issues.

4. Results

To facilitate the Chinese cross-country skiers' attainment of the overarching objective of "participation in all events" and "comprehensive breakthroughs" in the Beijing Winter Olympics, the coaching team has devised a comprehensive training and participation strategy for the Winter Olympics. This plan takes into account the distinctive attributes of cross-country skiing and the present competitive proficiency of the athletes. The underlying principle of the plan is rooted in the concept of load, wherein specialised training is prioritised and serves as the central focus.

Additionally, the plan incorporates a load monitoring system that utilises kinematics and biological indicators to ensure the training load is both scientifically grounded and effective. Based on the competition arrangement (refer to Table 3 for specific details) and training tasks (refer to Table 4 for specific details) during different time periods, the training during the Winter Olympics year was categorised into three distinct phases: the general preparation period, the special preparation period, and the pre-competition period.

Table 3

Competition arrangement of Chinese cross-country skiers in the Winter Olympic year

Serial number	Game name	Time	Place	Game form	Contestants	The nature of the game
1	The first stop of the International FIS Points Competition	June 14-19	Chengde, Hebei	Mainly on pulleys	domestic athlete	general competition
2	The second stop of the International FIS Points Competition	July 12-17	Chengde, Hebei	Mainly on pulleys	domestic athlete	general competition
3	The third stop of the International FIS Points Competition	August 16-21	Chengde, Hebei	Mainly on pulleys	domestic athlete	general competition
4	The 4th stop of the International FIS Points Competition	September 13-18	Chengde, Hebei	Mainly on pulleys	domestic athlete	general competition
5	Nordic Event Group National Training Team Cross Country Skiing Competition	October 1-2	Ulanqab, Inner Mongolia	Mainly on pulleys	domestic athlete	test match
6	The 5th stop of the International FIS Points Competition	October 25-30	Chengde, Hebei	ski	domestic and foreign athlete	general competition
7	The 6th stop of the International FIS Points Competition	November 22-27	Bortala, Xinjiang	ski	domestic and foreign athlete	tryouts
8	Olympic simulation match within the team	December 9-14	Chongli, Hebei	ski	domestic and foreign athlete	tryouts
9	The 7th stop of the International FIS Points Competition	December 18-19	Yangpu, Shanghai	ski	domestic and foreign athlete	tryouts
10	The 8th stops of the International FIS Points Competition	December 31st - January 6th of the following year	Bortala, Xinjiang	ski	domestic and foreign athlete	tryouts
11	Beijing Winter Olympics	February 5-20	Chongli, Hebei	ski	Excellent domestic and foreign athlete	International competition

Table 4

Training stage division and task arrangement of Chinese cross-country skiers in the Winter Olympic year

Training phase	Time	Game arrangement	Main mission
General preparation period	May 21 - October 31, 2021	25 FIS points competition, 2 domestic competitions	Comprehensively develop athletic ability through large load training, focusing on improving athletes' strength and aerobic capacity; accumulate competition experience to meet the qualification standards for the Beijing Winter Olympics
Special preparation period	November 1, 2021 - January 9, 2022	12 FIS points competition, 4 domestic competitions	Maintain a certain level of strength and aerobic capacity, improve anaerobic endurance level, special competition level; strategically participate in the competition, get a better starting position
Pre-competition period	January 10 - February 4, 2022	none	Adjust your best competitive state before the game and make final preparations for the Beijing Winter Olympics

4.1. Load Changes

The primary element of training is load, which can be defined as the cumulative quantity of activities performed during training. Load encompasses training time, distance covered, and the number of repetitions executed. The evaluation of load in many sports is commonly based on training time (Bompa & Buzzichelli, 2018). In the context of preparing for endurance events such as running, kayaking, and cross-country skiing, it is common practice to use training distance as a measure of training load (Bompa & Carrera, 2005). This study aims to provide a comprehensive summary of the load characteristics during the training process in the Winter Olympics year. To achieve this, statistical analysis is conducted, focusing on two key aspects: training time and training distance.

Figure 1 displays the variations in weekly workload experienced by male cross-country skiers from China during the Winter Olympics year. In terms of the overall load distribution, the load exerted on land surfaces was found to be greater in magnitude compared to the load applied to snow surfaces. Regarding the duration of training, athletes completed a total of 49029±687 minutes, with 35.4% of the time spent on snow and 64.6% on land. In terms of training distance, athletes covered a total distance of 8456.0±461.9 kilometres, with 47.4% of the distance on snow and 52.6% on land. The overall load in each period, ranging from the general preparation period to the pre-competition period, exhibited a downward trajectory. The magnitude of the load during the general preparation period is the most substantial, with the primary emphasis placed on the load borne on land.

Regarding the duration of training, the athletes collectively accumulated a mean of 35109±151 minutes, which accounted for approximately 71.6% of the total training time. Specifically, the athletes spent 22.6% of their training time on snow and 77.4% on land. In terms of training distance, the athletes covered a mean distance of 5970.0±209.0 km, which constituted approximately 70.6% of the total distance. The proportion of distance covered on snow and land was 29.8% and 70.2%, respectively. During the special preparation period, the magnitude of the load was reduced, with the primary focus being on the load exerted on snow. During the designated preparatory phase, the athletes collectively engaged in a training regimen that encompassed a total duration of 9946±620 minutes, constituting approximately 20.3% of the overall time. This training time was divided between activities conducted on snow and land, with respective proportions of 67.5% and 32.5%.

Furthermore, the athletes covered a distance of 1752.6±233.6 kilometres during their training, which accounted for approximately 20.7% of the total distance. The distribution of this training distance was predominantly allocated to activities conducted on snow (88.1%), with a smaller proportion dedicated to land-based exercises (11.9%). During the pre-competition period, the load experienced was minimal, with the primary load being exerted on the snow. During the pre-competition period, athletes accumulated a total training time of 3974±36 minutes, which accounted for 8.1% of the overall time. The distribution of training time between on-snow and land activities was 68.4% and 31.6%, respectively.

Additionally, athletes covered a total training distance of 733.4±36.6 km, representing 8.7% of the total distance. The breakdown of distance covered on snow and land was 93.5% and 6.5%, respectively. The aforementioned analysis reveals that there is a gradual decrease in the staged loads completed by athletes from the general preparation period to the pre-competition period. Additionally, there is an increasing proportion of the load allocated to snow training, while the proportion assigned to land training experiences a gradual decline.

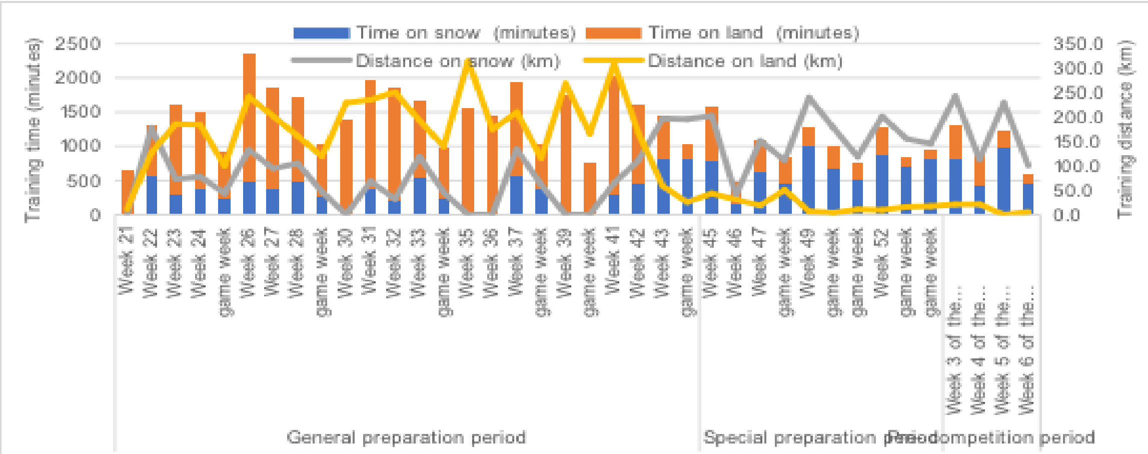

Figure1. Changes in weekly training time and distance on land and snow in the Winter Olympic year

Note: The training distance on snow does not include the distance completed by traction and turntable training; the distance on land does not include the distance completed by swimming, cycle ergometer and ski dynamometer.

Figure 2 shows the variations in weekly workload that athletes engaged in various training activities during the Winter Olympics year. The cumulative duration of training sessions for endurance, strength, speed, speed perception, and recovery training was found to be 39110±861 minutes (79.8%), 8159±206 minutes (16.6%), 185±6 minutes (0.4%), 840±0 minutes (1.7%), and 735±0 minutes (1.5%), respectively. During the general preparation period, athletes allocated 78.6% of their training time to endurance training, 16.8% to strength training, 0.3% to speed training, 2.4% to speed perception training, and 1.9% to recovery training.

In the special preparation period, athletes dedicated 83.7% of their training time to endurance training, 15.2% to strength training, 0.5% to speed training, and 0.6% to recovery training. Lastly, in the pre-competition period, athletes allocated 80.7% of their training time to endurance training, 18.9% to strength training, and 0.4% to speed training. Based on the aforementioned observations, it is evident that athletes engage in a range of training activities focused on endurance, strength, and speed. These training activities are distributed across different stages, with the load proportionately decreasing in the following order: endurance, strength, and speed.

The proportion of strength and speed training load increased initially during the transition from the general preparation period to the pre-competition period, then decreased. On the other hand, there was a temporary decrease and then an increase in the proportion of strength training load.

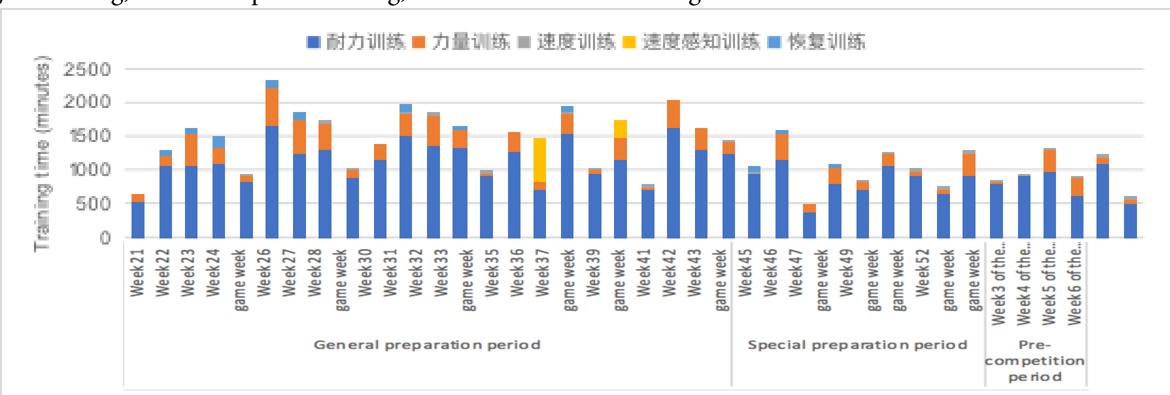

Figure 2 Changes in weekly training time of each training content during the Winter Olympic year

Note: Endurance training includes general endurance training (running, power cycling training) and special endurance training (skiing, pulley, ski ergometer, Nordic running with poles, traction skiing, turntable skiing, etc.); speed training refers to the high-speed pulley and skiing training for 8-20s; strength training refers to maximum strength, core strength and strength endurance training specially performed in the gym room; speed perception training refers to grass ski jumping training on a ski jumping training grounds; recovery training includes yoga and swimming training.

Throughout the various stages of the Winter Olympics year, there was a consistent and gradual alteration in the distribution of training load proportions between general endurance and special endurance for Chinese cross-country skiers. Due to the challenges associated with accurately measuring distances covered during turntable skiing training, the statistical analysis focused solely on the relationship between the load of endurance training and the corresponding time. Figure 3 illustrates the alterations in load pertaining to both general endurance and specific endurance training on a weekly basis during the Winter Olympics year. The duration of training for Winter Olympic athletes to complete general endurance and special endurance training was recorded as 5428±160 minutes (13.9%) and 33682±714 minutes (86.1%), respectively.

During the general preparation period and the pre-competition period, athletes allocated 13.0% and 87.0% of their time to general endurance and specific endurance, respectively. Similarly, in subsequent periods, the proportions of time dedicated to general endurance and specific endurance were 16.0% and 84.0%, as well as 15.7% and 84.3%, respectively. During the general preparation period, the special preparation period, and the pre-competition period, the athletes accomplished 66.1%, 24.6%, and 9.3% of the general endurance training load, respectively. Additionally, they completed 71.2%, 20.8%, and 8.0% of the special endurance training load during these respective periods.

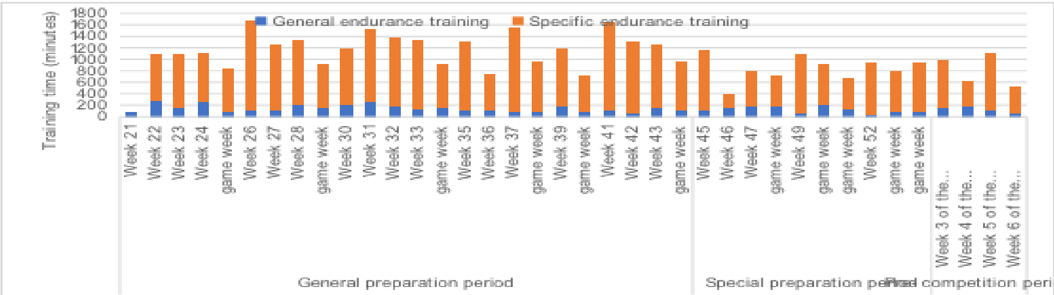

Figure 3 Changes in weekly training time of general endurance and special endurance in the Winter Olympic year

The assessment of load in strength training, particularly in relation to core strength and strength endurance training, is a complex task. In this context, the load of strength training was determined based on the duration of the training session. Chinese cross-country skiers engaged in weekly strength training sessions during the Winter Olympics season, as depicted in Figure 4, which illustrates the distribution of their weekly strength training load. The aggregate duration of strength training encompassed three components: maximum strength training, core strength training, and strength endurance training.

Athletes spent an average of 3925±137 minutes (48.1%) on maximum strength training, 2857±67 minutes (35.0%) on core strength training, and 1377±44 minutes (16.9%) on strength endurance training. The athletes' completion of the training load in each stage was measured in terms of the proportion of maximum strength, core strength, and strength endurance. In the general preparation period, proportions of 46.1%, 35.4%, and 18.5% were observed. Similarly, during the special preparation period, the proportions were 44.6%, 36.4%, and 18.9%.

Furthermore, the pre-competition period exhibited a proportion of 70.7% for maximum strength load and 29.3% for core strength load. During the general preparation period to the pre-competition period, the athletes accomplished 69.3%, 17.2%, and 13.5% of the maximum strength load, 73.0%, 19.3%, and 7.7% of the core strength load, and 79.2%, 20.8%, and 0.0% of the strength endurance load, respectively.

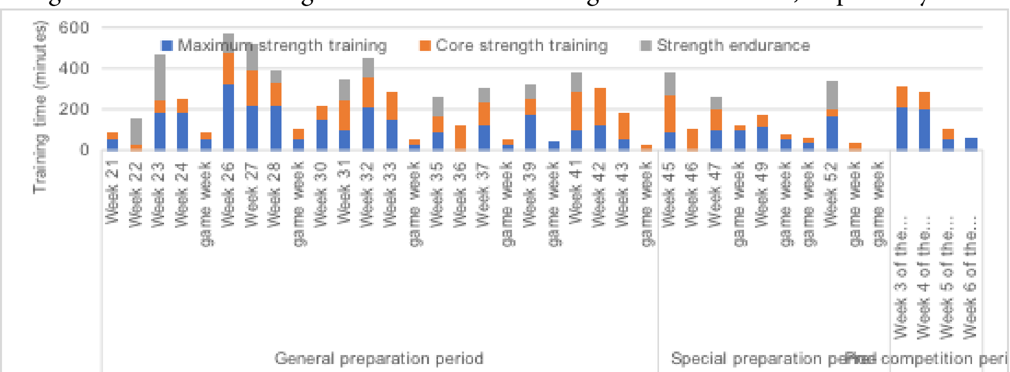

Figure 4 Changes in weekly training time of strength in Winter Olympic year

4.2. Changes in Load Intensity

The measurement of load intensity holds significant importance as it serves as a crucial factor in assessing the quality of an athlete's training, as referred to by Bompa and Buzzichelli (2018). Various researchers (Sandbakk & Holmberg, 2017; Solli et al., 2017; Torvik et al., 2021) have employed low, medium, and high-intensity intervals to assess the intensity of training load in cross-country skiers (2, 3, 5). In the year of the Winter Olympics, Chinese cross-country skiers allocated 87.3% of their training time to low-intensity endurance training, 7.7% to medium-intensity endurance training, and 5.0% to high-intensity endurance training.

The distribution of low-, medium-, and high-intensity endurance training during the general preparation period was 86.6%, 8.8%, and 4.6%, respectively. In the special preparation period, the proportion of time dedicated to low-, medium-, and high-intensity endurance training was 88.8%, 4.6%, and 6.6%, respectively. Similarly, during the pre-competition period, the distribution of time for low-, medium-, and high-intensity endurance training was 88.9%, 6.4%, and 4.7%, respectively (refer to Figure 5 for further details).

During the general preparation period, athletes allocated 69.6%, 21.9%, and 8.5% of their training time to low-intensity endurance exercises. In the special preparation period, they dedicated 80.3%, 12.8%, and 6.9% of their training time to medium-intensity endurance exercises. Lastly, during the pre-competition period, athletes allocated 63.9%, 28.3%, and 7.7% of their training time to high-intensity endurance exercises.

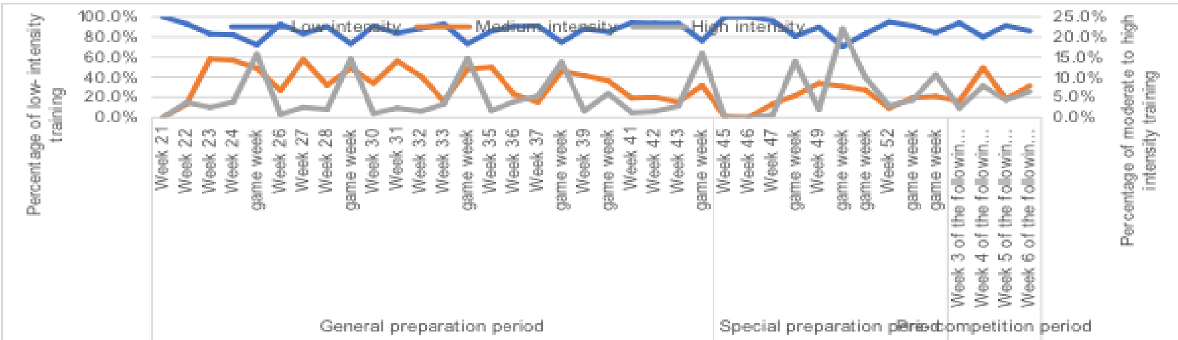

Figure 5 Changes in the percentage of low, medium and high-intensity endurance training time per week during the Winter Olympic year

Based on the comparative analysis of the intensity levels of specific endurance and general endurance training, it can be observed that the intensity of special endurance training surpassed that of general endurance training. In the context of specialised endurance training, it was found that low-intensity training comprised 85.9% of the total training volume, while medium-intensity training accounted for 8.6%, and high-intensity training made up 5.5%. From the standpoint of each phase of training, it can be observed that the level of intensity associated with special endurance training during the special preparation period was comparatively elevated.

During the general preparation period, the allocation of training time was as follows: 85.6% for low-intensity training, 9.6% for medium-intensity training, and 4.8% for high-intensity training. During the designated preparatory phase, the duration of training sessions categorised as low, medium, and high-intensity constituted 86.7%, 5.5%, and 7.8% of the total training time, respectively. During the pre-competition phase, the duration of training sessions categorised as low, medium, and high intensity constituted 86.9%, 7.6%, and 5.5% of the total training time, respectively (refer to Figure 6 for further information). During the general preparation period, athletes allocated 70.5%, 21.2%, and 8.2% of their training time to low-intensity special endurance exercises. In the special preparation period, the corresponding percentages were 79.4%, 13.4%, and 7.2% for medium-intensity special endurance training.

Lastly, during the pre-competition period, athletes dedicated 61.8%, 30.0%, and 8.2% of their training time to high-intensity special endurance exercises. In the context of overall endurance training, the durations allocated to low, medium, and high-intensity training were 95.5%, 2.5%, and 2.0%, respectively. During the general preparation period, the allocation of training time was as follows: 93.2% for low-intensity training, 3.8% for medium-intensity training, and 3.0% for high-intensity training.

In the special preparation period and the pre-competition period, the general endurance training was predominantly conducted at a low intensity, as depicted in Figure 7. The athletes' completion of low-intensity general endurance training time in the general preparation period, special preparation period, and pre-competition period was 64.5%, 25.7%, and 9.7%, respectively. Additionally, all medium- and high-intensity general endurance training was completed during the general preparation period.

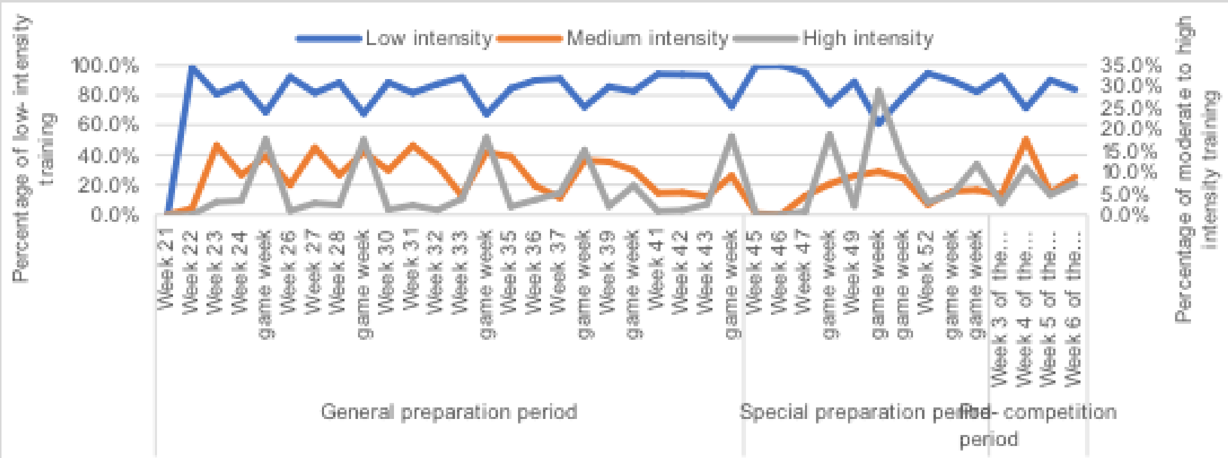

Figure 6 Changes in the percentage of low, medium and high intensity special endurance training time per week during the Winter Olympic year

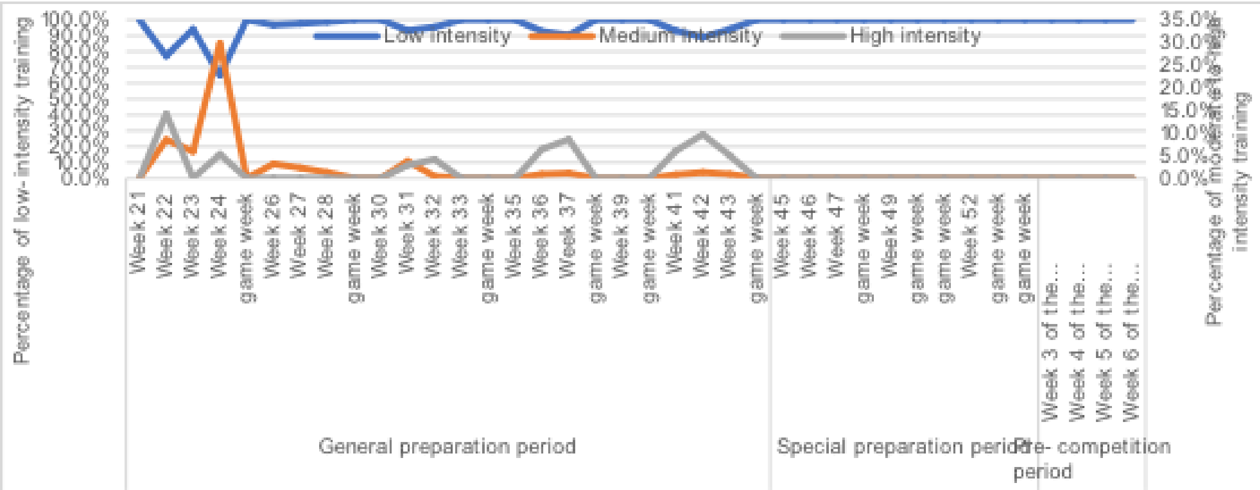

Figure 7 Changes in the percentage of low, medium and high-intensity general endurance training time per week during the Winter Olympic year

4.3. Changes in Training and Competition Frequency

Training frequency refers to the frequency at which athletes engage in training sessions on a weekly basis. It can also be described as the manner in which training sessions are distributed (Bompa & Buzzichelli, 2018). During the Winter Olympics year, Chinese cross-country skiers underwent a training regimen consisting of 260 days of training, which encompassed a total of 421 training sessions and 99 rest sessions. It is important to note that out of the 421 training sessions, 24 were dedicated to ground transition. Furthermore, the skiers participated in a total of 43 games, as outlined in Table 5.

During the transition from the general preparation period to the pre-competition period, there is a gradual reduction in the average number of weekly training sessions, as well as a gradual decrease in the ratio of training sessions to rest sessions. During the general preparation period, the special preparation period, and the pre-competition period, the frequency of weekly training sessions was recorded at 11.6, 10.9, and 10.6 times, respectively. Additionally, the ratios of training sessions to rest sessions were found to be 4.75, 3.67, and 3.33, respectively. The frequency of training sessions on snow and land experienced periodic fluctuations during the transition from the general preparation phase to the pre-competition phase.

Specifically, there was a gradual reduction in the number of training sessions conducted on land, accompanied by a corresponding gradual increase in the number of training sessions conducted on snow. During the general preparation period, the average number of weekly training sessions on snow was 2.77. In the special preparation period, this average increased to 6.70 times, and during the pre-competition period, it further increased to 7.27 times. Conversely, the average weekly training sessions on land during these respective periods were 8.85, 4.30, and 3.50 times (details See Figure 8).

Based on the organisation of the competition, it can be observed that Chinese cross-country skiers were actively engaged in participation during the dedicated preparatory phase. During the general preparation period, the athletes engaged in a cumulative total of 27 games, exhibiting a mean frequency of one game every 6.1 days. In the subsequent special preparation period, the athletes participated in a total of 16 games, with an average interval of one game occurring every 4.4 days.

Table 5

Arrangement of training sessions, rest sessions and competition sessions in each period of the Winter Olympic year

Training period	Training days	Training sessions	Rest sessions	Competition sessions
general preparation period	164 days	271	57	27
special preparation period	70 days	110	30	16
pre-competition period	26 days	40	12	0
total	260	421	99	43

Note: The training sessions include the training sessions occupied by the competition; the rest sessions include the sessions consumed by the ground transition (24 times).

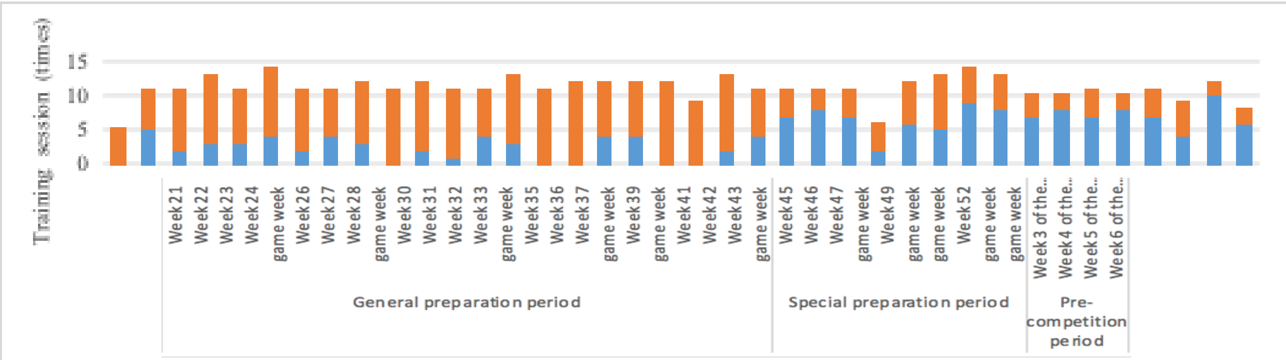

Figure 8 Changes in weekly snow and land training sessions during the Winter Olympic year

4.4. Changes in Physiological and Biochemical Indicators

During the general preparation period, the mean haemoglobin (Hb) value was recorded as 158.7±8.05g/L, with Hb test results ranging from 149.50 g/L to 174.75g/L, exhibiting a wave-like upward trajectory. In the subsequent special preparation period, the average Hb value was measured at 163.2±6.63 g/L, with Hb test results fluctuating between 155.50g/L and 172.33g/L. Although a downward trend was observed, the overall Hb levels remained relatively high. Notably, the Hb test results of athletes in the pre-competition period surpassed those of the previous test in the special preparation period, indicating a discernible growth pattern (see Figure 9 for details).

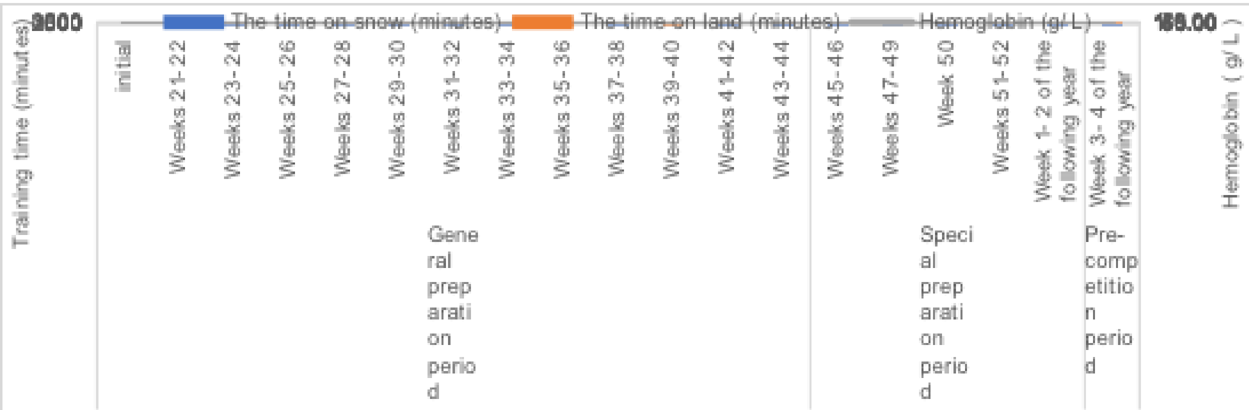

Figure 9 Changes in training time and Hb in different stages of the Winter Olympic year

During the general preparation period, the mean CK value was 359.1±200.69 U/L, with CK test results ranging from 136.75 U/L to 749.0 U/L. The results of the CK test exhibited a wave-like decline from the 21st to the 32nd week. Subsequently, from the 32nd to the 40th week, the CK test results consistently remained at low levels with relatively stable fluctuations. However, during the period from the 41st to the 44th week, the CK test results displayed a notable pattern of initial increase followed by subsequent decrease, accompanied by a significant range of variation. During the designated preparatory phase, the mean creatine kinase (CK) value was 288.9±75.62 U/L, and the CK test outcomes varied between 193.75 U/L and 376.45 U/L, exhibiting a narrow range of fluctuations (see Figure 10 for details).

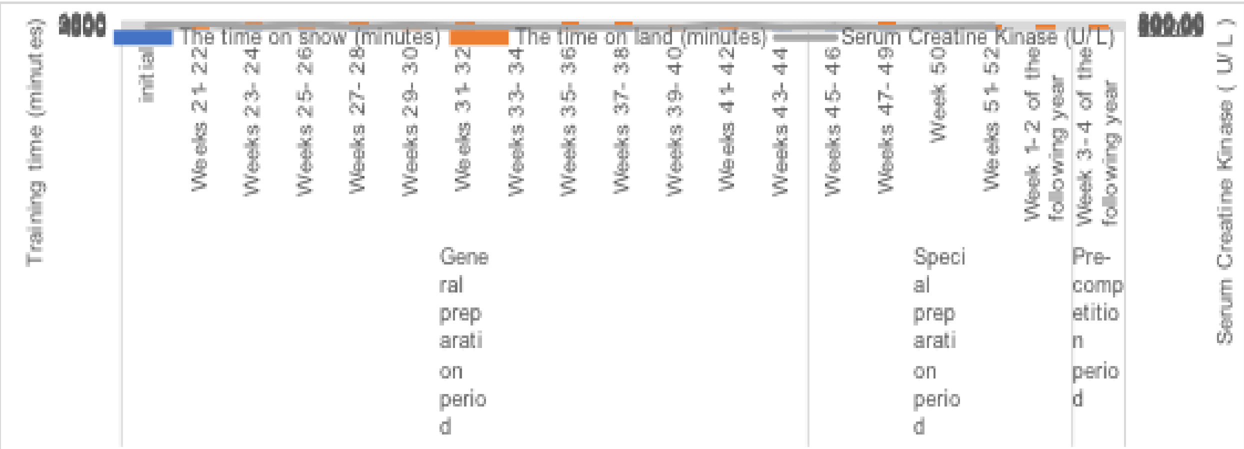

Figure 10 Changes in training time and CK in different stages of the Winter Olympic year

Note: CK test was not performed for several weeks due to certain constraints.

During the general preparatory phase, the mean value of blood urea nitrogen (BUN) was 7.89±1.11 mmol/L, with BUN test results ranging from 6.34 mmol/L to 9.78 mmol/L. These findings indicate a pattern of initial decline followed by subsequent increase. The BUN test results exhibited a declining pattern from the 21st to the 38th week, followed by an ascending trend from the 38th to the 44th week. During the designated preparatory phase, the mean BUN value was 8.19±0.55mmol/L, with BUN test results ranging from 7.31mmol/L to 8.73mmol/L. These findings indicate a pattern of "high level - wave-like" changes, with a relatively narrow range of fluctuations (details See Figure 11).

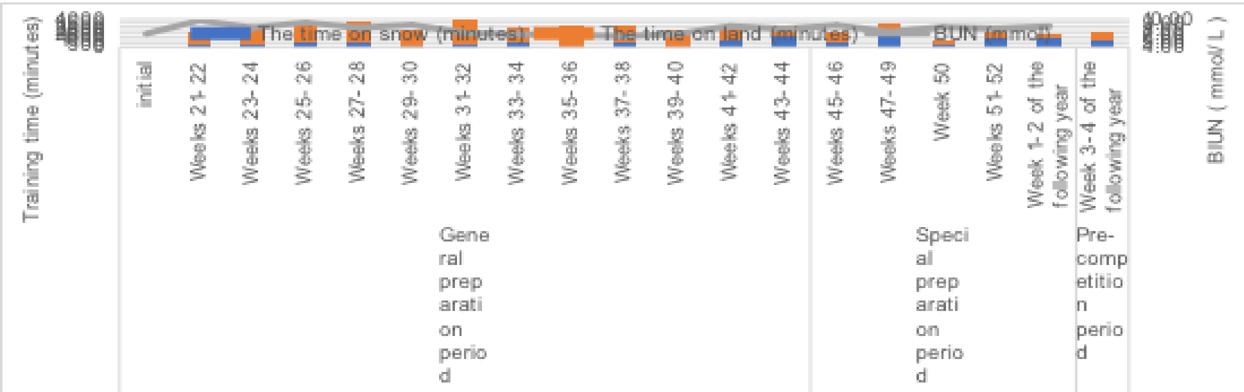

Figure 11 Changes in training time and BUN in different stages of the Winter Olympic year

Note: BUN tests were not performed for several weeks due to constraints.

During the general preparation period, the mean testosterone (T) value was observed to be 685.1±86.80ng/dl, with T test results ranging from 549.00ng/dl to 811.25ng/dl, exhibiting a fluctuating pattern characterised by a sequence of decreases, increases, and subsequent decreases. The T-test results observed during the period from the 21st to the 26th week exhibited a declining pattern. Conversely, the T-test results observed from the 29th to the 36th week displayed an ascending trend. Subsequently, the T-test results from the 37th to the 44th week demonstrated a declining pattern, yet they remained consistently high. During the designated preparatory phase, the mean testosterone (T) value was found to be 633.68±19.61ng/dl. The T test outcomes exhibited a range between 618.25ng/dl and 667.50ng/dl, indicating a relatively consistent overall change (see Figure 12 for details).

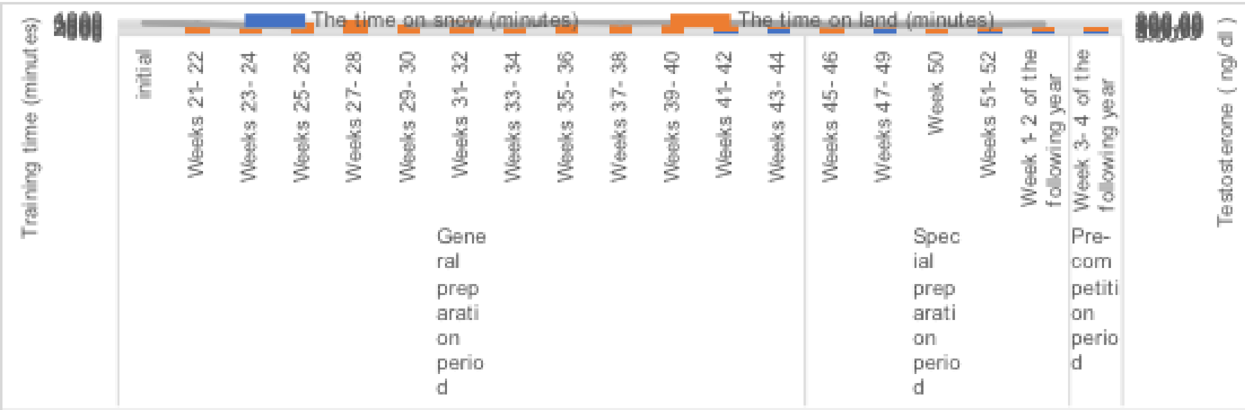

Figure 12 Changes in training time and T in different stages of the Winter Olympic year
Note: T tests were not performed for some of weeks due to constraints.

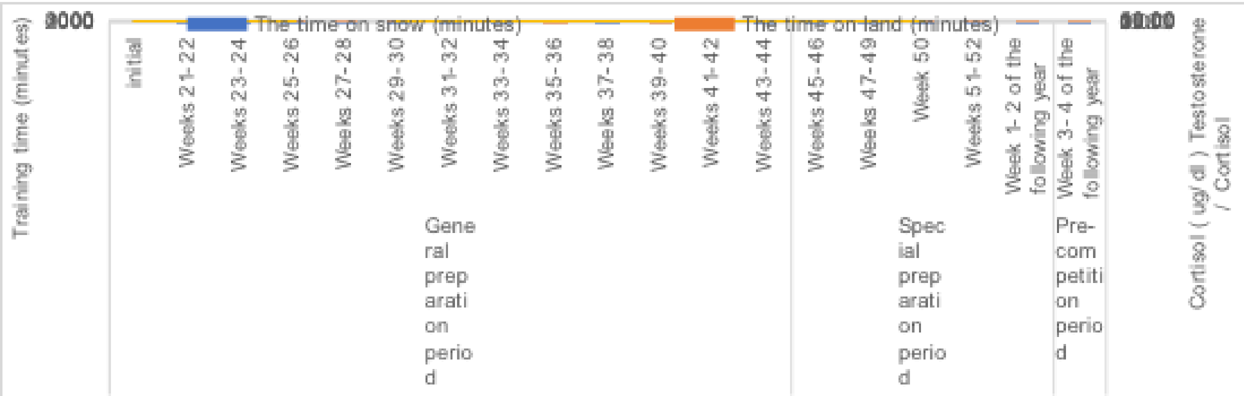

Figure 13 Changes in training time, C and T/C in different stages of the Winter Olympic year
Note: The C test was not carried out for several weeks due to constraints.

During the general preparation period, the average C value was 19.37±2.37ug/dl, and the C test results fluctuated between 15.91ug/dl and 21.94ug/dl; the average T/C value was 36.62±5.58, and the T/C varied between 27.46 and 42.75. During the special preparation period, the average C value was 21.16±2.37ug/dl, and the C test results fluctuated between 18.93ug/dl and 23.65ug/dl, showing a downward trend; the average T/C value was 29.85±3.11, and the T/C varied between 26.68 and 32.91, showing an upward trend (see Figure 13 for details).

5. Discussion

5.1. Analysis of Load Change Characteristics

Compared to elite athletes from around the world, Chinese cross-country skiers carried a heavier load during the Winter Olympics. Gold medallists in cross-country skiing (at the Olympics or the World Championships) train for about 11 months each year, from May to April. The average load during this period is reported to be 770±99 hours (Tønnessen et al., 2014). Additionally, it has been observed that the annual training load of the most exceptional long-distance cross-country skiers worldwide amounts to 861±90 hours (2).

In contrast to the world's top-tier athletes, Chinese athletes participating in the Winter Olympics experienced a comparatively substantial workload. This load, spanning from May 21st to February 4th of the subsequent year, encompassed a duration of approximately 9 months, totalling 49029±687 minutes or roughly 817±11 hours. The significant training load has emerged as a crucial determinant for the achievement of athletes participating in endurance events (Mujika, 2014; Seiler, 2010). The load arrangement of Chinese cross-country skiers during the Winter Olympics year aligns with the prevailing practice of incorporating high-load training regimens for endurance events.

The aggregate training distance accomplished by Chinese cross-country skiers was recorded as 8456.0±461.9km, a figure that falls short of the training distance (approximately 9700km) achieved by previous outstanding domestic cross-country skiers. The primary rationale lies in the emphasis placed on strength training within this preparatory regimen, wherein the proportion of strength load (16.6%) surpasses that of world-class athletes (Myakinchenko et al., 2021; Solli et al., 2017; Tønnessen et al., 2014).

Table 6

Percentage of annual endurance, strength and speed training loads of world elite cross-country skiers

Author	Athlete level	Load (h)	Endurance proportion	Strength proportion	Speed proportion
Torvik et al. (2021)	world elite athlete	860±90	92%	6%	2%
Solli et al. (2017)	World Series Gold Medallist	937±25	91%	8%	1%
Tønnessen et al. (2014)	World Series Gold Medallist	770±99	94±3%	5±2%	1±1%

Note: The annual training period (May-April of the following year) was about 11 months.

The overall workload exhibited a downward trajectory from the initial preparatory phase to the subsequent competition phase. During the general preparation period, the special preparation period, and the pre-competition period, the athletes allocated 71.6%, 20.3%, and 8.1% of the total training time, respectively. The average weekly load within each period initially decreased during the transition from the general preparation period to the competition period, then increased. The load during the general preparation period, estimated at approximately 1499 minutes per week, exhibited the highest magnitude and surpassed the weekly load observed among elite athletes worldwide during this same period (Tønnessen et al., 2014; Torvik et al., 2021).

The primary objective of this phase is to enhance the endurance and strength of athletes through high-intensity training while also ensuring the accumulation of physical energy reserves and training volume. This phase aims to transition athletes into the special preparation period in an optimal condition. During the designated time frame, the participants engaged in a 10-kilometre running activity and underwent a ski dynamometer test lasting for a duration of 1 minute and 30 seconds. Additionally, they took part in a total of 5 FIS point competitions and 1 domestic competition as part of their involvement in various sporting events (short-distance and long-distance skiing or pulley competitions, a total of 27 games).

Through assessments and competitions, coaches are able to promptly assess the aerobic and anaerobic capacities of athletes, as well as their qualifications for the Winter Olympics. This information serves as a foundation for the development of training strategies during each phase of the general preparation period. During the special preparation period, the load was observed to be the smallest, with an approximate duration of 995 minutes per week. This value is comparable to the weekly load of elite athletes worldwide during the same period, which was reported to be around 16.5±2.4 hours (Tønnessen et al., 2014). In comparison to the overall preparation period, there was a reduction of 33.62% in the weekly workload.

To enhance the physiological stimulation of the body through training, coaches strategically adjust the training load during the special preparation period. This involves reducing the load and increasing the proportion of high-intensity training time. The objective is to facilitate the swift conversion of athletic ability acquired during early training into specialised competitive prowess. The workload during the pre-competition phase, which averaged approximately 1070 minutes per week, ranked as the second lowest. Furthermore, the workload exhibited a pattern of periodic decline during this period. To enhance the phenomenon of "over-recovery," the load was consistently kept at a high level (1204 minutes) during the third week of the pre-competition phase. Subsequently, the load was significantly decreased to 557 minutes in the fourth week, spanning a duration of five days. This reduction in load corresponds to a weekly decrease of 27.1%.

There is a gradual decrease in the staged load on snow as the general preparation phase gives way to the pre-competition phase, and a corresponding increase in the proportion of load on snow. During the general preparation period, the loads experienced on snow amounted to an average of 7928±161 minutes. In the subsequent special preparation period, this figure decreased to an average of 6716±827 minutes. Finally, during the pre-competition period, the load on snow further decreased to an average of 2719±36 minutes. The proportion of the load on snow during each respective stage was found to be 20.3%, 67.5%, and 68.4%, respectively.

During the general preparation period, the majority of the load was focused on land, accounting for 79.7% of the total load. However, a significant portion of the load, specifically 45.7%, was also completed on snow. The ratio of the load exerted on snow during the special preparation period and the pre-competition period exhibited a higher value, suggesting that the training emphasis during these two stages shifted towards snow-based training.

According to Zhongtang's study conducted in 2016, it was found that Chinese cross-country skiers did not receive a specific load of snow during the general preparation period, which typically spans from May to October. The allocation of training loads on snow was organised during each phase of the Winter Olympics calendar year. The subjective factor pertains to the limited duration of ski training, while the objective basis encompasses the successful construction of the "snow cave on land"[1] and the "big turntable,"[2] as well as the advancement in high-temperature snowmaking technology[3].

During the Winter Olympics year, there was a notable disparity in the distribution of endurance and strength training loads between Chinese cross-country skiers and their global counterparts at the elite level. The allocation of training emphasis among Chinese athletes in the areas of endurance, strength, speed, speed perception, and recovery were found to be 79.8%, 16.6%, 0.4%, 1.7%, and 1.5%, respectively. According to Torvik et al. (2021), the training regimen of cross-country skiing gold medalists is primarily composed of endurance, strength, and speed exercises, which make up approximately 94±3%, 5±2%, and 1±1% of their annual training load, respectively. The study also revealed that the endurance component accounted for 795±88 hours (92%) of the training time for exceptional long-distance cross-country skiers, while strength exercises comprised 53±17 hours (6%), and speed training amounted to 13±14 hours (2%).

In contrast to elite athletes worldwide, Chinese cross-country skiers exhibited a relatively lower proportion of endurance training load and a higher proportion of strength training load. The rationale behind the arrangement of the endurance and strength training loads in this manner may be attributed to the fact that Chinese athletes undergo a relatively brief period of specialised training and possess limited specialised strength. Furthermore, in order to address the issue of Chinese athletes' apprehension towards downhill high-speed sliding, the coaching team has implemented a specialised training regimen focused on speed perception. This includes incorporating grass ski jumping training to enhance the athletes' ability to perceive and adapt to high speeds.

Throughout each stage of the Winter Olympics season, the proportion of the specialised endurance load carried by Chinese athletes remained consistently aligned with that of the global elite athletes during the competitive period. During the phases of general preparation, special preparation, and pre-competition, Chinese athletes allocated a proportion of their training time to general endurance and special endurance training. Specifically, the proportions were 13.2% versus 86.8% during the general preparation period, 16.0% versus 84.0% during the special preparation period, and 15.7% versus 84.3% during the pre-competition period.

According to Solli et al. (2017), the distribution of general endurance and specific endurance load among elite cross-country skiers worldwide is reported as 47% versus 53%, 22% versus 78%, and 15% versus 85%, respectively. The allocation of special endurance training loads for Chinese athletes during the general preparation period and the special preparation period was substantial, and the distribution of this load in each period is comparable to that of world-class athletes during the competition period. The potential connection between the training and competition regimen employed by Chinese athletes, consisting of a training duration of 3-5 weeks followed by a week of competition, and the training approach adopted by top-tier international cross-country skiers during the competitive phase may warrant further investigation.

Currently, there is a growing emphasis among the global elite cross-country skiers on the incorporation of strength training into their training regimens, with particular attention being given to the development of upper body strength (Sandbakk & Holmberg, 2014). The strength training duration of Chinese cross-country skiers (16.6%) exhibits a statistically significant disparity when compared to that of the global cohort of elite cross-country skiers. The range of interest rates under consideration is between 5% and 6%. (Tønnessen et al., 2014; Torvik et al., 2021) support the prevailing inclination among elite cross-country skiers worldwide to prioritise strength training. Throughout the various phases of the yearly training regimen, there was a consistent distribution of 63% for maximum strength load and 37% for core strength load among the world's top athletes (Torvik et al., 2021).

The stability of the proportion between the maximum strength and core strength load of Chinese athletes during the general and special preparation periods (46.1% vs. 35.4%, 44.6% vs. 36.4%) was also observed. During the pre-competition phase, there was a sudden increase in the proportion of the maximum strength load among Chinese athletes, reaching 70.7%. The primary factor influencing the competitive performance of cross-country skiers is the degree of maximum strength, as evidenced by a strong negative correlation ($r = -0.83$, $p<0.01$) (Sunde et al., 2019). Based on a study conducted by Yin et al. (2020), it was found that a period of 8 weeks of strength plate training resulted in a significant improvement ($P<0.001$) in the performance of cross-country skiers in both short-distance and long-distance competitions. Both Chinese athletes and world elite athletes place significant emphasis on core strength training, as it directly correlates with the demanding need for balance and stability of the body's centre of gravity during high-speed skiing (Bai, Zhong, & Wang, 2020).

5.2. Analysis of Load Intensity Change Characteristics

Table 7

The percentage of endurance training of world elite cross-country skiers with different intensities in the year

Author	Category	Low intensity	Medium intensity	High strength
Torvik et al. (2021)	endurance	88.7%	6.4%	4.8%
Solli et al. (2017)	endurance	92.3%	2.9%	4.8%
Tønnessen et al. (2014)	endurance	91.3%	3.3%	5.3%

The training regimen for Chinese cross-country skiers during the Winter Olympics year exhibited a "pyramid" structure, with a distribution of low-, medium-, and high-intensity endurance training. The distribution of endurance training time for Chinese athletes in terms of low, medium, and high load intensity was found to be 87.3%, 7.7%, and 5.0%, respectively. This distribution closely resembled the load intensity distribution observed in the annual endurance training of elite cross-country skiers worldwide, with proportions of 88.7%, 6.4%, and 4.8% for low, medium, and high intensity, respectively (Torvik et al., 2021). These findings highlight the distinctive "pyramid" load intensity distribution characteristics that are commonly observed in endurance events, with proportions of 89%, 6%, and 5% for low, medium, and high intensity, respectively (Stöggl & Sperlich, 2015).

Previous research has indicated that a significant component of the training regimen of elite cross-country skiers, namely low-intensity training, plays a crucial role in facilitating long-term endurance adaptation. This type of training is considered to be complementary to high-intensity endurance training (Laursen, 2010; Sandbakk & Holmberg, 2017). The training regimen during the Winter Olympics year primarily consisted of low-intensity endurance training. However, it is important to note that each period of training possessed distinct characteristics. During the general preparation period, the primary focus was on engaging in training activities characterised by low intensity levels. In contrast, a substantial volume of medium-intensity training was conducted, while a specific percentage of high-intensity training was sustained during competitive events. The intensity of training during the special preparation period exhibited a modest increase compared to that of the general preparation period.

The study observed a rise in the percentage of low-intensity training from 86.6% to 88.8%, as well as an increase in the percentage of high-intensity training from 4.6% to 6.6%. The intensification of the training load primarily occurred through the implementation of interval training and intensive competition. Notably, the proportion of high-intensity training during the pre-competition period decreased from 6.6% in the special preparation phase to 4.7%. Additionally, the training volume was reduced during this period. The primary approach employed in this study involves the utilisation of a skiathlon simulation race spanning a distance of 7.5 kilometres, followed by an additional 7.5 kilometres.

Additionally, high-intensity interval training sessions ranging from 1.5 to 3.75 kilometres are implemented to sustain a consistent level of training load intensity. It is worth noting that the high-intensity training load is comparatively lower in magnitude. Research has indicated that the implementation of high-intensity interval training (HIIT) yields substantial enhancements in the maximum aerobic capacity and overall efficiency of individuals engaged in cross-country skiing. It mainly adopts the skiathlon simulation race (7.5km + 7.5km) and high-intensity interval training of 1.5-3.75km to maintain a certain level of training load intensity, and the high-intensity training load is less. Studies have shown that high-intensity interval training significantly improves the maximum aerobic capacity and overall efficiency of cross-country skiers (Yin et al., 2022).

The load intensity of special endurance training for Chinese cross-country skiers (low 85.9%, medium 8.6% and high 5.5%) was higher than the load intensity of general endurance training (low 95.5%, medium 2.5% and high 2.0%). The distribution of low-, medium- and high-intensity training of special endurance training for Chinese athletes is as follows: 85.6%, 9.6%, and 4.8% for the general preparation period; 86.7%, 5.5%, and 7.8% for the special preparation period; 86.9%, 7.6% and 5.5% for the pre-competition period respectively. During the general preparation period, the training regimen primarily emphasises the development of athletes' aerobic capacity, with a particular focus on medium-intensity special endurance training. This type of training constitutes the largest proportion of the overall training programme during this period.

Conversely, in the special preparation period, where athletes engage in intensive competition, the training regimen places a greater emphasis on high-intensity special endurance training. This type of training comprises the highest proportion of the overall training programme during this period. During the pre-competition phase, athletes engage in specialised endurance training at a specific intensity level to facilitate the adaptation of their bodily functions to the demands of the upcoming competition. During the general preparation phase, athletes engaged in comprehensive general endurance training, encompassing both medium- and high-intensity exercises.

During this particular phase, the athletes' fundamental aerobic and anaerobic capacities were cultivated through a limited volume of medium- and high-intensity general endurance training. In the subsequent special preparation and pre-competition phases, general endurance training primarily involved low-intensity training loads. During this period, the purpose of general endurance training was predominantly focused on warm-ups and relaxation.

5.3. Analysis of the Change Characteristics of Training and Competition Frequency

Chinese cross-country skiers experienced a gradual decrease in training frequency during the transition from the general preparation period to the pre-competition period, along with a corresponding increase in training on snow frequency. Throughout the general preparation period, the special preparation period, and the pre-competition period, athletes exhibited a training frequency of 11.6 times per week, 10.9 times per week, and 10.6 times per week, respectively. This data indicates a declining trend in training frequency, with a decrease of 91.4%.

According to Mujika (2014), it is suggested that high-level athletes should maintain a training frequency during the pre-competition period that is no less than 80% of the frequency observed during the general preparation period. To uphold a proficient level of skiing proficiency, Chinese athletes continue to engage in frequent snow training sessions, averaging 7.27 times per week. From the initial phase of preparation to the period preceding competition, there is a noticeable upward trend in the frequency of training sessions conducted on snow, while a corresponding downward trend is observed in the frequency of training sessions conducted on land. The primary factor contributing to this phenomenon is the imminent competition schedule, which necessitates a progressively more specialised approach to the overall training arrangement.

During the general preparation period and the special preparation period, Chinese cross-country skiers exhibited a frequency of participation of 6.1 days/time and 4.4 days/time, respectively. Furthermore, it was observed that the competition arrangement durin the special preparation period was characterised by a higher level of intensity. Previous research conducted both domestically and internationally has indicated that cross-country skiers refrained from participating in competitions during the general preparation period (Li, 2016; Tønnessen et al., 2014). Chinese cross-country skiers actively engaged in additional competitions during the general preparation period with the aim of acquiring competition experience and expediting their qualification process for the Beijing Olympic Games (Mujika, 2009). The primary objective of the special preparation period is to enhance the athletes' specialised abilities and identify the most qualified participants for the Olympic Games. During this time period, a schedule of competitions was organised with a relatively high level of intensity. The selection of Olympic participants was based on the athletes' performance in multiple competitions.

5.4. Analysis of the Change Characteristics of Physiological and Biochemical Indicators

Research findings indicate that there is a positive correlation between athletes' adaptation to exercise load and higher levels of Hb. Conversely, when athletes experience a decline in their training state, such as overfatigue or overtraining, there is a decrease in Hb concentration (Qu & Yu, 2003). During the general preparation period, Chinese athletes exhibited a fluctuating increase in their haemoglobin (Hb) levels, suggesting a progressive enhancement in their aerobic capacity. This indicates that their bodies gradually adapted to the high-intensity training regimen implemented during this phase.

During the designated preparatory phase, the haemoglobin (Hb) levels of Chinese athletes exhibited a range of variability, spanning from 155.50 g/L to 72.33 g/L. Despite exhibiting a wave-like pattern of decline, the overall level remained high, indicating that athletes maintained a high aerobic capacity and their bodies were moderately adapted to the training load during this stage. During the pre-competition phase, there was an observed upward trend in the haemoglobin levels of Chinese athletes. The findings indicate an enhancement in the aerobic capacity of the athletes during the pre-competition phase, as well as an improved physiological state and a well-established adaptation of their bodies to the training load.

5.5. The Change in CK Concentration is More Sensitive to The Intensity of the Training Load.

The previously mentioned indicator possesses the capability to evaluate the athletes' adaptation to training load, rendering it a crucial and highly responsive biochemical measure for assessing fatigue and injury (Feng, Feng, & Feng, 2003). In accordance with a study conducted by Feng et al. (2003), the typical range of serum creatine kinase levels in male athletes falls within the range of 10 to 300 u/l. During the general preparation period, it was observed that the CK results of Chinese athletes, following individual training weeks, deviated from the normal range.

However, it is important to note that these deviations did not persist over consecutive periods. It is evident that the athletes demonstrated a high level of adaptation to the intensity of the training load during the general preparation period. During the designated preparatory phase, the creatine kinase (CK) test outcomes of Chinese athletes exhibited a narrow range of fluctuation, ranging from 193.75 U/L to 376.45 U/L. This suggests that the athletes effectively adjusted to the intensity of their training regimen during this preparatory period, resulting in satisfactory recovery of their skeletal muscles.

The measurement of blood urea nitrogen (BUN) is extensively employed in the field of sports training as a crucial tool for assessing training intensity and gauging the effectiveness of functional recuperation. According to Feng et al. (2003), the typical concentration range of blood urea nitrogen (BUN) is between 1.7 and 8.3 mmol/L. Nevertheless, the absence of a standardised criterion for monitoring this indicator arises from the significant variations observed among individuals. During the initial phase of the general preparation period (weeks 21–30), the BUN test outcomes of athletes exhibited variability around the threshold value without consistently surpassing it. This suggests that the athletes' physical performance and functional capacity were not completely restored during the early stage.

During the initial phase of training, the body experiences a specific level of stimulation. In the middle of the general preparation period, specifically from week 31 to week 40, the results of the BUN test exhibited a consistent decline, with all values falling below 8.3 mmol/L. This indicates that the athlete's body has successfully acclimated to the training load imposed during this particular period. The functional condition exhibited a satisfactory state. During the designated preparatory phase, athletes exhibited blood urea nitrogen test results that displayed a distinct pattern of fluctuation, characterised by a consistent high level. This consistent fluctuation within a narrow range may potentially be attributed to the consumption of a high-protein diet during this particular stage.

It is possible for thermoregulatory control (T/C) mechanisms to understand the balance between anabolism and catabolism in the human body. This makes it possible to effectively track exercise training. Excessive fatigue may be attributed to the reciprocal relationship between the dominance of anabolism and the high value of T/C. During the entirety of the training cycle, it was observed that the athletes' T levels decreased following the competition week in comparison to their pre-competition levels. Conversely, the athletes' C levels exhibited an increase when compared to their pre-competition levels. The post-competition total cortisol (T/C) ratio was comparatively low, suggesting a prevailing catabolic state in the athletes' bodies following the competition week, leading to a decline in physical performance.

During the general preparation period, the athletes exhibited a relatively high T, a relatively small C, and a relatively high T/C ratio. These findings suggest that the athletes were in a favourable overall functional state during this period and had successfully adapted to the training load. During the designated preparatory phase, the athletes exhibited a relatively low T value, while their C value was higher, resulting in a smaller T/C ratio. The data indicates that during the special preparation period, athletes experience a prevailing state of catabolism. This can be attributed to the combined effects of high-intensity training and the pressure associated with competitive events, resulting in a relatively low T/C value.

6. Conclusion

The training regimen for Chinese male cross-country skiers during the Winter Olympics year was structured into three distinct phases: a general preparation period spanning 164 days, a special preparation period lasting 70 days, and a pre-competition period of 26 days. The overall workload exceeded that of the world's top athletes, with a greater workload on land compared to snow. Throughout the general preparation period and the pre-competition period, there was a consistent decrease in the total workload, with a gradual decline in both land and snow loads. Additionally, there was a gradual increase in the proportion of workload on snow. The proportion of endurance training load in the given context is comparatively lower than that observed in world-elite athletes. However, the proportion of special endurance load during each training period is similar to that of world-elite athletes during competitive events.

On the other hand, the strength training load and its corresponding proportion are higher in the given scenario compared to world-elite athletes. Specifically, the distribution of maximum strength and core strength loads is spread across various training sessions. The load intensity surpasses that of elite athletes worldwide, with a distribution of low, medium, and high intensity following a pyramid-shaped pattern. During the transition from the general preparation period to the pre-competition period, there is a gradual reduction in the frequency of weekly training and land-based training, while the frequency of training on snow gradually increases.

Additionally, the competition schedule becomes more intensive during the special preparation period. Athletes demonstrate favourable adaptability to training load and load intensity during the general preparation period, accompanied by efficient recovery. However, during the special preparation period, the athlete's body experiences fatigue due to the impact of high-intensity training and intense competition. In the pre-competition period, the athlete's aerobic capacity reaches a heightened level as a result of load reduction. The outcomes of the Beijing Winter Olympics effectively showcased the athletes' optimal competitive condition throughout the event, thereby demonstrating the soundness of their training load scheduling during the Winter Olympics year.

6.1. Practical Implications

The findings indicate that Chinese male cross-country skiers exhibit a training regimen that is marginally more extensive compared to that of globally renowned athletes, placing a heightened emphasis on land-based training and strength conditioning.

This data can be utilised to enhance the training methodologies of other cross-country ski teams seeking to enhance their performance.

6.2. Policy Implications

This study emphasises the significance of monitoring and regulating the training load of athletes prior to significant competitions, such as the Winter Olympics, in order to optimise their physical preparedness.

The aforementioned data possesses the potential to contribute to the formulation of policies and guidelines pertaining to the training and preparation protocols for high-performing athletes.

6.3. Further Research Directions

It would be intriguing to conduct a comparative analysis between the findings of this study and those of other Olympic cross-country ski teams, in order to identify potential disparities or commonalities in training methodologies.

Moreover, conducting research on the enduring impacts of the training load on the physical and mental health of athletes would yield advantageous outcomes.

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