



OPEN Rasch model analysis of herbal medicine consumption and doping risk awareness among athletes

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This study examined herbal medicine consumption and athletes' awareness of doping, providing data for developing strategies to reduce doping risks. A survey of 2241 South Korean athletes investigated their consumption behaviors and awareness. Athletes mainly used herbal medicines for stamina enhancement, fatigue recovery, and injury rehabilitation, and most believed these effects to be beneficial. However, awareness of potential prohibited substances was low, with many athletes unaware of the doping risks linked to herbal medicine use. Pattern analysis identified trends in timing, purpose, purchasing sources, and forms of consumption, with stamina and fatigue recovery emerging as the most common reasons. These findings highlight the urgent need for systematic education and clear guidelines regarding herbal medicine in sports. Early education during athletes' developmental stages is particularly important to prevent unintentional doping. By analyzing athletes' consumption patterns and awareness, this study provides foundational evidence to guide policy and practice. The results can serve as a reference for establishing preventive strategies and ensuring safer use of herbal medicine in sports.

Keywords Herbal medicine, Athletes, Doping awareness, Pattern analysis, Rasch model

Sports inherently encompasses a variety of value systems, among which fairness is the fundamental principle that all participants must uphold. One of the primary reasons the public is enthusiastic about sports is their belief that sports competitions are conducted fairly¹. Therefore, fair competition has become a core value in sports. Athletes have the right to compete in a fair environment, and if fairness is not ensured, it could negatively impact the overall development of sports. Fairness must be guaranteed in sports competitions to allow athletes to participate confidently and accept the outcomes².

Although fairness in sports is widely recognized as a crucial value system within the sports domain, various factors undermine this principle. A prominent example is doping in sports. Doping refers to the use of substances or methods prohibited by athletes to artificially enhance their performance. Such practices create an unfair competitive advantage over athletes who comply with the rules. Moreover, if an athlete is caught doping, the consequences extend beyond personal disgrace, potentially damaging the reputation of their team and even the country³. Consequently, continuous efforts have been made to prevent sports-related doping through education, stricter regulations, and enhanced testing procedures.

Despite ongoing preventive efforts, doping remains a persistent issue in sports. Several studies have demonstrated continued use of banned substances such as steroids and testosterone to enhance athletic performance⁴. In addition, some athletes have reportedly taken diuretics to achieve rapid weight loss⁵. A well-known historical example is the so-called "Steroid Era" in Major League Baseball (MLB) during the 1990s, when the use of anabolic steroids became widespread⁶. Testosterone abuse has also been highlighted in swimmers who won four Olympic medals and two world titles⁷. These examples indicate that doping is not confined to a specific group of athletes but is prevalent even among elite competitors at the highest level.

Since the establishment of the World Anti-Doping Agency (WADA) in 1999, doping control and regulatory measures have been significantly strengthened in the global sports community⁸. Each year, WADA updates its International Standard Prohibited List, which includes substances and methods that can enhance athletic performance or pose potential health risks to athletes. This revised list is announced every September and officially comes into effect on January 1 of the following year⁹. In addition, regular doping tests are conducted at the national level, and data on doping violations are systematically collected and disclosed to reinforce athlete protection measures¹⁰. As a result of these ongoing efforts, the frequency of doping tests has steadily increased,

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and analytical techniques have become increasingly sophisticated, enabling the detection of trace amounts of prohibited substances¹¹.

However, current anti-doping regulations and testing protocols are primarily based on Western pharmaceuticals, with relatively limited guidelines and standards specifically addressing herbal medicines¹². Previous research has shown that certain herbal medicines traditionally listed in pharmacopoeia are associated with doping risks. For example, *Ephedra* (*Ma Huang*) contains ephedrine, a substance explicitly prohibited by the World Anti-Doping Agency (WADA), and has been linked to positive doping cases¹². Similarly, other traditional herbal ingredients such as *Deer Antler* and *Musk* have been reported by Korean Medicine Doctors as potential sources of doping violations¹³. These findings indicate that even herbal medicines considered safe in traditional medical contexts may pose inadvertent doping risks, underscoring the need for more systematic guidelines and education in this area. Since Western drugs are chemically synthesized, their active ingredients are clearly identified, making the detection and identification of prohibited substances relatively straightforward during doping tests. Herbal medicines consist of various natural compounds that function synergistically to produce therapeutic effects. This inherent complexity makes it considerably more challenging to detect and assess prohibited substances in herbal formulations. Herbal medicine has a long history of use in East Asian countries, particularly South Korea, China, and Japan. In modern sports settings, it is commonly used to enhance athletic performance, promote recovery from fatigue, strengthen immunity, and prevent injuries, often through the application of traditional medical knowledge¹⁴.

Additionally, there is a notable lack of concrete data and reliable information regarding the specific types of herbal medicines that athletes commonly consume¹². Herbal medicines typically contain a wide range of bioactive compounds with diverse therapeutic effects, which make them potentially useful for fatigue recovery, relief from muscle soreness, immune enhancement, and post-competition recovery¹⁵. However, there is currently a shortage of systematic research and statistical data on how traditional medicine practitioners prescribe herbal remedies and the specific therapeutic goals they aim to achieve through such prescriptions. The absence of clear evidence and standardized guidelines poses considerable challenges for anti-doping agencies and sports officials to establish effective and reliable recommendations for athletes.

In Korea, athletes may obtain herbal medicines not only through formal prescriptions by Korean Medicine Doctors but also via diverse channels such as pharmacies, online markets, or herbal shops. To reflect this reality, our survey included items on the sources of herbal medicine use, thereby addressing the overlap between common herb-based products and formally prescribed preparations.

Against this background, the present study aimed to provide foundational data for establishing clear guidelines on the use of herbal medicines in doping prevention. Specifically, it sought to investigate athletes' herbal medicine consumption habits by examining the types and frequency of herbal medicine use, as well as their overall awareness and perceptions. Furthermore, it identified patterns in herbal medicine consumption through association rule analysis, uncovering meaningful relationships among various consumption factors.

This study ultimately aimed to contribute to the creation of a safer environment where athletes can use herbal medicines without fear of violating anti-doping regulations. By providing clear standards and reliable information on their use, this study seeks to promote a fair competitive environment while exploring new approaches to performance enhancement that incorporate traditional medicine into sports.

Methods

Participants

This study employed a cross-sectional, descriptive design. To achieve the objectives of this study, the target population comprised athletes in South Korea who had used herbal medicines. As of 2024, the total number of registered athletes in South Korea is 53,846¹⁶. According to previous research, approximately 60% of athletes consume dietary supplements¹⁷. Based on this, the study population was estimated to be 32,308 athletes (60% of 53,846 athletes).

Applying a 95% confidence level with a $\pm 2\%$ margin of error, the required sample size was 2235 participants. To account for potential non-responses and incomplete or insincere answers, the initial target sample size was set at 2500 athletes.

A survey was conducted with these 2500 athletes, and after excluding 259 cases due to incomplete or unreliable responses, data from 2241 participants were ultimately included in the analysis. This final sample size satisfies the required sample size for a population of 53,846, ensuring a 95% confidence level with a $\pm 2\%$ margin of error.

The demographic characteristics of the participants are summarized in Table 1. A total of 55 sports disciplines were included in the sample, with the largest number of participants from track and field ($n = 456$), followed by taekwondo ($n = 207$), swimming ($n = 122$), handball ($n = 101$), and judo ($n = 100$).

Data collection

The survey was distributed using MoaForm (<https://www.moaform.com>), an online survey platform. To ensure clarity and accuracy, all researchers involved in the study were thoroughly briefed on the questionnaire and verbally explained each item to participants while assisting them in completing their responses.

The data collection period spanned approximately two months, from August 1, 2024, to October 14, 2024. This study was conducted in accordance with the principles outlined in the Declaration of Helsinki and approved by the Ethical Review Committee of Korea National Sport University (Approval No.: 1263-202407-HR-101-02). All participants voluntarily participated in the study after being informed of its objectives and procedures, and provided written informed consent, including an agreement on the handling of personal information and privacy protection.

Category		N	%
Gender	Male	1370	61.1
	Female	871	38.9
Affiliation	Middle school	324	14.5
	High school	791	35.3
	University	746	33.3
	Professional/elite	380	17.0
Career Length	Less than 5 years	628	28.0
	5 to less than 10 years	986	44.0
	10 to less than 15 years	461	20.6
	15 years or more	166	7.4

Table 1. Demographic characteristics.

No	Factor	Contents	Response types (Number of options)
1	Demographic characteristics	Gender	Categorical (2)
2		Affiliation	Categorical (4)
3		Athletic career	Open-ended
4		Type of sport	Open-ended
5	Consumption type	What is the primary reason for taking herbal medicine?	Categorical (8)
6		When did you first start taking herbal medicine?	Categorical (5)
7		Where do you usually purchase herbal medicine?	Categorical (7)
8		In what form do you usually take herbal medicine?	Categorical (5)
9	Consumption awareness	Have you ever received any explanation regarding the doping risks associated with the herbal medicine you have taken?	Categorical (2)
10		Are you aware that herbal medicines may contain substances prohibited in doping regulations?	Categorical (2)
11		Have you ever worried about testing positive in a doping test after taking herbal medicine?	Categorical (2)
12		Do you think herbal medicine poses a higher doping risk than conventional medicine (such as Tylenol)?	Categorical (3)
13		Do you believe herbal medicine helps enhance physical stamina?	4-point Likert Scale
14		Do you believe herbal medicine aids in injury recovery?	4-point Likert Scale
15		Do you believe herbal medicine helps with fatigue recovery?	4-point Likert Scale
16		Do you believe herbal medicine helps relieve tension or anxiety?	4-point Likert Scale
17		Do you believe herbal medicine aids in weight loss?	4-point Likert Scale
18		Do you believe herbal medicine helps with growth and development?	4-point Likert Scale
19		Do you believe herbal medicine assists in disease treatment or managing health conditions?	4-point Likert Scale

Table 2. Contents of questions. *Duplicate responses possible.

Survey instrument

The initial version of the survey was developed through meetings with four researchers. It was then revised and refined through two rounds of expert panel reviews, which included eight specialists: four experts in sports measurement and evaluation, two university athletic coaches, and two Korean medicine doctors. The final version of the questionnaire was confirmed through full consensus among the expert panel, who gathered valid evidence based on the test content in accordance with established psychometric principles. The detailed structures and contents of the survey items are listed in Table 2.

Data analysis

The collected data were analyzed using Excel Ver. 2015, and frequency analysis was conducted using SPSS Version 25.0. To identify patterns in herbal medicine consumption, the Apriori algorithm for association rule analysis was applied using Python 3. The Apriori algorithm identifies frequent item sets based on a predefined minimum support threshold and derives association rules from these item sets. In this study, support, confidence, and lift values were calculated as key indicators of association rules. The minimum support was set at 0.01, and the minimum confidence at 0.10. Among the generated rules, only those with lift values greater than 1 were selected for the final analysis. A lift value greater than 1 indicates that the co-occurrence probability of two items is higher than expected, making it a useful criterion for detecting meaningful associations¹⁸.

The formulas used to calculate the support, confidence, and lift are given in (1).

Formula 1. Calculation formulas for Support, Confidence, and Lift

$$\text{Support}(X) = \frac{\text{count}(X)}{N}$$

$$\text{Confidence}(X \rightarrow Y) = \frac{\text{Support}(X, Y)}{\text{Support}(X)}$$

$$\text{Lift}(X \rightarrow Y) = \frac{\text{Confidence}(X \rightarrow Y)}{\text{Support}(Y)}$$

In addition, to calculate the response ranking for items related to herbal medicine consumption awareness, the Rasch model based on Item Response Theory (IRT) was applied. The target items consisted of questions regarding whether herbal medicine was helpful for stamina enhancement, injury recovery, fatigue recovery, tension relief, weight loss, growth and development, and disease treatment (e.g., illness management), all measured using a 4-point Likert scale.

The Rasch model, a type of IRT model, focuses solely on item difficulty. In this model, difficulty is typically interpreted as an item being “difficult” or “easy” to endorse. However, since the items were measured on a 4-point Likert scale ranging from 1 (not helpful at all) to 4 (very helpful), lower difficulty values were interpreted as indicating that herbal medicine was perceived as more helpful.

The Facets Ver. 3.67.1 software was used to calculate item difficulty. To assess model fit, infit and outfit indices were analyzed. These indices indicate how well each item fits the expected response pattern, following a chi-square distribution with an expected value of 1.0. The acceptable fit range for both infit and outfit was set between 0.5 and 1.5, with values outside this range indicating a misfit¹⁹.

Results

Frequency analysis of herbal medicine consumption patterns

To examine patterns of herbal medicine consumption among athletes, a frequency analysis was conducted, and the results are presented in Table 3. In terms of consumption purpose, stamina enhancement was the most frequently reported reason, cited by 1520 of 2241 participants (67.8%). The second most common reason was fatigue recovery, followed by growth and development. Regarding purchasing sources, Korean medicine clinics were the most commonly reported (88.0%), followed by herbal pharmacies (14.0%). As for the timing of first use, the highest proportion of respondents (37.2%) reported beginning herbal medicine consumption in middle school, followed by elementary school (35.2%). In terms of the form of herbal medicine consumed, decoctions were the most prevalent, used by 91.5% of respondents, while herbal pellets were the second most common form, consumed by 24.3% of respondents.

Pattern analysis of herbal medicine consumption patterns

To identify patterns in herbal medicine consumption behavior among athletes, association rule analysis was applied. The minimum support threshold was set at 0.01, and the minimum confidence threshold at 0.1. This analysis generated 10,570 patterns, of which 7833 had lift values greater than 1. Given that the primary objective of this study was to examine overall consumption patterns among athletes, only patterns encompassing all four key variables—timing of consumption, purpose of consumption, place of purchase, and form of consumption—were selected for further analysis. The top five patterns with the highest support values are presented in Table 4.

The results indicate that the most common herbal medicine consumption pattern involved taking decoctions at a Korean medicine clinic for stamina enhancement during middle school, with a support value of 0.207, meaning this pattern occurred in 20.7% of cases. Similarly, consuming decoctions at a Korean medicine clinic

Question	N	%	Question	N	%
Purpose of consumption*			Place of purchase*		
Stamina enhancement	1520	67.8	Korean medicine clinic	1972	88.0
Injury recovery	283	12.6	Herbal pharmacy	314	14.0
Fatigue recovery	955	42.6	Pharmacy	176	7.9
Relieving tension	99	4.4	Mart (supermarket)	99	4.4
Weight loss	66	2.9	Online	156	7.0
Growth and development	586	26.1	Direct purchase from acquaintances	186	8.3
Medical treatment (disease management)	337	15.0	Others	85	3.8
Weight gain	14	0.6			
Timing of first consumption			Form of consumption*		
Before elementary school	131	5.8	Herbal pellet	545	24.3
Elementary school	788	35.2	Decoction	2050	91.5
Middle school	833	37.2	Capsule	106	4.7
High school	443	19.8	Extract (liquid concentrate)	343	15.3
Others	46	2.1	Powder	112	5.0

Table 3. Results of frequency analysis of herbal medicine consumption. *Duplicate responses possible.

Timing of consumption	Purpose of consumption	Place of purchase	Form of consumption	Support	Confidence	Lift
Middle school student	Stamina enhancement	Korean Medicine Clinic	Decoction	0.207	0.704	1.036
Elementary school student	Stamina enhancement	Korean Medicine Clinic	Decoction	0.199	0.887	1.076
Middle school student	Fatigue recovery	Korean Medicine Clinic	Decoction	0.125	0.375	1.002
High school student	Stamina enhancement	Korean Medicine Clinic	Decoction	0.121	0.768	1.130
Elementary school student	Growth and development	Korean Medicine Clinic	Decoction	0.120	0.498	1.517

Table 4. Results of pattern analysis on herbal medicine consumption behavior (Top 5 patterns based on support values).

Timing of consumption	Purpose of consumption	Place of purchase	Form of consumption	Support	Confidence	Lift
Elementary school student	Fatigue recovery	Mart (supermarket)	Decoction	0.010	0.277	2.087
Before elementary school	Medical treatment	Korean medicine clinic	Decoction	0.014	0.263	1.876
Elementary school student	Fatigue recovery	Korean medicine clinic	Extract (liquid concentrate)	0.031	0.231	1.738
Middle school student	Fatigue recovery	Herbal pharmacy	Herbal pellet	0.011	0.161	1.684
High school student	Fatigue recovery	Korean medicine clinic	Extract (liquid concentrate)	0.015	0.708	1.656

Table 5. Results of pattern analysis on herbal medicine consumption behavior (Top 5 patterns based on lift values).

for stamina enhancement during elementary school had a support value of 0.199 (19.9%), while consuming decoctions at a Korean medicine clinic for fatigue recovery during middle school had a support value of 0.125 (12.5%). Table 5 presents the top five patterns with the highest lift values. The highest lift value (2.087) was observed for the pattern of consuming decoctions purchased from a mart for fatigue recovery during elementary school. The second-highest lift value (1.876) corresponded to the pattern of consuming decoctions at a Korean medicine clinic for medical treatment before entering elementary school.

Analysis of awareness on herbal medicine consumption

To assess athletes' awareness of herbal medicine consumption, a frequency analysis was conducted, and the results are presented in Table 6. Regarding doping-related concerns, 66.2% of respondents indicated that they had ever received an explanation about the potential doping risks associated with herbal medicine. However, 57.6% reported being aware that herbal medicines may contain prohibited substances that could pose a doping risk. When asked whether they had ever been concerned about testing positive for doping after consuming herbal medicines, 77.7% responded "No." Additionally, 55.2% of respondents answered "Not sure" when asked about the perceived benefits of herbal medicine for various purposes—such as stamina enhancement, injury recovery, fatigue recovery, relieving tension, weight loss, growth and development, and disease treatment—the majority of respondents answered "Yes" for all categories.

To determine the response ranking of the 4-point Likert scale questions related to stamina enhancement, injury recovery, fatigue recovery, relieving tension, weight loss, growth and development, and disease treatment, the Rasch model based on Item Response Theory (IRT) was applied to calculate the difficulty level of each item. The results are summarized in Table 7. The infit and outfit values for all items ranged from 0.81 to 1.20, within the acceptable fit range of 0.5 to 1.5, indicating good overall model fit. Regarding item difficulty, the fatigue recovery item had the lowest difficulty value (−1.18), followed by the stamina enhancement item (−0.91). Since the 4-point Likert scale ranged from 1 (not helpful at all) to 4 (very helpful), lower difficulty values indicated that the item was perceived as more beneficial. Based on this interpretation, the perceived helpfulness of herbal medicines was ranked as follows: fatigue recovery, stamina enhancement, disease treatment, growth and development, injury recovery, tension relief, and weight loss.

Discussion

The purpose of this study was to provide the fundamental data necessary for establishing clear guidelines on herbal medicine to support doping prevention efforts. To achieve this, the study examined athletes' consumption behaviors and perceptions of herbal medicine use by analyzing the types and frequencies of consumption. Furthermore, it explored consumption patterns to gain a comprehensive understanding of athletes' usage tendencies.

Given the limited availability of data on athletes' use of herbal medicines, this study is significant because it comprehensively investigated the purposes, consumption behaviors, and doping-related perceptions of athletes. In this context, WADA has conducted survey-based studies in certain countries to assess the risks associated with athletes' use of supplements and herbal medicines, while emphasizing the importance of education and awareness regarding herbal medicine use²⁰. This underscores the timeliness and relevance of this study.

Furthermore, previous studies have reported that 40–70% of athletes consume various dietary supplements, with a significant proportion using products containing herbal ingredients²¹. Considering this reality, it is essential to examine large-scale consumption trends of herbal medicines among athletes and analyze potential

Question	N	%	Question	N	%
Explanation of doping risks			Awareness of doping risks		
Have heard	758	33.8	Aware	1291	57.6
Have not heard	1483	66.2	Not aware	950	42.4
Concern about doping			Doping risk compared to conventional medicine		
Concerned	500	22.3	Herbal medicine is riskier	358	16.0
Not concerned	1741	77.7	Conventional medicine is riskier	645	28.8
			Not sure	1238	55.2
Helpfulness for stamina enhancement			Helpfulness for injury recovery		
Not helpful at all	61	2.7	Not helpful at all	147	6.6
Not helpful	358	16.0	Not helpful	677	30.2
Helpful	1571	70.1	Helpful	1263	56.4
Very helpful	251	11.2	Very helpful	154	6.9
Helpfulness for Fatigue Recovery			Helpfulness for relieving tension		
Not helpful at all	64	2.9	Not helpful at all	196	8.7
Not helpful	309	13.8	Not helpful	755	33.7
Helpful	1531	68.3	Helpful	1132	50.5
Very helpful	337	15.0	Very helpful	158	7.1
Helpfulness for weight loss			Helpfulness for growth and development		
Not helpful at all	357	15.9	Not helpful at all	161	7.2
Not helpful	883	39.4	Not helpful	627	28.0
Helpful	893	39.8	Helpful	1226	54.7
Very helpful	108	4.8	Very helpful	227	10.1
Helpfulness for disease treatment					
Not helpful at all	143	6.4			
Not helpful	511	22.8			
Helpful	1366	61.0			
Very helpful	221	9.9			

Table 6. Results of frequency analysis on awareness of herbal medicine consumption.

Question	Calibration logit	SE logit	Mean square residual	
			Infit	Outfit
Helpfulness for Fatigue Recovery	-1.18	0.05	1.02	1.00
Helpfulness for Stamina Enhancement	-0.91	0.05	0.93	0.90
Helpfulness for Disease Treatment	-0.20	0.04	0.96	0.92
Helpfulness for Growth and Development	0.08	0.04	1.08	1.07
Helpfulness for Injury Recovery	0.25	0.04	0.86	0.81
Helpfulness for Relieving Tension	0.56	0.04	0.91	0.88
Helpfulness for Weight Loss	1.40	0.04	1.17	1.20

Table 7. Results of the Rasch model.

doping risks. This study provides a foundational resource for developing policies to protect athlete health and promote fair play in sports by providing empirical evidence on the relationship between herbal medicine consumption and doping risk.

The results indicate that the primary reasons for herbal medicine consumption among athletes were stamina enhancement and fatigue recovery. Many athletes use herbal medicine to reduce exercise-induced fatigue and enhance stamina, while others use it for injury treatment, recovery, and general health management.

This trend aligns with findings in Korean medicine, where herbal medicine is commonly prescribed to athletes for pain relief, fatigue recovery, and performance enhancement, with reports of high treatment satisfaction¹⁵. Many developing athletes use herbal medicine as a growth-promoting supplement, reflecting young athletes' desire to improve their performance using traditional medicine.

Athletes are commonly introduced to herbal medicine during elementary or middle school. Among respondents, 37.2% reported first taking herbal medicines in middle school, while 35.2% stated they began using them in elementary school. Many athletes are introduced to herbal medicines through recommendations from parents or coaches, which aligns with the traditional health management culture of using herbal medicines for stamina enhancement and disease treatment during growth stages.

Early exposure to herbal medicines appears to contribute to developing habits for physical condition management, leading athletes to perceive herbal medicines as performance supplements during intensive training and competitions. However, young athletes may lack awareness of doping regulations and prohibited substances, highlighting the need for educational guidance on herbal medicine consumption. Such education is essential for athletes to develop appropriate supplementation strategies as they mature and to foster awareness of banned substances, ensuring compliance with doping regulations.

A survey of herbal medicine purchasing channels revealed that most athletes obtain herbal medicines through official Korean medicine clinics. The majority (88.0%) reported purchasing herbal medicines from these clinics, followed by herbal pharmacies (licensed pharmacies selling herbal medicines) at 14.0%. These findings indicate that athletes primarily consume herbal medicines under the prescription and guidance of licensed Korean medicine doctors, which is beneficial in terms of drug safety management. As traditional Korean medicine clinics are likely to recognize their patients as athletes, they are more cautious in ensuring that prescribed herbal medicines do not contain prohibited substances.

This result contrasts with previous studies, which reported that only approximately 4% of athletes consulted experts before taking supplements²², and that 38% of elite athletes and 43% of amateur athletes relied on online information when purchasing medicine. In this regard, it can be inferred that Korean athletes may have a higher level of awareness of doping risks than athletes from other countries.

Although most athletes purchase herbal medicines through official channels, only a small proportion obtain herbal medicines through unregulated sources. Some acquire herbal medicines from acquaintances, whereas others purchase them from online shopping platforms or supermarkets. These informal purchasing channels pose potential doping risks, as the quality and composition of herbal medicines may not be verified.

Therefore, while most athletes adhere to safe purchasing practices, the risks associated with unofficial purchasing patterns should not be overlooked. Additional monitoring and education on safe herbal medicine consumption and doping prevention should be emphasized to mitigate potential risks.

Decoctions are the most common form of herbal medicines consumed by athletes. Traditionally, herbal medicines are consumed in decocted form, and the survey results reflect this trend, with 91.5% of the respondents reporting experience with decoction-based herbal medicines. The second most common form was herbal pellets (pill-form herbal medicine), reported by 24.3% of respondents, indicating some diversification in dosage forms.

Decoctions are advantageous in terms of customized prescriptions and absorption rates, as they are extracted directly from herbal ingredients. However, their bitter taste and inconvenient consumption are drawbacks. In contrast, herbal pellets and extracts (liquid concentrates) are easier to consume, allowing athletes to take them during training. The fact that most athletes in this survey chose decoctions suggests they prioritize efficacy and trust in professionally prescribed herbal medicines.

However, the use of industrialized forms such as herbal pellets or extracts remains less common, suggesting that athletes also consider convenience when selecting herbal medicines. Notably, herbal pellets are available not only in Korean medicine clinics but also in herbal pharmacies and as general health supplements, meaning that the choice and purchasing source could influence doping risk.

For example, unauthorized herbal pellets or supplements may contain prohibited substances, increasing the risk of unintentional doping violations. Therefore, athletes must carefully examine both the form and source of herbal medicines to ensure compliance with doping regulations.

This study analyzed the association patterns of athletes' herbal medicine consumption behaviors using the Apriori algorithm to identify key relationships among consumption timing, purpose, purchase source, and form of intake. Among the association rules generated, the most frequent patterns reflected the consumption of traditional herbal medicines.

For instance, the most common pattern, with a support value of 0.207 (20.7%), was the consumption of decoctions from a Korean medicine clinic for stamina enhancement during middle school. The second most common pattern (19.9%) was the consumption of a decoction from a Korean medicine clinic during elementary school for stamina enhancement. Additionally, the consumption of decoctions from a Korean medicine clinic during middle school for fatigue recovery ranked among the top patterns, with a support value of 12.5%.

These frequent patterns demonstrate that school-aged athletes (elementary and middle school) consume decoctions prescribed by Korean medicine clinics for performance enhancement, such as stamina improvement or fatigue recovery. Young athletes commonly use traditionally prescribed herbal medicines as performance supplements under the guidance of licensed Korean medicine doctors. This finding aligns with previous results, further supporting the notion that herbal medicine consumption among athletes in Korea largely occurs in regulated medical institutions.

A key issue in this study was the link between herbal medicine consumption and doping risks. While herbal medicines are generally perceived as safe owing to their natural origins, scientific analyses have revealed that some herbal ingredients contain chemical compounds similar to substances banned in international competitions or may be converted into prohibited substances during metabolism.

For example, Ephedra (Ma Huang), a well-known herbal ingredient, contains banned substances and is listed as prohibited by WADA¹². Furthermore, concerns exist regarding the potential formation of unexpectedly prohibited substances during the manufacturing and metabolic processes of herbal medicines. Some researchers have suggested that, during the decoction process, when multiple herbal ingredients are boiled at high temperatures and pressures, new chemical compounds may be synthesized. In addition, intermediate metabolites formed

during human metabolism can trigger positive doping test results²³. Therefore, herbal medicine consumption requires the same level of caution as conventional medicines, particularly when considering the potential doping risks.

As revealed in this study, the lack of doping awareness among athletes is a critical issue linking herbal medicine consumption to potential doping risks. The survey results showed that some athletes consumed herbal medicines without fully understanding their ingredients or potential implications for doping violations. This lack of awareness appears to stem from insufficient education on anti-doping regulations and the list of prohibited substances.

Studies in other countries, such as India, have found low awareness of anti-doping regulations, with fewer than 40% of athletes regularly receiving doping-related information²⁴. However, athletes who participated in anti-doping education programs demonstrated significant improvements in knowledge and attitudes, with over 80% consulting a team doctor before taking any medication²⁴.

Similarly, studies in South Korea indicate that both coaches and athletes lack sufficient awareness of the doping risks associated with herbal medicines¹⁵. The lack of systematic education on this topic is a major concern.

This study has several limitations that should be acknowledged. First, as the data were collected through a self-reported survey, there is a possibility of recall bias and socially desirable responses, which may have influenced the accuracy of the reported behaviors. Second, the participants were limited to athletes in South Korea, which may restrict the generalizability of the findings to athletes in other countries or cultural contexts. Finally, due to the cross-sectional design of this study, causal relationships between herbal medicine use and doping awareness cannot be established. Despite these limitations, the study provides meaningful insights into athletes' perceptions of herbal medicine use and its implications for doping prevention.

Although herbal medicines are composed of multiple ingredients, which makes it inherently difficult to directly establish doping violations from their use, the findings of this study still provide important applied value. Specifically, by documenting athletes' usage patterns, perceptions, and sources of herbal medicine, this research highlights areas where knowledge gaps and potential risks exist. Such evidence can serve as a foundation for designing targeted education programs that inform athletes about doping risks associated with herbal medicine, as well as for guiding policymakers in developing clearer regulations and guidelines. Therefore, despite the complexity of herbal formulations, the present study offers meaningful implications for both doping prevention strategies and the establishment of evidence-based policies.

In conclusion, this study provides a comprehensive analysis of herbal medicine consumption among athletes and its association with the risk of doping. These findings confirm that herbal medicine can support athletic performance and recovery when properly managed. However, without proper regulation and education, doping may pose unexpected risks.

A systematic national approach, supported by structured educational programs and institutional measures, is required to ensure that athletes receive clear information on herbal medicine consumption and doping risks.

Conclusions

This study examined the status of herbal medicine consumption among athletes and their awareness of the risks of doping. These findings reveal that many athletes consume herbal medicines for stamina enhancement and fatigue recovery. Athletes generally perceive herbal medicine as beneficial for stamina enhancement, fatigue recovery, and injury recovery. However, this study also identified a significant lack of awareness regarding doping risks among some athletes.

For example, some athletes were unaware of the potential presence of banned substances in herbal medicines, whereas others showed little concern about the possibility of testing positive in doping tests after consuming them. These findings reflect the fact that, while numerous studies have been conducted on the use of Western-style dietary supplements, there is a lack of systematic research and education on herbal medicine and its potential doping risks.

These results highlight that while athletes traditionally use herbal medicine for health management and performance enhancement, current anti-doping education and information systems primarily focus on Western supplements. This indicates a lack of systematic education and management concerning herbal medicines. Given that many athletes are exposed to herbal medicines at a young age, it is crucial to integrate appropriate supplemental education and anti-doping awareness programs during their developmental stages.

Additionally, further scientific analysis is needed to assess the effects of herbal medicine ingredients on doping test results and to evaluate the long-term impact of herbal medicine consumption on athletic performance and recovery. Future studies should focus on developing tailored guidelines for herbal medicine consumption that consider the characteristics of different sports. Furthermore, there is a need for systematic educational programs targeting athletes, coaches, and medical professionals, along with research to verify their effectiveness.

This study provides fundamental data to help athletes safely use herbal medicines by analyzing their consumption patterns and awareness of doping risks. Future research should focus on identifying the specific doping risks associated with herbal medicines and conducting detailed case studies linking herbal medicine consumption to doping violations. Such studies can contribute to policy and practical improvements in regulating the use of herbal medicines in sports.

Data availability

Data presented in this paper are available upon reasonable request from the corresponding author.

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References

- Cisneros, J. Leveling the E-sports playing field: an argument in favor of government regulation to ensure fair player contracts for young professional gamers in E-sports. *Cal. WL Rev.* **58**, 333 (2021).
- Kim, C., Park, J. H. & Lee, J. Y. AI-based betting anomaly detection system to ensure fairness in sports and prevent illegal gambling. *Sci. Rep.* **14**, 6470 (2024).
- Metushi, I. G. et al. Breaking boundaries: exploring performance enhancement and anti-doping testing in sports. *Clin. Chem.* **70**, 897–904 (2024).
- Bhasin, S. et al. The effects of supraphysiologic doses of testosterone on muscle size and strength in normal men. *N. Engl. J. Med.* **335**, 1–7 (1996).
- Cadwallader, A. B., De La Torre, X., Tieri, A. & Botrè, F. The abuse of diuretics as performance-enhancing drugs and masking agents in sport doping: Pharmacology, toxicology and analysis. *Br. J. Pharmacol.* **161**, 1–16 (2010).
- Bell, P., Ten Have, C. & Lauchs, M. A case study analysis of a sophisticated sports doping network: Lance Armstrong and the USPS Team. *Int. J. Law Crime Just.* **46**, 57–68 (2016).
- Cho, Y. Sport celebrity in South Korea: Park, Tae-Hwan from new generation to fallen angel. *Asia Pac. J. Sport Soc. Sci.* **4**, 223–236 (2015).
- Kim, S. H., Cho, S., Choi, J. H., Lee, Y. H. & Rhie, S. J. Sports pharmacy: New specialty of pharmacists and pharmaceutical care services. *Korean J. Clin. Pharm.* **31**, 12–20 (2021).
- World Anti-Doping Agency. World anti-doping code international Standard prohibited list 2023. https://www.wada-ama.org/sites/default/files/2022-09/2023list_en_final_9_september_2022.pdf. (2023).
- World Anti-Doping Agency. Anti-doping rule violations (ADRVs) report 2019. https://www.wada-ama.org/sites/default/files/2022-01/2019_adrv_report_external_final_12_december_2021_0_0.pdf. (2019).
- Lamon, S., Robinson, N., Mangin, P. & Saugy, M. Detection window of darbepoetin- α following one single subcutaneous injection. *Clin. Chim. Acta* **379**, 145–149 (2007).
- Kim, J., Yun, S. J., Lee, Y. K., Lee, H. J. & Kim, J. S. A review on safety of herbal medicines for doping. *J. Korean Med.* **40**, 139–176 (2019).
- Yun, H. J., Park, J. H., Yoon, J. & Lee, J. Y. Current practices of herbal medicine prescription for athletes and doping awareness among Korean medicine doctors. *J. Drug Issues* <https://doi.org/10.1177/00220426251364376> (2025).
- Engels, H. J., Kolokouri, I., Cieslak, T. J. & Wirth, J. C. Effects of ginseng supplementation on supramaximal exercise performance and short-term recovery. *J. Strength Cond. Res.* **15**, 290–295 (2001).
- Lee, T. H., Kang, C. K., Jung, W. S. & Lee, M. G. Investigation of perception of coaches and oriental medical doctors on oriental medicine and doping of elite athletes. *KAHPERD* **56**, 565–575 (2017).
- Korean Sport & Olympic Committee. Player registration status. <https://g1.sports.or.kr/stat/stat01.do?gubun=P>. (2024).
- Kang, C. K., Jung, W. S. & Lee, M. G. A national survey on oriental medicine supplementation and doping in Korean elite student athletes. *Korea J. Sports Sci.* **28**, 1175–1186 (2019).
- Cho, K. H. & Park, H. C. Study on the multi-intervening relation in association rules. *JKDAS* **13**, 297–306 (2011).
- Wright, B. D. & Masters, G. N. *Rating scale analysis* (MESA Press, 1982).
- Muwonge, H., Makubuya, T., Lubega, S., Zavuga, R. Supplements, herbs and doping products usage among Uganda athletes and coaches. *World Anti-Doping Agency – Social Science Research Project*. <https://www.wada-ama.org/en/resources/social-science-research/supplements-herbs-and-doping-products-usage-among-uganda-athletes>. (2024).
- Cadwallader, A. B. Seven points for athletes to consider before using a dietary supplement. *AMA J. Ethics* **24**, E443–451 (2022).
- Garcia, J. F. et al. Herbs as an active ingredient in sport: availability and information on the Internet. *Nutrients* **14**, 2764 (2022).
- Yoo, H. J., Choi, G. H., Lee, M. G., Kang, C. K. & Park, H. Verification of efficacy as an ergogenic aid and safety in doping of Sibjeondaebotang. *J. Exerc. Nutr. Biochem.* **18**, 189–195 (2014).
- Krishnan, A. et al. Survey of antidoping knowledge, attitudes and practices amongst elite Indian sportsmen and the way forward. *Med. J. Armed Forces India* **78**, 88–93 (2022).

Author contributions

P.J. H. and L. J. Y. designed the research study and methodology, contributed to data curation, and supervised the study. Y. H. J. provided the software. Y. J. and L. S. contributed to resources and data curation and participated in visualization creation. Y. H. J. and L. J. Y. revised the manuscript. All authors contributed to writing the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Review Committee of Korea National Sport University (Approval No. 1263-202407-HR-101-02). All participants were informed of the study's purpose and procedures and voluntarily provided written informed consent in accordance with privacy and data management policies.

Additional information

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