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Anti-Doping Knowledge and Educational Needs among Pharmacists in Taiwan

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Abstract

Distinct health practices in Taiwan, including widespread use of Chinese Herbal Medicine (CHM), may increase the likelihood of unintentional doping among competitive athletes. Pharmacists play a crucial role in guiding athletes on the appropriate and safe use of medications. This study aims to evaluate the level of anti-doping knowledge and related educational requirements among pharmacists in Taiwan, as well as to identify factors associated with knowledge differences.A nationwide, cross-sectional online survey was conducted among licensed pharmacists in Taiwan. The questionnaire comprised five sections: demographic information, sources of prohibited substances, recognition of banned substances, knowledge of doping control procedures, and perceived educational needs related to anti-doping. A total of 491 completed questionnaires were included in the final analysis.Participants were predominantly female (65%), with a mean age of 41.9 ± 11.4 years, and most held a bachelor's degree (68%). The average anti-doping knowledge score was 37.2 ± 4.9, with scores ranging from 21 to 48 out of a maximum of 51. Only 15% of respondents reported having previously provided counselling on medication use in sports. Higher knowledge levels were significantly associated with younger age, indicating an age-related trend ($p < 0.001$). Pharmacists working in southern Taiwan and those employed in clinical settings demonstrated lower knowledge levels compared with their counterparts in northern regions and hospital settings. While the majority correctly identified ephedrine as a prohibited stimulant (90%), fewer respondents recognised furosemide as a banned diuretic (38%) or identified CHM products containing the β_2-agonist higenamine (7%). Nearly 90% of participants expressed a strong need for further education in anti-doping.The findings reveal considerable variation in anti-doping knowledge among pharmacy professionals in Taiwan and underscore the importance of targeted educational initiatives. These results provide valuable guidance for developing future training programmes and research-driven educational strategies in anti-doping practice.

Keywords: Sport, Pharmacy education, Performance-enhancing drugs, Athlete, World anti-doping agency, Chinese herbal medicine

Introduction

Competitive sport relies on a comprehensive international framework to preserve fairness and credibility, overseen by the World Anti-Doping Agency (WADA). As part of this framework, WADA updates and releases the Prohibited List on an annual basis [1] and applies analytical and longitudinal monitoring tools, including the Athlete Biological Passport [2], to detect and deter intentional doping practices such as the use of anabolic steroids, erythropoiesis-stimulating agents, and human growth hormone. Despite these efforts, a substantial proportion of Adverse Analytical Findings (AAF) arise from circumstances in which athletes assert that the presence of prohibited substances was accidental. Even in cases where athletes are later exonerated, sanctions or provisional suspensions are often imposed, necessitating lengthy and resource-intensive investigations.

A well-documented example involves a Thai badminton player, formerly ranked first worldwide in women's

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singles, who returned an AAF for clenbuterol, a substance associated with animal growth promotion. Following extensive inquiry, the athlete demonstrated that the substance originated from contaminated meat and that there was no fault or negligence on her part, resulting in no period of ineligibility after approximately six months [3]. In contrast, a Russian figure skater tested positive for trimetazidine one day after her team secured a gold medal at the Beijing 2022 Winter Olympic Games. The positive finding was attributed to accidental exposure via a contaminated drinking vessel containing her grandfather's cardiovascular medication [4]. Nevertheless, the athlete remains at risk of a potential four-year ban. These cases illustrate that, while strict liability rests with athletes, practical prevention of inadvertent doping requires professional support beyond the athletes themselves.

The Prohibited List, which forms the operational foundation of anti-doping enforcement, is developed according to criteria outlined in Article 4.3 of the World Anti-Doping Code [5]. The most recent edition categorises banned items into prohibited substances (S), prohibited methods (M), and substances prohibited in specific sports (P) [1]. Prohibited substances account for the largest proportion and are further classified into nine subgroups. Substances restricted during competition only (S6–S9) include stimulants (e.g., ephedrine, methylphenidate, cocaine, and amphetamines), narcotics, cannabinoids other than cannabidiol, and glucocorticoids administered via oral, rectal, or injectable routes. In contrast, substances prohibited at all times (S1–S5) encompass anabolic agents; peptide hormones, growth factors, related substances, and mimetics; β_2-agonists with limited inhalation exemptions; hormone and metabolic modulators such as clomifene and insulin; and diuretics and masking agents, including furosemide and hydrochlorothiazide.

Pharmacists are increasingly recognised as key stakeholders in anti-doping prevention. The International Pharmaceutical Federation (FIP), through its guidance The role of the pharmacist in the fight against doping in sport [6], emphasises pharmacists' responsibilities in identifying prohibited ingredients in medicines and advising athletes on the appropriate use of nutritional supplements. Although educational initiatives exist—including WADA's Anti-Doping e-Learning Platform (ADeL) designed for healthcare professionals—the extent of pharmacists' engagement and competence in this area varies internationally. Survey-based investigations assessing pharmacists' knowledge of drugs in sport have been conducted in diverse settings, including hospital and community pharmacists in Qatar (n = 300) [7], pharmacists employed by chain pharmacies in the United States (n = 143) [8], pharmacists in Australia (n = 135) [9], community pharmacists in Dessie, Ethiopia (n = 61) [10], pharmacists in Finland (n = 246) [11], community pharmacists in Malaysia (n = 384) [12], and community pharmacists in Sydney, Australia (n = 100) [13]. Despite differences in healthcare systems, these studies consistently report limited anti-doping knowledge and insufficient confidence among pharmacists when advising athletes.

Taiwan presents a distinctive healthcare context. Its compulsory universal health insurance system covers approximately 99% of the population and ranked first globally in the Health Care Index in 2023 [14]. By 2022, Taiwan's healthcare infrastructure comprised approximately 420 hospitals, 12,000 clinics, and 8,200 pharmacies, delivering services widely regarded for their quality and accessibility [15]. A defining characteristic of Taiwan's healthcare system is the formal integration of Chinese Herbal Medicine (CHM), with over 300 single-herb preparations and more than 500 compound formulations reimbursed under national health insurance [16]. Population-based data indicate that more than half of Taiwanese citizens used CHM at least once over a six-year period [17]. While culturally ingrained, this widespread utilisation introduces a notable risk of inadvertent doping for athletes. Exposure may occur through naturally occurring steroids in musk, ephedrine-containing herbs such as Ephedrae Herba and Pinelliae Rhizoma, or higenamine present in Plumula Nelumbinis and Aconiti Tuber [18–21]. Within this context, pharmacists have a critical responsibility to support athletes in making informed and compliant medication choices.

Internationally, structured approaches to sports pharmacy have been implemented in response to similar challenges. For example, the Japan Anti-Doping Agency established a Sports Pharmacist certification programme in 2009, providing systematic education and credentialing for pharmacists involved in athlete care [22]. Comparable, standardised educational pathways remain scarce in Taiwan and in many other regions.

Although the professional role of pharmacists in supporting athletes is increasingly acknowledged and Taiwan's healthcare characteristics are well documented, empirical data regarding Taiwanese pharmacists' anti-

doping knowledge and training needs remain limited. A preliminary investigation involving healthcare professionals attending anti-doping training at a local hospital reported that, among 42 participating pharmacists, only 24% had ever provided counselling to athletes [23]. Furthermore, merely 5% felt confident in offering anti-doping advice, and 62% were unfamiliar with the WADA Prohibited List. Beyond this pilot work, systematic evaluations of knowledge levels—and their variation according to educational background, practice setting, or access to information—are lacking.

Accordingly, the present study aimed to examine anti-doping knowledge among registered pharmacists in Taiwan and to identify factors associated with knowledge variability. By identifying specific gaps and at-risk subgroups, the findings are intended to inform curriculum development, prioritise educational content, and support the design of evidence-based training initiatives for sports pharmacy practice in Taiwan.

Materials and Methods

Study ethics and setting

This research was conducted as a national, cross-sectional online survey in Taiwan during September 2022, aimed at registered pharmacists. Approval for the study was granted by the Institutional Review Board at Kaohsiung Medical University Chung-Ho Memorial Hospital (reference: KMUHIRB-E(I)-20,220,158).

Development of the questionnaire

The survey was designed using SurveyCake (25sprout, Taipei, Taiwan), following the seven-step framework for creating robust surveys in medical education research, as outlined by Artino *et al*. [24]. This approach included a comprehensive preliminary literature review, interviews, synthesis of findings from both the literature and the interviews, formulation of survey items, expert validation, cognitive interviews, and a pilot testing phase. A scoping review was conducted to explore the role of pharmacists in preventing athletes from unintentionally using banned substances. Given Taiwan's specific healthcare context, including the use of Chinese Herbal Medicine (CHM) and easily accessible over-the-counter medications, no existing survey tool was found to be appropriate for this study after reviewing the literature [7-13]. This gap indicated the need to create a context-specific questionnaire. Three potential participants were then invited to review and suggest improvements to the proposed survey items. The review process resulted in the identification of five main domains: demographic details, sources of prohibited substances, identification of banned substances, understanding of doping regulations, and educational needs related to anti-doping.

After drafting the initial version of the survey, three medical education experts reviewed it for content validity. The experts evaluated the clarity and relevance of each item using a 4-point Likert scale, where 1 indicated unclear or irrelevant, 2 meant needing revision, 3 indicated clarity or relevance with minor adjustments required, and 4 represented very clear or highly relevant items [25]. As a result, the original set of 16 items was modified, including the removal of one item, revision of three items, and the addition of four new items (further details in Text S1). Demographic data were included to examine how variables like changes in the pharmacy education system, the roles of pharmacists, and cultural or social factors might influence the survey results

Following these revisions, the second version of the questionnaire was tested by three practicing pharmacists and three pharmacy students. This version was administered three times over different days to assess the reliability of the items. Minor modifications were made based on their feedback, specifically addressing wording and technical issues. The internal consistency of the survey was evaluated using Cronbach's alpha, which yielded a value of 0.92, indicating excellent reliability. The finalized questionnaire was therefore deemed both valid and reliable for the study.

The final questionnaire consisted of 21 items, categorized into three sections: demographic information (10 items), anti-doping knowledge (10 items with 51 possible responses), and educational needs on anti-doping (1 item with 6 response options). Anti-doping knowledge was evaluated using a summative score, where a correct answer received a score of 1 and an incorrect answer received 0, with the total score being a maximum of 51. The section on educational needs was assessed using a 5-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree), where a higher score indicated a greater need for educational content. Respondents were informed that completing the survey would take approximately 10–15 minutes and were instructed to answer without consulting external resources to ensure that the results accurately reflected their current knowledge and opinions.

Data quality and sampling control

This study focused on registered pharmacists across Taiwan. Based on the total number of 30,389 pharmacists as of December 2022, a minimum sample size of 379 was calculated using the Krejcie and Morgan formula. The population was divided into four geographical regions—northern, central, southern, and eastern Taiwan, as well as the outlying islands. The stratified random sampling technique was employed to ensure equal representation from each area. Invitations to participate in the survey were shared with pharmacy associations in each region through communication apps.

To maintain data integrity, responses were monitored for validity. Entries from identical IP addresses or responses completed in less than 200 seconds were discarded. An attention check was also included: "Pharmacists ensure the safe prescribing and dispensing of medications to patients." Responses indicating disagreement with this essential pharmacist responsibility were excluded. Ultimately, 491 valid responses were considered for analysis.

Data analysis

Statistical analyses were performed using SPSS version 20.0. Descriptive statistics, including means, proportions, and standard deviations, were used to summarize participant data. Differences in anti-doping knowledge and educational needs across demographic groups were assessed with independent t-tests for two-group comparisons, and one-way ANOVA with Tukey's post-hoc tests for three or more group comparisons. Chi-square tests were applied to compare the rates of correct responses to knowledge questions and the agreement levels regarding educational topics across different demographic groups. The relationship between anti-doping knowledge scores and continuous variables, such as age, was explored using simple linear regression. A p-value of less than 0.05 was considered statistically significant.

Results and Discussion

The survey had a total of 491 respondents, with 64.6% identifying as female (**Table 1**). The participants' mean age was 41.9 ± 11.4 years, with ages ranging from 23 to 74. Most respondents (68.4%) held a Bachelor's degree, while 19.3% had a postgraduate degree, and 12.2% had an associate degree. Respondents were primarily employed in community pharmacies or drugstores (40.9%), hospitals (38.3%), and clinics (17.1%). Notably, 15.3% of respondents (n = 75) had previously provided advice on drug use in sports. Among these, 76.0% were asked to identify prohibited substances in medications or supplements, and 17.3% were approached regarding performance-enhancing drugs **(Figure 1a).**

Table 1. Demographic characteristics of the respondents (n = 491)

Demographic Characteristic	Subcategory/Category	Percentage (%)	Count
Age Group	20–29 years	16.1	79
	30–39 years	29.9	147
	40–49 years	28.5	140
	Over 50 years	25.5	125
Gender	Male	35.4	174
	Female	64.6	317
Main Workplace	Community pharmacy or drugstore	40.9	201
	→ Chain	26.9 (of community)	54
	→ Independent	72.1 (of community)	145
	→ Non-NHI contract	1.0 (of community)	2
	Hospital	38.3	188
	→ Regional hospital	36.7 (of hospitals)	69
	→ District hospital	22.9 (of hospitals)	43
	→ Medical center	40.4 (of hospitals)	76
	Government agency	1.2	6
	Pharmaceutical industry or wholesale	2.3	11
	Clinic	17.1	84
	Unemployed	0.2	1
Highest Education Level	Associate degree	12.2	60
	Pharm.D	0.4	2

	Doctorate degree	0.8	4
	Bachelor's degree	68.0	334
	Master's degree	18.5	91
Practice Region	Northern Taiwan	41.8	205
	Eastern Taiwan and outlying islands	5.5	27
	Central Taiwan	21.6	106
	Southern Taiwan	31.2	153
Years of Professional Experience	Fewer than 5 years	18.7	92
	6–10 years	21.8	107
	11–15 years	16.7	82
	16–19 years	10.2	50
	More than 20 years	32.6	160
Current Role	Supervisor	17.7	87
	Pharmacist in primary care clinics	15.3	75
	Ambulatory care pharmacist	32.6	155
	Clinical pharmacist	5.5	27
	Community pharmacist	27.1	133
	Other positions	2.9	14
Ever Provided Counseling on Drug Use in Sports to Athletes or Support Staff (e.g., parents, coaches, medical personnel)	Yes	15.3	75
	No	84.7	416

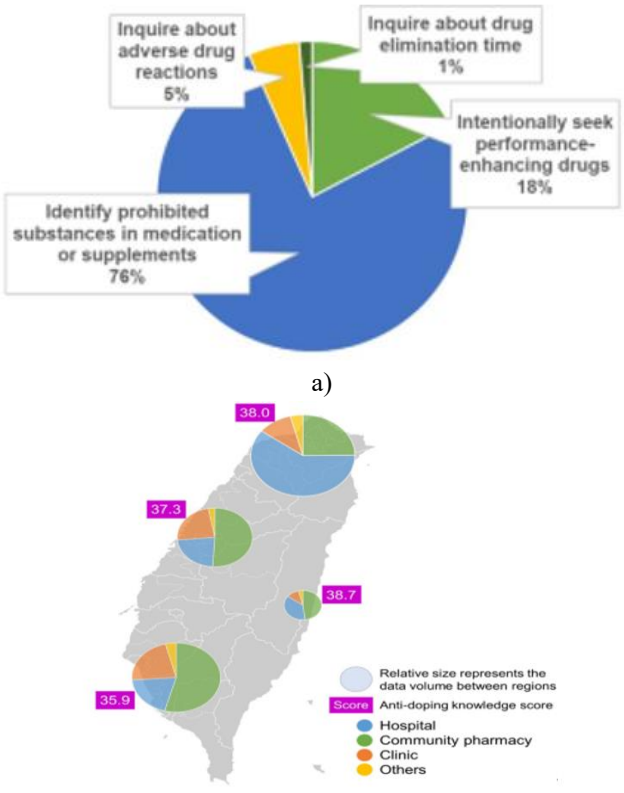

Figure 1. Illustrates **a** the categories of inquiries regarding drug use in sports that registered pharmacists in Taiwan encountered (from the 75 who reported such experience), and **b** a geographical map showing the

proportional distribution of respondents' workplaces alongside the regional distribution of anti-doping knowledge scores across northern, central, southern, and eastern Taiwan.

The average anti-doping knowledge score among all respondents was 37.2 ± 4.9 (out of a maximum of 51), with scores ranging from 21 to 48. **Figure 1b** highlights geographical differences in these knowledge scores. Pharmacists practising in eastern Taiwan achieved the highest mean score (38.7 ± 3.8), while those in southern Taiwan recorded the lowest (35.9 ± 5.3). In central, southern, and eastern Taiwan, approximately half of the responses came from community pharmacies. In contrast, the majority of responses from northern Taiwan originated from hospitals (61%), and eastern Taiwan also had a substantial proportion from hospitals (37%). Experience in counselling athletes on drug use varied significantly by workplace, with the highest rate in community pharmacies or drugstores (21.4%), followed by hospitals (11.2%) and clinics (9.5%).

Detailed correct-answer rates for individual knowledge items across the three domains are presented in **Table 2**. In the domain of 'sources of prohibited substances', respondents strongly recognised that Western medicines may contain banned substances, but demonstrated only moderate to low awareness that Chinese herbal medicines (CHM; 64.6%), dietary supplements (42.2%), and even certain foods (23.8%) could also contain them. Notably, fewer respondents believed pharmacists (66.8%) were likely to inadvertently dispense prohibited substances compared with physicians (75.8%).

In the domain of 'identification of prohibited substances', over 90% correctly identified pseudoephedrine (a stimulant) as prohibited in competition and ibuprofen (a non-steroidal anti-inflammatory drug) as permitted. Acceptable awareness was shown for triamcinolone acetonide (a glucocorticoid; 70.7%) being on the Prohibited List, but knowledge was limited regarding furosemide (a diuretic) being banned at all times (38.3%). For the over-the-counter (OTC) products surveyed, respondents accurately detected ephedrine in the domestically produced Suzulex Bien A Capsule (U.C. Pharma; 76.6%), yet were less familiar with foreign products: only 55.0% recognised ephedrine in Pabron "Taisho" (Taisho Pharmaceutical, Japan), and 55.6% correctly identified that Otrivin Moisturizing Nasal Metered-Dose Spray 0.05% (GlaxoSmithKline, UK) does not contain ephedrine. Regarding Chinese herbal medicines, a high proportion (91.4%) correctly identified Ephedra Herb as containing multiple ephedrine alkaloids, whereas very few recognised that Clove (17.9%) or Lotus Seed (6.5%) contain the β2-agonist higenamine.

For common workout and joint-support supplements, most respondents correctly classified whey protein (88.2%), branched-chain amino acids (82.7%), and undenatured type II collagen (86.4%) as permitted. However, only about half accurately identified creatine as allowed (57.2%) and diosgenin-containing dehydroepiandrosterone as prohibited (45.6%).

In the domain of 'understanding of doping control', the prohibition criterion of "representing a health risk to the athlete" was less well known (63.7%) than "potential to enhance sports performance" (88.2%). Regarding testing procedures, more respondents were aware that urine and blood samples are collected (89.4%) than that athletes can be tested at any time (55.2%). Correct-answer rates for scenario-based questions on the principle of strict liability in doping control ranged moderately from 60.1% to 83.7%.

Table 2. Respondents' anti-doping knowledge (n = 491)

Category	Questions	Correct Answer	Respondents with Correct Answer, n (%)
Source of Prohibited Substances	Could any of these contain banned substances?		
Over-the-counter drugs	True	373 (76.0)	118 (24.0)
Chinese herbal remedies	True	317 (64.6)	174 (35.4)
Food items	True	115 (23.8)	374 (76.2)
Prescription medication	True	431 (87.8)	60 (12.2)
Supplements	True	207 (42.2)	284 (57.8)
Who could potentially supply prohibited substances?			

Pharmacist	True	328 (66.8)	163 (33.2)
Doctor	True	372 (75.8)	119 (24.2)
Athletic trainer	True	301 (61.3)	190 (38.7)
Online sources	True	375 (76.4)	116 (23.6)
Coach	True	385 (78.4)	106 (21.6)
Family or friends	True	383 (78.0)	108 (22.0)
Identifying Banned Substances	Which of these substances are prohibited in sports?		
Chlorpheniramine	False	425 (86.6)	66 (13.4)
Pseudoephedrine	True	442 (90.0)	49 (10.0)
Ibuprofen	False	445 (90.6)	46 (9.4)
Furosemide	True	188 (38.3)	303 (61.7)
Triamcinolone acetonide	True	347 (70.7)	144 (29.3)
Which of these over-the-counter products contain prohibited substances?			
歐治鼻去鼻塞噴劑 (Otrivin Moisturizing Nasal Metered-Dose Spray 0.05%)	False	273 (55.6)	218 (44.4)
斯斯鼻炎膠囊 (Suzulex Bien A Capsule)	True	376 (76.6)	115 (23.4)
普拿疼加強錠 (Panadol Extra with Optizorb)	False	394 (80.2)	97 (19.8)
大正百保能感冒藥 (Pabron "Taisho")	True	270 (55.0)	221 (45.0)
肌立酸痛貼布 (Panadol Diclofenac Oil Plaster)	False	442 (90.6)	46 (9.4)
Which of these Chinese herbal medicine products contain prohibited substances?			
蓮子心 (Lotus Seed)	True	32 (6.5)	459 (93.5)
麻黃 (Ephedra Herb)	True	449 (91.4)	42 (8.6)
杜仲 (Eucommia Bark)	False	431 (87.8)	60 (12.2)
當歸 (Chinese Angelica Root)	False	432 (88.0)	59 (12.0)
丁香 (Clove)	True	88 (17.9)	403 (82.1)
Which of these supplements contain prohibited substances?			
Creatine	False	281 (57.2)	210 (42.8)
Undenatured collagen type II (UC-II)	False	424 (86.4)	67 (13.6)
Whey protein	False	430 (88.2)	58 (11.8)
Diosgenin (with DHEA)	True	224 (45.6)	267 (54.4)
BCAA	False	406 (82.7)	85 (17.3)
Understanding Doping Control	What are the criteria for adding substances to the prohibited list?		
Represent a health risk to athletes	True	313 (63.7)	178 (36.3)
Improve sleep	False	459 (93.5)	32 (6.5)
Increase appetite	False	439 (89.4)	52 (10.6)
Enhance athletic performance	True	433 (88.2)	58 (11.8)
Violate the spirit of sports	True	387 (78.8)	104 (21.2)
Which of the following statements about anti-doping testing are true?			
Testing only during competition	False	304 (61.9)	187 (38.1)
Blood and/or urine samples are used for testing	True	439 (89.4)	52 (10.6)
Skin tests	False	371 (75.6)	120 (24.4)
Refusing a test for any reason is acceptable	False	463 (94.3)	28 (5.7)
Testing can occur anytime and anywhere	True	271 (55.2)	220 (44.8)

Which practices help prevent accidental doping when using supplements?			
Buy supplements based on online best-sellers	False	469 (95.5)	22 (4.5)
Prioritize "muscle-building" products	False	446 (90.8)	45 (9.2)
Choose supplements from reputable GMP-certified companies	True	371 (75.6)	120 (24.4)
Verify ingredients with the List	True	440 (89.6)	51 (10.4)
Do not accept supplements from unknown sources via coaches or teammates	True	442 (90.6)	46 (9.5)
Consequences of an Athlete Taking a Doctor-Prescribed Cold Medicine and Testing Positive			
Athletes are responsible for any banned substance found in their system	True	295 (60.1)	196 (39.9)
Not considered a violation if the drugs are used unintentionally	False	404 (82.3)	87 (17.7)
Athletes may violate anti-doping rules	True	374 (76.2)	117 (23.8)
Athlete may be disqualified, sanctioned, and banned	True	371 (75.6)	120 (24.4)
Not considered a violation if the medicine is doctor-prescribed	False	411 (83.7)	80 (16.3)

Differences in knowledge based on demographic factors: There were notable differences in the total anti-doping knowledge scores based on several factors, including age, workplace setting, geographical location, current job role, years of experience, and experience with athlete counseling **(Table 3).** As depicted in **Figure 2a**, the analysis showed a clear age-related trend ($p < 0.001$ via simple linear regression). Younger individuals tended to score better, with scores decreasing progressively as participants got older and had more years of experience. Participants from southern Taiwan had lower scores compared to those from the northern region ($p < 0.001$) and eastern Taiwan ($p < 0.050$). Those working in clinics scored significantly lower than their counterparts in hospitals ($p < 0.010$). Furthermore, those with athlete counseling experience scored higher in anti-doping knowledge than those without such experience ($p < 0.050$).

Table 3. Significance (p-value) of anti-doping knowledge and educational gaps based on demographic factors

Parameter	p-value (Association with Knowledge in anti-doping)	p-value (Association with Education need)
Gender[a]	0.150	0.740
Age[b]	0.000	0.393
Academic qualification[b]	0.098	0.105
Primary workplace[b]	0.005	0.707
Region of practice[b]	0.000	0.762
Current position[b]	0.043	0.806
Years of practice[b]	0.046	0.998
Athlete counselling experience[b]	0.017	0.715

[a.] Independent t-test
[b.] One-way ANOVA
The p-value in bold indicates statistical significance ($p < 0.050$).

Figure 2. a. Statistically significant variations in the total anti-doping knowledge score across different respondent demographics, evaluated using an independent sample t-test or one-way ANOVA with Tukey's posthoc; b. Correct response rates to each knowledge question across different workplaces, assessed with a chi-square test; and c. Level of agreement on each educational topic based on academic qualifications, assessed with a chi-square test.

The average score for respondents' educational needs was 26.9 ± 3.6 (out of 30). No significant differences were found in the overall education needs score across demographic factors **(Table 3).** For six anti-doping topics, the average score was 4.49 ± 0.67 (on a 5-point

Likert scale), reflecting general support for anti-doping education. However, respondents showed less enthusiasm for the 'anti-doping testing procedure' topic (4.39 ± 0.72) compared to the others ($p < 0.010$)

Figures 2b and c display results with significant differences from the chi-square analyses. Respondents in community pharmacies had higher correct response rates than those in other workplaces, especially for questions about prohibited substances in OTC products and supplements. Respondents with higher academic qualifications showed stronger agreement with the need for education on topics like the 'up-to-date prohibited list', 'therapeutic use exemption', and 'athlete counselling & medication management'.

This study found that only 15.3% of pharmacists (75 out of 491) had received counseling on drug use in sports. This percentage is considerably lower than the 67.9% reported by a similar study of 246 Finnish pharmacists, where participants had encountered doping user groups [11]. When comparing health workforce data from Taiwan and Finland, Taiwan has 31.7 medical doctors and 13.1 pharmacists per 10,000 people, while Finland has 46.4 doctors and 19.2 pharmacists [26]. Given these figures, it is expected that athletes in both countries would have similar access to pharmacists for counseling. Anti-doping testing data over the last three years show that the AAF rates for Taiwan were between 0.5% and 0.9%, while in Finland, they ranged from 0.3% to 0.4% [27]. Despite the differences in testing programs, doping prevalence among top-level athletes does not seem to be higher in Finland. The significant difference in pharmacists' experiences between the two studies may be attributed to more complex factors, such as varying roles of pharmacists (e.g., patient counseling vs. customer service) or the habits of recreational athletes, who may engage in drug use but rarely undergo testing at local or school events.

Pharmacists from northern and eastern Taiwan scored better in knowledge assessments than those from southern Taiwan. This regional disparity could be due to the uneven distribution of respondents, with more from hospitals in the northern and eastern regions **(Figure. 1b),** where the highest scores were observed **(Figure. 2a).** While pharmacists in community pharmacies and drugstores had slightly lower scores, they were more likely to engage in athlete counseling. This suggests that future anti-doping education should prioritize community pharmacy professionals.

Younger pharmacists (aged 20−29) and those with less than 5 years of experience performed best in the knowledge test, with scores decreasing as age or years of practice increased. This trend may be explained by the introduction of the postgraduate year training program in 2007, which is designed to ensure that trainee pharmacists develop a strong foundation in medication knowledge [28]. Younger pharmacists, who are accustomed to using diverse learning methods, may have greater exposure to anti-doping topics. In Taiwan, anti-doping education resources have grown in recent years. Anti-doping lectures are now mandatory in national sports federations' seminars for coaches and officials, as well as in high school physical education curricula. Additionally, the Taiwan Anti-Doping Association, with support from the Sports Administration, launched a mobile app in 2017 that allows users to check over 40,000 pharmaceutical products for prohibited substances. By 2021, an anti-doping education platform covering key topics for youth athletes had been launched [29]. These developments, including the availability of resources in traditional Chinese, are tailored to meet the needs of the local population. Moreover, numerous news articles, blogs, online seminars, and some aimed at medical professionals, have increased awareness of clean sport issues.

The study found that while Ephedra and ephedrines were well recognized by pharmacists (with a 90% correct answer rate), diuretics and Chinese herbal medicines (CHMs) containing higenamine were less commonly identified. Diuretics are not used to directly enhance performance but are prohibited because they can mask the presence of other drugs or help with weight loss in weight-class sports. Higenamine, which is a β2 agonist, was only added to the prohibited list in 2017, and unlike the long-known ephedrines, pharmacists are still unfamiliar with this plant-derived substance. Higenamine is found in many traditional medicines, including CHMs like Aconite, Asarum Root, Clove, and Lotus Seed [20, 21]. Additionally, knowledge of certain products varied between workplaces. Community pharmacists were better at identifying OTC medications and nutritional supplements compared to hospital pharmacists, who, while having superior clinical knowledge, were less familiar with products they encounter less frequently.

Our findings on anti-doping education needs, where around 90% of respondents agreed on each topic, align with previous studies by Lemettilä *et al.* [11] (Finland),

Mottram *et al*. [7] (Qatar), and Shibata *et al*. [30] (Japan). These studies showed that 70−90% of participants expressed interest in receiving further education. Despite this, only 20−60% of pharmacists expressed a willingness to engage in anti-doping activities, especially those related to 'doping testing' [11]. This mirrors our findings, where Taiwanese pharmacists showed less enthusiasm for the 'anti-doping testing procedure' topic.

Limitations

First, although the sample size was deemed sufficient and a stratified random sampling method was employed to ensure the sample's representativeness, there may still be response bias. Invitations to participate in the survey were distributed via communication platforms such as LINE and Facebook, which made it impossible to track how often the advertisements were posted, forwarded, or the total number of pharmacists reached. As a result, determining a response rate was not feasible. Additionally, the regional differences observed in the results could be influenced by the varying distribution of practice settings among the respondents.

Second, ensuring high-quality responses in an online self-administered survey is challenging. To address this, we attempted to filter out invalid data, detect unusually quick responses, and included an attention-check question. Although participants were instructed to respond based on their own knowledge without referring to external sources, there remains a possibility that some respondents did not follow these instructions.

Implications and conclusions

Pharmacists are viewed as experts in delivering pharmaceutical care and have increasingly emerged as vital members of athlete support teams in efforts to combat doping. Unlike earlier research that examined anti-doping knowledge among pharmacists in a specific setting (such as community pharmacies), this study highlights specific knowledge deficiencies and pinpoints areas where certain pharmacist subgroups demonstrated weaker comprehension. For example, older pharmacists, those practising in southern Taiwan, or individuals employed at clinics displayed these shortcomings.

Substances not directly linked to performance enhancement, including diuretics and masking agents, along with recently prohibited novel compounds commonly present in dietary supplements or traditional folk remedies, were less familiar to pharmacists. It is also reasonable to assume that pharmacists in Taiwan have fewer opportunities to interact with athletes or receive inquiries from them compared to their counterparts in other nations.

The findings indicate that a critical factor in designing future educational programmes for pharmacy professionals should be the careful selection of content and topics tailored to their daily practice. For community pharmacists, strengthening their ability to detect prohibited substances—such as the stimulant methylhexanamine, the β2-agonist higenamine, cannabinoids, opium, and ecdysterone—in over-the-counter medications, nutritional supplements, and herbal products is recommended. These insights could similarly benefit pharmacists in other countries with rich traditions of herbal medicine, particularly across the Asia–Pacific region, including Japan, Korea, Malaysia, and China.

For pharmacists in medical centres, who typically possess robust clinical expertise, introducing an alert mechanism—such as labelling for athlete patients and flagged prohibited medications—would prove highly valuable, especially in facilities dispensing large volumes of drugs. Furthermore, familiarising pharmacists with practical resources like Global DRO or other pertinent databases, beyond the Prohibited List itself, should be prioritised.

With the growing prominence and international acknowledgement of sports pharmacy, exploring the inclusion of sports-related drug use and anti-doping education within pharmacists' ongoing professional development offers an exciting direction for future investigation. Upcoming research might evaluate various educational elements—such as pharmaceutical care specific to athletes, procedures for sample collection and analysis, therapeutic use exemptions, and results management—to identify which topics are most applicable and engaging for pharmacists.

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