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Sleep Assessment in Competitive Athletes: Development and Validation of French Versions of the Athens Insomnia Scale and the Athlete Sleep Behavior Questionnaire

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Abstract

Objective The purpose of this study was to develop and validate French versions of two questionnaires assessing competitive athletes' sleep: the Athens Insomnia Scale (AIS-FR) and the Athlete Sleep Behavior Questionnaire (ASBQ-FR).

Methods Four complementary studies were carried out, with a total sample of 296 French competitive athletes from different sports and expertise levels. The studies aimed to develop preliminary versions of the AIS-FR and the ASBQ-FR (study 1), and then to examine their respective dimensionality and reliability (study 2), temporal stability (study 3), and concurrent validity (study 4). The dimensionality was established using confirmatory factor analysis. Similar and correlated psychological factor scales were used to examine the concurrent validity (the Insomnia Severity Index, the Pittsburgh Sleep Quality Index, the State-Trait Anxiety Inventory and the Positive and Negative Affect Schedule).

Results The AIS-FR consists of eight items with two subfactors: nocturnal symptoms and diurnal symptoms, assessed by a uniformized 4-point Likert-type scale. The ASBQ-FR is composed of 15 items with three subfactors, which differs from the original English version: behaviors affecting sleep, behaviors related to anxiety, and sleep disturbances. Due to the Covid context and curfews, three items of the original scale were excluded from the statistical analyses because non-applicable. Both scales presented satisfactory psychometric properties.

Discussion The AIS-FR and ASBQ-FR appear to be valid and reliable tools that can be used with competitive athletes for everyday training and research purposes. An ASBQ-FR version that includes the three excluded items should undergo validation testing once pandemic restrictions are eased.

Keywords
- Surveys and Questionnaires
- Sleep Initiation and Maintenance Disorders
- Sleep Hygiene
- Sleep
- Sports
- Athletes

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Introduction

Sleep is a well-recognized factor of physical and psychological health, and research interest in sleep quality in the sports domain has exponentially increased in the past last decade.[1] Recent literature reviews have shown that good sleep quality, sufficient sleep quantity and optimized sleep behaviors are associated with better athletic performance, better recovery and less injury risk.[2–5] Thus, assessing athletes' sleep may be an important parameter in better managing their lifestyles, training, and performances. Several validated tools to measure athletes' sleep have been developed.[6,7] In addition to the objective tools (e.g., polysomnography, actigraphy) that require specific material, subjective tools like questionnaires appear to be time- and cost-effective and are adapted to assess athletes' sleep quality and their sleep behaviors and habits.[4,8,9]

The most frequently used French questionnaires to assess the sleep quality of athletes are the Insomnia Severity Index (ISI)[10] and the Pittsburgh Sleep Quality Index (PSQI).[11] However, these questionnaires are not adapted to the characteristics of competitive athletes.[2] Indeed, athletes have specific needs and behaviors that differ from those of the general population[12]: (a) they have high training loads requiring more sleep to recover, (b) they train and compete late at night or early in the morning and are exposed to jetlag, (c) they must deal with competitive anxiety, (d) they have worse sleep quality than the general population,[13] and (e) they do not have enough sleep quantity.[14] For these reasons, it is important to monitor their sleep with specific validated tools.[8] To our knowledge, only three sleep questionnaires have been developed and validated for these athletes: (a) the Athens Insomnia Scale (AIS), (b) the Athlete Sleep Screening Questionnaire (ASSQ), and (c) the Athlete Sleep Behavior Questionnaire (ASBQ). The AIS is a diagnostic scale based on the criterion for insomnia of the International Classification of Diseases-10 (ICD-10),[15] and it includes nocturnal symptoms and diurnal perturbations due to insomnia. It was developed by Soldatos et al.[16] to detect insomniac individuals in a clinical sample and validated by Dickinson and Hanrahan[17] among elite athletes. It has been validated in 8-item and 5-item versions, considering only nocturnal symptoms in the short version. In the 8-item version, two factorial structures have been validated: an unifactorial structure[16] and a bifactorial structure.[18] The ASSQ is a preclinical tool assessing elite athletes' sleep with a decisional tree to classify the severity of sleep problems.[19] Last, the ASBQ assesses athletes' sleep behaviors and habits. It was adapted from the Sleep Hygiene Index (SHI)[20] to the specificities of the elite athlete population by Driller et al.[21] Nevertheless, none of these three has a valid French version, and the factor structure of the ASBQ shows inconsistent results,[22] requiring further investigation.

We designed a study for the transcultural validation of the AIS in order to provide coaches and health practitioners with validated questionnaires assessing the sleep quality of French athletes in an everyday training context. This validation study was conducted concurrently with a study to validate the ASBQ, which captures sleep hygiene behaviors, to better understand the reasons for an altered sleep quality revealed by the AIS assessment. Together, these two complementary questionnaires should provide sports/medical staff and researchers with valid and reliable tools to assess French athletes' sleep. The present study aimed to develop and validate French versions of the AIS and ASBQ specifically for athletes, following Vallerand's[23] and Boateng's[24] recommendations.

Material and Methods

Overview of the Present Studies

Successive studies were carried out in French samples of competitive athletes according to current methodological recommendations,[23,24] as follows: (a) develop a preliminary version of the scales and evaluate the clarity of the items (study 1), (b) examine the dimensionality and reliability of the questionnaires (study 2), (c) examine their temporal stability (study 3), and (d) examine the concurrent validity of the scales (study 4). The Research Ethics Committee of the Université Côte d'Azur approved all procedures (authorization number: 2021-011).

Athletes over 16 years old were included in these studies. Participants for two samples were contacted by word of mouth and at the University Sports School to respond to questions on item clarity for study 1 (►**Figure 1**). For the other studies, a large sample of competitive athletes, with a minimum of three training sessions per week and three years of experience in their sport, were recruited in French university sports schools, in sports club and via social networks. A pre-screening survey verified that the inclusion criteria were met and excluded athletes with sleep problems (other than insomnia) or depression according to the Patient Health Questionnaire-9 items (PHQ-9),[25] i.e., with a total global score >9.

Statistical analyses were performed using SPSS version 25 (IBM Corporation; Chicago, IL, USA). Values of $p < .05$ were considered statistically significant.

Study 1

This first study aimed to develop preliminary French versions of the AIS and ASBQ questionnaires: respectively, the AIS-FR and ASBQ-FR.

Questionnaires

The AIS[16] is an 8-item self-administered questionnaire assessing insomnia with two axes: nocturnal symptoms (5 items) and diurnal symptoms (3 items), validated in an unidimensional[16] and a bifactorial structure.[18] Respondents report on each item of sleep difficulty that has occurred at least three times per week in the past month. Answers are presented on a 4-point Likert-type scale (0 = no problem at all and 3 = a serious problem) with differently labeled scales. The survey provides a total score ranging from 0 (absence of any sleep-related problem) to 24 (the most severe degree of insomnia). The authors suggest a cut-off score of 6 to identify insomniac individuals. Previous research has shown that the

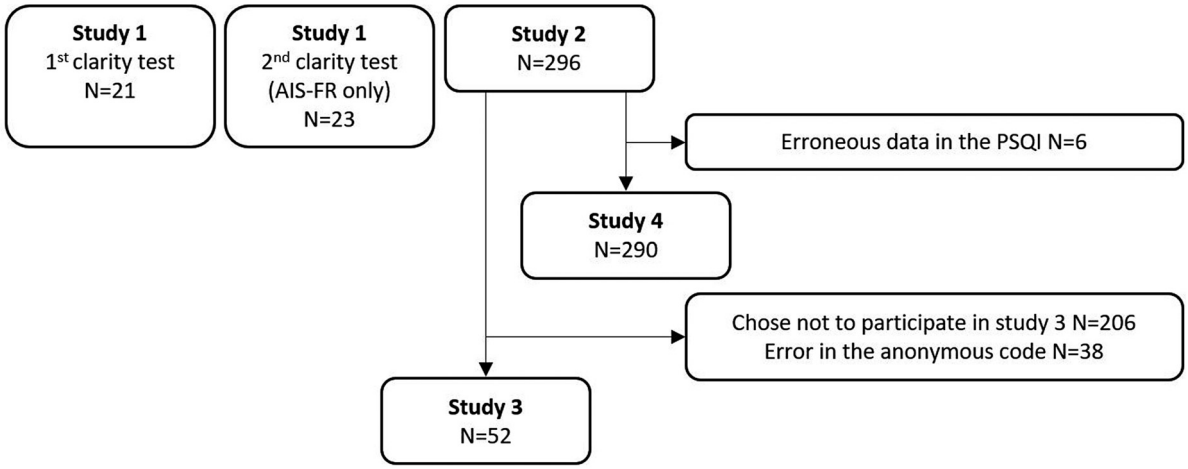

Fig. 1 Study samples. AIS-FR: French version of the Athens Insomnia Scale; PSQI: Pittsburgh Sleep Quality Index

scale has very satisfactory psychometric properties in terms of internal consistency: (a) among elite athletes with Cronbach's alpha = .81,[17] (b) in a Greek clinical population with Cronbach's alpha≥.85 in the 8-item version and Cronbach's alpha≥.81 in the 5-item version, which only considers nocturnal symptoms,[16] and (c) in a Japanese clinical population in the bifactorial 8-item version with Cronbach's alpha≥.85.[18] The temporal stability also appeared very satisfactory over one week ($r \geq .88$)[16] and one month ($r = .78$).[17]

The ASBQ[21] is an 18-item questionnaire assessing the sleep behaviors and habits of elite athletes with three factors: routine/environmental factors (6 items), behavioral factors (7 items), and sports-related factors (5 items). The questionnaire asks participants how frequently they engage in specific behaviors. Answers are rated with a 5-point Likert scale (1 = never, 2 = rarely, 3 = sometimes, 4 = frequently, 5 = always), and they are summed to provide a global ASBQ score from 18 to 90. A higher global score indicates poorer sleep behaviors. This survey was designed to better identify the maladaptive sleep behaviors of athletes that can affect sleep quality. It demonstrated good temporal stability over a one-week test-retest (r = .88) and acceptable psychometric properties in terms of internal consistency in the original version (Cronbach's alpha = .63), and good psychometric properties in the Brazilian version (Cronbach's alpha = .78).[26]

Translations and Adaptations of the Questionnaires

As recommended by Vallerand and Halliwell,[23] transcultural translations of the questionnaires were made by (a) translations and reverse translations by four bilingual researchers to develop preliminary versions of the ASBQ-FR and AIS-FR, (b) committee examination and adaptation of the surveys with four experts in sports psychology, (c) item clarity examinations with a representative sample of the population, and (d) examinations of the psychometric properties of the tools (studies 2-4).

To examine the clarity of the preliminary version of the questionnaires, participants were asked to rate each item's clarity on a 6-point Likert-type scale from 1 = not clear at all to 6 = totally clear. Participants had the opportunity to write comments about what was not clear and suggest potential enhancements. Mean scores and comments for each item were considered to propose a final version of the questionnaires.

Study 2

The objective of this study was to examine the dimensionality and reliability of the two questionnaires.

Procedure

A sample of 437 competitive athletes gave their informed consent to participate in the study. This sample size was selected according to sample size recommendations for confirmatory factor analysis (CFA),[27] established a priori at 300 participants. Ultimately, 296 athletes met the inclusion criteria and fully completed all questionnaires. They were between 17 and 33 years old, practiced 40 different sports (individual and collective), and four were insomniac (►**Table 1**). Data were collected online via the LimeSurvey interface of the Université Côte d'Azur, using an anonymous code, without missing data permission. Mean completion time of the AIS-FR and ASBQ-FR was, respectively, 1.33 minutes and 2.25 minutes.

Dimensionality of the Questionnaires

A CFA of the AIS-FR was run according to the bifactor structure of the Japanese version of the AIS[18] in order to take into account the difference between nocturnal symptoms of insomnia and the diurnal consequences, in line with the definition of the criterion of chronic insomnia disorder of the International Classification of Sleep Disorders – Third edition.[28] The original three-factor structure of the ASBQ[21] was conserved for the CFA of the ASBQ-FR. The next four steps were followed[29]: (a) testing the unifactorial model of both scales, (b) testing the first-order two-factor (for the AIS-FR) and three-factor (for the ASBQ-FR) models according to the respective structure of the surveys, and (c) testing the second-order hierarchical structure and (d) the confirmatory bifactor models of each scale (►**Figure 2**).

Table 1 Descriptive statistics.

Characteristics	Mean ± SD [Min_t-Max_t]/ Number (Frequency)
Age (year)	20 ± 2
Gender	
Female	126(43%)
Male	164(57%)
Sport	
Individual	167(56%)
Collective	129(44%)
Sport experience (year)	11 ± 4
Level	
District	14(5%)
Departmental	34(11%)
Regional	109(37%)
National	112(38%)
International	27(9%)
Questionnaire global scores	
AIS-FR	5 ± 3 [0-24]
NoctAIS	3 ± 2 [0-15]
DiuAIS	2 ± 2 [0-9]
ASBQ-FR	31 ± 6 [15-75]
ASBQ-F1	14 ± 3 [6-30]
ASBQ-F2	10 ± 3 [5-25]
ASBQ-F3	7 ± 2 [4-20]
ISI*	7 ± 5 [0-28]
PSQI*	5 ± 3 [0-21]
STAI-YB*	40 ± 9 [20-80]
PANAS-PA*	33 ± 6 [10-50]
PANAS-NA*	18 ± 6 [10-50]

Notes. *On 290 participants; AIS: Athens Insomnia Scale; NoctAIS: nocturnal symptoms factor of the AIS-FR; DiuAIS: diurnal symptoms factor of the AIS-FR; ASBQ: Athlete Sleep Behavior Questionnaire; ASBQ-F1: Factor 1 affecting sleep behaviors of the ASBQ-FR; ABSQ-F2: Factor 2 behaviors related to anxiety of the ASBQ-FR; ASBQ-F3: Factor 3 sleep disturbance of the ASBQ-FR; ISI: Insomnia Severity Index; STAI-YB: Trait Anxiety Inventory; PANAS-PA: positive affect factor of the Positive and Negative Affects Schedule; PANAS-NA: negative affect factor of the Positive and Negative Affects Schedule; PSQI: Pittsburgh Sleep Quality Index; SD: standard deviation; Min_t: minimal theoretical scores; Max_t: maximal theoretical scores.

Reliability

Composite reliability was used to evaluate internal consistency, according to the method of Béland et al.[30] This method appears to be the most adequate indicator given the multifactorial structure of the surveys and their short length.

Statistical Analyses

Normality of the data was verified using skewness, kurtosis, and Shapiro-Wilk normality tests. For abnormal distribution, a model was considered suitable for use with these data if it fit with the Bollen-Stine bootstrap method, $p < .05$.

Each model fit was tested using the following good model fit index levels[24,31]: minimal chi-square test (χ^2(df), χ^2/df < 3, $p > .05$), root mean squared error of approximation (RMSEA) $< .05$ with an upper limit of 90%CI$\leq .08$, Tucker-Lewis's index (TLI) $> .95$, and comparative fit index (CFI) $> .95$. Model enhancement was determined by a decrease in Akaike's information criterion (AIC) and the expected cross-validation index (ECVI), as well as a significant difference in the chi-square from one model to the next ($\Delta\chi^2$(df), $\Delta p < .05$).

The composite reliability (ω) was based on the factor structure of the final models of the AIS-FR and ASBQ-FR according to the method of Béland et al.,[30] as follows:

$$\omega = \frac{[(\sum_{i=1}^{n} \lambda G_i)^2 + \sum_{j=1}^{N} (\sum_{i=1}^{n} \lambda F_{ji})^2]}{[(\sum_{i=1}^{n} \lambda G_i)^2 + \sum_{j=1}^{N} (\sum_{i=1}^{n} \lambda F_{ji})^2] + \sum_{i=1}^{n} \psi_i^2}$$

where λG is the standardized factor loading of the n items of the scale, λF is the standardized factor loading of each item of the N factors of the scale, and ψ^2 is the standardized error variance of each item. $\omega \geq .70$ is satisfactory.

Study 3

This study aimed to verify the temporal stability of the scales. Fifty-two voluntary participants from the study 2 sample took part in this third study, using the same anonymous code. They completed the AIS-FR and ASBQ-FR a second time within a period of 14 ± 3 days. Data were analyzed using the intraclass correlation coefficients (ICC) and the 95% confidence interval of the ICC, based on a mean-rating, absolute-agreement, 2-way mixed-effects model. As recommended by Terwee et al. (2007),[32] results were interpreted as acceptable over .70, in a sample size of 50 participants or more.

Study 4

The purpose of the fourth study was to examine the concurrent validity of the AIS-FR and ASBQ-FR. After giving informed consent, a sample of 290 athletes (164 males/126 females, 125 team sport athletes/165 individual athletes, mean ± SD, age = 20 ± 2 years) completed the AIS-FR, the ASBQ-FR, and the following questionnaires:

The Insomnia Severity Index (ISI),[10] a seven-item reliable and valid questionnaire designed to help practitioners to evaluate perceived insomnia severity in a clinical population, over the last two weeks. Each item scores from 0 = not at all to 4 = extremely. Items evaluate the severity of insomnia problems, sleep satisfaction, interference with daily functioning, noticeability of impairment attributed to the sleep problem, and level of distress caused by the sleep problem. The global score ranges from 0 to 28 and higher scores indicate greater insomnia severity. In our sample, the French version of the scale was used and demonstrated satisfactory internal consistency (Cronbach's α = .84).

The Pittsburgh Sleep Quality Index (PSQI),[33] a reliable and valid instrument evaluating sleep quality and difficulties

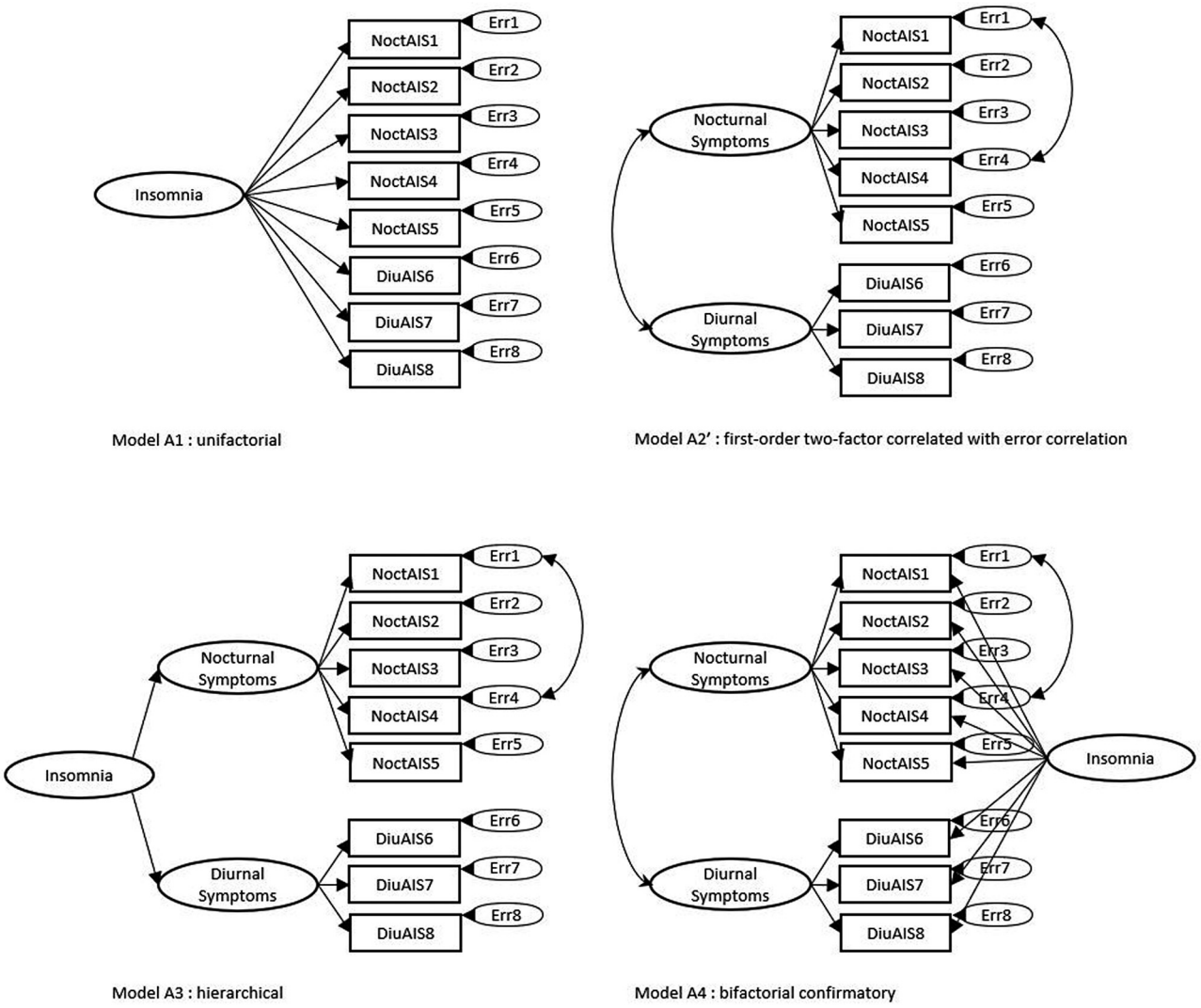

Fig. 2 Four-step confirmatory factorial analysis method applied to the AIS-FR. ↔: correlations between latent factors; ⟶: factor loading; NoctAIS Ni: item $N^{8}_{i=1}$ of the nocturnal symptoms factor of the AIS; DiuAIS Nj: item $N^{8}_{j=5}$ of the diurnal symptoms factor of the AIS

over the last month, differentiating "good" and "poor" sleepers. It contains 19 self-rated items, combined in seven components (Subjective sleep quality, Sleep latency, Sleep duration, Habitual sleep efficiency, Sleep disturbances, Use of sleeping medication, and Daytime dysfunction). Each component scores from 0 = no sleep difficulty, to 3 = severe sleep difficulty. Global scores range from 0 (no sleep difficulty) to 21 (severe sleep difficulty). It was validated in its French-Canadian version by Blais et al. (1997). We used the similar French PSQI version elaborated by the "Centre du sommeil et de la vigilance Hôtel-Dieu, Paris," which is better adapted to a French sample and used in other scientific publications [e.g., Perney et al.[34]; Ribeiro et al.[35]]. In our sample, internal consistency was satisfactory (Cronbach's $\alpha = .65$).

The State-Trait Anxiety Inventory (STAI-Y),[36] which evaluates the anxiety "state" (form YA, 20 items) and the anxiety "trait" (form YB, 20 items). Each item scores from 1 = almost never to 4 = almost always, graduating the presence or absence of anxiety (with some reversed items). A high global score indicates a high level of anxiety. In the present study, the French version of the STAI-YB[37] was used. It has shown very good psychometric properties and is positively correlated with insomnia and sleep-related behaviors.[38,39] It demonstrated good internal consistency in our sample (Cronbach's $\alpha = .85$).

The Positive and Negative Affect Schedule (PANAS)[40] assesses affect as a "trait" or a "state" and has been validated with various modeling structures (two-factor, three-factor, bifactor). The initial two-factor version of the PANAS was used in the present study, as recommended by Heubeck and Wilkinson.[41] Positive affect (PA, 10 items) and negative affect (NA, 10 items) were rated separately on 5-point Likert scales from 1 = not at all or very slightly to 5 = extremely, using the French-Canadian version of the questionnaire[42] validated among athletes. This questionnaire was selected because of the positive correlation between NA and sleep quality (scored with PSQI), and the negative correlation between

Table 2 Items and clarity scores of the modified preliminary version of the AIS-FR, in the second clarity test.

AIS-FR items		Clarity means scores /6
Items of nocturnal symptoms factor (NoctAIS)		
1.	Difficultés d'endormissement (difficultés à m'endormir après avoir éteint la lumière) *Difficulties falling asleep (difficulties to fall asleep after lights off)*	5.7
2.	Réveils pendant la nuit *Awakenings during the night*	5.7
3.	Réveil matinal plus tôt que l'heure fixée *Final awakening earlier than the appointed time*	5.5
4.	Durée totale de sommeil insuffisante *Insufficient total sleep duration*	5.3
5.	Sommeil de mauvaise qualité (i.e., sensation d'avoir mal dormi, peu importe le temps que j'ai dormi) *Poor overall quality of sleep (i.e., feeling of not sleeping well, no matter how long you slept)*	5.5
Items of diurnal symptoms factor (DiuAIS)		
6.	Sensation de bien-être diminuée pendant la journée (sans lien avec une contrariété ou un tracas) *Reduced sense of well-being during the day (unrelated to irritation or worry)*	4.8
7.	Activité (physique et mentale) diminuée pendant la journée (sans raison évidente) *Functioning (physical and mental) diminished during the day (without obvious reason)*	5.1
8.	Somnolence / envie de dormir durant la journée *Sleepiness / urge to sleep during the day*	6.0
Global clarity score (Mean ± SD)		5.5 ± 0.4

Notes. English translations are in italics. For each item, the participant had to answer on a 6-point Likert-type scale from 1 = not clear at all, to 6 = totally clear. AIS-FR: French version of the Athens Insomnia Scale; SD: standard deviation.

PA and sleep quality.[43,44] In our sample, the survey was used to assess affect as a trait and showed good internal consistency [Cronbach's $\alpha = .84$ (PA), and $\alpha = .83$ (NA)].

The median total completion time was 15 minutes. Correlations between the questionnaires were examined using bilateral bivariate Pearson's correlations and interpreted as: <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; and 0.9-1.0, almost perfect correlation.

Results

Results of the AIS-FR

Study 1

The expert committee agreed on a preliminary eight-item version of the AIS-FR, after the two reversed transcriptions. The Likert scales for all items were uniformized with the following specification: "Severity of my sleep disturbances occurring at least three times per week in the last month" and ranging from 0 = no disturbance to 3 = severe disturbance for each item. To keep the essence of the original AIS, the following statement was provided: "Here, we are not evaluating the frequency of each disturbance but only its severity" and an example of an answer was given.

Next, a sample of 21 athletes (8 females/13 males) evaluated the clarity of the items. All items were perceived as totally clear (score≥5.0/6) except for item 6: "reduced sense of well-being during the day," which scored 4.4/6. As recommended by Vallerand and Halliwell,[23] lower scored items were reformulated considering the participants' remarks to make them more precise [i.e., item 6: "reduced sense of well-being during the day (unrelated to irritation or worry)"]. The global clarity score was 5.5 ± 0.4[4.8-6.0] after a second clarity test with the modified items on a new sample of 23 athletes (6 females/17 males) (►**Table 2**).

Study 2

Preliminary Test

The skewness of the AIS-FR was between .55 and 1.08 depending on the item, with a critical ratio >1.96 for all items. The kurtosis test was between -.47 and .91 depending on the item, with a critical ratio >1.96 for items 3 and 6, and the Shapiro-Wilk normality test was significant ($p < .01$), showing that the data did not follow a normal distribution.

Using Bootstrap ML on SPSS,[45] the Bollen-Stine bootstrap with 200 iterations of the data showed a better fit to the final model in 178 bootstrap samples, and worse or fail to fit in 22 bootstrap samples. The test of the null hypothesis showed $p = .11$ (>.05), allowing the use of the model despite the non-normal data distribution.

Dimensionality of the Questionnaires

The successive model testing according to Myers et al.[29] showed significant improvement in the models from the unifactorial structure (model A1) to the confirmatory bifactor model (model A4) (►**Table 3**). After we tested the bifactor first-order model (model A2), in order to improve the A2 model fit, the modification index section of the software recommended that we correlate the error terms of items 1 and 4 [1:

Table 3 Goodness of fit indexes of the AIS-FR models.

AIS-FR	χ^2(df)	p	χ^2/df	RMSEA	RMSEA 90% CI	TLI	CFI	AIC	ECVI	Model comparison	$\Delta\chi^2$(df)	Δp
Criterion		**>.05**	**<3**	**<.05**	**<.08**	**>.95**	**>.95**					**<.05**
Model A1: Unifactorial	86.70 (20)	.00	4.34	.11	[.08-.13]	.76	.83	118.70	.40	–	–	–
Model A2: Two factors correlated	55.36 (19)	.00	2.91	.08	[.06-.11]	.86	.91	89.36	.30	A2 vs. A1	31.34 (1)	.00
Model A2': Two factors, Err1 & Err4 correlated	49.94 (18)	.00	2.78	.08	[.05-.10]	.87	.92	85.94	.29	A2' vs. A2	5.40 (1)	.02
Model A3: Hierarchical	78.19 (19)	.00	4.12	.10	[.08-.13]	.77	.85	112.19	.38	A3 vs. A2'	–	–
Model A4: Bifactorial Confirmatory	**17.33 (11)**	**.10**	**1.58**	**.04**	**[.00-.08]**	**.96**	**.98**	**67.34**	**.23**	**A4 vs. A2'**	**32.61 (7)**	**.00**

Notes. Err1: error term of item 1; Err4: error term of item 4; χ^2(df): chi-square (degree of freedom), RMSEA: root mean squared error of approximation; 90% CI: confidence interval at 90%; TLI: Tucker-Lewis's index; CFI: comparative fit index; AIC: Akaike's information criterion; ECVI: expected cross-validation index; $\Delta\chi^2$(df): difference in chi-squares.

"Difficulties falling asleep (difficulties falling asleep after lights off)" and 4: "Insufficient total sleep duration"]. As this recommendation was deemed theoretically meaningful and the most parcimonious,[46] we did so and named this improved model A2'. Whereas the unifactorial (model A1), the two bifactor first-order (models A2 and A2'), and the second-order hierarchical (model A3) models presented unsatisfying fit indexes (►**Table 3**), the CFA confirmed the confirmatory bifactor structure of the AIS (model A4) (►**Table 3** and ►**Figure 3**). The null hypothesis "there is no difference between the data and the model" was accepted with χ^2 (df) = 17.33,[11] $p > .05$, $\chi^2/df = 1.58$. The model provided good model fit indexes: RMSEA = .04[.00-.08], CFI = .98, TLI = .96.

Reliability

From the bifactorial confirmatory model A4 of the AIS-FR, the composite reliability of the AIS-FR on this sample was $\omega = .72$.

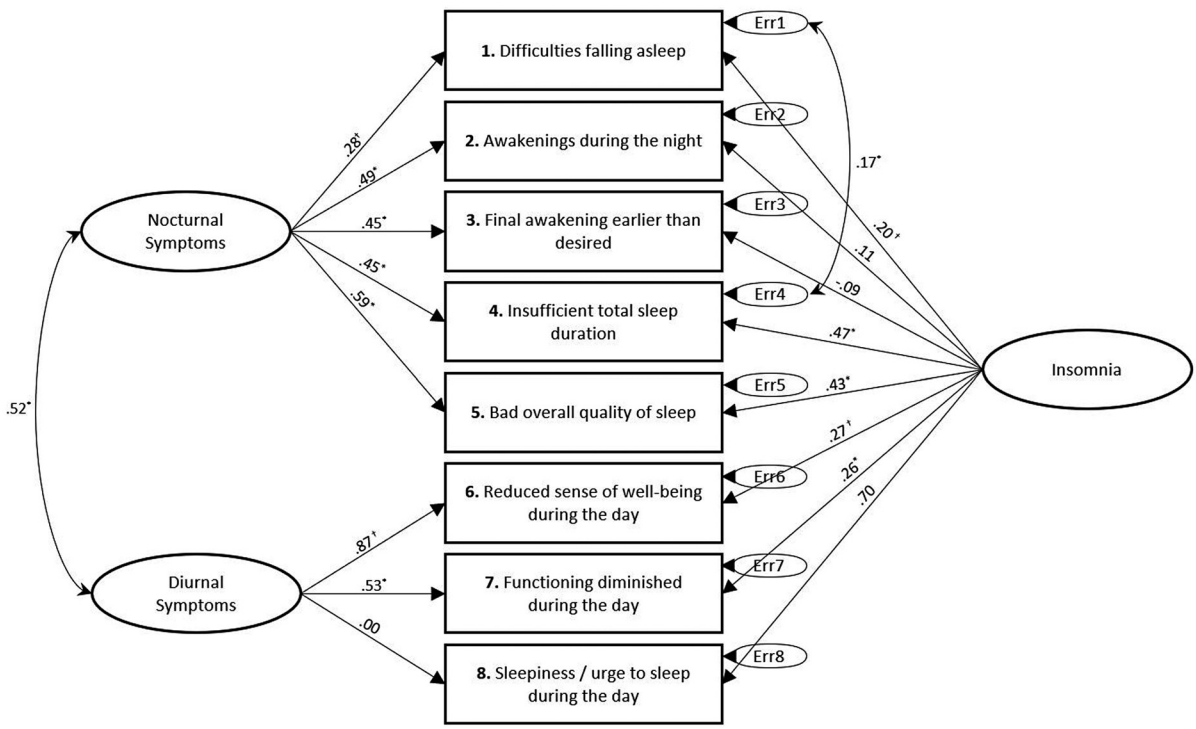

Fig. 3 Model of the confirmatory factor analysis of the AIS-FR. $\overset{\Delta}{:}$ = correlations between latent factors or error terms; $\lambda \rightarrow :\lambda$ = factor loading; Err Ni: error terms of the item $N^{8}_{i=1}$; *: significant ($p < .05$); †: items fixed to 1.0

Study 3

The temporal stability of the AIS-FR was good between the two times of the study for the total global score (i.e., sum of all the item scores) [$ICC_{AIS\text{-}FR}$(95%CI) = .90(.82-.94), $p < .001$], the nocturnal symptoms factor [$ICC_{NoctAIS}$(95%CI) = .85(.74-.91), $p < .001$], and the diurnal symptoms factor [ICC_{DiuAIS} (95%CI) = .84(.72-.91), $p < .001$] at 14 ± 3 days interval.

Study 4

All the Pearson's correlations between the AIS-FR global score and the various questionnaires were significant ($p < .01$). The AIS-FR global score was highly correlated with the ISI ($r = .71$), another insomnia assessment scale, and the PSQI ($r = .56$) measuring sleep quality. The AIS-FR was moderately correlated with the STAI-YB ($r = .42$), an anxiety evaluation survey, and minimally correlated with the PANAS scores ($r = .27$ for NA and $r = -.19$ for PA). The nocturnal symptoms factor of the AIS-FR was positively and significantly related to the first five components of the PSQI and related to nocturnal dysfunction (PSQI-1–PSQI-5; $.23 \leq r \leq .60$). The diurnal symptoms factor of the AIS-FR was moderately correlated with the daytime dysfunction component score of the PSQI (PSQI-7; $r = .38$).

Results of the ASBQ-FR

Study 1

The expert committee agreed on an 18-item preliminary version of the ASBQ-FR after the two reversed transcriptions and discussions. A sample of 21 participants (6 females/13 males) evaluated the clarity of the items of this preliminary version. All items were totally clear (item 18 scored 5.0/6 and other items scored ≥ 5.5/6) (►**Table 4**). Following the remarks of the participants, item 18 "Travel gets in the way of building a consistent sleep-wake routine" was rephrased using more accessible vocabulary "My travels get in the way of building a regular routine of bedtime and wake-up."

Study 2

Preliminary Test

Items 11 "I use sleeping pills/tablets to help me sleep" and 13 "I wake myself and/or my bed partner with my snoring" had skewness > 2 and kurtosis > 7; the Shapiro-Wilk normality test was significant ($p < .01$). Data did not follow a normal distribution. Using Bootstrap ML on SPSS,[45] the Bollen-Stine bootstrap with 250 iterations of the data showed a better fit to the final model in 157 bootstrap samples, and worse or fail to fit in 93 bootstrap samples. The test of the null hypothesis showed $p = .38$ (>.05), allowing the use of the model despite the non-normal data distribution.

Dimensionality of the Questionnaires

In the context of the Covid-19 travel restrictions and curfew, item 3 "I exercise (train or compete) late at night (after 7pm)," item 17 "I sleep in foreign environments (e.g., hotel rooms)" and item 18 "Travel gets in the way of building a consistent sleep-wake routine" were deleted from the three-factor 18-item model of Driller et al.[21] (model b2), leading to a three-factor 15-item model (model b2'). CFA of the 15- and 18-item models failed to confirm the initial structure of the ASBQ of Driller et al.[21] Instead, the analysis revealed unsatisfactory fit indexes (models b1 to b2') or no convergent results with the tested models (models b3 and b4) (►**Table 5**).

Given the divergent results concerning the ASBQ structure in previous research,[21,22,47] an exploratory factor analysis with varimax rotation and committee analysis of the items was conducted (**Supplementary File 1**).[48] The authors agreed on a new three-factor structure for the ASBQ-FR: (a) behaviors affecting sleep, (b) behaviors related to anxiety, and (c) sleep disturbances (►**Figure 4**). The fit statistics from CFA are reported in ►**Table 5**. The bifactor confirmatory model of the modified structure of the 15-item ASBQ-FR (model B4) fitted the data better than the other models. It showed good fit indexes: $\chi^2(df) = 76.59\ (72)$, $p > .05$, $\chi^2/df = 1.06$, $RMSEA = .02$ 90%CI [.00-.04], $CFI = .99$, $TLI = .98$.

From the confirmatory model B4 of the ASBQ-FR, the composite reliability of the ASBQ-FR on this sample was $\omega = .67$.

Study 3

The 15-item ASBQ-FR global score demonstrated very good reliability [$ICC_{ASBQ\text{-}FR}$ (95%CI) = .93(.88-.96), $p < .001$] for the test-retest at a 14 ± 3-day interval. Each factor of the ASBQ-FR (Factor 1, Factor 2 and Factor 3) also demonstrated good to very good temporal stability [respectively, $ICC_{ASBQ\text{-}F1}$(95%CI) =.91(.84-.95), $p < .001$; $ICC_{ASBQ\text{-}F2}$(95%CI) =.92(86-95), $p < .001$; and $ICC_{ASBQ\text{-}F3}$(95%CI) = 0.81(.67-.89), $p < .001$].

Study 4

All the Pearson's correlations between the ASBQ-FR global score and the different questionnaires were positive and significant ($p < .05$), except for the PA factor of the PANAS ($r = -.02$, $p > .05$). The ABSQ-FR was moderately correlated with the insomnia survey ISI ($r = .39$) and the sleep quality questionnaire PSQI ($r = .43$). It was also moderately correlated with the trait anxiety inventory STAI-YB ($r = .31$) and minimally correlated with the NA factor of the PANAS ($r = .27$). Factor 2 of the ASBQ-FR "behaviors related to anxiety" was moderately and significantly correlated with the two sleep questionnaires ISI and PSQI (respectively, at $r = .33$ and $r = .38$) and the STAI-YB ($r = .38$).

Furthermore, the AIS-FR and ASBQ-FR showed a moderate correlation of their total scores ($r = .47$, $p < .01$). Their respective subscales were also significantly and positively correlated ($.18 \leq r \leq .34$, $p < .01$). This supports the theoretical foundations of these questionnaires, assessing complementary but different dimensions of athletes' sleep.

Discussion

The Athens Insomnia Scale (AIS) and the Athlete Sleep Behavior Questionnaire (ASBQ) are easy-to-use self-administrated surveys that can evaluate the sleep quality and sleep behaviors and habits of athletes, both during regular sports

Table 4 Items and clarity scores for the preliminary version of the ASBQ-FR.

ASBQ-FR		Clarity means scores /6
Factor 1–Routine / environmental factors		
Q1	Je fais des siestes l'après-midi de deux heures ou plus *I take afternoon naps lasting two or more hours*	6.0
Q5	Je vais au lit à des heures différentes chaque soir (variation de plus de ± 1 heure) *I go to bed at different times each night (more than ± 1 hour variation)*	5.7
Q15	Je me lève à des heures différentes chaque matin (variation de plus de ± 1 heure) *I get up at different times each morning (more than ± 1 hour variation)*	5.8
Q16	Chez moi, je dors dans un environnement qui n'est pas idéal (ex: trop lumineux, trop bruyant, lit/oreiller inconfortable, trop chaud/froid) *At home, I sleep in a less than ideal environment (e.g., too light, too noisy, uncomfortable bed/pillow, too hot/cold)*	5.9
Q17[d]	Je dors dans des environnements peu familiers (ex: chambres d'hôtel) *I sleep in foreign environments (e.g., hotel rooms)*	5.5
*Q18[d]	Mes voyages entravent la construction d'une routine sommeil-veille cohérente *My travels get in the way of building a consistent sleep-wake routine*	5.0
Factor 2–Behavioral factors		
Q2	J'utilise des stimulants lorsque je m'entraine/participe à une compétition (ex: la caféine) *I use stimulants when I train/compete (e.g., caffeine)*	5.7
Q4	Je consomme de l'alcool ou des boissons stimulantes (ex: cola, boissons énergisantes, thé...) dans les 4 heures avant d'aller au lit *I consume alcohol or energy drinks (e.g., cola, sports drinks, tea...) within 4 hours of going to bed*	5.9
Q8	J'utilise des appareils électroniques émettant de la lumière dans l'heure précédant l'endormissement (ex: ordinateur portable, smartphone, télévision, jeux vidéo) *I use light-emitting technology in the hour leading up to bedtime (e.g., laptop, phone, television, video games)*	5.9
Q10	Je pense (ex: réflexions, planifications) et m'inquiète à propos de problèmes non liés à mon sport quand je suis au lit *I think (e.g., ruminating or planning) and worry about issues not related to my sport when I am in bed*	5.6
Q11	J'utilise des somnifères/comprimés pour m'aider à dormir *I use sleeping pills/tablets to help me sleep*	5.9
Q12	Je me réveille pour aller aux toilettes plus d'une fois par nuit *I wake to go to the bathroom more than once per night*	6.0
Q13	Je me réveille et/ou je réveille mon/ma partenaire avec mes ronflements *I wake myself and/or my bed partner with my snoring*	5.9
Factor 3–Sport-related factors		
Q3[d]	Je fais de l'exercice (entraînement ou compétition) tard le soir (après 19h) *I exercise (train or compete) late at night (after 7pm)*	6.0
Q6	Je vais au lit en ayant soif *I go to bed feeling thirsty*	5.8
Q7	Je vais au lit avec des douleurs musculaires *I go to bed with sore muscles*	5.8
Q9	Je pense (ex: réflexions, planification) et m'inquiète au sujet de ma performance sportive quand je suis au lit *I think (e.g., ruminating or planning) and worry about my sports performance when I am in bed*	5.5
Q14	Je me réveille et/ou je réveille mon/ma partenaire à cause de secousses musculaires involontaires dans mes membres *I wake myself and/or my bed partner with involuntary muscle twitching in my limbs*	5.6
Global clarity score (Mean ± SD)		5.7 ± 0.3

Notes. English translations are in italics. For each item, the participant had to answer on a 6-point Likert-type scale from 1 = not clear at all, to 6 = totally clear. ASBQ-FR: French version of the Athlete Sleep Behavior Questionnaire; SD: standard deviation; *: item rephrased after clarity test; d: items deleted following the confirmatory factor analysis

Table 5 Goodness of fit indexes of the ASBQ-FR models.

ASBQ-FR	χ^2(df)	p	χ^2/df	RMSEA	RMSEA 90% CI	TLI	CFI	AIC	ECVI	Model comparison	$\Delta\chi^2$ (df)	Δp
Criterion		**>.05**	**<3**	**<.05**	**<.08**	**>.95**	**>.95**					**<.05**
ASBQ-FR initial factor structure												
Model b1	377.58 (135)	.00	2.80	.08	.07-.09	.43	.49	449.58	1.52	–	–	–
Model b2	295.79 (132)	.00	2.24	.07	.06-.08	.55	.61	373.79	1.45	b2 vs. b1	81.79 (3)	.00
Model b2'	162.86 (86)	.00	1.89	.06	.05-.07	.72	.77	230.86	.90	b2' vs. b2	214.72 (49)	.00
Model b3	–	–	–	–	–	–	–	–	–	–	–	–
Model b4	–	–	–	–	–	–	–	–	–	–	–	–
ASBQ-FR modified factor structure												
Model B1	246.79 (89)	.00	2.77	.08	.07-.09	.50	.57	308.79	1.05	–	–	–
Model B2	109.58 (87)	.05	1.26	.03	.00-.05	.92	.93	175.58	.68	B2 vs. B1	137.21 (2)	.00
Model B3	245.04 (90)	.00	2.72	.08	.07-.09	.46	.54	305.04	1.187	B3 vs. B2	–	–
Model B4	**76.59 (72)**	**.33**	**1.06**	**.02**	**.00-.04**	**.98**	**.99**	**172.59**	**.59**	**B4 vs. B2**	**32.99 (15)**	**.01**

Notes. **ASBQ-FR initial factor structure**: b1: unidimensional model, b2: three-factor model from Driller et al. (21), b2': model b2 without items impacted by Covid-19 restriction items (Q3, Q17 and Q18) ErrQ7 and ErrQ14 correlated, b3: hierarchical model from model b2', b4: confirmatory model from model b2'. **ASBQ-FR modified factor structure**: B1: unidimensional without items Q3, Q17 and Q18, B2: new three-factor structure, B3: hierarchical model from model B2, B4: confirmatory model from model B2. **Indexes**: χ^2(df): chi-square (degree of freedom), RMSEA: root mean squared error of approximation; 90% CI: confidence interval at 90%; TLI: Tucker-Lewis's index; CFI: comparative fit index; AIC: Akaike's information criterion; ECVI: expected cross-validation index; $\Delta\chi^2$(df): difference in chi-squares.

training and for research. The present research aimed to develop and validate French versions of these two questionnaires. The AIS-FR (►**Supplementary File 2**) and the ASBQ-FR (►**Supplementary File 3**) showed satisfactory psychometric properties (i.e., good reliability and validity in this population), indicating that they are reliable tools to assess sleep in French competitive athletes.

Psychometric Properties of the Tools

Psychometric Properties of the AIS-FR

Compared to the AIS of Soldatos et al.,[16] the AIS-FR is completed by rating all items on a common Likert-type scale. Precisions were added to the original items to increase the athletes' understanding, as recommended by Dickinson and Hanrahan[17] in their AIS validation among athletes.

Dimensionality

This eight-item scale conserved five items exploring nocturnal sleep problems, corresponding to the AIS-5 items,[16] and three items dealing with daytime dysfunction. The structure was corroborated by the good fit indexes of the confirmatory bifactor model of the AIS-FR. These results differ from those of other transcultural AIS versions,[16,49–51] which showed a one-factor structure but examined the dimensionality with exploratory factor analysis or principal component analysis. The bifactor structure of the AIS-FR is in line with the validated Japanese version of the AIS[18] and the definition of the criterion of chronic insomnia disorder.[28]

Reliability

The reliability of the AIS-FR is the same as that of the original version, with $\omega = .72$ versus $\alpha = .75$ in the $N = 50$ non-patient control group of Soldatos et al.[16] It is slightly lower than Dickinson and Hanrahan's[17] results among elite athletes ($\alpha = .81$), and also lower than in other reports in patient or working populations ($.78 \leq \alpha \leq .90$).[18,49–53] However, it is acceptable reliability for a non-clinical tool, even better in our sample than the PSQI ($\omega = .65$), the gold standard of the sleep quality questionnaires.

Temporal Stability

The AIS-FR specifies that only the sleep disturbances occurring within the last month are evaluated. To consider a similar period and minimize the recording bias, one month or more and one week or less interval test-retest were excluded. A two-week interval was selected and showed the good reliability of the AIS-FR among athletes [$ICC_{AIS\text{-}FR}$ (95%CI) = .90(.82-.94)]. These results are comparable to those of the original version of Soldatos et al.[16] ($r = .89$) at a one-week interval. Unsurprisingly, the AIS-FR reliability was better than that reported by Dickinson and Hanrahan[17] ($r = .78$) at a one-month interval and not as good as the results of Sun et al.[53] ($r = .94$) at a three-day interval.

Concurrent Validity

The AIS and the ISI have the best sensitivity and specificity to assess insomnia of the three most frequently used sleep questionnaires: AIS, ISI and PSQI.[54] The very strong positive correlation between the AIS-FR and the ISI ($r = .71$) confirmed the initial hypothesis of concurrent validity. The PSQI has high sensitivity but low specificity regarding insomnia, differing from the AIS and ISI. The strong positive correlation ($r = .56$) between the AIS-FR and the PSQI, which is lower than with the ISI, confirmed their difference in specificity (respectively, insomnia *vs* global sleep quality). These strong

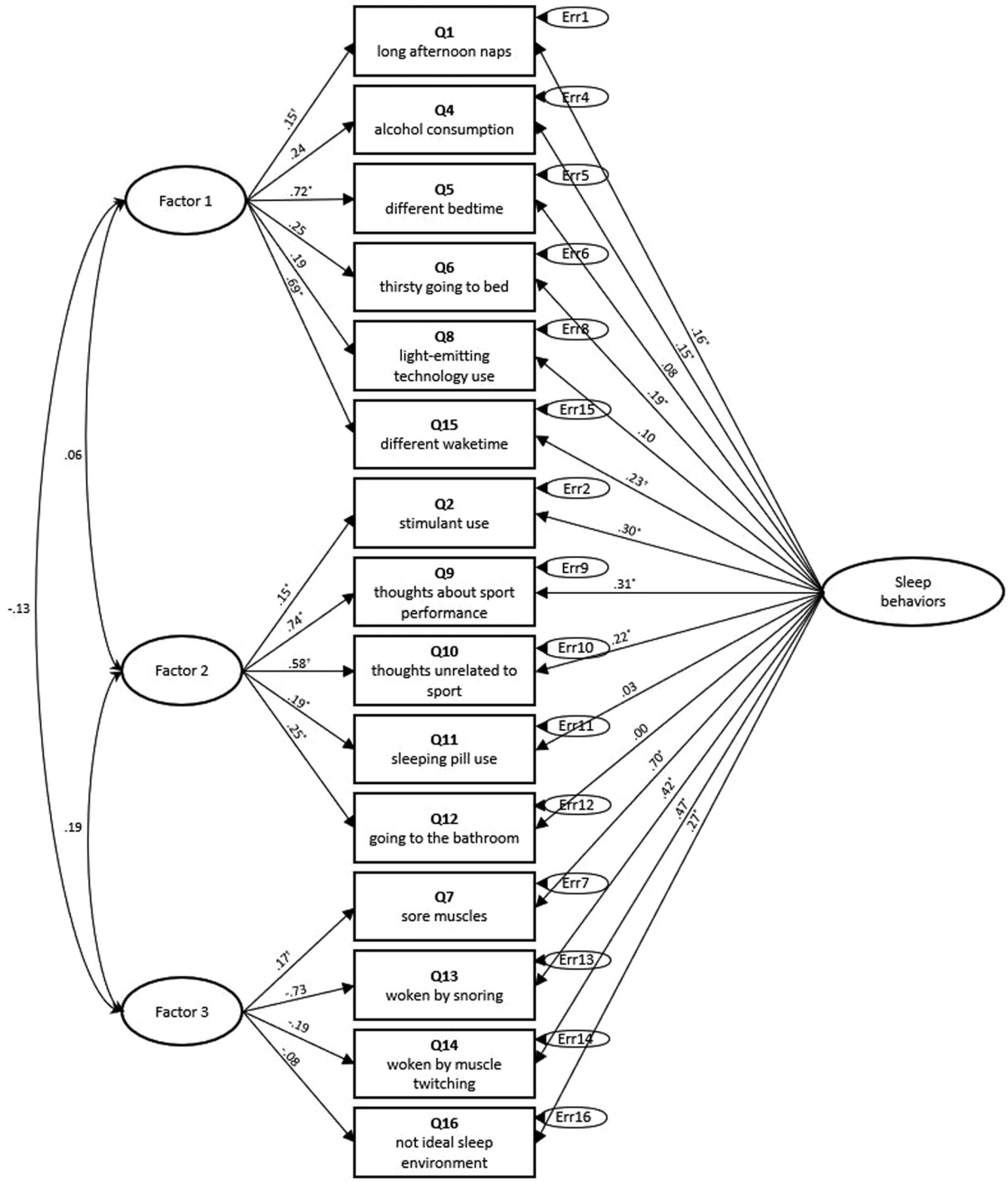

Fig. 4 Confirmatory factor analysis of the ASBQ-FR. $\overset{\phi}{}$:= correlations between latent factors; $\overset{\lambda}{}$:= factor loading; *: significant ($p < .05$); †: items fixed to 1.0; Q Ni: item $N_{i=1}^{18}$ of the AIS-FR (Q3, Q17 and Q18 have been removed); Err Ni: error terms of the corresponding item $N_{i=1}^{18}$; Factor 1: behaviors affecting sleep; Factor 2: behaviors linked to anxiety; Factor 3: sleep disturbances

positive correlations are consistent with previous research[18,51,52] and demonstrate good convergent validity. Furthermore, in our sample, the AIS-FR and the ISI were significantly and positively related to other questionnaires (i.e., PSQI, STAI-YB, PANAS) with the same magnitude. The positive correlations of the AIS-FR with the PANAS-NA and the STAI-YB, and the negative correlations with the PANAS-PA, confirmed the well-established links between affect, anxiety trait and sleep quality.[43,44]

Psychometric Properties of the ASBQ-FR

The ASBQ[21] is a very recent 18-item scale, based on the SHI[20] and adapted for athletes' needs. These studies provide a new analysis of the questionnaire, reinforcing the psychometric properties.

Dimensionality

The ASBQ has been translated into Portuguese in Brazil[26] and into Turkish.[47] The CFA findings were published for the first

time very recently,[22] however, showing divergent results from the factor structure reported by Driller et al.[21] Whereas Driller et al.[21] found a three-factor structure (i.e., routine/environmental, behavioral and sports-related factors) and Darendeli et al.[47] a four-factor structure (i.e., sports-related, sleep quality, habitual efficiency and sleep disturbance factors) using exploratory factor analysis and principal component analysis, Miley et al.[22] rejected the original structure of the scale and produced a nine-item scale with a new item dispersion into the three original factors (i.e., routine, behavior and sports). The results of the present French study confirm the unsuitability of the original scale structure for competitive athletes. Given the heterogeneity of the factor constructs, a modified structure around behaviors affecting sleep (factor 1), behaviors related to anxiety (factor 2), and sleep disturbances (factor 3) was examined. Factor 1 encompasses the behaviors and habits of athletes in their everyday routines (e.g., bedtime, light-emitting technology use). Factor 2 encompasses behaviors related to anxiety [e.g., overthinking, pill use, nocturia[55]], and factor 3 addresses sleep disturbances not directly linked to athletes' choices (e.g., snoring, noisy sleep environment). This structure of the ASBQ-FR was validated in the present study with the CFA and very good fit indexes (Figure 3 4) once the items impacted by Covid-19 travel restrictions and curfew were removed (i.e., items 3, 17 and 18 of the Driller et al. version). Regarding the heterogeneity of the ASBQ structure, further CFA on other samples and invariance analysis is needed to confirm its structure.

Reliability

The internal consistency of the ASBQ-FR ($\omega = .67$) was slightly higher than those of the English and Turkish versions (respectively, $\alpha = .63$ and $\alpha = .62$),[21,47] and lower than the Brazilian version ($\alpha = .78$).[26] The ASBQ-FR is thus as reliable as the original ASBQ, which remains a limitation of this questionnaire since the reliability value is under the classic recommendation of .70. The lack of reliability of these scales might stem from the specific design of the questionnaire, which includes diverse aspects of sleep behavior.

Temporal Stability

Similar to the AIS-FR, the ASBQ-FR has a one-month screening period. To limit the recording bias risk without entirely changing the assessed period, a 14-day test-retest was selected, contrary to the other ASBQ validations that considered a seven-day period. The ASBQ-FR had very good temporal stability [$ICC_{ASBQ\text{-}FR}$ (95%CI) = .93(.88-.96)], comparable to that of the other language versions of the ASBQ ($.74 \leq r \leq .88$)[21,47] using a similar sample size.

Concurrent Validity

There is no gold standard for assessing the sleep hygiene of athletes available in the French language. Yet, sleep behaviors are correlated with their sleep quality ($r_{ASBQ/\ PSQI} = .38$).[21] The results of the ASBQ-FR confirmed its correlation with sleep quality and insomnia questionnaires, showing moderate positive and significant correlations ($.39 \leq r \leq .43$). The moderate correlation between Factor 2 of the ASBQ-FR (behaviors related to anxiety) and the STAI-YB ($r = .38$) assessing anxiety trait corroborates the concurrent validity of the questionnaire.

To conclude, except for the factor structure of the ASBQ-FR, which has been entirely revised, these transcultural adaptations of the AIS and the ASBQ demonstrates satisfactory psychometric properties like those of the original scales.

Practical Applications

The AIS-FR is a very short scale (8 items only) that focuses on the diagnostic criterion for insomnia of the ICD-10.[16] Time-effective, it takes only about a minute and 20 seconds to complete, making it easy to use in daily practice (training or research). It is also very quick and easy to interpret as it uses a uniformized Likert scale to answer, thus providing a single global score. This makes the analysis easier than with questionnaires having dichotomic questions or subtotals to count, such as the ASSQ and the PSQI.[19,33] The AIS is also very well established. It has been translated into numerous languages and administered among a wide range of populations (e.g., insomniacs, psychiatric and cancer patients, general population, students),[18,49–51,53,56] including elite athletes,[17] which is contrary to most other sleep quality questionnaires. Now validated in French for competitive athletes, the AIS-FR is currently the most suitable questionnaire for assessing sleep quality among these athletes.

However, assessing the sleep of athletes cannot be limited only to the assessment of sleep quality. This should be associated at least with total sleep time, which athletes can directly self-report. Also, attention must be paid to the frequent overestimation of this measure (around 20 minutes) when it is self-reported rather than objectively measured.[57,58] Together, sleep quality and quantity form the first step in assessing athletes' sleep. If sleep problems are detected (i.e., high score on the AIS-FR and/or sleep under 8h per night), the recommendation is to look for the cause. Athletes should be referred to a sleep specialist in the case of moderate to severe problems, and they need to identify the sources for sleep insufficiencies (e.g., poor sleep habits) in order to improve mild sleep problems.[4] To our knowledge, the ASBQ-FR is the only French survey validated among athletes that explores sleep habits and behaviors, including the behaviors affecting sleep (e.g., regularity of bed and wake-up times or late-night use of light-emitting technology), behaviors related to anxiety (e.g., overthinking at night), and sleep disturbances (e.g., muscle twitches or a not-ideal sleep environment). It takes only two minutes to spot the insufficiencies in sleep hygiene so that athletes can improve their sleep by improving their sleep hygiene.[59]

Methodological Considerations and Limits

These studies present some limitations. The AIS-FR and the ASBQ-FR were validated among athletes coming from different regions of metropolitan France. Regional adaptations should be made according to local dialects and further research should be engaged before using the scales with other French-speaking athletes (e.g., Canadian, African, Belgian).

The two questionnaires usually consider an evaluation over the last month. To take into account the measures put into place to limit the spread of Covid-19 (e.g., curfews, travel restrictions, limited access to sports facilities, canceled competitions for amateur athletes), the initial introductory statement of the ASBQ-FR was adapted to "During a usual month (without constraints linked to the pandemic) …." Yet, the pandemic was found to increase anxiety levels, change the usual sleep patterns and behaviors, and modify the training habits in the athlete population.[60] This is one of the main limitations of the present study, prompting a 15-item version of the ASBQ-FR instead of the initial 18-item version and decreasing the reliability of the questionnaires. A further validation of the 18 items in a period without training and traveling restrictions might improve it.

Furthermore, according to the aim of the present studies, the AIS-FR was validated as a sleep quality indicator for athletes and not as a tool to diagnose insomnia, contrary to the original version of the AIS.[61] Given that this questionnaire was only validated among athletes, it should be validated in a non-athlete population before being used outside of a sports context. The next step would be to define the sensitivity, specificity and cut-off score of this French version of the AIS. Verifying the invariance of the factor structure in a longitudinal study and across a wide range of athletes would also provide a more complete analysis of its psychometric properties.

To achieve this next validation studies, a larger sample is recommended. Indeed, the sample size in studies 2 (N = 296) and 4 (N = 290) did not reach the recommendation of 300 participants, which is a limitation of this work.

Conclusion

Contrary to other sleep tools, the AIS-FR and ASBQ-FR are valid and reliable questionnaires that can be used in a large population of French competitive athletes practicing a range of sports (individual and collective) at different levels (from district to international). Sports staff, athletes, and researchers are now able to screen athletes' sleep monthly, both to monitor changes in sleep hygiene and quality over time and to more comprehensively enhance scientific knowledge.

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Conflict of Interest
None declared.

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