

ORIGINAL RESEARCH

Psychometric Properties of the 10-item Athletic Mental Energy (AME-10): Construct Validity, Reliabilities, and Gender Invariance

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Abstract

Current research uses the 6-factor model, which includes motivation (enthusiasm for sport), confidence (belief in performance), concentration (focused attention), vigour (perceived vitality), tirelessness (lack of vitality), and calmness (absence of anxiety), 18-item Athletic Mental Energy Scale (AMES, Lu et al., 2018) to examine its influence on athletes' cognition, behaviour, and emotion. However, two factors (i.e., vigour and tirelessness) in AMES are conceptually redundant and overlapping. We aimed to revise the AMES to improve its brevity. In Study 1, a 5-factor AMES (i.e., vigour, motivation, confidence, concentration, and calmness) was tested and analysed. In Study 2, we tested the gender invariance of the 5-factor AMES and examined nomological validity. In Study 3, we examined the test-retest reliability of the 5-factor AMES. Across these phases, the results showed that the 5-factor, 10-item AMES had an adequate factor structure, construct validity, reliability, and gender invariance. Future studies may utilise the 5-factor, 10-item AMES to examine its influence on athletes' psychological and physical responses in field or laboratory settings. We further recommend that sports psychologists adopt the 5-factor, 10-item AMES.

Introduction

In sport domains, researchers suggest that athletes' mental energy is linked to elite sport performance. For example, Loehr (2005) proposed a “pyramid model of athletic success” and contended that to achieve peak performance, athletes need four types of energy: namely, physical energy (fundamental level), emotional energy (second level), mental energy (third level), and spiritual energy (top level).

Mental energy plays a central role in regulating physical and emotional energy, governing athletes' higher levels of functioning, including perception, abstract reasoning, creativity, memory, attention, motivation, self-awareness, and self-regulation.

Similarly, Sindik et al. (2015) suggested that mental energy is a core component of sports excellence. In developing a multi-dimensional inventory

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of sporting excellence (MUSI), they recruited 248 male and female athletes and administered a battery of psychological tests, including measures of mental energy, attention skills, awareness of attention, internal and external attention during performance, internal speech, and narrow external attention. Results showed MUSI is a multi-dimensional measure with satisfactory validity and reliability, and mental energy correlated with all factors of MUSI. Sindik et al. (2015) concluded that mental energy has a significant contribution to all factors of sports excellence. In empirical studies, researchers have examined the influence of mental energy on athletes' cognition, affect, and performance (Chiou et al., 2020; Lu et al., 2018; Shieh et al., 2023). For example, in a study that examined how athletes' mental energy moderates athletes' life stress and burnout, Chiou et al. (2020) recruited two different samples engaging in diverse sports and administered the College Student-Athletes Life Stress Scale (CSALSS, Lu et al., 2012), the Athletes' Burnout Questionnaire (ABQ, Raedeke & Smith, 2001), and the athletic mental energy scale (AMES, Lu et al., 2018). Two separate hierarchical multiple regression analyses found that athletic mental energy moderated the relationship between athletes' life stress and burnout in both single-sport and multiple-sport samples. Chiou et al. (2020) concluded that athletic mental energy is a positive strength in buffering stress-burnout relationships.

Similarly, some research (e.g., Chuang et al., 2022; Novan et al., 2023; Shieh et al., 2023) found that athletes' mental energy plays a significant role in predicting competition performance. For example, Shieh et al. (2023) recruited 81 male volleyball players in a college volleyball tournament. Shieh et al. (2023) measured participants' mental energy the night before the competition and used six indices of the Volleyball Information System (VIS), developed by the International Volleyball Federation

(FIVB), as criterion variables. They found that all mental energy factors—vigour, motivation, tirelessness, concentration, confidence, and calmness—were correlated with volleyball competition performance. A hierarchical regression analysis revealed that mental energy predicted the performance of volleyball receivers ($R^2 = .23$).

Notably, current research examining athletes' mental energy and their psychological and physical responses primarily utilises Lu et al.'s (2018) Athletic Mental Energy Scale (AMES). These studies include research examining the relationship between athletes' mental energy and personality (e.g., Singh, 2024; Yazici et al., 2023), imagery ability (Kaplan, 2022), psychological skills (İslam, 2023), mindfulness (Öner, 2022), eating behaviour (Ilhan, 2020; Yildiz, 2020), psychological well-being (Singh et al., 2024), and quality of sleep (Tan et al., 2023).

The AMES, developed by Lu et al. (2018), adopts the conceptual framework of mental energy from the International Life Science Institute and defines athletic mental energy as "an athlete's perceived existing state of energy, which is characterised by its intensity in motivation, confidence, concentration, and mood." Through six studies, Lu et al. (2018) found that the 6-factor, 18-item AMES had adequate content validity, factor structure, nomological validity, discriminant validity, predictive validity, measurement invariance, and reliability. The six factors of AMES include vigour, tirelessness, confidence, motivation, concentration, and calmness, with each factor of the 15-item AMES comprised three items. Recently, several studies (e.g., Singnoy et al., 2023; Yildiz et al., 2020) translated AMES into Thai (Singnoy et al., 2023) and Turkish (Yildiz et al., 2020) and found both Thai and Turkish versions had appropriate psychometric properties, including factorial structures, reliabilities, and content validities.

Despite these developments, the 6-factor, 18-item AMES needs further investigation. First, it is redundant with an overlap of vigour and tirelessness. Conceptually, tirelessness is derived from vigour. In Lu et al.'s (2018; p. 8) study, the confirmatory factor analysis (CFA) showed that vigour can be represented by two factors—vigour (direct statements of vigour; for example, “I feel there is an endless energy coming from my body”) and tirelessness (indirect statements of vigour; for example, “Even the training is over, I still feel I have endless energy to use.”) For succinctness, a single factor would be better for interpreting results. The inconsistent findings from empirical studies might also indirectly echo this proposition. For example, Shieh et al. (2023) found that all six dimensions of AMES positively predicted athletic performance. In contrast, Yang and Lu (2019) reported that only tirelessness resistance positively predicted performance. This inconsistency may stem from conceptual distinctions between tirelessness and the other five dimensions, as well as from differences in item wording and measurement orientation.

Practically, tiredness has frequently been used as a negative behavioural indicator of vigour. For example, in the vitality subscale of the Short-Form Health Survey (SF-36; Ware & Sherbourne, 1992), both positive indicators (e.g., “Do you have a lot of energy?”) and negative indicators (e.g., “Do you feel tired?” and “Do you feel worn out?”) are included to reflect overall vitality. However, incorporating both positively and negatively worded items to

measure vitality may compromise the validity of the measurement. In the Subjective Vitality Scale (Ryan & Frederick, 1997), one item (i.e., I don't feel very energetic) was negatively worded. Bostic et al. (2000), using CFA, found that removing this negatively worded item improved the psychometric properties of the scale. These findings support the conceptual alignment between vigour and the absence of tirelessness (Lu et al., 2018) and highlight the importance of consistent item wording in scale construction.

In line with this approach, items with consistent design in each dimension are also warranted. The original version of AMES reveals several measurement design issues, including the presence of double-barrelled items, outcome- versus skill-referenced wording, ego- versus task-oriented motivation, and mixed positive and negative semantic valences, that might lead to target inconsistency (DeVellis & Thorpe, 2021), situational inconsistency (Tourangeau et al., 2000), response direction inconsistency (Zhang et al., 2016), and might impede the psychometric properties of AMES.

Thus, the objective of this study was to refine the existing 6-factor 18-item AMES. Specifically, we attempted to achieve the following purposes: (a) to examine the factorial structure and basic psychological properties of the 5-factor AMES by deleting tirelessness; (b) to examine nomological validity and gender invariance of the 5-factor AMES; (c) to examine test-retest reliability.

Participants

A total of 318 collegiate student-athletes (151 males and 167 females; $M_{age} = 19.77 \pm 1.75$) were recruited from 17 universities in Taiwan. The participants participated in diverse sports, including individual sports (e.g., golf, weightlifting, archery, judo, swimming, gymnastics, taekwondo, table tennis, dance, martial arts, kendo, and badminton) and team sports (e.g., baseball, basketball, rugby, hockey, soft tennis, tug

Methods

Study 1

Purpose

The objective of Study 1 was to examine the factorial structure and basic psychological properties of the 5-factor AMES by deleting the factor of tirelessness.

of war, handball, and volleyball). On average, they had 7.72 ± 3.02 years of experience in sports and trained an average of 3.43 hours per day ($SD = 1.53$).

Measurements & Procedures

Ethical approval for the present study was obtained from the ethics committee of a local institute (Antai-Tian-Sheng Memorial Hospital Institutional Review Board, TSMH IRB No./Protocol No. 23-090-B) prior to the survey. The coaches were contacted via phone or email and were informed of the study's objectives, as well as the confidentiality and anonymity of participation. Upon receiving consent from the coaches, the first author and assistants visited the respective teams at a convenient time. Participants listened to a briefing on the study's purposes, ethical statements, and participation procedures. If they agreed, they completed informed consent forms and a survey package, which included a demographic questionnaire and a 15-item AMES. The survey took approximately 15 minutes to complete and was conducted either before or after each team's training session. The survey package included the following:

Demographic questionnaire

The demographic questionnaire was designed to collect participants' gender, age, types of sports, and years of athletic experience, including training hours per day and week.

The 15-item AMES. The 15-item AMES was revised from an early version of AMES (Lu et al., 2018) by deleting the factor of tirelessness. The 15-item AMES includes five factors - vigour, motivation, confidence, concentration, and calmness. Each factor in the 15-item AMES has three items. To respond to the 15-item AMES, participants read short instructions asking them to identify "how do you feel right now in sports training/competition." Then, participants read each item of the 15-item AMES and circle a number that reflects

their level of agreement. Sample questions for each factor are as follows:

For vigour, the sample question is "Either in competition or training, I feel full of energy"; for motivation, the sample question is "I am full of passion for attending my sports"; for confidence, the sample question is "I can control all sports movements and skills"; for concentration, the sample question is "There's nothing distracting me in competition"; and for calmness, the sample question is "Facing upcoming competitions, I don't feel anxious." The AMES uses a six-point Likert scale to rate participants' responses, with "1" representing "not at all" and "6" representing "completely so."

Statistical Analyses

Before primary analyses, data screening was performed to assess means, standard deviations, skewness, kurtosis, the proportion of missing data, normal distribution, as well as the presence of univariate and multivariate outliers. Subsequently, CFA and reliability analysis were employed to produce a representative set of items (Marsh et al., 1998; Tabachnick & Fidell, 2018).

The statistical analyses were separated into two stages. The first stage examined the representative items of the 15-item AMES using CFA, while the second stage assessed the reliability of the 15-item AMES.

Results

Following the data screening process, Little's test indicated 13 instances of random missingness across 7 cases, $\chi^2(39) = 53.64$, $p = .071$. Additionally, 20 univariate outliers (with absolute Z-scores exceeding 2.58) and 35 multivariate outliers (identified by Mahalanobis distance greater than 25.26, all $p < .05$) were excluded from subsequent analysis. The primary variables exhibited a non-normal distribution, with skewness values ranging from 0.98 to 1.37, as confirmed by the Kolmogorov-Smirnov test (all $p < .01$).

To address the non-normal distribution in model estimation, Bollen-Stine bootstrapping ($n = 2,000$) CFA was employed (Bollen & Stine, 1992; Nevitt & Hancock, 2001). The Bollen-Stine method employs a non-parametric bootstrap resampling procedure to adjust the reference distribution of the chi-square statistic through multiple resampling iterations (typically over 1,000). Instead of relying on the theoretical chi-square distribution under normality assumptions, it constructs an empirical distribution of the

test statistic under the null hypothesis of model fit. This results in a corrected p -value that better reflects the actual sampling distribution in ordinal Likert-type data or non-normal conditions (Bollen & Stine, 1992). As a result, a total of 55 cases were excluded during data screening, resulting in a valid sample size of 263 participants (124 males and 139 females; $M_{\text{age}} = 19.69 \pm 1.61$). The statements, means (M), and standard deviations (SD) for each item are detailed in Table 1.

Table 1. Statements, Means, and Standard Deviations of each item in the revised 15-item AMES

Dimension	Item	Content	M	SD
Concentration	AME5	There's nothing distracting me in competition.	4.05	1.13
	AME6	There's nothing distracting me in training.	4.11	1.05
	AME10	There's nothing I have to care about in competition/training.	3.89	1.18
Motivation	AME4	I feel excited in future competitions.	4.44	1.10
	AME8	I am full of passion to attend my sports.	4.62	1.00
	AME16	I want to show my best to others in sports.	4.67	1.09
Calmness	AME14	When facing my opponents I am calm.	3.87	1.04
	AME17	Facing coming competitions, I don't feel anxious.	3.83	1.16
	AME18	Even facing a tough opponent, I don't feel anxious.	3.81	1.25
Confidence	AME3	I feel I can win all competitions in the future.	3.77	1.12
	AME9	I can smoothly perform all sport skills.	4.11	1.00
	AME13	I can control all sports movements and skills.	3.90	0.95
Vigour	AME1	I feel spiritual to do everything in sports.	4.07	0.90
	AME2	I feel there is an endless energy coming from my body.	3.92	0.89
	AME15	Either in competition or training, I feel full of energy.	3.94	1.02

Note. AME refers to athletic mental energy; the number after AME represents each item.

First round of CFA results

The first round of CFA showed the 15-item AMES has acceptable but not entirely sufficient fit indices. The Bollen-Stine bootstrapped results yielded $\chi^2/df = 4.83$, GFI = .83, CFI = .89, RMSEA = .12, and SRMR = .08. The factor loadings derived from the CFA indicated that several items had not achieved sufficient loadings (ranging from .62 to .72.) They are item #10 for concentration, item #16 for motivation, item #14 for calmness, item #3 for confidence, and item #15 for vigour. To reduce the 15-item AMES into a more concise measure, we decided to delete

specific items and create a 10-item AMES for subsequent CFA analyses (see Table 2).

Table 2. Factor loading of each item and the corrected Cronbach's α if item is removed

Dimension	Original Cronbach's α	Item	Factor loading	Cronbach's α if low factor loading items removed
Concentration	.81	AME5	.88	.79
		AME6	.85	.77
		AME10	.76	<u>.86</u>
Motivation	.78	AME4	.80	.74
		AME8	.89	.72
		AME16	.66	<u>.82</u>
Calmness	.79	AME14	.72	<u>.92</u>
		AME17	.92	.77
		AME18	.91	.77
Confidence	.78	AME3	.62	<u>.83</u>
		AME9	.86	.64
		AME13	.80	.65
Vigour	.81	AME1	.83	.77
		AME2	.83	.72
		AME15	.76	<u>.87</u>

Note. The underlined Cronbach's α in the 5th column represents the final results after removing low-factor-loading items.

Second round CFA and reliabilities

The new results of the CFA for the 10-item AMES demonstrated satisfactory model fit (shown as Figure 1), with Bollen-Stine bootstrapped indices indicating $\chi^2/df = 2.16$, GFI = .96, CFI = .98, RMSEA = .07, and SRMR = .02. The factor loadings for this model ranged from .78 to .94 (all $p < .001$). The CR and AVE for each subscale surpassed the established thresholds. Specifically, the CR for the subscales were as follows: vigour (.87), concentration (.86), motivation (.82), calmness (.92), and confidence (.83). The AVE for the

subscales were .78 for vigour, .76 for concentration, .69 for motivation, .85 for calmness, and .72 for confidence. The Pearson correlation coefficients among these factors ranged from .45 to .73, and the square root of AVE ranged from .83 to .88 (presented in Table 3). Additionally, the chi-square difference test indicated that the 10-item AMES outperformed the 15-item AMES, with a significant difference of $\Delta\chi^2(55) = 332.52, p < .001$.

Table 3. Discriminant validity of the AMES-10

	Vigour	Concentration	Motivation	Calmness	Confidence
Vigour	.88				
Concentration	.62***	.87			
Motivation	.61***	.72***	.83		
Calmness	.45***	.60***	.60***	.85	
Confidence	.67***	.73***	.73***	.59***	.85

Note. The square root of AVES in bold is on the diagonals. Off-diagonal elements are Pearson correlations among the five factors of the AMES-10. *** $p < .001$.

CFA of 10-item AMES
 chi-square=53.988 df=25
 chi-square/df=2.160
 CFI=.983 GFI=.960 NNFI=.970
 RMSEA=.067

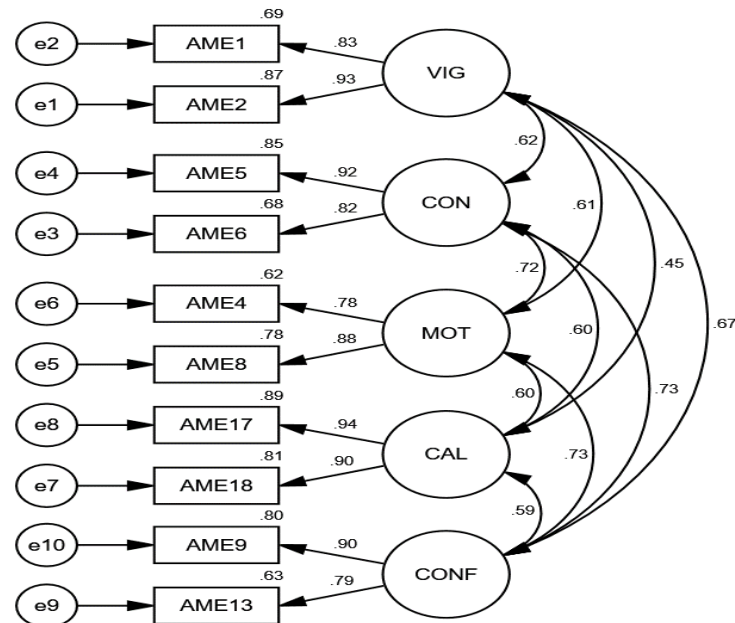


Figure 1. The measurement model of the AMES-10

Note. VIG=vigour, Con=concentration, MOT=motivation, CAL=calmness, CONF=confidence.

Study 2

Purpose

The purpose of Study 2 was to examine the gender invariance of the AMES-10 and to test its nomological validity by examining the relationships among AMES-10, athletic burnout, and athletes' life stress. To ensure the AMES-10 functions equally well across different athlete populations, it is important to test gender invariance. Prior studies suggest that males and females may differ in their psychological experiences in sport (Del Giudice, 2015). Without confirming measurement invariance, comparisons across genders may be misleading (Cheung & Rensvold, 2002; Putnick & Bornstein, 2016). Therefore, evaluating whether the AMES-10 is interpreted similarly by male and female athletes strengthens its validity and supports its broader application in both research and practice.

Participants

A total of 231 collegiate student-athletes (139 males and 92 females; M_{age}

$=20.11 \pm 1.09$) who participated in various individual and team sports were recruited from northern China. On average, they had 8.15 ± 3.53 years of experience in their respective sports and trained for an average of 2.86 hours per day ($SD = 1.79$).

Measurements & Procedures

The procedures were identical to those in Study 1 and Study 2. The measures are as follows:

Demographic questionnaire

The demographic questionnaire was identical to that used in Study 1. The AMES-10, derived from Study 2, was used in this study. The Cronbach's α of the five factors of the AMES-10 for the present sample were .82 for vigour, .83 for motivation, .76 for confidence, .80 for concentration, .84 for calmness, and .87 for total AMES.

The Athlete Burnout Questionnaire (ABQ; Raedeke & Smith, 2001). Athletes'

burnout experiences were assessed by the ABQ (Raedeke & Smith, 2001). The ABQ comprised 15 items and encompassed three dimensions: reduced sense of athletic accomplishment (e.g., “I am not performing up to my ability in sport.”); perceived emotional and physical exhaustion (e.g., “I feel overly tired from my sports participation.”); and devaluation of sports participation (e.g., “I don't care as much about my sports performance as I used to”). Participants rated items on a 6-point Likert scale ranging from 1 (never) to 6 (always). The Cronbach's α outcomes for the present sample were: 0.86 for reduced sense of accomplishment, 0.87 for emotional and physical exhaustion, and 0.75 for sport devaluation. The overall reliability for all items was .92.

The College Student-Athletes Life Stress Scale (CSALSS, Lu et al., 2012). The 24-item CSALSS (Lu et al., 2012) was used to assess the stressors that athletes encountered in their daily lives and sports. The CSALSS comprised eight factors, which included: (a) sports injury (e.g., “I worry about being frequently injured.”), (b) performance demand (e.g., “I worry about dragging my team down.”), (c) coach relationships (e.g., “I am annoyed by my coach's bias against me.”), (d) training adaptation (e.g., “I am annoyed with the training program now.”), (e) interpersonal relationships (e.g., “I am annoyed with being friendless.”), (f) romantic relationships (e.g., “I am annoyed with not getting along with my romantic partner.”), (g) family relationships (e.g., “I am bothered by difficult situations in my family.”), and (h) academic requirements (e.g., “I am annoyed when preparing for exams.”). Participants rated items on a 6-point Likert scale ranging from 1 (never) to 6 (always). The Cronbach's α values for each subscale were as follows: .79 for sports injury, .63 for performance demand, .73 for coach relationships, .63 for training adaptation, .74 for interpersonal relationships, .66 for romantic relationships, .56 for family relationships,

and .74 for academic requirements. These eight factors could be categorised into two major components: general-life stress (e.g., factors e, f, g, h) and sport-specific stress (e.g., factors a, b, c, and d). The Cronbach's α values were: .80 for general life stress, .85 for sport-specific stress, and .88 for overall CSALSS.

Statistical Analyses

Pearson correlation analysis was performed to examine the relationships among the AMES-10, ABQ, and CSALSS. Additionally, model invariance was confirmed through the following procedures: (a) establishing acceptable results from the CFA for each group; (b) comparing a model that imposes equality constraints (i.e., the nested model) with a less-constrained model (i.e., the parent model), which includes configural invariance, metric invariance, factor variance/covariance invariance, and error variance invariance (Kline, 2023).

Results

Pearson correlation analyses indicated that all subscales, as well as the overall score of the AMES-10, displayed a negative correlation with both athlete burnout and athletes' life stress. These results provided evidence for the nomological validity of the AMES-10. The detailed *M*, *SD*, Cronbach's α of each dimension, and bivariate correlation coefficients are presented in Table 4.

Table 4*The bivariate correlations among AMES-10, ABQ, and CSALSS*

	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
AME	.87												
S-10													
2													
ABQ	-.38	.92											
**													
3													
CSA	-.22	.39	.88										
**	**												
LSS													
4													
VIG	.65	-.21	-.06	.82									
**	**												
5													
CON	.80	-.34	-.19	.40	.80								
**	**	**	**	**									
6													
MOT	.83	-.34	-.16	.55	.58	.83							
**	**	*	**	**	**								
7													
CAL	.66	-.17	-.24	.16	.44	.40	.84						
**	*	**	*	**	**	**							
8													
CON	.75	-.35	-.12	.43	.53	.53	.35	.76					
**	**		**	**	**	**	**						
F													
9													
GLS	-.18	.29	.89	-.08	-.13	-.13	-.21	-.12	.80				
**	**	**					**						
10													
SSS	-.20	.39	.89	-.03	-.20	-.16	-.22	-.09	.58	.85			
**	**	**		**	*	**	**		**				
11													
RSA	-.07	.60	.33	.04	-.11	-.05	-.03	-.09	.28	.30	.86		
**	**	**							**	**			
12													
PEE	-.32	.84	.46	-.19	-.28	-.30	-.16	-.27	.35	.46	.43	.87	
**	**	**	**	**	**	**	*	**	**	**	**	**	
13													
SDE	-.39	.87	.19	-.23	-.33	-.35	-.16	-.37	.13	.21	.32	.53	.75
**	**	**	**	**	**	**	*	**	**	**	**	**	**
<i>M</i>	38.	48.	62.	7.7	7.3	8.0	7.3	8.1	31.	31.	17.	15.	15.
	60	51	44	7	4	2	5	2	30	14	89	19	44
<i>SD</i>	8.9	13.	18.	1.9	2.5	2.6	2.6	2.1	10.	10.	3.1	5.9	7.6
	3	47	33	5	3	9	4	9	21	41	4	1	1

Note. AMES-10 = total score of athletic mental energy; ABQ = total score of athlete burnout; CSALSS = total score of student-athlete's life stress; VIG = vigour; CON = concentration; MOT = motivation; CAL = calmness; CONF = confidence; GLS = general life stress; SSS= sport-specific life stress; RSA = reduced sense of accomplishment; PEE = physical/emotional exhaustion; SDE = sport devaluation. Cronbach's α of each measure is on the diagonals.

* $p < .05$; ** $p < .01$.

The results of CFA indicated good model fit indices for both male and female samples. The Bollen-Stine bootstrapped indices revealed $\chi^2/df = 1.18$ for males and 2.07 for females; GFI = .99 for males and .98 for females; CFI = .96 for males and .91 for females; RMSEA = .04 for males and .07 for females; and SRMR = .02 for males and .04 for females. The metric-restricted model demonstrated satisfactory model fit, with changes in χ^2 , CFI, TLI, and RMSEA when comparing the metric-restricted model to the configural invariance model falling within acceptable ranges. When compared to the metric invariance model, the changes in χ^2 , CFI, TLI, and RMSEA for the variance/covariance invariance model also demonstrated acceptable values. Similarly, the changes in χ^2 , CFI, TLI, and RMSEA between the residual invariance

model and the variance/covariance invariance model were within acceptable limits. Overall, the configural, metric, variance/covariance, and error variance invariance models exhibited equivalent performance in terms of changes in CFI, TLI, and RMSEA. The values of these indicators are presented in Table 5.

Conclusion

Results revealed that five factors of the AMES-10 were negatively correlated with sport-specific life stress, general life stress, physical and emotional exhaustion, sport devaluation, and a reduced sense of accomplishment. The negative correlations among overall scores of AMES-10, ABQ, and CSALSS support the nomological validity of the AMES-10.

Table 5. Gender invariance of the measurement model of the AMES-10

Model	$\Delta\chi^2$	<i>p</i>	Δ CFI	Δ RMSEA	Δ TLI
Configural	(81.266)	(.003)	(.966)	(.055)	(.940)
Metric	5.230	.389	<-.001	.002	-.005
Co/Variance	14.309	.502	<.001	.007	-.013
Residual	19.455	.035	-.010	-.003	.006

Note. The numbers in parentheses represent the values of the basement model.

The results of the CFA with group comparisons indicated that configural, metric, covariance and error variance invariance demonstrated equivalent performance across genders, thereby supporting strict model invariance (Kline, 2023). These findings confirmed that both males and females had a comparable understanding of the content of the AMES-10. Furthermore, the relationships among the five factors remained consistent between males and females. Also, the results supported the invariance of item reliability across genders.

Study 3

Purpose

The purpose of Study 3 was to examine the test-retest reliability of the AMES-10.

Participants

The sample consisted of 54 collegiate soccer players (36 males, 18 females; $M_{age} = 20.77 \pm 1.68$).

Measurements & Procedures

The procedures were identical to those in Study 1 and Study 2. Participants in this study completed the AMES-10 twice, with a 14-day interval between the two surveys to examine test-retest reliability. The measures are as follows:

Demographic questionnaire

The demographic questionnaire was the same as Study 1 and the AMES-10.

Statistical Analyses

We used an inter-class correlation coefficient (ICC) to examine the test-retest reliability (Koo & Li, 2016; Qin et al., 2019). The ICC uses a two-way mixed-effect analysis of variance model with interaction to assess the absolute agreement between two scores.

Results

The ICC analysis indicated a moderate degree of correlation between the measurements at the two-time points. The ICC for the five dimensions were as follows: vigour (ICC = .59), concentration (ICC = .63), motivation (ICC = .61), calmness (ICC = .66), and confidence (ICC = .57). The overall score of the 5-factor, 10-item AMES demonstrates a high degree of consistency (ICC = .83).

Conclusion. The results of the ICC analyses showed that each factor demonstrated acceptable test-retest reliability (>.5), while the total score of the AMES-10 revealed excellent reliability (>.8).

General Discussion

Theoretical implications

The present study, utilising a standardised research procedure, compared the model fit between the original 15-item five-factor version of the AMES and a refined AMES-10. The findings supported the factorial structure and model fit of AMES-10. The only distinction between AMES-10 and the original AMES lies in the exclusion of the tirelessness dimension from the former; the remaining four dimensions are consistent across both versions. These results directly respond to Lu et al.'s (2018) theoretical distinction between vigour and tirelessness, which represent positive and negative conceptualisations of energy, respectively. However, the findings suggest that these two dimensions do not reflect conceptually

distinct constructs. This aligns with prior research on measurement issues, indicating that mixing positively and negatively worded items can confuse respondents, introduce method effects, and ultimately compromise the reliability and structural stability of the scale (Roszkowski & Soven, 2010; Zhang et al., 2016).

In addition to enhancing the parsimony of AMES, Study 1 examined the appropriateness of items within each dimension using factor loadings and internal consistency indices. The analyses identified one item per dimension that had notably lower factor loadings than the others, and the deletion of these items either maintained or improved the internal consistency of the respective dimensions. These items exhibited methodological inconsistencies from different perspectives. For instance, in the vigour dimension, Item 1 was contextually inconsistent with the other two items, which may have contributed to its diminished suitability (Tourangeau et al., 2000; Schwarz, 1999). In the confidence dimension, Item 3 demonstrated target inconsistency relative to the other items (DeVellis & Thorpe, 2021), which may undermine its appropriateness. Similarly, in the concentration dimension, Item 10 displayed inconsistent response contexts with the other two items (Tourangeau et al., 2000; Schwarz, 1999), resulting in low factor loading and inter-item correlation. In the calmness dimension, Item 14 was inconsistent in its response direction compared to the other items, which may have compromised its measurement integrity. Finally, in the motivation dimension, the target inconsistency of Item 16 relative to the other items also appeared to reduce its appropriateness.

The five factors of the AMES-10 not only represent core components of athletic mental energy (Lu et al., 2018) but also align with the extant literature on sport excellence. The emotional factor of vigour in sport excellence can be traced to the early work of Morgan's (1979; 1980) iceberg

profile model, where he found successful athletes scored high on vigour but low on anxiety, fatigue, depression, anger, and confusion compared to unsuccessful athletes. Vigour is defined as an individual's subjective feeling with heightened arousal (Lane & Terry, 2000). Athletes with high vigour can engage in harsh sports training and competition. In contrast, when athletes are low in vigour, they would not be able to finish the required training schedule and sports skills practice. Thus, the role of vigour in sports' success is essential.

Similarly, the emotional factor of calmness also links to peak performance. Early works on the psychological characteristics of peak performance (Ravizza, 1977; Garfield & Benett, 1984; Loehr, 1984) indicated that when athletes achieve their best performance, they experience calmness and emotional stability and are physically and mentally relaxed. Similarly, Anderson et al. (2014) interviewed elite Australian athletes to investigate their psychological state during their best performance. Participants reported that during their best performance, they felt calm and relaxed.

The cognitive component of confidence is crucial for achieving peak performance. Self-confidence is defined as an athlete's belief in their ability to accomplish the required task (Vealey & Chase, 2008). High-confidence athletes exhibit better concentration, emotional control, and effective competition focus (Lane, 2016). A recent meta-analysis synthesised 41 studies involving 3711 athletes and found that the confidence-sports performance relationship ranges from 0.14 to 0.39 (Lochbaum et al., 2022). Thus, it can be concluded that confidence plays a pivotal role in sports success.

Motivation, another cognitive factor in athletic mental energy, is theoretically significant. Motivation is an inner drive for athletes to engage in sports training and competition (Gill et al., 2017). The gold medal profile for sport psychology (GMP-

SP) asserts that motivation is crucial for achieving sport excellence (Durand-Bush et al., 2023). With high motivation, athletes sacrifice their leisure time and tolerate harsh training to pursue their goals. High athletic mental energy would promote athletes' investment in sports training and competition. In contrast, low athletic mental energy would reduce sport engagement (e.g., participation, persistence, effort, intensity, and willingness to accept a challenge).

Concentration is another vital component of athletic mental energy. To successfully achieve peak performance in sports, athletes need to block distractions from audiences, referees, media, competition officials, and many others. Specifically, when performing sports skills, individuals need to focus on what is most important for movement execution while ignoring distractions (Moran, 2012). Some elite athletes describe their experience when performing their best as "... feeling completely detached from the external environment and any potential distractions" (Williams et al., 2015). These experiences highlight the importance of concentration for outstanding performance.

The results of nomological validity provide several implications. Specifically, we found athletic mental energy negatively correlated with burnout and life stress. The negative athletic mental energy-burnout relationship can be explained in several ways. According to Smith's (1986) cognitive-affective model of athletic burnout, burnout is the consequence of cognitive appraisal of situational demands and personal abilities/coping resources. It leads to perceived low achievement, emotional and physical exhaustion, and is characterised by low athletic mental energy (i.e., low motivation and vigour). We suggest that future studies examine the influence of athletic mental energy on burnout.

The relationship between athletic mental energy and life stress is a unique aspect of athletic mental energy research

(e.g., Lu et al., 2018; Chiou et al., 2020). High levels of stress have been linked to an increased risk of injury (Chyi et al., 2023), depression (Risch et al., 2009), decreased performance (Humphrey et al., 2000), and burnout (Lin et al., 2021). Our results add to the research on athletes' stress. Despite this novel finding, whether high mental energy leads to low-life stress or low-life stress causes high mental energy needs to be examined in the future.

Moreover, gender invariance is theoretically meaningful. Despite males and females having differences in biological or psycho-social attributes (Del Giudice, 2015), our study found that there is gender invariance in the AMES-10. Gender invariance implies that both males and females similarly respond to the AMES-10.

Strengths of the Study

This study has several strengths. First, the measurement of psychological energy in sport settings has often relied on composite and multi-dimensional instruments, such as the Profile of Mood States (POMS; McNair et al., 1981), the State Sport Confidence Inventory (SSCI; Vealey, 1986), the Competitive State Anxiety Inventory-II (CSAI-2; Lane et al., 1999), the revised Sport Motivation Scale (SMS-II; Pelletier et al., 2013), and the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). In contrast, the development of the AMES-10 offers a more integrated approach that simultaneously captures the cognitive, affective, and motivational components of competitive mental energy. Compared with the original AMES (Lu et al., 2018), the AMES-10 further considers critical concerns related to item construction within each dimension. Specifically, it addresses methodological issues that can impair the reliability and validity of measurement outcomes, such as the inclusion of both positively and negatively worded items, inconsistencies in response context, and discrepancies in target objects (DeVellis & Thorpe, 2021;

Tourangeau et al., 2000; Roszkowski & Soven, 2010; Zhang et al., 2016). The AMES-10 not only demonstrates strong psychometric properties but also adopts concise and thematically consistent items, facilitating its application in both experimental and survey research while enhancing procedural rigour and research validity.

Second, from a practical standpoint, time efficiency is a key factor influencing individuals' willingness to engage in psychological consultation services. The use of brief instruments helps reduce the time burden, thereby increasing athletes' receptiveness to psychological support (Horvath & R othlin, 2018). Likewise, in research settings, the duration of participant involvement may influence both psychological state and motivation to complete the study. Short-form instruments, such as the AMES-10, contribute to improved participant engagement and reduce the potential adverse effects of time burden on research validity (Koitsalu et al., 2018; Thomas et al., 2022). Therefore, researchers may employ the AMES-10 in both experimental and survey contexts to explore its impact on athletes' cognition, emotions, and behaviours. In applied practice, the AMES-10 also offers a valuable tool for professionals to assess athletes' psychological energy levels during periods of stress, performance decline, or fatigue. Additionally, it can serve as a monitoring index for sport scientists aiming to evaluate training load and psycho-physiological status in relation to mental energy.

Limitations

There are several limitations in our study. First, our participants were all college student-athletes; whether the AMES-10 applies to youth athletes or professional athletes needs to be examined. Further, the AMES-10 is a sport-specific measure developed in the sport context. Whether it can be used for exercisers or sports professionals, such as referees or coaches,

needs further validation. Moreover, we adopted Lu et al.'s (2018) definition and conceptualisation to refine the AMES-10, considering whether the core components of athletic mental energy extend beyond the five factors that need further examination.

Recommendations

It is recommended that researchers employ the AMES-10 in field or laboratory settings to examine its influence on athletes' cognition, emotion, and behaviour. We also suggest that sports scientists use the AMES-10 as a tool to monitor athletes' training loads and psycho-physiological responses, as past research indicates that excessive training loads can increase athletes' anger, anxiety, depression, and fatigue (Raglin et al., 1996). Additionally, sports psychology consultants may utilise the AMES-10 to evaluate athletes' mental energy state when they encounter stress, periods of underperformance, or fatigue. The appendix provides the content and scoring of the AMES-10. We estimate that athletes scoring above 45 on the AMES-10 exhibit high levels of mental energy. In contrast, athletes who score below 25 exhibited low levels of mental energy.

Conclusion

To obtain a concise measure of athletic mental energy, we conducted two studies and developed a 5-factor, 10-item AMES. This is a further refinement and development of the athletic mental energy. We hope that more researchers will use the AMES-10 to examine the influence of athletes' mental energy on cognition, emotion, and behaviour, and explore the relationship between mental energy and sport excellence.

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Statement of Research and Publication Ethics

The work fully complies with APA ethical publication standards and has been approved by the Antai-Tian-Sheng Memorial Hospital Institutional Review Board (TSMHIRB-23-090-B)

Data Availability Statement

Anyone who interested in this paper can obtain research data from correspondence author.

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Appendix

The AMES-10

Directions: Below are 10 statements that describe “ how do you feel right now ” in sports training/competition. Please circle a number that mostly represents your feelings.		Completely not	Hardly ever	A little bit	Much	Very much	Completely so
1	I feel there is an endless energy coming from my body.	1	2	3	4	5	6
2	I feel excited about future competitions.	1	2	3	4	5	6
3	There’s nothing distracting me in competition.	1	2	3	4	5	6
4	I am full of passion to attend my sports.	1	2	3	4	5	6
5	I can execute my sports movements and skills automatically in sports.	1	2	3	4	5	6
6	I am free of distraction during competition and training.	1	2	3	4	5	6
7	I can control all sports movements and skills.	1	2	3	4	5	6
8	Either in competition or training, I feel full of energy.	1	2	3	4	5	6
9	Facing upcoming competitions, I don’t feel anxious.	1	2	3	4	5	6
10	Even facing a tough opponent, I don’t feel anxious.	1	2	3	4	5	6

Note: (a) Vigour=1、 8; (b) Confidence=5、 7; (c) Motivation=2、 4;
 (d) Concentration=3、 6; (e) Calmness=9、 10