The development and validation of the Secondary Exercise Addiction Scale

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Abstract (248/250)

Objectives: Exercise addiction can be secondary to eating disorders, or a primary condition in the absence of another disorder. Currently, to determine secondary exercise addiction, two screening tools must be administered. The aim of this study was to validate a novel screening tool able to stratify between primary and secondary exercise addiction, called the Secondary Exercise Addiction Scale (SEAS).

Methods: Phase 1 (*n*=339) described the statistical reduction of an initial pool of scale items. Phase 2 (*n*=382) used a confirmatory factor analysis (CFA) to examine the robustness of the latent structure. Phase 3 (n=721) determined cut off scores for the eating disorder and exercise addiction sections of the SEAS and determine concurrent reliability with the Exercise Addiction Inventory (EAI) and the SCOFF questionnaires. Phase 4 (*n*=45) determined test-retest reliability.

Results: Phase 1 extracted two components: exercise addiction and eating disorder symptomology, with 11 items retained. The CFA in Phase 2 showed an acceptable fit to the proposed model (Comparative Fit Index=0.93; Tucker Lewis Index=0.91). Phase 3 determined cut off scores of ≥28 (specificity=91.97%), and ≥20 (specificity=96.27%) in the respective exercise addiction and eating disorders sections of the SEAS. The respective sections also correlated well with the EAI (*r*=0.70; *p*=<0.001*)* and the SCOFF (*r*=0.72; *p*=<0.001). Phase 4 showed excellent test-retest reliability (exercise addiction *r*=0.95; *p*=<0.001; eating disorders *r*=0.93; *p*=<0.001).

Conclusion: The SEAS appears to be a valid and reliable tool for measuring primary and secondary exercise addiction. Further studies are warranted to further validate this tool amongst clinical populations.

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Compliance with Ethical Standards: The authors have no conflicts of interest to declare. Ethical approval was sought after and approved by Anglia Ruskin University Sport and Exercise Sciences Departmental Ethics Panel (ESPGR-13 and ESPGR-20). All participants in this study provided their informed consent including the right to withdraw.

Introduction

A person with exercise addiction can be characterised as obsessive and/or compulsive about exercise to an extent where an exerciser can experience several negative experiences[1, 2]. Exercise addiction is not currently an officially recognised behavioural disorder in either the Diagnostic statistical manual of mental disorders (DSM-5) [3] or the International Classification of Diseases [4], mainly because of a lack of research and clinical data to support inclusion. Indeed, it has been widely reported that exercise addiction symptomology commonly exists in the presence of other disorders: notably eating disorders[5–7], with some authors hypothesising that exercise addiction only exists as a symptom of other disorders [8].

Currently there are several tools available to screen for exercise addiction, with the Exercise Dependence Scale[9] (EDS) and the Exercise Addiction Inventory[10] (EAI) being described as 'broadly comparable'[11, 12]. One of the key differences between the EDS and the EAI is their length: with the EDS [13] having 21 items compared to the EAI's six. The number of questions in a scale is likely to affect how questionnaires are used in practice. Indeed, it has been reported that shorter-form questionnaires provide less of a burden on participants[14], and could be useful when time is a limiting factor. Regarding eating disorders, there are several tools available, such as the Eating Attitudes Test (EAT)[15] and the SCOFF questionnaire[16]. Like the exercise addiction tools, consideration needs to be taken as to the practicality of using eating disorder tools in applied settings. For example, the EAT-26 is longer (26 items) than the SCOFF (five items).

Currently, two screening tools need to be administered to determine participants at risk of exercise addiction and eating disorders, which provides both the researcher and practitioner with a wealth of choices as to which tool to use. As previous research has suggested, the creation of one tool able to screen for both is warranted[5]. The creation of a screening tool that is also able to stratify between potential indicated eating disorders, and in so doing stratify between potential primary and secondary exercise addiction, would be beneficial for several reasons, including the ability to quickly and easily determine potential secondary exercise addiction, and refer the individual to treatment/support for pathological eating behaviours, which carry with them significant morbid characteristics[17]. Furthermore, considering that it has been reported that maladaptive exercise could manifest before the development of an eating disorder[18, 19], such a tool could be used to identify people who are at risk of an eating disorder and be referred to treatment before the potential eating disorder becomes clinically significant.

The aim of this study, therefore, was to create and validate a novel short-form screening tool able to stratify exercise addiction and eating disorder status. To achieve this, four phases were conducted, with the following aims:

- Phase 1: To create an initial pool of items and reduce these to a short form questionnaire with two distinct sections - eating disorder pathology and exercise addiction.
- Phase 2: To confirm the underlying latent structure of the newly reduced items.
- Phase 3: To determine sensitivity and specificity of the items against currently available eating disorder and exercise addiction questionnaires and to determine suitable scoring cut offs.
- Phase 4: To determine test-retest reliability of the final measure and assess further concurrent validity with other eating disorder and exercise addiction measurement tools.

Methods

For all phases, ethical approval was obtained from the Anglia Ruskin University Sport and Exercise Sciences Departmental Ethics Panel (ESPGR-13 and ESPGR-20).

Public and patient involvement

There was no public involvement in the design, conduct, reporting, or dissemination plans in this study.

Phase 1

The initial question pool was developed to measure two factors: (a) exercise addiction based on the six components of behavioural addictions (salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse) [20–22], and (b) symptoms of eating disorders, based on the DSM-5 [3] criteria for anorexia and bulimia nervosa (restriction of intake, fear of gaining weight, body image disturbances, recurring episodes of binge-eating, and the use of vomiting, laxatives, medications, and/or fasting to control weight gain). In the initial pool of items, two items related to each factor. Initial content validity was established by consulting a psychometric expert in scale development (DM) and a psychiatrist specialising in the diagnosis and treatment of eating disorders (AM). Each item on the initial pool of 22 items was scored on a Likert scale of 1-6, with higher scores indicating more positive responses to the questions.

For Phases 1, 2 and 3, participants were recruited via social media platforms from 1/3/2020 to 15/6/2020. Participants provided informed consent to prior to taking part in the survey, including the right to withdraw and access to further support if participation invoked distress. To be eligible, participants were required to be adults (>18 years) undertaking >150 minutes of physical activity per week, as per the UK Department of Health guidelines [23]. Broad inclusion criteria were selected because it was desirable for the participants to be as heterogeneous as possible to make the generalisation of results as wide as possible. For Phases 1 and 2, participants were randomised into two groups so that two different pools of participants were used for each phase.

Data analysis

All analyses were conducted using Stata 16[24].To reduce the initial 22 questions to an 11-item short-form scale, a principal component analysis (PCA) was conducted. To aid

interoperability of the resulting factor loadings, an orthogonal rotation was employed. The initial suitability of the PCA was assessed prior to analysis by (a) correlations of >0.3, (b) a Kaiser-Meyer-Olkin (KMO) measure of >0.7, and (c) a statistically significant Bartlett's test of sphericity. Components were identified by assessing a scree plot for an inflection point: because the initial pool of questions were based on two theoretical models, a two-factor solution was hypothesised. Questions that loaded the highest on their respective factors were retained in the final scale.

Results

A total of 721 participants completed the survey, with 82.4% (n=594) female, a mean age of 35.60 years (SD=11.93) and a mean BMI of 23.74 (SD=4.10). This sample were then randomised into two sub-groups: Phase 1 and Phase 2. In the Phase 1 group there was a total of 339 participants, with a mean age of 35.89 (SD=11.55), mean BMI of 23.50 (SD=4.18), and 82.0% of participants were female. Full demographic information for all studies are shown in Table 1.

Table 1: Descriptive statistics for all phases

	Phase 1	Phase 2	Phase 3[a]	Phase 4		
n	339	382	721	45		
Gender (female)	82.0% (278/339)	82.7% (316/382)	82.4% (594/721)	62.2% (28/45)		
Age (years)	35.89 (11.55)	35.35 (12.27)	35.60 (11.93)	32.87 (7.80)		
BMI[b]	23.50 (4.18)	23.95 (4.02)	23.74 (4.10)	23.96 (3.49)		
EAI[c] total score	21.43 (4.43)	21.37 (4.36)	21.40 (4.39)	NA		
SCOFF total score	1.35 (1.29)	1.25 (1.33)	1.30 (1.31)	NA		
EDS-R total score	NA	NA	NA	64.60 (20.57)		
EAT-26 total score	NA	NA	NA	11.02 (11.47)		
				First administration (*n*=45)	**Second administration (*n*=31)**	**Intra-class correlation (95% CI; p-value)**
SEAS exercise addiction score	NA	NA	NA	21.93 (5.98)	20.68 (6.91)	0.933 (0.860-0.968; *p*=<0.001)
SEAS eating disorder score	NA	NA	NA	13.53 (6.41)	12.61 (5.48)	0.949 (0.893-0.975; *p*=<0.001)

All statistics are reported as mean (SD) unless otherwise stated; BMI=Body Mass Index; EAI=exercise addiction inventory. EDS-R=Exercise Dependence Scale - revised; EAT-26=Eating Attitudes Test; SEAS-Secondary Exercise Addiction Scale

[a]=Note that Phase 3 used all participants from Phases 1 and 2.

The PCA correlation matrix showed that all variables had at least one correlation coefficient greater than 0.3. The KMO measure was 0.868, and Bartlett's test of sphericity was statistically significant ($X^2(231)=4170.831$; $p < 0.001$), indicating that the included data was factorizable.Although six components had an Eigenvalue of >1, the scree plot (see

Supplementary Figure 1) indicated that there was an inflection point after two components, and a two-component solution met the interpretability criteria, therefore two components were extracted: one for exercise addiction and one for eating disorder symptomology. The fully rotated component matrix with which items were retained for the final version of the SEAS can be found in Table 2.

Table 2: Rotated structure matrix with direct oblimin rotation for the two-factor model (items in bold were retained)

Construct		**Exercise addiction**	**Disordered eating**
Restriction of intake	***'I often restrict my intake of food'***	-	**0.61**
	'I limit the number of calories I eat'	-	0.53
Fear of gaining weight	*'I'm afraid of putting on weight'*	-	0.59
	'I feel that I look fat'	-	**0.80**
Body image disturbance	***'I hate the way my body looks'***	-	**0.66**
	'People often say I look too thin'	-	-0.12
Recurring episodes of binge-eating	***'I often binge-eat on foods and feel that I cannot stop'***	-	**0.71**
	'I often eat lots of food in a short space of time'	-	0.69
Use of vomiting, laxatives, diuretics, medications, fasting to control weight gain	***'I have used medication, (e.g. laxatives, diuretics) fasting (not eating), or have vomited to help me lose weight in the last 3 months'***	-	**0.61**
	'Medication, fasting, and/or vomiting after meals helps me to lose weight'	-	0.62
Salience	***'Exercise is my number 1 priority'***	**0.73**	-
	'I don't think I would manage very well without exercise'	0.69	-
Mood modification	***'I find I need to exercise to improve my mood'***	**0.72**	-
	'Exercise is the only way I can deal with stress'	0.72	-
Tolerance	***'I feel I need to do more exercise to get the same buzz'***	**0.71**	-
	'The more exercise I do, the more I need to keep doing to get the same feelings'	0.67	-
Withdrawal	*'When I take a break from exercise, I feel irritable and moody'*	0.72	-
	'I dread having to take a break from exercise (e.g. due to injury/illness/social commitments)'	**0.76**	-
Conflict	*'I often find my exercise habits affect my relationships (e.g. family/friends/partners)'*	0.64	-
	'I neglect friends/family/relationships because I want to exercise'	**0.65**	-
Relapse	***'The urge to exercise is stronger than my want to do less exercise.'***	**0.76**	-
	'If I were to stop exercising, I would start again at the same level as before.'	0.62	-

Discussion

The aim of Phase 1 was to report how questions were conceptualised and described how the 22 items were reduced to an 11-item, short-form scale. After the PCA was conducted, two emerging constructs were extracted: exercise addiction and disordered eating. From here, the scale was reduced to 11 items (one item per theoretical construct), retaining the respective construct item that had the highest factor loading. Moreover, as well as strong statistical support, the extracted two-component model also has strong conceptual support considering that these matched the two components that the scale was based on.

Phase 2

The aim of Phase 2 was to confirm the latent two-factor structure of the reduced SEAS, based on the factors that were extracted in Study 1. In brief, the proposed model contains two latent factors: exercise addiction and eating disorder symptomology.

Data analysis

To confirm the proposed structure, a maximum likelihood confirmatory factor analyses (CFA) was conducted on the Phase 2 sample of participants, against the two-factor model. The CFA yields several fit indexes that allow the assessment of fit against proposed models in order to assess which latent variables best explain the observed variables [25]. Of these fit indices, several were used to deemed if the data were an acceptable fit in the current study, using the guideless suggested by Hu and Bentler (1999), including (a) comparative fit index (CFI) > 0.90; (b) Tucker-Lewis index (TLI) >0.90; and (c) root mean square error of approximation (RMSEA) <0.08.

Results

The mean age for participants in Phase 2 was 35.35 (SD=12.27), mean BMI was 23.95 (SD=4.02), and 82.7% of participants were female. Full demographic information is shown in Table 1. The CFA (X^2=147.896) of the proposed model yielded a CFI of 0.933, TLI of 0.914, and a RMSEA of 0.08, indicating an acceptable fit to the model. Standardised factor loadings are shown in Table 3 and Figure 1.

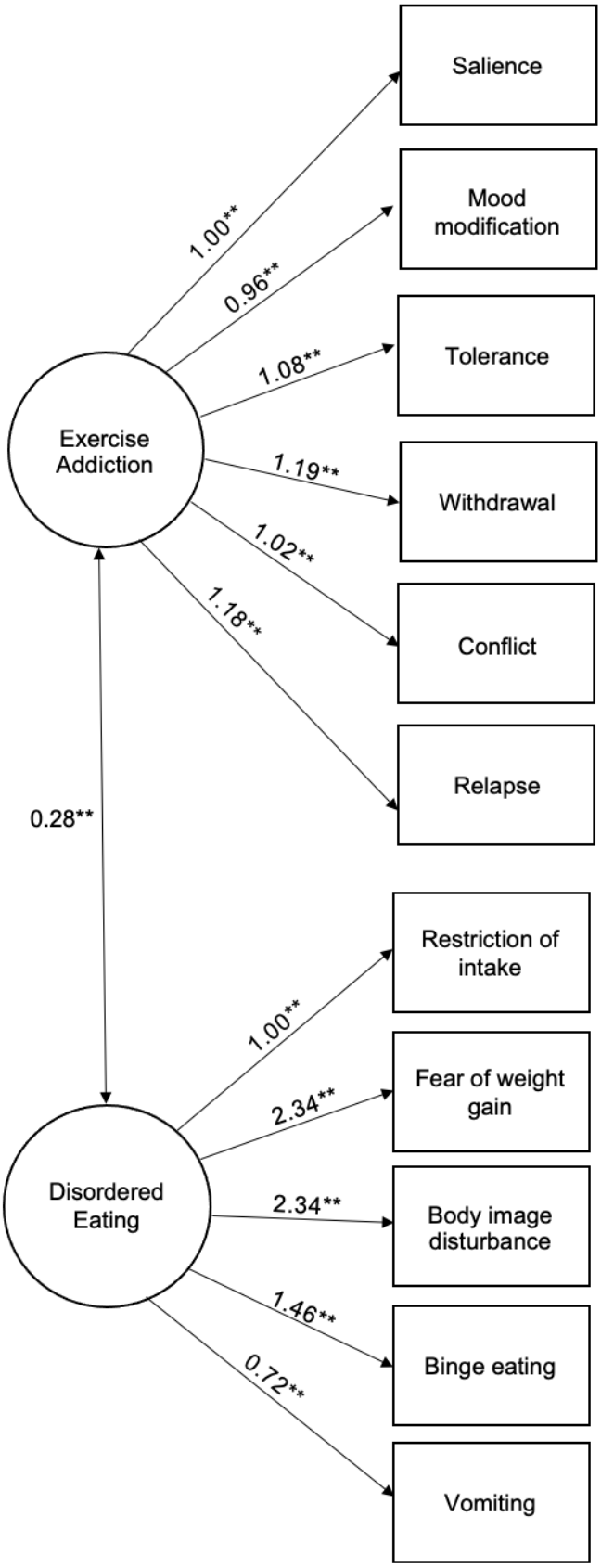

Figure 1: Confirmatory factor analysis of the proposed Secondary Exercise Addiction Scale constructs before modification (p=<0.001)**

Table 3: Standardized factor loadings of the Secondary Exercise Addiction Scale

Construct	Items	Factor loadings (95% CI)	Standardized error
Disordered Eating			
Restriction of intake	'I often restrict my intake of food'	1 (constrained)	
Fear of gaining weight	'I feel that I look fat'	2.34 (1.71-2.97)	0.32
Body image disturbance	'I hate the way my body looks'	2.34 (1.71-2.97)	0.32
Recurring episodes of binge-eating	'I often binge-eat on foods and feel that I cannot stop'	1.46 (1.02-1.90)	0.22
Use of vomiting, laxatives, diuretics, medications, fasting to control weight gain	'I have used medication, (e.g. laxatives, diuretics) fasting (not eating), or have vomited to help me lose weight in the last 3 months'	0.72 (0.44-1.00)	0.14
Exercise Addiction			
Salience	'Exercise is my number 1 priority'	1 (constrained)	
Mood modification	'I find I need to exercise to improve my mood'	0.96 (0.81-1.11)	0.78
Tolerance	'I feel I need to do more exercise to get the same buzz'	1.08 (0.91-1.25)	0.87
Withdrawal	I dread having to take a break from exercise (e.g. due to injury/illness/social commitments)'	1.19 (1.01-1.37)	0.92
Conflict	'I neglect friends/family/relationships because I want to exercise'	1.02 (0.85-1.19)	0.88
Relapse	'The urge to exercise is stronger than my want to do less exercise.'	1.18 (1.00-1.36)	0.96

Discussion

The aim of Phase 2 was to confirm the latent structure of the scale, based on the two-component model, with the results showing that the data, based on a different sample of participants as Phase 1, acceptably fitted the proposed model. Although this was unsurprising (given that the items were developed based on two respectively developed models of exercise addiction and disordered eating), the results indicate that the underlying factor structure is robust when tested under different populations and appears to be measuring the same constructs across populations.

Phase 3

The aim of Phase 3 was to determine sensitivity and specificity of the scale against currently available short-form exercise addiction and eating disorder questionnaires, and to determine suitable scoring cut-offs based on these comparisons. A further aim was to determine concurrent validity of the SEAS against currently available short form exercise addiction and disordered eating questionnaires.

Method

Participant recruitment has been described in detail in Phase 1. For this study, the entire sample was used.

Measures

Exercise Addiction

The EAI was used as the tool to measure against the exercise addiction section of the scale. Each question is scored on a Likert scale of 1-5, with a higher score indicating higher risk of exercise addiction. Participants who score □24 are classified as 'at risk' of exercise addiction[10]. The EAI has been shown to have good reliability and validity across physically active populations [10, 26, 27].

Eating disorder symptomology

The SCOFF questionnaire[16] was used as the tool to measure against the eating disorder symptomology section of the scale. The SCOFF is a five-item questionnaire that assess core features of anorexia and bulimia nervosa, with dichotomous answers for each question. The authors defined a total of two or more positive answers as indicative of either anorexia or bulimia nervosa. The SCOFF has shown excellent sensitivity (100%) and specificity (87.5%) against clinically diagnosed eating disorder patients[28].

Data analysis

To determine that the final version of the SEAS gave adequate predictive values two Receiver Operator Characteristic (ROC) curves were plotted against the respective sections of the new scale against the EAI and SCOFF. To further establish concurrent validity, total scores of the respective exercise addition and disordered eating sections of the scale were compared with the total scores from the EAI and SCOFF. Cut off points were determined based on the sensitivity and specificity of the respective sections of the survey against the EAI or SCOFF. Because one of the potential uses of this tool is in primary care settings, it was decided that high specificity be preferential to sensitivity, to reduce the amount of potential false-negative results. To establish concurrent validity, a Pearson's correlation was

used to measure associations between the respective total scores of two sections of the SEAS and the results of the EAI and SCOFF. Internal reliability using a Cronbach's alpha was also assessed.

Results

The mean age of participants was 35.60 years (SD=11.93) with a mean BMI of 23.74 (SD=4.10). Full demographic information is shown in Table 1. The ROC curves yielded excellent areas under the curve (exercise addiction= 0.89 95% CI 0.86-0.91; disordered eating=0.87 95% CI 0.85-0.90). In the exercise addiction section, a cut-off score of ≥28 yielded sensitivity of 62.90% and specificity of 91.97%, and a cut off score of ≥20 in the disordered eating section yielded sensitivity of 46.23% and specificity of 96.27%. See Supplementary Tables 2 and 3 for more information. The total scores of both the exercise addiction and eating disorder sections yielded significant associations with the total scores of the EAI (r = 0.701, *p*=<0.001) and SCOFF (0.717, *p*=<0.001) respectively. Cronbach's alpha was 0.85 (95%CI 0.83-0.86) for the total scale, 0.84 (95% CI 0.82-0.85) for the exercise addiction section and 0.75 (95% CI 0.72-0.78) for the disordered eating section.

Phase 3 Discussion

The aim of Study 3 was to establish concurrent validity and determine the cut offs for the exercise addiction and disordered eating sections of the scale, using already existing short-form exercise addiction and eating disorder screening tools. Each respective ROC analysis confirmed that the sections predict exercise addiction and eating disorder symptomology well against their respective short form tools. Both of Phase 3's reported yielded excellent predictive value. The cut-off score for the exercise addiction section was ≥28, with a specificity of 91%. The cut off score of the eating disorder symptomology section was ≥20, with a specificity of 96%. Although the sensitivity of the disordered section was 46.23%, very high specificity was chosen over sensitivity to limit false negative results. Figure 2 shows the full Secondary Exercise Addiction Scale (SEAS) with scoring instructions.

Figure 2: The Secondary Exercise Addiction Scale

The Secondary Exercise Addiction Scale

	Over the previous three months, how much do you agree or disagree over the following statements?	1 (completely disagree)	2	3	4	5	6 (completely agree)
Section A	1 'Exercise is my number 1 priority'						
	2. 'I find I need to exercise to improve my mood'						
	3. 'I feel I need to do more exercise to get the same buzz'						
	4. 'I dread having to take a break from exercise (e.g., due to injury/illness/social commitments)'						
	5. 'I often find my exercise habits affect my relationships (e.g., family/friends/partners)'						
	6. 'If I were to stop exercising, I would start again at the same level as before.'						
Section B	7. 'I often restrict my intake of food'						
	8. 'I feel that I look fat'						
	9. 'I hate the way my body looks'						
	10. 'I often binge-eat on foods and feel that I cannot stop'						
	11. 'I have used medication, (e.g., laxatives, diuretics) fasting (not eating), or have vomited to help me lose weight in the last 3 months'						
Total score for Section A.....							
Total score for Section B.....							

Scoring for the Secondary Exercise Addiction Scale

		Section A	
		Total score between 6-28	Total score between 29-36
Section B	Total score between 5-20	No exercise addiction or eating disorder risk	Risk of primary exercise addiction
	Total score between 21-30	Risk of eating disorder	Risk of secondary exercise addiction

Phase 4

The aim of Phase 4 was to determine test-retest reliability of the SEAS and to confirm further concurrent validity with longer-form exercise addiction and eating disorder measurement tools.

Methods

For Phase 4, a convenience sample was invited to take part in the study via email. To be eligible participants were required to be adults (>18 years) undertaking >150 minutes of physical activity per week. Participants who took part in this study were then invited to take part in re-test of the SEAS two weeks after completion of the first questionnaire. Participants completed an online battery of questions including measures of age, sex, exercise addiction, eating disorder symptomology, and the SEAS.

Measures

Exercise addiction

The Revised Exercise Dependence Scale (EDS-R) [13] was used as the longer-form tool to measure exercise addiction. The EDS-R is a 21-item questionnaire, with each question scored on a Likert scale of 1-6, with three questions addressing each of the DSM-IV[29] respective criteria for substance abuse (tolerance, withdrawal, continuance, lack of control, reduction in other activities, time, and intention effects). The EDS-R yields three different results: (1) nondependent asymptomatic; (2) nondependent symptomatic; and (3) at risk. The EDS-R has been well validated in active populations and has shown excellent internal reliability in previous studies[13].

Eating disorder symptomology

The Eating Attitudes Test 26 (EAT-26)[15] was used as the longer-form tool to measure eating disorder symptomology. The EAT-26 is a 26-item questionnaire scored on a Likert scale of 1-6. A score of ≥20 is sufficient to be classified as having eating disorder symptomology. The EAT-26 has been well validated in athletic populations [30, 31].

To determine test-retest reliability of the SEAS, two weeks after the completion of the first questionnaire, participants were invited to take part in a second online questionnaire consisting of the SEAS only.

Data analysis

To compare the results of the first and second SEAS answers, an intra-class coefficient (ICC) was conducted, with an *r*=>0.7 being deemed as acceptable [32]. The sample size required for estimating an ICC *r* of 0.7 with 95% confidence interval (CI) and a standard deviation (SD) of 0.2, with estimated 25% dropout rate between the two weeks' questionnaires, for two repeated measures was 35 participants[33], therefore the study aimed to recruit 40 participants. To determine concurrent reliability with the respective sections of the SEAS and the EAT-26 and EDS-R, a Pearson's correlation was conducted.

Results

A total of 45 participants completed the first survey, with 62.2% (n=28) female, a mean age of 32.87 years (SD=7.80), and a mean BMI of 23.96 years (SD =3.49). The second survey yielded a 31 (68%) completion rate. Full demographic information is shown in Table 1.

The intra-class-correlation between the first and second administrations of the eating disorder section of the SEAS was 0.95 (95% CI 0.89-0.98; *p*=<0.001), and the exercise addiction section of the SEAS 0.93 (95% CI 0.86-0.97; *p*=<0.001). The association between the total score of the exercise addiction section and the total score of the EDS-R was 0.718 (*p*=<0.001). The association between the total score of the disordered eating section of the SEAS and the total score of the EAT-26 was 0.721 (*p*=<0.001).

Phase 4 Discussion

The primary aim of Phase 4 was to confirm the test-retest reliability of the SEAS. A secondary aim of Phase 4 was to further confirm the concurrent validity of the SEAS against longer-form exercise addiction and eating disorder screening questionnaires.

The results of the test-retest reliability were 0.95 and 0.93 for the respective eating disorder and exercise addiction sections, indicating excellent reliability[34]. Furthermore, when comparing the scores of the respective sections of the SEAS against longer form exercise

addiction and eating disorder questionnaires, the SEAS yielded excellent concurrent validity, adding evidence that the results from the SEAS are robust when measured against respective longer-form questionnaires.

General Discussion

This study describes the development and validation of a novel screening tool for exercise addiction, that can stratify between exercise addiction with and without indicated eating disorders. When compared to other short-form exercise addiction and eating disorder screening tools, the development of the SEAS has arguably been more rigorous at every stage. For example, both the EAI and SCOFF questionaries do not appear to have item-reduction as a method of determining questions to be included and does not appear to have a confirmatory factor analysis.

The SEAS has potential for several different areas of practice, including in exercise addiction and eating disorder related research. Previous research has shown that exercise addiction appears to have different aetiology in indicated vs. no-indicated eating disorder populations [5, 35–37], and the application of the SEAS could help researchers determine these groups quickly and easily. Furthermore, there is potential for the SEAS to be used in clinical practice, as a tool to identify people with suspected eating disorders - while the SCOFF already exists for this purpose, the SEAS can also identify whether people are at risk of morbid exercise behaviours, potentially informing potential treatments quicker.

The results of this study should be considered within its limitations. Firstly, the eating disorders section of the SEAS was validated against non-clinical populations, therefore its use as a clinical tool is limited. Moreover, women were overrepresented in this sample, which could lead to gender bias in our results. Further study should focus on validation against clinical populations and representative populations. Secondly, because there are no diagnostic criteria for exercise addiction, the results from the exercise addiction section of the SEAS should be used as a continuous variable wherever possible. Further study is required to validate the exercise addiction section of the SEAS in a clinical setting.

Strength and limits

The key strengths of this study is that it utilises a systematic approach to create and validate a questionnaire that is able to stratify exercise addiction with versus without indicated eating disorders. Furthermore, the tool appears to be valid. On key limitation of this study is that the tool has not been validated in clinical populations, so its utilisation as a clinical tool is limited.

What is already known on this subject?

Exercise addiction appears to exist in the presence and absence of eating disorders, however to differentiate between the two, currently two screening tools need to be administered.

What this study adds?

This study describes the creation and validation of a tool that is able to stratify between exercise addiction in the presence or absence of indicated eating disorders using a short-form screening tool. This tool could be used in a variety of practical and research settings.

Conclusion

This study explains the creation and validation of a novel screening tool, the Secondary Exercise Addiction Scale, or SEAS. This tool has 11 items and has been developed to assess symptoms of exercise addiction and eating disorders, respectively using Brown's theory of general addiction and the DSM-5 criteria for eating disorders.

Phase 1 explains how the initial pool of items was developed, and then describes how the initial pool was reduced to for a short-form tool using a PCA. The results of the PCA showed two latent factors - exercise addiction and eating disorders, suggesting that the questions being asked in the SEAS are well suited to the initial aims of their development. Furthermore, most questions in the SEAS load highly onto their respective domains. Phase 2 found that the underlying structure yielded an acceptable fit indicating that the underlying structure was robust. Phase 3 described how the cut-off scores were determined for each section of the SEAS, and determined concurrent reliability against short form exercise addiction and eating disorder questionnaires. Concurrent reliability was further strengthened in Phase 4, finding strong associations between the exercise addiction and eating disorders sections of the SEAS against respective longer-form questionnaires. Furthermore, test-retest reliability was established.

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Supplementary Table 1: Initial pool of questions and corresponding factors

Construct	Question
Eating disorders	
Restriction of intake	I often restrict my intake of food
	I limit the number of calories I eat
Fear of gaining weight	I'm afraid of putting on weight
	I feel that I look fat
Body image disturbance	I hate the way my body looks
	People often say I look too thin
Recurring episodes of binge-eating	I often binge-eat on foods and feel that I cannot stop
	I often eat lots of food in a short space of time
Use of vomiting, laxatives, diuretics, medications, fasting to control weight gain	I have used medication, (e.g., laxatives, diuretics) fasting (not eating), or have vomited to help me lose weight in the last 3 months
	Medication, fasting, and/or vomiting after meals helps me to lose weight
Exercise addiction	
Salience	Exercise is my number 1 priority
	I don't think I would manage very well without exercise
Mood modification	I find I need to exercise to improve my mood
	Exercise is the only way I can deal with stress
Tolerance	I feel I need to do more exercise to get the same buzz
	The more exercise I do, the more I need to keep doing to get the same feelings
Withdrawal	When I take a break from exercise, I feel irritable and moody
	I dread having to take a break from exercise (e.g., due to injury/illness/social commitments)
Conflict	I often find my exercise habits affect my relationships (e.g., family/friends/partners)
	I neglect friends/family/relationships because I want to exercise
Relapse	The urge to exercise is stronger than my want to do less exercise.
	If I were to stop exercising, I would start again at the same level as before.

Supplementary Table 2: Sensitivity and specificity for potential cut off scores for the exercise addiction section of the Secondary Exercise Addiction Scale.

	Cut off score	Sensitivity	Specificity
No risk of exercise addiction	20	95.97%	49.05%
	21	94.76%	54.76%
	22	92.34%	61.31%
	23	90.73%	69.34%
	24	86.69%	74.42%
	25	83.47%	79.92%
	26	77.42%	84.99%
	27	69.76%	87.95%
At risk of exercise addiction	**28**	**62.90%**	**91.97%**
	29	54.44%	94.29%
	30	45.97%	96.19%
	31	36.29%	97.89%
	32	25.00%	98.73%

Supplementary Table 3: Sensitivity and specificity for potential cut off scores for the disordered eating section of the Secondary Exercise Addiction Scale.

	Cut off score	Sensitivity	Specificity
No indicated eating disorder	14	88.01%	68.76%
	15	83.56%	76.92%
	16	76.37%	83.68%
	17	67.81%	87.65%
	18	61.99%	91.14%
	19	52.40%	94.64%
Indicated eating disorder	**20**	**46.23%**	**96.27%**
	21	39.38%	97.90%
	22	29.45%	99.07%
	23	23.97%	99.53%
	24	18.15%	99.53%
	25	15.75%	99.77%
	26	9.93%	99.77%

Supplementary Figure 1: Scree plot for principal component analysis for the initial pool of 22 items.