Appetite 200 (2024) 107516

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

The development and validation of the food insecurity physical activity concerns scale

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ARTICLE INFO

Keywords:
Food insecurity
Physical activity
Exercise
Obesity

ABSTRACT

Food insecurity – defined as having limited access to nutritious foods – is linked with obesity. Previous research has also shown that food insecurity is associated with lower levels of leisure-time physical activity (physical activity performed outside of essential activities). This association may occur in part due to concerns about preserving levels of energy during times of food shortage. Currently, no scale exists which measures this construct. Therefore, we aimed to develop and validate such a scale – the food insecurity physical activity concerns scale (FIPACS). Participants (N = 603, individuals with food insecurity = 108) completed an online survey, consisting of the FIPACS, the International Physical Activity Questionnaire short-form (IPAQ), the restraint subscale of the Dutch Eating Behaviour Questionnaire (DEBQ), the amotivation subscale of the Behaviour Regulation In Exercise Questionnaire-2 (BREQ-2), and the Behavioural Inhibition System/Behavioural Approach System Reactivity scale (BIS/BAS) to assess convergent and divergent validity. An exploratory factor analysis revealed a four-factor model of the FIPACS - namely 'Concerns relating to hunger', 'Concerns of replenishment and calories', 'Concerns of physiological effects of exercise' and 'Compensatory behaviours' which was verified through a confirmatory factor analysis. To assess test-retest reliability, 100 participants completed the FIPACS again two weeks later. The FIPACS had good internal, test-retest reliability and divergent validity. However, there was limited evidence of convergent validity. Future studies could incorporate this scale when investigating the association between food insecurity and physical activity.

1. Introduction

Food insecurity – defined as limited and unstable access to nutritious foods – is a global issue. A substantial number of households in the UK and other industrialised countries live in poverty, struggle to buy food and depend on food banks (Food Foundation, 2024; Loopstra et al., 2015; Trussell Trust, 2021). For example, recent estimates show that 14.8% of the UK population experience either moderate or severe food insecurity (Food Foundation, 2024). Food insecurity is a major public health concern and is reliably associated with both mental and physical negative health outcomes, including depression (Leung et al., 2015), diabetes (Seligman et al., 2012), and a poor diet quality (Hanson & Connor, 2014).

Food insecurity is also positively associated with obesity levels (Dhurandhar, 2016; Morales & Berkowitz, 2016). Explanations of this finding include the insurance hypothesis (Nettle et al., 2017). This hypothesis argues that when living in an environment where access to food is unstable (a characteristic of living with food insecurity), evolutionary mechanisms designed to maximise the chance of survival - namely consumption and storage of energy - become active and work as a buffer to combat future starvation. Evidence in support of this has demonstrated that in non-human animals, when food availability becomes unstable, weight and fat stores increase (Andrews, Zuidersma, Verhulst, Nettle, & Bateson, 2021), as does energetic efficiency (Bateson et al., 2021).

In addition to changes in dietary behaviour, food insecurity is also negatively associated with physical activity (Bruening et al., 2018; Dhurandhar, 2016; Gulliford et al., 2006; Lee & Cardel, 2019; Martinez

Abbreviations: FIPACS, (Food Insecurity Physical Activity Concerns Scale); IPAQ, (International Physical Activity Questionnaire); MET, (metabolic equivalent of task); BMI, (body mass index); DEBQ, (Dutch Eating Behaviour Questionnaire); BREQ-2, (Behavioural Regulations in Exercise Questionnaire-2); BIS/BAS, (Behavioural Inhibition System/Behavioural Approach System).

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https://doi.org/10.1016/j.appet.2024.107516
Received 7 December 2023; Received in revised form 24 April 2024; Accepted 23 May 2024
Available online 25 May 2024

et al., 2019; To et al., 2014). For example, in one observational study, Bruening et al. (2018) found that food insecurity was negatively associated with engagement in healthy physical activity habits on campus in a sample of first-year undergraduate students. Gulliford et al. (2006) showed that in a sample of 16-year-old students from Trinidad, food insecure individuals were more likely to spend their free time participating in activities which involved little physical effort, compared with food secure individuals. To et al. (2014) demonstrated that in a sample of US adults, food insecurity was associated with lower odds of adhering to physical activity. These findings are consistent with the association between physical activity and socioeconomic status (SES) whereby individuals from low SES backgrounds have lower physical activity levels, however this association appears to be most commonly observed when measuring leisure-time physical activity (activities such as exercise, sports, walking for recreation, and any other physical activity performed outside of essential activities), but not other domains of physical activity (Stalsberg & Pedersen, 2018).

Previous explanations for lower physical activity levels in low SES groups (a construct related to food insecurity) are wide-ranging. Taking a social ecological model approach, factors relating to the individual level (e.g., psychosocial factors), the microsystem level (e.g., social support), mesosystem level (e.g., community engagement, urban planning), exosystem (e.g., work-life integration), and macrosystem (e.g., financial constraints) have been identified as contributing to a reduced level of physical activity in those with low SES (Rawal et al., 2020). Individual-level factors have been implicated in the reduction of physical activity in those with food insecurity. Building on the insurance hypothesis, previous researchers have postulated that, as an extension of this model, individuals with food insecurity may wish to minimise energy expenditure by limiting the amount of physical activity they perform, in order to preserve energy (Lee & Cardel, 2019). To date, research which has tested this suggestion is limited, however a recent randomised controlled trial investigated the effect of experimentally induced subjective social status on physical activity (Lee et al., 2022). In this study, consisting of a sample of Hispanic adolescents, participants were randomly allocated to experience either high or low subjective social status (induced by completing a rigged game of Monopoly). Findings revealed that experimentally manipulated social status did not affect moderate-to-vigorous physical activity (MVPA) and sedentary behaviour.

Although currently no quantitative evidence supports the suggestion that individuals with food insecurity may limit their physical activity levels due to energy preservation concerns, findings from qualitative research have identified the presence of energy preservation concerns within individuals with food insecurity (Puddephatt et al., 2020). In this study, individuals who used foodbanks reported behaviours indicative of preserving energy and minimising activity as a strategy to cope with food insecurity (Puddephatt et al., 2020). Taken together, existing evidence suggests that individuals with food insecurity may consider physical activity levels in response to energy preservation, however research which has tested this directly, is limited.

In light of this gap in the literature, the current study builds upon these initial findings and theoretical suggestions which link food insecurity, physical activity, and energy preservation together. Using an online survey, the present study aimed to develop and validate a self-report scale which captures concerns about performing physical activity in the context of food insecurity. The scale focusses solely on one domain of physical activity – leisure time physical activity, this was for two main reasons. Firstly, given the previously mentioned evidence that the association between socioeconomic status and physical activity is most consistently associated with leisure-time physical activity (Stalsberg & Pedersen, 2018) and given that food insecurity is related with a lower socioeconomic status, we may expect physical activity levels to be lowest in the leisure-time domain. Secondly, performing physical activity in certain domains may be largely unavoidable for some individuals (e.g., a physically demanding job may necessitate performing a high level of work-based physical activity, despite having no desire to expend energy). However, leisure-time physical activity is a domain of physical activity which would allow an individual who is conscious of preserving energy levels, to consciously restrict the amount of leisure-time physical activity performed as this type of physical activity is typically performed recreationally.

A large (but not exclusive) focus of the scale was to capture concerns about energy preservation. Additionally, the scale also aimed to capture other behaviours and concerns which may affect physical activity levels, namely, concerns relating to the physiological effects of performing physical activity. Given that food insecurity is linked with poor diet quality (Hanson and Connor, 2014), food insecure individuals may experience negative physiological effects, such as elevated levels of physical fatigue, known to be linked with diet (e.g., Ivy, 1999) after completing physical activity to a greater extent than food secure individuals, the experience of which may in turn produce greater concerns about performing leisure-time physical activity.

2. Methods

2.1. Participants

Participants (N = 603) completed an online survey hosted on Qualtrics. Participants were recruited via two strategies. Firstly, participants were recruited via Prolific (an online participant recruitment platform). Our second recruitment strategy was via social media and word-of-mouth. The inclusion criteria were the following, participant must: be living in the UK, be aged 18 or over, have no history of or current eating disorder(s), be fluent in English, and be physically capable to complete physical activity (such as sport, exercise, walking for recreation). This final criterion was included to ensure that participants did not produce low scores on the scale simply because they were unable to perform this type of physical activity. We did not set out to recruit individuals with food insecurity only. This was to ensure that we achieved a sample with a wide range of food insecurity scores, as we anticipated that food insecurity scores would be related to scores on our scale. Obtaining a sample with this wide range of scores would allow us to determine the validity of our scale by performing correlational analyses with other variables (see data analysis section).

Participants who completed the survey through Prolific were reimbursed for their time. Those who completed the survey outside of Prolific were entered into a prize draw to win one of 2 x £25 Amazon vouchers. The study was approved by the University of Liverpool Research Ethics Committee (approval code: 11336). The study protocol and analysis plan were pre-registered: https://osf.io/x53vg/.

2.2. Measures

Food Insecurity Physical Activity Concerns Scale (FIPACS). An initial pool of 22 self-devised items was created to capture different behaviours relating to concerns about performing leisure-time physical activity specifically relevant to those with food insecurity. This was done by reviewing literature on food insecurity and physical activity, and considering different aspects of food insecurity and how they may be applied to physical activity levels. Broadly, items in the pool focus on energy preservation concerns within the context of physical activity within three themes. Firstly, as measures of household food insecurity focus largely on a lack of ability to buy foods (United States Department of Agriculture, 2012), several of the items focussed on concerns of energy replenishment after performing physical activity (e.g., I worry if I will be able to afford to buy food after performing physical activity). Secondly, items also focussed on concerns surrounding the physiological effects of performing physical activity (e.g., I worry about having a hunger I cannot satisfy after performing physical activity). This may be a more pronounced concern for those with food insecurity due to a lack of access to foods but also because food insecurity is linked with poorer diet

quality (Hanson & Connor, 2015), which may produce negative physiological effects experienced from performing physical activity. Thirdly, we also included items which focussed on compensatory behaviours in response to performing physical activity (e.g., I consciously reduce levels of physical activity in the hours after performing physical activity). These items were included to capture situations where an individual may have performed leisure-time physical activity or may plan to perform leisure-time physical activity in the future but may be motivated to limit their physical activity before and/or after this, to limit energy expended. Responses were scored on a 5-point Likert scale, ranging from 'Strongly disagree' to 'Strongly agree'. Higher scores are indicative of greater concerns of performing physical activity.

Household food insecurity. The 10-item United States Department of Agriculture (USDA) Household Food Insecurity survey module was used (United States Department of Agriculture, 2012). These items measure the frequency with which participants had difficulties in acquiring food due to a lack of money within the last 12 months. Responses of "Often true", "Sometimes true", "Almost every month", "Some months but not every month", and "Yes" were scored as 1, all other responses were scored as 0. Scores ranged from 0 (low food insecurity) to 10 (high food insecurity). The USDA also provides guidance for categorising scores as food insecure and food secure: scores 0–2 can be described as 'food secure' whereas scores 3–10 can be described as 'food insecure'. Internal reliability of this survey for the total current sample was $\omega_t = 0.93$.

Dutch Eating Behaviour Questionnaire (DEBQ; van Strien et al., 1986) restraint subscale. This subscale consists of 10 items which measure concerns of dietary restraint. Internal reliability for the total current sample was $\omega_t = 0.93$.

International Physical Activity Questionnaire short-form (IPAQ; Craig et al., 2003). Participants reported the frequency (number of days in the last 7 days) and amount of time spent in a day which they engaged in three levels of physical activity: walking, moderate physical activity, and vigorous physical activity. The metabolic equivalent of task (MET) for each level of physical activity was calculated and multiplied by the duration and frequency of the physical activity – expressed as MET-minutes per week (MET-min/wk). The MET-min/wk scores for the three levels were then summed and presented as a measure of total physical activity. In line with guidelines (IPAQ, 2005), scores were excluded where the combined amount of time for walking, moderate, and vigorous exercise exceeded 960 min. Further, responses of less than 10 min of each activity were re-coded as zero. Lastly, walking, moderate, and vigorous times which exceed 180 min were re-coded to 180 min. The short-form version of the IPAQ was used instead of the long-form in order to reduce participant burden, due to the substantially greater length of the long-form version.

Behavioural Regulations in Exercise Questionnaire-2 (BREQ-2; Markland & Tobin, 2004) amotivation subscale. Participants were asked four questions relating to amotivation within the context of exercise (e.g., "I think exercise is a waste of time"). Internal reliability for the total current sample was $\omega_t = 0.95$.

Demographic questions. Participants self-reported their gender, age, household income, equivalised household income (household income which is adjusted for household size and composition (Office for National Statistics, 2015) (averages and frequency counts are presented in Table 1). Participants also reported their ethnicity and highest education qualification (frequency counts are reported in the supplementary materials).

Behavioural Inhibition System/Behavioural Approach System Reactivity (BIS/BAS; Carver & White, 1994). This questionnaire consists of 20-items which assesses the Behavioural Inhibition System (BIS) and the Behavioural Approach Systems (BAS). The measure provides one total BIS score and three scores for each of the three BAS subscales: Drive, Fun seeking, and Reward Responsiveness. Internal reliability for the total current sample was: BIS: $\omega_t = 0.89$, BAS Drive: $\omega_t = 0.81$, BAS Fun seeking: $\omega_t = 0.78$, BAS: Reward Responsiveness $\omega_t = 0.74$.

Table 1
Participant Characteristics (mean ± SD or frequency counts) split by analysis group.

	Exploratory (N = 220)	Confirmatory (N = 383)	Total (N = 603)
DEBQ Restraint (out of 5)[a]	2.72 ± 0.84	2.68 ± 0.83	2.70 ± 0.83
BMI (kg/m^2)[b]	26.97 ± 7.52	26.35 ± 5.90	26.57 ± 6.53
USDA Total Score (out of 10)	1.22 ± 2.41	1.20 ± 2.39	1.21 ± 2.40
Food Insecurity Status (Insecure/Secure)	42/178	66/317	108/495
Gender (Male/Female/Non-binary)[c]	96/116/1	173/198/5	269/314/6
Age (years)[d]	44.12 ± 15.18	46.41 ± 21.43	45.59 ± 19.42
IPAQ MET Total[e]	4,312.11 ± 3,375.07	4,255.17 ± 3,414.71	4,275.58 ± 3,396.99
Household Income[f]	£43,378.16 ± £29,306.10	£47,926.62 ± £51,410.11	£46,281.76 ± £44,721.62
Equivalised Household Income[g]	24,406.61 ± 16,859.43	27,037.14 ± 24,033.45	26,085.86 ± 21,735.98
FIPACS (out of 80)	33.70 ± 11.42	31.77 ± 11.24	32.47 ± 11.34
BREQ-2 amotivation (out of 4)[h]	0.45 ± 0.65	0.45 ± 0.76	0.45 ± 0.72

[a] Two data points missing from the exploratory and confirmatory samples.
[b] Twelve data points missing from the exploratory sample, ten missing from the confirmatory sample.
[c] Seven data points missing from the exploratory sample, seven missing from the confirmatory sample.
[d] Eight data points missing from the exploratory sample, seven missing from the confirmatory sample.
[e] Nineteen cases and 25 cases removed due to exceeding 960 min in the exploratory and confirmatory samples, respectively, one additional data point is missing from the exploratory sample.
[f] Seven cases each from the exploratory and confirmatory samples are missing.
[g] Seven cases missing from the exploratory sample and confirmatory sample each.
[h] Two cases missing from the exploratory sample, one case missing from the confirmatory sample.

2.3. Procedure

All participants completed the survey online, hosted on Qualtrics. Participants who were recruited from outside of Prolific completed a reCAPTCHA in order to prevent bots and malicious programs from completing the survey (this was not required for participants recruited via Prolific). Participants provided informed consent and then completed the IPAQ, BIS/BAS, USDA Household Food insecurity 10-item module, FIPACS, BREQ-2; amotivation subscale, DEBQ restraint scale, ethnicity, education level, household income, number of adults and children aged above and below the aged of 14 living in their household (to calculate equivalised household income), gender, weight and height, and debrief. Two attention checks were embedded in the survey, both asking participants to select a particular response. One of these checks was embedded within the FIPACS, and the other within the BIS/BAS. A randomly selected subset of participants (N = 100) who completed the survey via Prolific were invited to complete part 2. They did this 2 weeks after completing part 1. Part 2 consisted of the FIPACS and debrief only.

2.4. Data analysis

2.4.1. Analysis sample

Participants were excluded if they failed both attention checks within the survey, however zero participants failed both attention checks.

2.4.2. Pre-analysis checks

Scale items were assessed based on skewness and kurtosis. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) statistic. Bartlett's test of sphericity was conducted to determine whether correlations between items were large enough to perform an exploratory factor analysis. We also checked whether any item had a correlation coefficient of less than 0.2 for all other items within the scale (i.e., whether an item was weakly correlated with all other items).

2.4.3. Exploratory factor analysis

An exploratory factor analysis was performed in order to generate factor structures from the scale items. For this analysis, 220 participants of the full sample were randomly selected for inclusion in the exploratory factor analysis. The sample size was chosen based on recommendations that for exploratory factor analysis, there should be at least 5 to 10 observations per item (Comrey & Lee, 2013). Therefore, a sample size of 220 was adequate as the number of items identified to be included in the analysis for the FIPACS was 22. In order to identify an initial factor solution, a parallel analysis was performed and a scree-plot was produced. An exploratory factor analysis with an oblimin rotation was performed (this was because factors were assumed to correlate with each other). Items with a factor loading below 0.40 (Osborne & Costello, 2009) or with loadings greater than 0.35 for more than one factor were removed (Kiffin-Petersen & Cordery, 2003). Items which produced a low item-total correlation (<0.40) (Gleim & Gleim, 2003; Ruddock et al., 2017) and items which did not share a similar conceptual meaning with other items in a factor were also removed (O'Rourke & Hatcher, 2013). The analysis was performed using the 'paran' and 'psych' packages in R.

2.4.4. Confirmatory factor analysis

A confirmatory factor analysis was conducted on the factor structure derived from the exploratory factor analysis in order to determine the model fit of this factor structure. A total of 383 participants from the full sample were included in the confirmatory factor analysis, none of these participants were included in the exploratory factor analysis. Sample size for the confirmatory factor analysis was determined by including all participants who had not been included in the exploratory factor analysis – there was no upper limit to the target sample size for the confirmatory factor analysis. Our sample size falls within the recommended range of participants for conducting confirmatory factor analysis (Mundfrom et al., 2005).

Due to the non-normality of responses to the items, a maximum likelihood estimator with a Satorra-Bentler correction was used to fit the model. Model fit was assessed by examining the normed χ^2 statistic, Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Residual (SRMR). Interpretations of these statistics are the following: normed χ^2 between 1 and 5 is considered an acceptable model fit (Schumacker & Lomax, 2004). CFI values above 0.90 are deemed acceptable, RMSEA value indications are <0.05 for good fit, between >0.05 and < 0.08 for a fair fit, between >0.08 and 0.10 for mediocre fit and >0.10 for a poor fit (Hu & Bentler, 1999; MacCallum et al., 1996). Lastly, for SRMR, values < 0.08 are considered a good fit (Hu & Bentler, 1999). We also inspected modification indices and, if equal to or greater than ten, covariance pathways were added between error terms (only when these made conceptual sense and items loaded onto the same factor). The analysis was performed using the 'Lavaan' package in R.

2.4.5. Internal reliability

Internal reliability was assessed for each factor of the FIPACS (and also for all FIPACS items combined) using McDonald's omega (total and hierarchical, respectively).

2.4.6. Convergent and divergent validity

Using correlational analyses, convergent validity was assessed by examining whether FIPACS scores were negatively correlated with IPAQ scores and DEBQ restraint scores. This analysis was performed because firstly, FIPACS scores would be expected to be negatively correlated with IPAQ scores as greater IPAQ scores are indicative of greater physical activity, whereas greater FIPACS scores indicate greater concerns to perform physical activity. Secondly, we may expect a negative correlation between FIPACS scores and restraint scores because some behaviours and concerns measured by the FIPACS (e.g., concerns of a calorie deficit) may be the opposite type of behaviour to someone who has high dietary restraint (characterised as maintaining weight and/or avoiding weight gain, which may produce a lack of desire to preserve calories). Therefore, this type of person is unlikely to show concerns of a calorie *deficit* or display *reduced* levels of physical activity, as these individuals are driven to avoid a calorie *surplus* and may *increase* levels of physical activity, to maintain their weight.

We also tested for divergent validity by examining whether FIPACS scores showed no correlation with scores on the BIS/BAS scale and the amotivation subscale of the Behavioural Regulations in Exercise Questionnaire-2 (BREQ-2; Markland & Tobin, 2004). We selected the BIS/BAS scale as previous studies which have validated food-related measures have used the BIS/BAS scale to assess divergent validity (Ruddock et al., 2017). We have selected the amotivation subscale of the BREQ-2 as we predict that the FIPACS will capture concerns about physical activity, which we expect to be separate and uncorrelated to amotivation of performing exercise. Correlational analyses were performed on SPSS v.29.

2.4.7. Test-retest reliability

100 participants from the Prolific pool who completed part 1 were randomly selected to complete the FIPACS two weeks after part 1. For these 100 participants, we calculated the intra-class correlation coefficients between scores on the FIPACS during part 1 and part 2 of the study. A score of 0.60 or greater is indicative of good test-retest reliability (Cicchetti, 1994).

3. Results

3.1. Exploratory factor analysis (sample 1)

The Kaiser-Meyer-Olkin measure of sample adequacy was acceptable (KMO = 0.928). Bartlett's test of sphericity confirmed that the correlations between items were sufficiently large for factor analysis (χ^2 (231) = 2902.05, $p < 0.001$). None of the items had a correlation coefficient of less than 0.2 with all other items within the scale (i.e., no items were weakly correlated with all other items). Horn's parallel analysis indicated that there were four factors within the dataset. An exploratory factor analysis revealed a clear 4-factor solution. Of the original 22 items, six were removed. Two items were removed because of multiple loadings >0.35 – (items 11 and 15), one item was removed because of a factor loading below 0.40 (item 10). A further three items (items 2, 3, and 4) were removed due to a lack of conceptual meaning with other items in their factor. This is because Items 2 and 3 loaded onto factor 3, this factor reflects concerns relating to appetite (e.g., hunger and fullness), whereas items 2 and 3 do not. Item 4 loaded onto factor 1, however this was the only item related to weight loss concerns, whereas other items focussed on energy replenishment concerns. See Table 2 for list of all items and factor loadings.

Following removal of those six items, the four-factor solution consisted of 16 items – see Table 2 for factor names, factor items, and factor loadings. Together, the four factors explained 59% of variance. Factor 1 explained 18% (Eigenvalue = 2.80), and consists of five items which focus on an individual's concerns of energy/calorie replenishment after performing physical activity (e.g., 'I worry if I will be able to find somewhere to buy the food I need after performing physical activity' and 'I consciously reduce my level of physical activity to control the number of calories I burn'). Factor 2 explained 17% (Eigenvalue = 2.74) and consists of four items which focus on concerns regarding the

Table 2
Factor loadings of all items. Items in italics are those which were deleted for reasons stated in the data analysis section.

Item	Factor Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
Item 1 - I worry about having a hunger I cannot satisfy after performing physical activity.	0.08	−0.07	0.89	−0.01
Item 2 - I worry about having low energy levels after performing physical activity.	−0.23	0.34	0.49	0.30
Item 3 - I worry that performing physical activity might affect my ability to concentrate.	−0.03	0.08	0.60	0.22
Item 4 - I worry about unintentional weight loss after performing physical activity.	0.43	−0.15	0.31	0.13
Item 5 - I have concerns about how hungry I will be after performing physical activity.	0.06	0.19	0.66	−0.13
Item 6 - I plan ways to manage the level of physical activity I perform, in order to conserve energy.	0.15	0.01	0.09	0.45
Item 7 - I worry about having enough food to make me feel full after performing physical activity.	0.31	0.20	0.45	−0.03
Item 8 - I worry if I will be able to find somewhere to buy the food I need after performing physical activity.	0.57	0.06	0.23	−0.04
Item 9 - I worry if I will be able to afford to buy food after performing physical activity.	0.50	0.13	0.13	0.07
Item 10 - I worry about my ability to eat the right amount of nutrients and minerals for my body to recover after performing physical activity.	0.35	0.21	0.18	−0.02
Item 11 - I worry if performing physical activity will make me feel physically bad because I am not able to replenish myself with food.	0.45	0.38	0.23	−0.07
Item 12 - I worry if performing physical activity will make me feel physically drained because of my diet.	0.18	0.75	0.04	−0.12
Item 13 - I worry if performing physical activity will make me feel physically drained because of my usual energy levels.	−0.14	0.73	0.06	0.21
Item 14 - I worry if performing physical activity will make me feel physically drained because I cannot replenish my energy levels afterwards.	0.09	0.72	0.07	0.09
Item 15 - I worry if performing physical activity will make me feel bad emotionally because I am not able to replenish myself with food.	0.45	0.40	0.18	−0.09
Item 16 - I consciously reduce my level of physical activity to control the number of calories I burn.	0.74	0.09	−0.13	0.10
Item 17 - I preserve the calories I have eaten by reducing my physical activity levels.	0.76	−0.01	0.04	0.13
Item 18 - I preserve the energy I have by limiting the amount of physical activity I perform.	0.19	0.32	−0.13	0.51
Item 19 - I experience concerns about using energy which I would otherwise need to function when I perform physical activity.	0.19	0.46	0.05	0.30
Item 20 - I worry about having burnt off calories when I perform physical activity.	0.64	−0.02	0.09	0.13
Item 21 - In the hours before performing physical activity, I consciously restrict the amount of energy I use on other tasks.	0.22	−0.10	0.11	0.60
Item 22 - I consciously reduce levels of physical activity in the hours after performing physical activity.	0.09	0.11	0.00	0.62

physiological effects of performing physical activity (e.g., 'I worry if performing physical activity will make me feel physically drained because I cannot replenish my energy levels afterwards.'). Factor 3 explained 13% (Eigenvalue = 2.12) and consists of three items which focus on concerns relating to experiencing hunger after performing physical activity (e.g., 'I have concerns about how hungry I will be after performing physical activity.'). Factor 4 explained 11% (Eigenvalue = 1.73) and consists of four items which focus on compensatory behaviours in the form of reduced energy expenditure in response to performing physical activity (e.g., 'I consciously reduce levels of physical activity in the hours after performing physical activity.'). The complete FIPACS and scoring criteria is available in the supplementary materials.

3.2. Confirmatory factor analysis (sample 2)

Items were free to load onto their respective latent factors established from the exploratory factor analysis. Inclusion of covariance pathways were used based on modification indices (see Fig. 1 for the complete factor model). Without including covariance paths between error terms, the initial CFA produced the following borderline acceptable fit: normed $\chi^2 = 3.45$, $p < 0.001$, CFI = 0.90, RMSEA = 0.080 (90% CI [0.073, 0.088], SRMR = 0.070, AIC = 14796.16). Inspection of modification indices showed that covariance pathways should be created between four pairs of error terms. Covariance pathways for error terms were created between: 'I consciously reduce my level of physical activity to control the number of calories I burn' and 'I preserve the calories I have eaten by reducing my physical activity levels' (modification index = 68.68); 'I worry about having a hunger I cannot satisfy after performing physical activity.' and 'I have concerns about how hungry I will be after performing physical activity.' (modification index = 19.57); 'I worry if performing physical activity will make me feel physically drained because of my diet.' and 'I worry if performing physical activity will make me feel physically drained because of my usual energy levels.' (modification index = 18.65); 'In the hours before performing physical activity, I consciously restrict the amount of energy I use on other tasks.' and 'I consciously reduce levels of physical activity in the hours after performing physical activity.' (modification index = 33.50). With covariance paths between error terms included, the model displayed acceptable-to-good fit (normed $\chi^2 = 2.64$, $p < 0.001$. CFI = 0.93, RMSEA = 0.066 (90% CI [0.057, 0.074]), SRMR = 0.056, AIC = 14662.35).

3.3. Test retest reliability

Using a single measures two-way random effects model, it was shown that inter-rater reliability on the FIPACS between baseline and two weeks later was deemed good (ICC = 0.82, 95% CI [0.75, 0.88]).

3.4. Internal reliability, convergent and divergent validity (samples 1 and 2)

Internal reliability was deemed to be acceptable for all factors – 'Concerns of replenishment of calories' $\omega_t = 0.89$; 'Physiological effects of physical activity' $\omega_t = 0.88$; 'Concerns relating to hunger' $\omega_t = 0.85$; 'Compensatory behaviours' $\omega_t = 0.77$. The internal reliability for the full

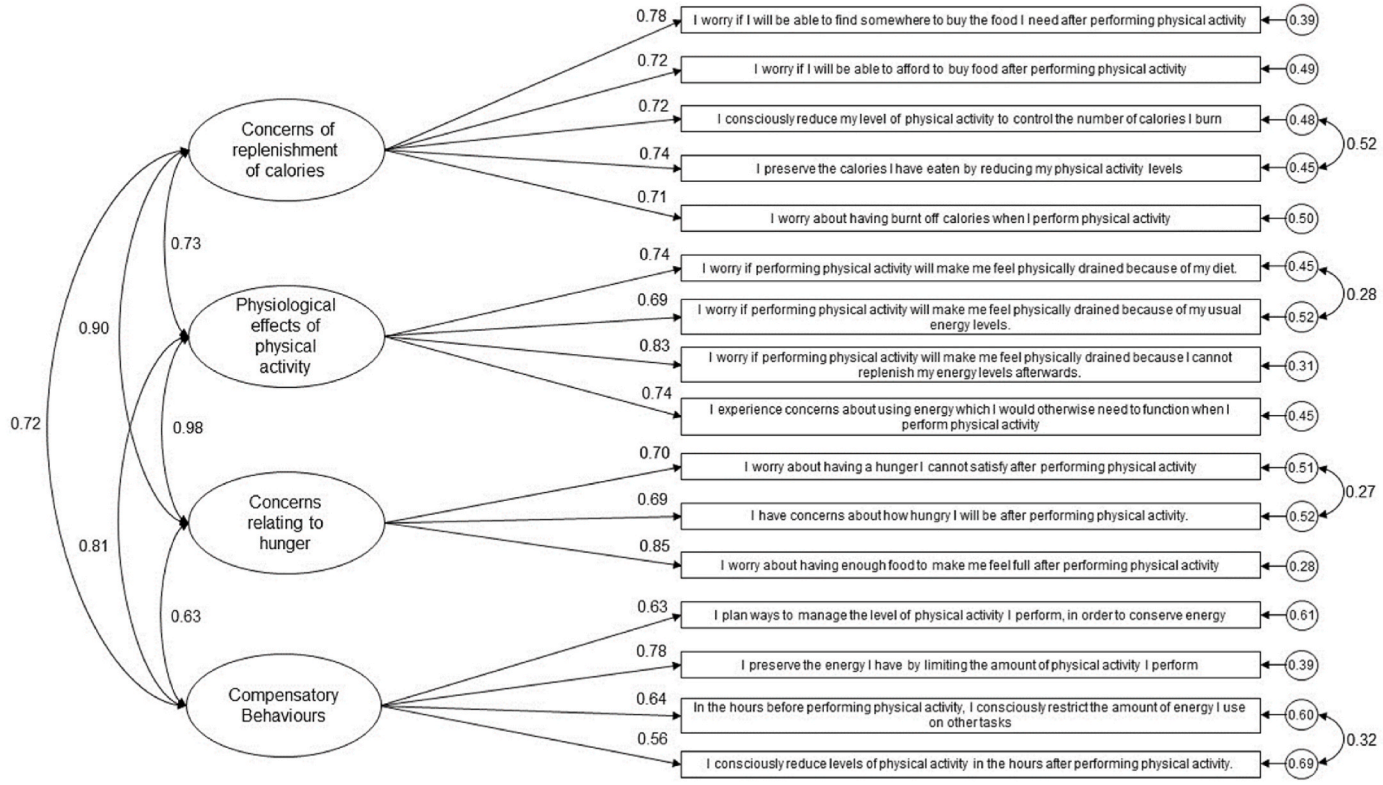

Fig. 1. Factor model of the FIPACS. Values displayed are: standardised factor loadings (values accompanied with a one-way arrow), error terms (circled values), and covariances (values accompanied with a two-way arrow).

FIPACS scale was $\omega_h = 0.76$, suggesting that the full scales score can be reliably used. Total FIPACS scores were shown to be uncorrelated with DEBQ restraint scores ($r(597) = 0.063$, $p = 0.123$), the reward responsiveness subscale of the BAS ($r(601) = -0.029$, $p = 0.473$), and the BIS ($r(601) = 0.044$, $p = 0.283$), but showed a small positive association with the BAS drive subscale ($r(601) = 0.165$, $p < 0.001$), the BAS fun seeking scale ($r(601) = 0.160$, $p < 0.001$), total IPAQ scores ($r(556) = 0.136$, $p = 0.001$) and the BREQ-2 amotivation subscale ($r(598) = 0.197$, $p < 0.001$).

3.5. Unplanned analysis (samples 1 and 2)

Due to the unexpected finding that FIPACS scores and IPAQ total scores were positively associated (albeit weakly), additional correlational analyses were performed to determine whether the separate factors of the FIPACS correlated with total IPAQ scores and also with IPAQ scores separately for walking, moderate exercise, and vigorous exercise. 'Concerns of replenishment of calories' was significantly positively correlated with vigorous MET score $r(556) = 0.211$, $p < 0.001$, moderate MET score $r(556) = 0.184$, $p < 0.001$, and total MET score $r(556) = 0.208$, $p < 0.001$, but not with walking MET score $r(556) = 0.015$, $p = 0.718$. 'Physiological effects of physical activity' was significantly correlated only with moderate MET score $r(556) = 0.097$, $p = 0.022$, but not with vigorous MET $r(556) = 0.024$, $p = 0.577$, walking MET $r(556) = 0.013$, $p = 0.755$, or total MET score $r(556) = 0.053$, $p = 0.211$. 'Concerns relating to hunger' was significantly correlated with vigorous MET $r(556) = 0.142$, $p < 0.001$, moderate MET score $r(556) = 0.129$, $p = 0.002$, and total MET scores $r(556) = 0.119$, $p = 0.005$, but not walking MET score $r(556) = -0.055$, $p = 0.195$. 'Compensatory Behaviours' was significantly correlated with moderate MET score $r(556) = 0.106$, $p = 0.013$, but not with vigorous MET $r(556) = 0.043$, $p = 0.306$, walking MET $r(556) = 0.020$, $p = 0.638$, or total MET scores $r(556) = 0.071$, $p = 0.092$.

We also investigated whether scores on the USDA household food insecurity scale were associated with total FIPACS scores as this would offer an additional form of convergent validity, given that food insecurity scores would theoretically be expected to be associated with food insecure-specific concerns of performing physical activity. Findings revealed a significant positive association between food insecurity and FIPACS scores ($r(556) = 0.331$, $p < 0.001$). Additionally, there was a significant difference of FIPACS scores between individuals with food insecurity (mean = 40.42, SD = 11.44) and those without food insecurity (mean = 30.74, SD = 10.56) $t(601) = -8.50$, $p < 0.001$, $d = -0.90$. We also analysed the association between food insecurity and total IPAQ scores, findings also revealed a significant positive association between food insecurity and total IPAQ scores ($r(556) = 0.092$, $p = 0.029$).

Lastly, we tested whether USDA food insecurity scores were associated with each individual component of the IPAQ short-form questionnaire (walking, moderate, vigorous physical activity). Findings revealed a nonsignificant correlation between food insecurity scores and vigorous MET scores ($r(556) = 0.046$, $p = 0.278$), and moderate MET scores ($r(556) = 0.076$, $p = 0.075$) but a significant correlation between food insecurity and walking MET scores ($r(556) = 0.103$, $p = 0.015$).

4. Discussion

The current study reports on the development and validation of a novel scale – the Food Insecurity Physical Activity Concerns Scale. This scale assesses the extent to which individuals display behaviours and concerns relating to performing leisure-time physical activity which focus specifically on food insecurity. The FIPACS is comprised of a four-factor solution, which was verified by confirmatory factor analysis. Factor 1 (Concerns of replenishment of calories) captures concerns relating to replenishment of calories in the context of physical activity. Factor 2 (Physiological effects of physical activity) captures physiological effects of performing physical activity, with a focus on experiencing low energy levels. Factor 3 (Concerns relating to hunger) focusses on a similar factor, capturing concerns of experiencing hunger and a lack of

fullness in response to performing physical activity. Lastly, Factor 4 (Compensatory Behaviours) captures compensatory behaviours in response to performing physical activity. Total FIPACS scores demonstrated good test-retest reliability two weeks after first completing the scale, and demonstrated acceptable internal reliability. Similarly, individual subscales of the FIPACS produced above acceptable levels of internal reliability.

As this is the first scale which has aimed to measure concerns of performing physical activity within the context of food insecurity, it is not possible to directly compare the factor structure of the scale with existing theoretical models. However, the rationale and theoretical reasoning for why food insecurity may increase concerns of performing physical activity stems from theories which focus on food insecurity and obesity. For example, previous researchers have suggested that, as an extension of the insurance hypothesis, individuals with food insecurity may limit their energy expenditure through lowering their levels of physical activity (Lee & Cardel, 2019). Evidence from the current study provides preliminary support for this suggestion. Namely, unplanned analyses revealed a positive correlation between FIPACS scores and food insecurity scores. This finding in of itself demonstrates a form of convergent validity because food insecurity scores and concerns of performing physical activity specifically relating to food insecurity would be expected to be correlated on theoretical grounds, which therefore suggests that the FIPACS is measuring behaviour specific to food insecurity. However, as this was an unplanned analysis, research should formally test the association between FIPACS and food insecurity.

Of note, planned tests of convergent validity revealed that total IPAQ scores were significantly positively associated with FIPACS scores. We expected scores on the FIPACS to be negatively associated with scores on the IPAQ due to our prediction that greater concerns of performing physical activity would lead to a reduction in physical activity levels. One explanation for not demonstrating a negative association could be because the FIPACS focuses exclusively on leisure-time physical activity, whereas the IPAQ short-form measure does not differentiate between different forms of physical activity, but instead focuses on intensity of physical activity (i.e. walking, moderate physical activity, vigorous physical activity). Previous findings have demonstrated that socioeconomic status is consistently positively associated with leisure-time physical activity, but not for occupational, transport, or household physical activity (Stalsberg & Pedersen, 2018). Therefore, an individual who has high concerns of energy preservation may not be able to alter their physical activity levels in domains outside of leisure-time physical activity (e.g., an occupation may require an individual to perform physical activity at a moderate or vigorous intensity). Therefore, the small positive association found in the current study may be due to the IPAQ capturing physical activity which is largely outside of an individuals' control. This suggestion is further supported from findings of the exploratory analysis which revealed a weak positive association between household food insecurity scores and IPAQ scores. Breaking this association down further, we found a weak positive correlation between food insecurity scores and walking MET, but not moderate or vigorous physical activity MET scores. This weak positive correlation may be due to higher levels of physical activity in certain domains of physical activity for individuals who are food insecure, such as occupational physical activity and transport physical activity. This finding suggests that food insecurity and physical activity may not be negatively correlated when measuring domain-general levels of physical activity but could be when measuring certain domains such as leisure-time physical activity, which has been demonstrated in previous research (e.g., Martinez et al., 2019). Future research should look to test whether scores on the FIPACS are successful in predicting physical activity, specifically relating to separate physical activity domains.

The positive association between FIPACS scores and total IPAQ scores could also be explained by the wording of the questions. Many of the items ask participants how they feel and behave in response to performing physical activity (e.g. I consciously reduce levels of physical activity in the hours after performing physical activity). This means that for such items, a response of 'Strongly Disagree' could be selected if the respondent has little interest in compensating for their physical activity, but this selection could also occur if the participant simply does not perform physical activity (i.e., they do not compensate for their leisure-time physical activity because this is not performed in the first place). Therefore, this positive correlation between FIPACS and total IPAQ scores could be partially driven by inactive participants producing low scores on the FIPACS.

We also investigated whether the FIPACS would demonstrate divergent validity against behaviours which are not expected to be strongly correlated with concerns of performing physical activity. Findings revealed that, although statistically significant, the FIPACS was weakly associated with BREQ-2 amotivation scores, BAS drive and BAS fun seeking scores. Findings also revealed that total FIPACS scores were not correlated with DEBQ restraint scores, which goes against our expectation that these variables would be negatively correlated – we predicted a negative correlation due to increased concerns of leisure-time physical activity possibly being incompatible and opposite to concerns of an individual who scores highly on the DEBQ restraint subscale (i.e., a greater focus on avoiding weight gain should be related to lower concerns of achieving a calorific deficit caused by performing physical activity). These findings suggest that, despite the weak significant correlation, the FIPACS appears to be only weakly associated with behaviours measured on the BIS/BAS and to a lack of motivation to perform physical activity.

There are some limitations with the present study. Participants overall were fairly equally balanced in terms of gender and the range of participant ages was also wide. However, as characterised by the USDA food insecurity module, only 18% of the sample were characterised as having food insecurity. However, we did not wish to recruit an exclusively food insecure population in order to produce greater variability in scores on the FIPACS – an exclusively food insecure sample may have produced scores which cluster towards the higher end of the scale. An additional limitation is that no field work was done in the process of scale development and validation (for example interviewing of individuals who have food insecurity). However, the items were partially based off previous qualitative research involving individuals with food insecurity (Puddephatt et al., 2020). Lastly, we used the IPAQ short-form rather than the long-form version. This was done in order to reduce participant burden. However, the long-form version does allow for measurement of physical activity across different domains (e.g., leisure-time physical activity). Given that, the FIPACS primarily focuses on leisure-time physical activity, the long-form version would likely have been a more appropriate measure.

Future research should investigate whether scores on the FIPACS are negatively correlated with physical activity when looking at separate domains of physical activity (e.g., household, occupational, transport, leisure time). Given that the FIPACS focuses solely on leisure-time physical activity, it is likely that FIPACS scores will be most strongly negatively correlated with leisure-time physical activity. Future studies should also investigate whether FIPACS scores mediate the relationship between food insecurity and leisure-time physical activity to understand whether this is a factor which may partially explain the link between food insecurity and physical activity. Additionally, moderators of this mediation could be investigated. Given that many of the items in the FIPACS relate to concerns of energy preservation, it may be reasonable to expect that the level of understanding an individual has of physical activity and energy expenditure, may moderate the mediation. For example, the strength of the mediation indirect effect may be greater in those with good knowledge of nutrition.

5. Conclusion

The present study developed and validated a scale to capture food

insecurity-related concerns of performing leisure-time physical activity. To our knowledge, this is the first scale which aims to measure the role of energy preservation concerns and other factors which may reduce leisure-time physical activity levels (e.g., physiological effects). Findings of the confirmatory factor analysis revealed that a four-factor solution of the FIPACS provided an acceptable-to-good fit. Future research should look to measure FIPACS scores as a predictor of physical activity levels for individuals with food insecurity.

Availability of data and materials

The study dataset, registered protocol, and R analysis code is available on the Open Science Framework repository at https://osf.io/x53vg/

Funding

This research was in part supported by the University of Liverpool Institute of Population Health Research Support Fund.

Ethics approval and consent to participate

All participants provided written informed consent to participate. Ethical approval was gained by the University of Liverpool Institute of Psychology, Health and Society Research Ethics Committee.

CRediT authorship contribution statement

Thomas Gough: Writing – review & editing, Writing – original draft, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Paul Christiansen:** Writing – review & editing, Formal analysis. **Charlotte A. Hardman:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Gregory S. Keenan:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

CAH and PC receive research funding from the American Beverage Association for work outside of the submitted manuscript. CAH has also received speaker fees from International Sweeteners Association and the International Food Information Council.

Data availability

The study dataset, registered protocol, and R analysis code is available on the Open Science Framework repository at https://osf.io/x53vg/

Acknowledgements: N/A

Ethical approval and consent to participate: This study was approved by the University of Liverpool research ethics committee. Consent for publication: N/A.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2024.107516.

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