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RESEARCH ARTICLE

Psychometric validation of the hyperglycaemia avoidance scale UK (HAS-UK)

Vicky McKechnie[1,2] | **Shaila Khan**[1] | **Rob Saunders**[3] | **Stephanie A. Amiel**[4] | **Linda A. Gonder-Frederick**[5] | **Nick Oliver**[1]

[1]Department of Metabolism, Digestion and Reproduction, Imperial College London, London, UK

[2]Department of Clinical Health Psychology and Neuropsychology, Imperial College Healthcare NHS Trust and West London NHS Trust, London, UK

[3]CORE Data Lab, Centre for Outcomes Research and Effectiveness (CORE), Research Department of Clinical, Educational, and Health Psychology, University College London, London, UK

[4]Department of Diabetes, Faculty of Life Sciences, King's College London, London, UK

[5]Center for Diabetes Technology, School of Medicine, University of Virginia, Charlottesville, Virginia, USA

Correspondence
Vicky McKechnie, Department of Metabolism, Digestion and Reproduction, Imperial College London, London, UK.
Email: v.mckechnie@imperial.ac.uk

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Abstract

Aims: Hyperglycaemia aversion in type 1 diabetes can be associated with severe hypoglycaemia and impaired awareness of hypoglycaemia but is not routinely assessed clinically. This study aimed to undertake the first psychometric validation of the UK version of the Hyperglycaemia Avoidance Scale (HAS-UK).

Methods: The HAS-UK was completed by adults with type 1 diabetes in three separate research studies. Psychometric properties were evaluated, using exploratory factor analysis, internal consistency, and convergent validity.

Results: Of the 431 participants who completed the HAS-UK in the three studies, mean age was 49.5 years, and 58.0% were women. Mean duration of diabetes was 29 years, with 192 (44.5%) using multiple daily injections and 229 (53.1%) using an insulin pump. Five participants were excluded from analyses due to incomplete HAS-UK responses. Exploratory factor analysis revealed a 3-factor solution, with acceptable internal consistency for 'worry' and 'blood glucose decisions' factors. HAS-UK total score was higher in those using insulin pumps versus multiple daily injections, and 'blood glucose decisions' score was higher in those using a continuous blood glucose sensor versus a meter.

Conclusions: The HAS-UK is a reliable measure with acceptable structural validity and is likely to be useful for evaluating hyperglycaemia aversion in people with type 1 diabetes. Future research would benefit from investigating further psychometric properties including test–retest reliability, sensitivity to change, and clinical significance of scores.

KEYWORDS

hyperglycaemia, hypoglycaemia, psychometrics, questionnaire, type 1 diabetes

1 | INTRODUCTION

Hyper- and hypoglycaemia are frequent occurrences for those living with type 1 diabetes, and both are associated with unpleasant symptoms and adverse health outcomes,[1] as well as cost implications related to healthcare utilisation. Hypoglycaemia symptoms include irritability, dizziness, and sweating, as well as more serious consequences such

as confusion, loss of consciousness, seizure, and risk of death. Micro- and macro-vascular complications arise from persistent hyperglycaemia. These adverse outcomes are reduced when glucose is maintained within target range,[2] but achieving this is challenging.

From the time of diagnosis onward, hyperglycaemia is frequently discussed during diabetes consultations, including informing individuals of the risk of serious complications that can occur, and while substantial work has been conducted investigating fear of hypoglycaemia,[3–5] there is less literature on fear of, or aversion to, hyperglycaemia.

Distress related to hyperglycaemia is common,[6] and in some individuals this distress includes hyperglycaemia aversion[7,8] which is characterised by concerns related to hyperglycaemia and a detail-focused self-management approach to avoid or alleviate hyperglycaemia, often running blood glucose below the recommended levels.[7,8] Anecdotally, hyperglycaemia aversion is frequently seen clinically but is not routinely assessed formally. Hyperglycaemia aversion is important to identify as it may associate with a preference for low glucose and increase the risk of hypoglycaemia.[7,8] Exposure to frequent hypoglycaemia is a risk factor for the development of impaired awareness of hypoglycaemia,[9] itself a recognised risk factor for severe hypoglycaemic episodes. Hyperglycaemia aversion and consequent avoidance have the potential to lead to greater acceptance of hypoglycaemia, which in turn may lead to increased frequency and severity of hypoglycaemia.[10] The ability to identify and support individuals at risk requires validated tools that assess the extent, and emotional experiences and behavioural manifestations, of hyperglycaemia aversion.

The Hyperglycaemia Avoidance Scale (HAS) was developed and validated in the USA, aiming to quantify the extent and impact of hyperglycaemia-related concerns.[11] The scale includes 22 items distributed over four subscales: immediate action, worry, low blood glucose preference, and avoid extremes. The scale was found to have excellent reliability across all factors. The validation study data found that the HAS subscales were predictive of prospective severe hypoglycaemia as well as adverse mishaps during driving.

The HAS-UK is a modified version of HAS.[11] Content and face validity were previously assessed by the investigators of the HypoCOMPaSS trial.[12] Fourteen adults living with type 1 diabetes completed the HAS and were interviewed before and after doing so, including cognitive debriefing. Both participant and specialist clinician input identified areas of change needed. The areas identified included linguistic adaptations for UK English (e.g. changing 'feeling mad at yourself' to 'feeling annoyed at yourself'), adjustments needed to reflect relevance for users of insulin pumps and multiple daily injection users and changes to the blood glucose measurement units from mg/dL to mmol/L. The response format was also altered from a numerical Likert scale (comprising end and midpoint anchors of 'never', 'sometimes' and 'always') to a tick-box scoring grid with five frequency ratings ('never', 'rarely', 'sometimes', 'often' and 'always'). The full HAS-UK questionnaire and the original HAS questions can be found in Appendix S1.

What's new?

- Hyperglycaemia aversion is often seen clinically in people with type 1 diabetes and can be associated with severe hypoglycaemia and impaired awareness of hypoglycaemia.
- Hyperglycaemia aversion is not routinely assessed clinically.
- The Hyperglycaemia Avoidance Scale (HAS) was developed in the USA, and the HAS-UK was subsequently adapted for use in the UK, and to update for changing methods of insulin delivery.
- This study comprises the first validation of the HAS-UK.
- It found that the HAS-UK could be useful for assessing hyperglycaemia aversion in people with type 1 diabetes.

The HAS-UK has a number of differences when compared to the original HAS and has not been subject to formal psychometric evaluation. This study aimed to validate the HAS-UK via exploratory factor analysis in the adult type 1 diabetes population, as well as examine the internal consistency and convergent validity of the measure in order to assess its clinical utility.

2 | RESEARCH DESIGN AND METHODS

2.1 | Study populations

A validation study was conducted using the HAS-UK. This questionnaire was completed by participants recruited from three studies, all of whom lived with type 1 diabetes. Data were aggregated to create a larger individual participant sample size to increase power of the current analysis. The three studies were as follows.

2.1.1 | *HYPE* (Avoidance of hyperglycaemia in people with type 1 diabetes)

The study was about hyperglycaemia aversion in type 1 diabetes. People living with type 1 diabetes who attended

clinics at Imperial College Healthcare NHS Trust or who consented to be contacted for research were invited to complete a set of online questionnaires. They were also asked to provide demographic, general medical history and specific diabetes history information as part of a research study about avoidance of hyperglycaemia in type 1 diabetes. Questionnaires were completed on Qualtrics (www.qualtrics.com), with the opportunity for individuals to request pen and paper versions if preferred. Eligibility criteria were aged ≥18 years; type 1 diabetes of at least 1 year's duration; not be pregnant; and have adequate English proficiency to complete the survey. Participants were not paid for their time. HYPE was approved by the Cornwall and Plymouth Research Ethics Committee (Integrated Research Application System no. 20/SW/0174). Data were collected between March and November 2021.

2.1.2 | *HARPdoc* (Hypoglycaemia awareness restoration programme for people with type 1 diabetes and problematic hypoglycaemia persisting despite optimised self-care)

HARPdoc was a randomised controlled trial (RCT) of psychoeducational interventions for people living with type 1 diabetes and problematic hypoglycaemia despite having undergone structured education in insulin adjustment and access to diabetes technology. Participants were recruited from four centres where specialist type 1 diabetes services are provided. Participants were aged over 18 years, had lived with type 1 diabetes for 4 years or more, experienced problematic hypoglycaemia for at least 1 year, and had adequate written and spoken communication in English to complete the questionnaire. Participants were not paid for their time. This study was granted ethical approval by the London – Dulwich Research Ethics Committee, 16/LO/1992, and is posted on ClinicalTrials.gov (NCT02940873). All participants gave written informed consent prior to any study procedure. Recruitment to the study ran from March 2017 to March 2019.

2.1.3 | *COBrAware* (Characterisation of cognitions, outcomes, and behaviours around hypoglycaemia in adults with type 1 diabetes and preserved awareness of hypoglycaemia)

This was a study which recruited people living with type 1 diabetes, attending the specialist clinics of the UK sites of the HARPdoc RCT, who were matched for sex and diabetes duration with people recruited into the HARPdoc RCT, but who did not have impaired awareness of hypoglycaemia (Gold score ≤3) or recurrent severe hypoglycaemia, as a comparator group to the HARPdoc RCT participants.[13] Participants were not paid for their time. This study was granted ethical approval by the London Dulwich and Wales Research Ethics Committees (IRAS numbers 216381 and 271164) and the Institutional Review Board of the Joslin Diabetes Center. All participants gave written informed consent prior to any study procedure. Data were collected from 2019 to 2020.

2.2 | HAS-UK

The HAS-UK is a 24-item questionnaire which asks respondents about behaviours engaged in to avoid high blood glucose levels, and feelings around high blood glucose levels. Responses are selected on a five-point scale ('Never', 'Rarely', 'Sometimes', 'Often' and 'Always'), and total scores are summated resulting in a range from 0 to 96 points. Higher total scores indicate greater hyperglycaemia aversion. The questionnaire contains two additional items asking respondents the highest blood glucose level that they would feel comfortable with on a given day, and the highest HbA1c that they would feel comfortable with. When participants complete the HAS-UK, it is titled 'The high blood sugar survey'.

2.3 | Additional questionnaires

Along with HAS-UK, HYPE participants were invited to complete additional measures related to diabetes and well-being to assess convergent validity and the HAS-UK's clinical utility.

2.3.1 | Gold score[14]

This is a single item which asks participants 'Do you know when your hypos are commencing?'. Participants respond on a seven-point Likert scale from 1 (always aware) to 7 (never aware). Scores of ≥4 indicate impaired awareness of hypoglycaemia.

2.3.2 | Hypoglycaemia fear survey II (HFS-II)[15]

This is a 33-item questionnaire, comprising the 15-item behaviour (scored 0–60) and 18-item worry subscales

(scored 0–76; in both cases higher scores represent greater fear of hypoglycaemia). Questions about frequency of worries and behaviours related to blood glucose level are answered on a five-point Likert scale from 'never' to 'almost always'.

2.3.3 | Problem areas in diabetes 5 (PAID-5)[16]

This measure asks participants to select on a five-point Likert scale how much each of five areas of diabetes is a problem for them at present, ranging from 'not a problem' to a 'serious problem'. The measure yields scores of 0–20. Higher scores suggest greater diabetes-related stress, and a score of ≥8 suggests high levels of distress.

2.3.4 | General anxiety disorder 7 (GAD-7)[17]

A seven-item measure of anxiety, where respondents are asked the frequency with which they have experienced certain symptoms within the past 2 weeks ranging from 'not at all' to 'nearly every day'. The measure is scored 0–21, with higher scores suggesting greater levels of anxiety.

2.3.5 | Patient health questionnaire 9 (PHQ-9)[18]

A nine-item measure of depression, where respondents are asked the frequency with which they have experienced certain symptoms within the past 2 weeks from 'not at all' to 'nearly every day'. The measure is scored 0–27, with higher scores suggesting greater levels of depression.

2.3.6 | State–trait anxiety inventory, trait subscale (STAI-T)[19]

The STAI-T measures trait anxiety. Individuals answer 20 questions about how they generally feel, and each item is on a four-point Likert scale from 'almost never' to 'almost always'. The measure is scored 20–80, with higher scores suggesting greater trait anxiety.

PAID-5 and Gold score data were available for HARPdoc and COBrAware participants, and HFS-II data were available for HARPdoc participants. These were therefore also included in analyses.

2.4 | Data analysis

Statistical analyses were carried out using SPSS (version 26).

First, exploratory factor analysis was carried out using combined data from all three studies (HYPE, HARPdoc, COBrAware). Individuals with missing data on any HAS-UK items were excluded from analyses. Sensitivity analyses including only the HYPE study, as the cohort recruited comprised general type 1 diabetes with no specific requirements for additional characteristics such as severe hypoglycaemia or preserved hypoglycaemic awareness, were also performed. Principal component analysis (PCA) was performed, with orthogonal rotation (varimax) used due to the exploratory nature of the analysis. The factor structure of the HAS-UK was informed by considering both the eigenvalues of factors (above 1.0) and also from observing the elbow in the scree plot.[20] Items with loading ≤0.3 were removed from analysis given concerns about stability of items with loadings below this threshold.[21] Once the optimum factor structure was ascertained, factor scores were calculated for each individual across studies to use in subsequent analyses by adding together the items from that factor to create subscales.

The next stage of validation comprised evaluating internal consistency. This step assessed correlation of questions loading onto a common factor and measured reliability regarding the consistency of responses. This study calculated Cronbach's Alpha (α), considering $\alpha \geq 0.7$ to represent acceptable internal consistency.

Convergent validity was assessed with data from all three study cohorts, using Pearson's correlation between the HAS-UK and the PAID-5, which measures diabetes-related distress.

Associations with psychological and clinical factors were then considered to assess the HAS-UK's clinical utility, using independent samples *t*-tests and Pearson's correlations. Results were considered statistically significant when $p < 0.05$.

3 | RESULTS

3.1 | Characteristics of participants

3.1.1 | All participants (total)

Of the 431 participants in the three studies, the mean age was 49.5 years and 58.0% were women. Mean duration of diabetes was 29 years, with 192 (44.5%) participants using multiple daily injections and 229 (53.1%) using an insulin pump (Table 1). Four HARPdoc participants and one

TABLE 1 Participant characteristics.

	HYPE	HARPdoc	COBrAware
N	253	99[a]	79[b]
Sex (% women)	58.9	55.6	58.2
Ethnicity	93.3% white	96.0% Caucasian	93.7% Caucasian
Age, years, mean (SD)	48.7 (15.8)	53.6 (13.4)	46.8 (14.4)
Duration of diabetes, years, mean (SD)	26.6 (16.3)	35.4 (15.4)	28.8 (12.3)
Insulin delivery, MDII/CSII, *n* (%)	107/146 (42.3/57.7)	52/47 (52.5/47.5)	33/36 (41.8/45.6)
Blood glucose monitoring method, *n* (%)			
SMBG	27 (10.7)	52 (52.5)	37 (46.8)
Flash glucose monitoring	146 (57.7)	11 (11.1)	26 (32.9)
Continuous glucose monitoring	80 (31.6)	35 (35.4)	5 (6.3)
HbA1c			
HYPE: mmol/mol, mean (SD)	53.3 (10.6)[c]	57.3 (13.1)[d]	64.3 (4.3)[d]
HARPdoc and COBrAware: mmol/mol, median (IQR)	(*n* = 234)	(*n* = 98)	(*n* = 68)

[a]95 included in the present analyses.

[b]78 included in the present analyses.

[c]Self-reported, or taken from clinic notes.

[d]Taken from publication.

COBrAware participant had missing HAS-UK data and were subsequently excluded from the analyses.

3.1.2 | HYPE

465 potential participants were contacted by email, and 253 complete survey responses were received following this, comprising 54.4% response rate. Of the 253 responses, 252 were completed online and one was returned on paper. The mean age was 48.7 years and 58.9% were women. Mean duration of diabetes was 26.6 years with 107 (42.3%) participants using multiple daily injections and 146 (57.7%) using an insulin pump.

3.1.3 | HARPdoc[22]

As published, 626 people were assessed, including a large US cohort identified and 'cold-called' from research-permitted medical records. Of these, 123 consented, 118 completed a baseline assessment, and 99 were recruited. The mean age was 54 years, and 55.6% were women. Mean duration of diabetes was 35.8 ± 15.4 years with 31 of 97 participants with data (32%) using an insulin pump. HAS-UK data were available for 95 participants.

3.1.4 | COBrAware[13]

Also as published, 106 people consented to the COBrAware study and 81 returned questionnaire data. Three participants did not include useable HAS-UK scores, leaving 78. Their mean age was 47 years, and 58% were women. Their mean diabetes duration was 29 years, with 34.8% on pump.

Further population characteristics for all three study subgroups are summarised in Table 1. The three groups were roughly comparable in terms of age, ethnicity, and sex, with long mean diabetes duration, which was shortest in the HYPE group.

3.2 | Scale structure and internal consistency

A total of *n* = 426 were included in the factor analysis (four observations from HARPdoc and one from COBrAware had missing HAS-UK data and were excluded). The Kaiser–Meyer–Olkin (KMO) of sampling adequacy was 0.851, with Barlett's test of sphericity statistically significant ($p < 0.001$) indicating that the sample was adequate for factor analysis.[21] PCA identified six factors with eigenvalues >1.0; however, from observing the scree plot (Figure 1), there was a clear elbow after

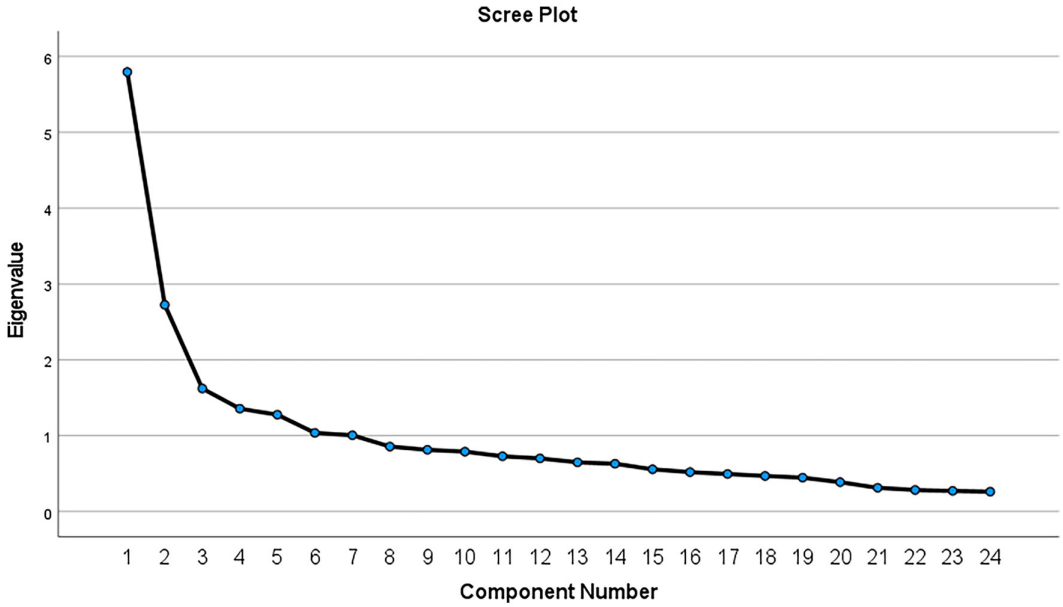

FIGURE 1 Scree plot from exploratory factor analysis.

the third factor, with scores levelling off after this factor. As a result, the three-factor solution was retained explaining 42.26% of the variance. These factors were named F1: 'Worry', F2: 'Blood glucose decisions', and F3: 'Lifestyle decisions'. Any item that loaded onto two factors was placed under a single factor, determined by strength of factor loading and face validity. There were no items with factor loadings <0.3, and no concerning levels of cross-loading were observed. Sensitivity analyses including only the HYPE sample observed an identical factor solution (see Appendices S2 and S3). Table 2 shows all scale items with factor loadings of greater than 0.3, together with their respective factor weights. All factors were retained. Table 2 also shows mean HAS-UK item scores.

To evaluate internal consistency, Cronbach's alphas were calculated: worry: $\alpha = 0.866$; blood glucose decisions: $\alpha = 0.761$; lifestyle decisions: $\alpha = 0.539$, indicating acceptable internal consistency for the worry and blood glucose decisions factors, but not for the lifestyle decisions factor.

3.3 | Convergent validity

Correlations between HAS-UK total score and both worry and blood glucose decisions factors were strong, and between the HAS-UK total score and the lifestyle decisions factor was moderate (Table 3).

The combined data also showed a moderate correlation between the HAS-UK total score and the PAID-5 ($r = 0.550$, $p < 0.001$), and convergent validity was therefore supported.

3.4 | Associations with other variables

Analyses were carried out to compute the correlations between total HAS-UK scores, the three-factor scores, and the total scores of other psychometric questionnaires, as well as the Gold scores and HbA1c measures. Pearson correlation coefficients are shown in Table 3, which indicates which study cohorts are included in each correlation.

Independent samples *t*-tests were conducted to investigate associations with clinical variables. Pairwise comparisons were made for HAS-UK total score, worry, blood glucose decisions, and lifestyle decisions factors with: age at diagnosis (<18 or ≥18 years) (HYPE cohort), glucose sensor monitoring (all three study cohorts), insulin modality (pump or MDI) (all three study cohorts), presence of impaired awareness of hypoglycaemia (all three study cohorts), and occurrence of severe hypoglycaemia over the last year (HYPE and HARPdoc). A pairwise comparison was also made for participants' highest comfortable blood glucose level and occurrence of severe hypoglycaemia over the past year (HYPE and HARPdoc).

HAS-UK total score was greater in participants using insulin pumps compared to MDI users (pump mean score 46.19 (SD 12.97) vs. MDI mean score 42.42 (SD 11.70), $p = 0.002$), as was worry score (pump mean score 23.31 (SD 7.70) vs. MDI score 21.25 (SD 7.96), $p = 0.008$) and blood glucose decisions score (pump mean score 18.32 (SD 5.86) vs. MDI score 16.97 (SD 5.29), $p = 0.015$). Blood glucose decisions score was higher in those using a continuous sensor than a meter for self-monitoring of blood glucose (sensor mean score 18.10 (SD 5.68) vs. meter mean score 16.67 (SD 5.47), $p = 0.02$). Those with IAH had higher

TABLE 2 Mean item scores and exploratory factor analysis of the HAS-UK for HYPE, HARPdoc, and COBrAware cohorts.

		Factor solution[a]		
		1	2	3
	Mean score (SD)	Worry	Blood glucose decisions	Lifestyle decisions
1. Try to lower your blood glucose when it is higher than 10 mmol/L	2.88 (1.01)		0.615	
2. Choose to take a little more insulin rather than risk taking too little	2.08 (0.98)		0.607	
3. Choose to under-treat low blood glucose rather than risk high blood glucose later	1.20 (1.03)		0.453	0.351
4. Keep your blood glucose below 8 mmol/L	2.47 (0.94)		0.600	
5. Give extra insulin when you know your blood glucose is above 8 mmol/L	1.98 (1.21)		0.600	
10. Check your blood glucose more often when you think it is high	3.01 (0.90)		0.405	
11. Choose to keep your blood glucose low rather than risk being high	1.68 (0.18)		0.686	
12. Keep your blood glucose low because you want to avoid unpleasant symptoms	1.36 (1.27)		0.602	
17. Feel comfortable about being hypo if that is what it takes to avoid high blood glucose	1.05 (1.10)		0.464	0.301
6. Exercise to lower your blood glucose when you know it is high	1.49 (1.10)			0.380
7. Avoid restaurants/social situations that tempt you to have food/drink which raise your blood glucose	0.98 (1.09)			0.698
8. Miss meals when you know your blood glucose is high	1.17 (1.08)			0.484
9. Avoid stressful situations that might raise your blood glucose	0.73 (0.89)			0.689
13. Worry about complications of high glucose, e.g. blindness, kidney failure, amputation	2.41 (1.12)	0.772		
14. Worry that you might die early due to diabetes	2.07 (1.24)	0.773		
15. Worry about high blood glucose	2.66 (0.94)	0.714	0.311	
16. Feel upset (e.g. frustrated, distressed) when your blood glucose is too high	2.69 (1.07)	0.655		
18. Worry about going into DKA (diabetic ketoacidosis)	1.28 (1.11)	0.581		
19. Worry about losing your health due to your diabetes	2.44 (1.06)	0.804		
20. Worry about not recognising when your blood glucose is high	1.46 (1.02)	0.469		0.362
21. Feel annoyed at yourself when your blood glucose is high	2.73 (1.05)	0.543	0.322	
22. Worry about not knowing how to lower your blood glucose when it is high	1.12 (1.02)	0.452		
23. Worry about your doctor's reaction if your blood glucose is high	1.35 (1.23)	0.575		
24. Worry that you will experience unpleasant symptoms if your blood glucose is high	2.05 (1.17)	0.601	0.373	

Grey shade indicates which factor each questionnaire item is part of (1, 2 or 3).

[a]Factor loadings of <0.3 are not presented.

TABLE 3 HAS-UK total and factor correlations.

	1.	2.	3.	4.	5.
1. HAS-UK total score[a]					
2. HAS-UK – Worry[a]	**$r=0.853$** **$p<0.001$**				
3. HAS-UK – Blood glucose decisions[a]	**$r=0.721$** **$p<0.001$**	**$r=0.312$** **$p<0.001$**			
4. HAS-UK – Lifestyle decisions[a]	**$r=0.520$** **$p<0.001$**	**$r=0.282$** **$p<0.001$**	**$r=0.252$** **$p<0.001$**		
5. HAS-UK Highest comfortable blood glucose level[a]	**$r=-0.251$** **$p<0.001$**	$r=0.083$ $p=0.091$	**$r=-0.351$** **$p<0.001$**	**$r=-0.153$** **$p=0.002$**	
GAD-7[b]	**$r=0.448$** **$p<0.001$**	**$r=0.508$** **$p<0.001$**	**$r=0.149$** **$p=0.018$**	**$r=0.243$** **$p<0.001$**	$r=-0.050$ $p=0.435$
PHQ-9[b]	**$r=0.418$** **$p<0.001$**	**$r=0.452$** **$p<0.001$**	**$r=0.159$** **$p=0.011$**	**$r=0.256$** **$p<0.001$**	$r=0.027$ $p=0.675$
PAID-5[a]	**$r=0.550$** **$p<0.001$**	**$r=0.681$** **$p<0.001$**	**$r=0.103$** **$p=0.034$**	**$r=0.280$** **$p<0.001$**	$r=0.038$ $p=0.433$
HFS-II – Behaviour[c]	**$r=0.286$** **$p<0.001$**	**$r=0.343$** **$p<0.001$**	**$r=-0.036$** **$p=0.506$**	**$r=0.392$** **$p<0.001$**	**$r=0.145$** **$p=0.008$**
HFS-II – Worry[c]	**$r=0.123$** **$p=0.022$**	**$r=0.158$** **$p=0.003$**	$r=0.013$ $p=0.815$	$r=0.077$ $p=0.152$	$r=-0.025$ $p=0.651$
STAI-T[b]	**$r=0.452$** **$p<0.001$**	**$r=0.525$** **$p<0.001$**	**$r=0.122$** **$p=0.053$**	**$r=0.267$** **$p<0.001$**	$r=-0.004$ $p=0.953$
Gold score[a]	$r=0.087$ $p=0.074$	$r=0.036$ $p=0.456$	$r=0.065$ $p=0.181$	**$r=0.151$** **$p=0.002$**	$r=-0.056$ $p=0.249$
HbA1c[b]	**$r=-0.155$** **$p=0.017$**	$r=0.101$ $p=0.122$	**$r=-0.430$** **$p<0.001$**	**$r=-0.147$** **$p=0.024$**	**$r=0.412$** **$p<0.001$**

Bold values highlight results that were statistically significant

[a]HYPE, HARPdoc, and COBrAware participants.

[b]HYPE participants.

[c]HYPE and HARPdoc participants.

scores on lifestyle decisions than those with intact awareness (IAH mean score 4.73 (SD 2.81), aware score 4.16 (SD 2.62), $p=0.038$). There were no differences in total or subscale scores between those with and without experience of severe hypoglycaemia in the previous 12 months.

4 | DISCUSSION

This study confirms the validity of HAS-UK following its adaptation from a US version to reflect cultural and practice differences in adults with type 1 diabetes living in the UK, and to update terminology to reflect changing methods of insulin delivery. The study found excellent internal consistency amongst worry and blood glucose decisions factors, although the internal consistency for lifestyle decisions was not considered acceptable. Convergent validity was supported by a moderate correlation between the HAS-UK total score and the PAID-5. The HAS-UK total score was greater in insulin pump users than MDI; blood glucose decisions score was higher in those using a continuous blood glucose sensor compared to a meter. The HAS-UK total scores and worry subscale were both positively associated with all self-report questionnaires around emotional and psychological health and hypoglycaemia fear. Blood glucose decisions and lifestyle decisions factors also showed a positive correlation with these questionnaires, apart from the HFS-II worry subscale in both cases, but less strongly. This aligns with expectations as 'worry' represents an emotional construct, and these questionnaires are designed to measure distress, whereas the other two factors relate more to behaviours and preferences, and some individuals with hyperglycaemia aversion may not express associated distress.[8]

Blood glucose decisions and the single question about highest comfortable blood glucose level were both moderately negatively correlated with HbA1c, suggesting that adults living with type 1 diabetes are able to enact this preference for lower blood glucose levels effectively. The items comprising the blood glucose decisions factor

generally have good face validity for self-management decisions that may be indicative of hyperglycaemia aversion[8] and be associated with clinical risks such as severe hypoglycaemia and impaired awareness of hypoglycaemia[9] (e.g. item 17: 'Feel comfortable about being hypo if that is what is takes to avoid high glucose'), and thus are likely to have utility in supporting clinicians to identify individuals who may be at risk.

It is noteworthy that total HAS-UK score was greater in those using insulin pumps than MDI. Problematic hypoglycaemia is one of the clinical indications for insulin pump usage.[23] There is, however, a risk that transitioning an individual with problematic hyperglycaemia aversion, as indicated by severe hypoglycaemia, onto an insulin pump may in fact inadvertently further enable them to run their blood glucose at a lower level, especially if combined with a continuous glucose monitor,[8] which may further increase the risk of hypoglycaemia. It is also likely that those who are more motivated to avoid hyperglycaemia may choose to use an insulin pump to support them in enacting this preference.

Hypoglycaemia frequency, severity, awareness, and fear are routinely assessed in clinical practice and in research. Fear of hypoglycaemia is often quoted as a contributor to higher HbA1c, but the role of hyperglycaemia aversion as a risk factor for problematic hypoglycaemia is less well established. Validation of the HAS-UK instrument and demonstration of associations with outcomes suggest that this may be a useful adjunct to understand both the risk of problematic hypoglycaemia and a potential for intervention. Despite improvements in diabetes treatment technology, current data suggest that nearly 9% of people using automated insulin delivery systems still report recurrent severe hypoglycaemia in a year,[24], with evidence that cognitions around hypoglycaemia including prioritisation of hyperglycaemia avoidance may contribute to the residual problem.[10] It is likely that the HAS-UK may be a valuable tool to identify people who need additional support to avoid hypoglycaemia even with technology. The two standalone questions about highest comfortable blood glucose level and highest comfortable HbA1c may also prove useful guides to understanding whether the person's concerns are 'excessive' or clinically concerning. Given that the questionnaire assesses both active avoidance of hyperglycaemia and affective concerns around hyperglycaemia, which may not associate with behavioural responses, it may be prudent to consider whether the measure may more accurately be called the 'Hyperglycaemia Aversion Scale' as opposed to the 'Hyperglycaemia Avoidance Scale'.

Although the HYPE cohort was a general type 1 diabetes population, there may have been some selection bias in terms of those who showed interest and participated in the study, which may have implications for generalisability. The HARPdoc and COBrAware cohorts were biased by intention to be enriched by participants with and without problematic hypoglycaemia, respectively. For all three studies, it is not possible to determine if there were any differences between those who chose to participate and those who did not.

The present analyses sought to undertake psychometric evaluation of the existing HAS-UK. The variance explained by the final solution was lower than recommended in the general literature, indicating that further approaches to refine the structure of the measure may enhance the properties of the HAS-UK. Additional psychometric validation might further the clinical utility of the measure, including identifying individual items that might be contributing to poorer reliability and arguably be less clinically valuable in the assessment of hyperglycaemia aversion (e.g. the 'lifestyle decisions' factor). This should include examining the HAS-UK for test–retest reliability, as well as measurement invariance and differential item functioning across demographic and clinical subgroups.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Vicky McKechnie https://orcid.org/0000-0003-4480-5188
Rob Saunders https://orcid.org/0000-0002-7077-8729
Stephanie A. Amiel https://orcid.org/0000-0003-2686-5531
Nick Oliver https://orcid.org/0000-0003-3525-3633

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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