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Griffiths, A.W., White, S., Norman, P. et al. (2026) Development of a complex intervention to support high calorie diets for people with amyotrophic lateral sclerosis. Muscle and Nerve. ISSN: 0148-639X

https://doi.org/10.1002/mus.70269

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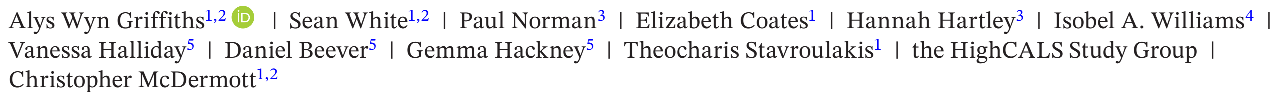
Development of a Complex Intervention to Support High Calorie Diets for People With Amyotrophic Lateral Sclerosis



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Received: 3 February 2026 | **Revised:** 27 April 2026 | **Accepted:** 2 May 2026

Keywords: amyotrophic lateral sclerosis | behavior change | calorie intake increase | COM-B

ABSTRACT

Introduction: Weight loss in people with amyotrophic lateral sclerosis (pwALS) is a poor prognostic factor. We aimed to develop an intervention to support pwALS to increase calorie intake and explore feasibility and acceptability.

Methods: Intervention development was underpinned by the Capability, Opportunity and Motivation (COM-B) model and Person Based Approach (PBA). Phase 1: healthcare professional (HCP) focus groups ($n = 47$), national survey ($n = 281$), mapping review and National Health Service (NHS) organization Freedom of Information requests ($n = 251$) charted current nutritional support. Systematic reviews of correlates (65 studies) and interventions supporting nutritional behaviors (14 studies), and interviews/focus groups with pwALS ($n = 18$), carers ($n = 18$) and HCPs ($n = 51$) identified barriers/facilitators. Phase 2: Think Aloud interviews (verbalizing thoughts whilst using the intervention) with pwALS ($n = 12$), carers ($n = 10$) and HCPs ($n = 10$). Phase 3: three pilot cycles, interviews with pwALS ($n = 9$), carers ($n = 6$) and HCPs ($n = 5$).

Results: Limited evidence-based nutritional guidelines, late dietetic referral post-diagnosis, little HCP training, and few effective interventions were identified. Key facilitators/barriers included capabilities (physical ability), opportunities (social support), and motivations (dietary beliefs). The intervention was developed and piloted to refine content, presentation, and functionality. Concerns around high calorie diets and increasing intake were addressed. The final intervention comprises: (1) interventionist training, (2) calorie target setting, (3) food diaries, (4) feedback provision, (5) online resources, and (6) oral nutritional supplements. User feedback indicates high usability, acceptability, and feasibility.

Discussion: The theoretically grounded intervention targets calorie intake through tailored behavior change techniques to support dieticians in practice to deliver personalized care and oral nutritional support for pwALS.

1 | Introduction

Weight loss is an important prognostic factor in people with amyotrophic lateral sclerosis (ALS), with both pre-diagnostic [1] and post-diagnostic [2] weight loss predictive of increased risk of death [3]. Weight loss is compounded by hypermetabolism, with resting energy expenditure being up to 20% higher than healthy individuals [4]. Weight loss from an energy deficit leads to accelerated muscle loss and reduced physical function [5].

Correction of the energy deficit with a high calorie diet extends life by 20% in ALS mouse models [6]. However, there is limited evidence for the effectiveness of a high calorie diet to prevent weight loss and increase survival in people with ALS

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[7, 8]. A meta-analysis of randomized controlled trials (RCTs) of high calorie nutrition support interventions reported significant effects on body weight and body mass index (BMI), but not physical function or survival [8]. However, the review only included six RCTs with 370 people with ALS. The largest RCT to date found that prescribing high fat supplements to deliver an additional 405 kcal per day had non-significant effects on body weight, physical function, and survival (versus placebo control), although post hoc analyses revealed significant effects on body weight and survival among fast progressing people with ALS [9]. However, the trial was hampered by low adherence, indicating that many people were unable or unwilling to increase their calorie intake. Moreover, the trial did not report providing any support to patients to overcome negative beliefs about nutritional interventions or difficulties adhering to a high calorie diet. Therefore, there remains a need to test the impact of a high calorie diet using interventions that are usable and acceptable to people with ALS, to ensure greater adherence. This paper provides an overview of the development, design and refinement of a theoretically underpinned complex nutrition support intervention.

2 | Methods

2.1 | Development of the OptiCALS Intervention

The intervention was developed by a multidisciplinary team comprising expertise in behavior change, health services, ALS, public health and nutrition, and specialist dieticians, alongside a patient and public involvement (PPI) group of people with ALS and their carers. Intervention development incorporated three phases to: (1) identify initial intervention components, (2) develop and refine the content and usability of these intervention components, and (3) pilot the intervention to assess and improve acceptability and feasibility in practice (see Figure 1).

2.2 | Theoretical Underpinnings

We were guided by the UK Medical Research Council framework [10] for developing and evaluating complex interventions, which encourages the use of theory to underpin interventions, and the incorporation of users' views and experiences to improve acceptability, feasibility, and implementation of interventions, to increase likelihood of effectiveness [11]. The process is reported in line with Stage 1 and 2 of CReDECI 2 guidance [12].

The Capability Opportunity Motivation—Behavior model (COM-B) [13], which proposes that behavior is a function of a person's capability (physical or psychological capability to enact a behavior), opportunity (physical/social environment that enables/inhibits the behavior), and motivation (reflective/automatic mechanisms that guide behavior), underpinned intervention development. This provides a "behavioral diagnosis" of the key target facilitators and barriers for interventions (i.e., what to change) and specific behavior change techniques (BCTs) are then selected to address these (i.e., how to change behavior) [14].

The intervention was refined using Person Based Approach (PBA), which supports intervention development and refinement through a systematic in-depth understanding of the perspectives of potential intervention users, to improve usability, acceptability, and feasibility [15]. These views are then incorporated into an iterative refinement process during the development phase.

2.3 | Ethics

Ethical approval for Phase 1 was provided by the School of Health and Related Research Ethics Committee at the University of Sheffield (ref: 018781) and governance approval from the Health Research Authority (ref: 245296). Ethical approval for Phases 2 and 3 was provided by the North West Greater Manchester East NHS Research Ethics Committee (ref: 18/NW/0638), and governance approval from the Health Research Authority (ref: 250732). All participants provided written informed consent prior to involvement.

2.4 | Phase 1: Identifying Initial Components of the Intervention

Phase 1 aimed to understand current practice of nutritional management services for people with ALS and to identify the key enablers of and barriers to increasing calorie intake. Findings were used to guide the initial development and design of the intervention.

Phase 1a explored the perspectives of healthcare professionals (HCPs) and people with ALS on current nutritional support practice. This involved a sequential mixed methods study of (i) focus groups with HCPs who support people with ALS ($n=47$) and people with ALS ($n=4$) analyzed using reflexive thematic analysis [16], (ii) a national cross-sectional survey of HCPs ($n=281$), and (iii) Freedom of Information (FOI) requests from NHS Trusts and Clinical Commissioning Groups ($n=251$ organizations). The FOI questions addressed the size, structure, and location of the ALS service, dietetic provision, and commissioning of ALS nutrition Services [17]. Survey data was summarized descriptively [17, 18].

In Phase 1b, systematic reviews were undertaken to identify (i) factors associated with eating difficulties and nutritional outcomes in people with ALS and (ii) interventions to help people with ALS to achieve a high calorie diet. The first systematic review included quantitative and qualitative studies exploring eating behaviors and outcomes in people with motor neurodegenerative diseases (65 studies), to identify potential barriers/facilitators, mapped to COM-B [19]. The second systematic review identified intervention components including behavioral change techniques and modes of delivery associated with effective interventions to support nutritional behaviors to achieve a high calorie diet in people with motor neurodegenerative diseases (14 studies) [20]. A mapping review of nutritional management for people with ALS identified 109 documents including 13 specific guidelines or pathways utilized within the UK [21].

In Phase 1c, interviews and focus groups were conducted with people with ALS ($n=18$), their informal carers ($n=16$), and

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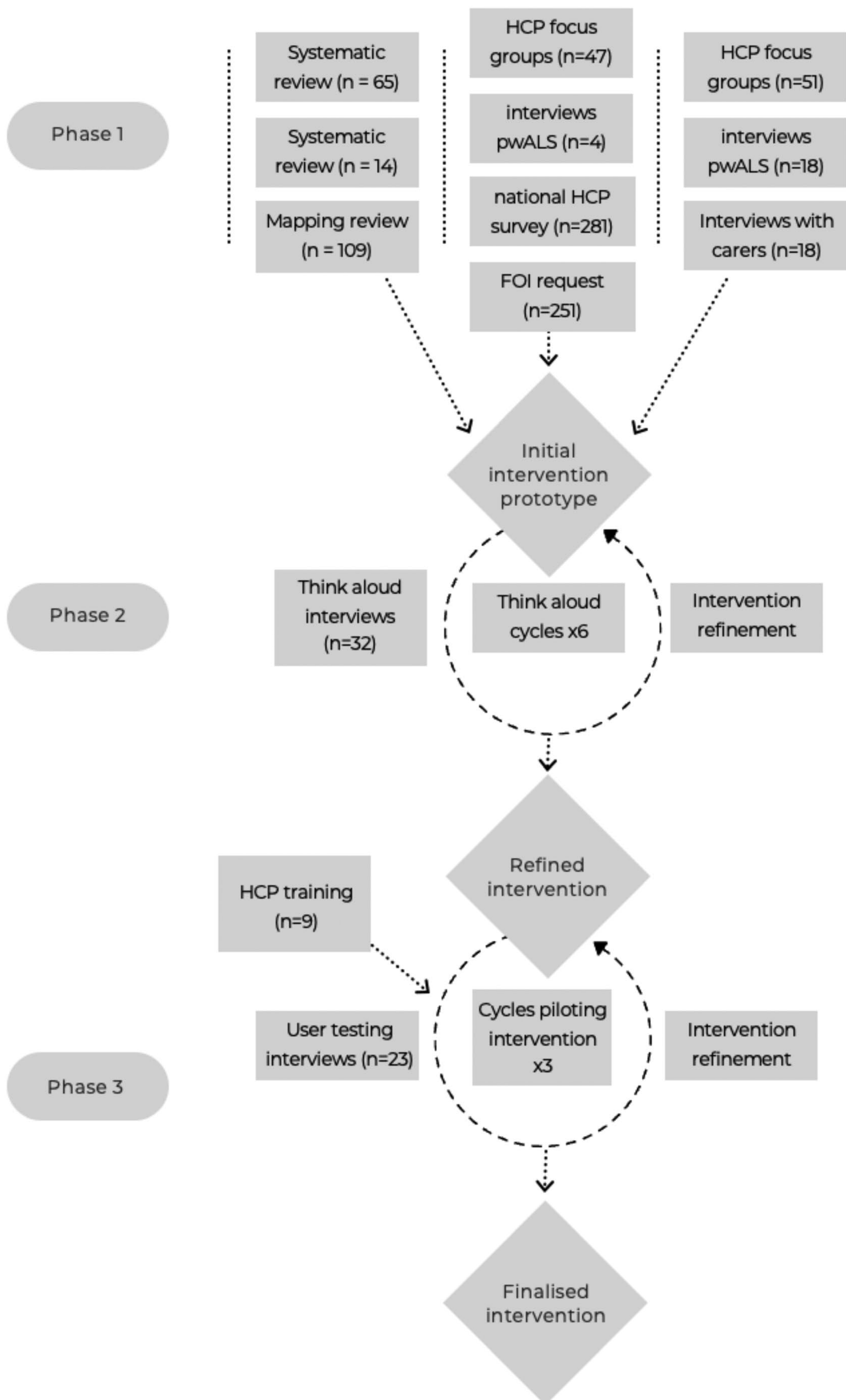

FIGURE 1 | Overview of OptiCALS intervention development.

HCPs ($n = 51$) to explore knowledge of the importance of, barriers to, and facilitators of consuming a high calorie diet [22, 23], analyzed using template analysis [24].

2.5 | Phase 2: Assessing and Refining the Content and Usability of Intervention Components

2.5.1 | Design

Phase 2 utilized the Person Based Approach (PBA) to assess the acceptability and usability of the intervention materials, to refine these [15]. Prototype materials were presented as an interactive portable document format (PDF), mimicking the website to demonstrate the intervention and gather feedback on purpose, acceptability, content and presentation.

2.5.2 | Participants and Procedure

A total of 34 Think Aloud [25] interviews ($m = 56$ min) were conducted with 32 participants, in monthly cycles over 6 months (see Supporting Information 1) by EC, DB and GH. Participants were pwALS ($n = 12$), carers ($n = 10$) and HCPs ($n = 10$). The sample included repeat participants to promote continuity. Interviews were undertaken until all feedback was resolved from participants' perspectives.

Participants were presented with the intervention materials and observed whilst using these, verbalizing their thoughts (i.e., 'thinking aloud'). Experiences of using the intervention were explored in more detail using specific questions adapted in each cycle in line with the area of intervention focus at that time.

2.5.3 | Analysis

To facilitate the rapid completion of the intervention development cycles, interviews were analyzed using content analysis [26]. A template was used to structure findings, with feedback grouped by area of intervention. The intervention development team met weekly to review and incorporate participant feedback. The MoSCoW prioritization method (i.e., 'Must have', 'Should have', 'Could have', 'Won't have) [27] was used to consider all potential changes to the intervention. All decisions were recorded, capturing the participant feedback, suggested change, reason for change, ease/difficulty of making the change, MoSCoW rating, team comments, decision and date changed (see Supporting Information 2 for examples).

2.6 | Phase 3: Piloting the Intervention to Assess and Improve Acceptability and Feasibility

2.6.1 | Design

Phase 3 aimed to pilot online intervention delivery over 1 month to explore acceptability. Three rounds of user testing and feedback interviews were completed with pwALS, carers, and HCPs from three UK ALS Care Centres.

2.6.2 | Participants and Procedure

2.6.2.1 | Training of HCPs Delivering the Intervention. Initially, six HCPs were trained by SW and PN in intervention delivery and use of the online portal. Training sessions covered intervention aims, key functionalities and overview of the online portal. HCPs familiarized themselves with the portal functionality and content until they felt confident navigating this and signposting participants to different areas. HCPs were provided with a user guide and a checklist of key actions to support systematic delivery of the intervention, including setting a personalized calorie target, reviewing online food diaries (myfood24) [28], and identifying strategies for reducing calorie gaps (see Table 1 for an example list).

2.6.2.2 | Participants' Intervention Enrolment Visit. Five people with ALS and four carers were provided access to the full OptiCALS portal during their intervention enrolment appointment. Their HCP directed them to the most relevant areas of the portal to their current needs. Participants completed specific portal tasks regularly as per the intervention protocol, for example, daily food diaries, dietary change behaviors to increase calorie intake to reach their personalized target, action plans, and accessing supportive information. After 1 month of portal use, semi-structured interviews were conducted. Use of the portal was monitored using Google Analytics (Google, Mountain View, California, USA), to identify how participants navigated the portal, which areas they accessed, the number of times and duration of time they accessed it for.

2.6.2.3 | User Testing Interviews. Across three rounds of user testing, 23 interviews were completed with people with ALS ($n = 9$), carers ($n = 6$), and HCPs ($n = 5$). Interviews were completed face-to-face, by telephone, or online and ranged from 40 to 60 min. The interview schedule was underpinned by the Theoretical Framework of Acceptability [29] and adapted for each participant to incorporate areas of interest, such as specific tasks completed on the portal and Google Analytics data.

TABLE 1 | Key tasks for HCPs to complete during the participant's first intervention visit.

1	Setting a personalized calorie target on the portal
2.	Reviewing the participant's food diary entries and current calorie intake
3.	Identifying any calorie gap between the current calorie intake and the target intake, and how this might be reduced
4.	Communicating the rationale behind achieving a high calorie diet for person with ALS
5.	Understanding participants' disease stage and needs for ALS support
6.	Directing participants to appropriate information and support within the portal
7.	Reviewing other functionalities of the portal, e.g., action planning, 'quick wins' set by the person with ALS

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2.6.3 | Review Process by Intervention Development Team

We reviewed each participant's use of the digital intervention, engagement with and understanding of the materials and key messages, and experiences of using the intervention. Issues related to acceptability and usability were identified using template analysis [24], grouped by what worked well and less well.

3 | Results

3.1 | Phase 1: Identifying Initial Components of the Intervention

Phase 1a identified (i) a lack of standardized, evidence-based guidelines around providing nutritional management services for people with ALS, despite the majority of HCPs providing nutritional advice to people with ALS, (ii) a need for education and training given HCPs' perceived lack of knowledge of dietary advice for people with ALS, and (iii) the importance of nutritional support soon after diagnosis, as most people with ALS were only referred to dietetic support after significant weight loss had occurred [17, 18, 23].

Phase 1b highlighted a range of correlates of oral nutrition behaviors in people with ALS and other motor neurodegenerative diseases that included physical (e.g., skills) and psychological (e.g., knowledge) capabilities, physical (e.g., environment) and social (e.g., social influence) opportunities and reflective (e.g., goals) and automatic (e.g., emotion) motivations [18]. 'Instruction on how to perform the behaviour' was the most commonly used BCT in nutritional interventions in people with ALS, although goal setting, self-monitoring and feedback were also included in some studies [19]. Delivery was most commonly face-to-face, although remote delivery was also used. There was no evidence linking the use of specific BCTs and modes of delivery to intervention effectiveness.

Phase 1c identified 53 factors impacting the consumption of a high calorie diet for people with ALS. These factors were mapped to COM-B components and included physical symptoms of ALS, eating habits, knowledge and beliefs about high calorie diets and healthy eating, and availability of informal and formal carers [22].

Triangulating data from Phase 1a-c, the research team, in collaboration with experts and the PPI group, designed an intervention with six components: (1) interventionist and participant training, (2) setting a calorie target, (3) completing and reviewing food diaries, (4) providing feedback on progress, (5) online resources with individualized support, and (6) an oral nutritional supplement protocol.

3.1.1 | Intervention Prototype Development

To set a calorie target (component 2), an algorithm was developed with specialist dietitians. An equation was used to estimate total daily energy expenditure [5] with adjusted targets to promote weight gain in individuals with BMI < 30 kg/m2 and weight maintenance in people with ALS with BMI 30-35 kg/m^2. A key principle of the algorithm was that people with ALS felt that targets generated were attainable. To address all other intervention target components, a prototype PDF of website content was developed, addressing key barriers identified in Phase 1, using BCTs to support achieving a high calorie diet. The prototype comprised five sections that included information on the rationale for increasing calorie intake and weight in ALS, an online food diary (myfood24) [28] to record calorie intake, a feedback page to indicate users' weight and current calorie intake in relation to their target, resources and advice to help overcome common barriers to achieving a high calorie diet (i.e., how to increase calorie intake, make eating and drinking easier, manage chewing and swallowing difficulties, use high calorie supplements, maintain enjoyment and interest in eating and drinking, and how family and friends can help), and a personalized area where users could save 'favorite' pages, make personalized plans, view 'quick wins' to increase calorie intake, and note questions to discuss with HCPs.

Oral nutritional supplements (ONS) were provided to participants not meeting their calorie targets by an enteral nutrition company. Interventionists used an online system to order ONS and change doses, which were then delivered to the participant's home. A protocol was developed, in collaboration with specialist dietitians, to guide interventionists on the use, timing and dose of ONS. Several ONS were available, with interventionists encouraged to explore participants' preferences and aim to meet any calorie deficit. At the first study visit (week 1) participants were supported to meet their calorie target using dietary methods. Discussions about commencing or increasing ONS were held if the participant was over 300 kcals from meeting calorie target at subsequent study visits or over 100 kcals at follow up phone calls. The ONS protocol was included in the interventionist guide and the HCP portal.

3.2 | Phase 2: Assessing and Refining the Content and Usability of Intervention Components

Overall, participants gave positive feedback on the aim and content of the prototype intervention, although they highlighted a range of issues to be addressed. There were two key types of feedback: (1) Beliefs towards and understanding of the key concept around increasing calories; (2) How information was presented across the intervention. Conceptual feedback focused on the key messages or the wording used, their relevance to participants, and the most appropriate time for pwALS to see information, considering the emotional impact of this. Presentation feedback focused on the amount, size and tone of the text, use of pictures and color, ratio of text to pictures, and risk of fatigue. These issues were fundamental for engagement with the intervention. Changes were made in response to user feedback during each cycle, which led to iterative intervention refinement, as changes often resulted in unintended consequences from user perspectives.

Discussions between the research team and the portal development team were a key part of intervention development in relation to content, functionality, and format. Once all user feedback on the acceptability and usability of the prototype intervention

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materials was addressed, a full online version of the intervention was ready to pilot.

3.3 | Phase 3: Piloting the Intervention to Assess and Improve Acceptability and Feasibility

Key issues raised by participants are listed below, and example quotes from researcher field notes from interviews can be found in Supporting Information 3.

1. Use of and engagement with the range of OptiCALS resources, including online resources, food diaries and feedback.
2. Functionality of the food diaries, and how many days these are completed on and visible, to allow participants to explore patterns in their calorie intake.
3. (Lack of) understanding of the rationale for high calorie diets in ALS.
4. Attempts to meet calorie targets and change food and drink intake based on how achievable these were felt to be.
5. Concerns about increasing calories due to comorbidities such as high cholesterol.
6. Burden and potential for burnout, given the time needed to complete food diaries.
7. Maintaining relevance of OptiCALS, at the current stage of ALS (i.e., if someone is yet to notice any weight changes).
8. Participants' views on how their own eating and drinking had changed over time, both before and since diagnosis.
9. Recall of events, such as being able to access accurate information to complete food diaries and remembering to speak to HCPs about their usage of the intervention.
10. How training to use OptiCALS aligned with previous understanding and knowledge of calories, weight, and weight gain.
11. Participant's concerns with the accuracy of their weight measurements.

These issues were presented to the intervention development team to identify solutions, guided by two key questions: (1) What are the implications of these issues? (2) Now what needs to be done? Final decisions on intervention changes were documented and made by group consensus. Some issues were complex and had conflicting practical, clinical, theoretical, and person based solutions, and linked to unintended consequences. Decisions focused on the best solution for the purpose of the intervention, with potential unintentional consequences identified and avoided.

The solutions to the key issues raised were evaluated and refined through the subsequent two rounds of user testing. No new issues were raised by participants in the subsequent two rounds, with earlier issues adequately resolved. At the end of Phase 3 the intervention was ready to be tested in an RCT. The final intervention materials were mapped to COM-B model components and BCTs by AWG, EC and SW (see Table 2 and Supporting Information 4).

4 | Discussion

A theoretically underpinned intervention to increase calorie intake for people with ALS was developed. We incorporated users' perspectives into the design to ensure acceptability and feasibility. Interventions underpinned by behavior change are often criticized due to unclear application of theory (e.g., COM-B [13]) and intervention development frameworks [11], the active intervention components chosen for behavior change (e.g., BCTs), an absence of user input, and poor reporting. Inconsistent intervention design and reporting has hindered the development of effective behavior change interventions [12]. With interventions being increasingly delivered online, understanding on how to design, refine and evaluate digital interventions which integrate theory and PBA is required. Effectiveness of such interventions is often dependent on factors relating to the use of behavior change theory and the incorporation of participant perspectives such as the tailoring to personal characteristic and website interactivity [30, 31]. In the present study, participant or researcher suggestions could not always be applied by web developers on a digital platform, presenting challenges. Once intervention materials were added to the digital platform, we reviewed these to assess whether they were acting as intended for the intervention, for example, presentation, functionality. This added further complexity to the review process when incorporating participant feedback and increased the importance of subsequent user testing.

The development of the present intervention highlighted key challenges in evidence-based intervention development. Drawing together multiple theoretical frameworks allowed the intervention content and format to be informed by barriers and facilitators to behavior change, whilst also ensuring appropriateness for the intended audience. This prevented the development of an intervention that would not be implementable within the NHS, or that was unacceptable to people with ALS. We add to the evidence that behavior change theory and PBA can be integrated together, without detracting from the unique contribution of each approach, developing an intervention that is grounded in theory, despite implementation of changes in response to feedback. However, developing an intervention in this way requires a large multidisciplinary team, utilizing clinical and methodological expertise. Whilst issues related to intervention content and implementation are challenging to anticipate at the outset, specific funding for robust intervention development is needed to ensure sufficient time is allocated to this crucial part of complex intervention development and evaluation.

To date, there is limited high quality evidence for efficacy of nutritional interventions for people with ALS [7], and concerns with high dropout rates [9]. Utilizing behavior science to develop and refine interventions can help to address issues with acceptability, which should reduce issues with intervention-related dropout and withdrawal. However, for people for whom a 'healthy lifestyle' is important, Phase 3 suggested that an increased focus on calorie intake may lead them to focus on restriction as they

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TABLE 2 | Final intervention components, target behavior change techniques (BCTs) and intervention delivery plan.

Area of intervention	BCTs targeted	Final intervention delivery plan
1. Interventionist and participant training	5.1. Information about health consequences 6.1. Demonstration of the behavior 9.1. Credible source	• Interventionist attends 5 h online training prior to implementation of intervention. • Those unable to attend full training, asked to watch recording of training, and attended a 1 h question and answer session with the trainers. • Interventionists train pwALS how to use the OptiCALS portal in the first study visit • Interventionist guide to support delivery of intervention
2. Setting a calorie target	1.1. Goal setting (behavior) 1.4. Action planning 1.6 Discrepancy between current behavior and goal	• Interventionist and information in OptiCALS portal provides pwALS rationale for increasing calories and weight in ALS. • Calorie targets presented in the OptiCALS portal. • Interventionist and information in OptiCALS portal supports pwALS to set a calorie target to maintain or increase weight. • New calorie targets set at each study visit by interventionists aimed at promoting weight maintenance or gain.
3. Completing food diaries	2.2 Feedback on behavior 2.3. Self-monitoring of behavior 8.3 Habit formation 12.5 Adding objects to the environment	• Link to online food diary system (myfood24) embedded into OptiCALS • Interventionist trains pwALS on how to complete food diary. • PwALS complete food diary prior to each study visit and 1 month follow up phone call, recording their daily dietary intake. • PwALS complete ad hoc food diaries between study visits to check calorie intake.
4. Obtaining feedback on progress: "how am I doing?"	1.5. Review behavior goal(s) 1.6 Discrepancy between current behavior and goal 2.2 Feedback on behavior 8.7 Graded tasks 10.4 Social reward 11.2. Reduce negative emotions	• PwALS receive feedback via OptiCALS portal and from their interventionist about if their calorie intake is meeting their calorie target. • PwALS can view graphs and tables of their calorie target vs. calories intake. • Interventionists review food diaries to check if participants have implemented plans to increase calorie intake. • Participants receive feedback on their weight and weight changes.

(Continues)

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TABLE 2 | (Continued)

Area of intervention	BCTs targeted	Final intervention delivery plan
5. Online information resources with individualized support	1.4. Action planning 4.1. Instruction on how to perform the behavior 5.1. Information about health consequences 6.1. Demonstration of the behavior 11.2. Reduce negative emotions 12.6. Body changes	• Interventionist shows pwALS how to access online resources on OptiCALS portal, containing advice for increasing calorie intake, managing common barriers to eating and drinking in ALS and supporting caregivers. • Interventionists tailor guidance to pwALS preferences, symptoms or concerns. • PwALS engage with resources aimed at supporting them to meet calorie target. • PwALS and/or interventionist can 'favorite' pages in OptiCALS that are relevant to them. • PwALS can make and save individual action plans for increasing calorie content. • PwALS and interventionist can create 'quick wins' support them meeting calorie target. • pwALS can make notes to remind them to ask questions of interventionists at study visits
6. Oral nutritional supplements	8.3 Habit formation 12.6. Body changes	• Interventionist commence or increase oral nutritional supplements (high calorie drinks and desserts) if participant unable to meet calorie target from oral diet.

realize how 'unhealthy' the advised high calorie diet may be. If individuals have eaten low calorie diets for a long time, these behaviors are harder to change. Conversely, for people with a comorbidity who have previously been advised to reduce calorie intake, asking them to move to a high calorie diet can be very challenging, as this is seen as competing advice. Further work is required to examine specific barriers to behavior change within these sub-groups of people with ALS.

4.1 | Limitations

While the intervention was informed by multiple phases, including systematic and mapping reviews of international research, participants for primary data collection were only recruited from UK settings. Therefore the barriers to nutritional management identified may reflect the UK ALS care delivery context and might not be transferable across different countries or healthcare systems, for example the cost and reimbursement of intervention components. We drew together several approaches to robustly develop a theoretically-informed intervention, which should have international applicability, given the identified targets for behavior change. However, this was time and resource intensive, and the efforts required to develop an intervention in this way should not be underestimated. Core components of the intervention, such as the formula for calculating calorie targets, provision of oral nutritional supplements and the online portal/resources could be used across healthcare services. If an early high calorie intake improves function in ALS as is hypothesized here, this will be applicable internationally. The intervention was acceptable to participants; however, given its complex nature, care must be taken to ascertain the key active ingredients of the intervention, if implementation is successful. A process evaluation is providing insights into participant and interventionist experiences [32].

4.2 | Clinical Implications

This intervention is likely to be utilized in practice by dietitians as an additional tool to supplement the oral nutritional support with people with ALS. Whilst designed for non-dietitians to deliver, for this to happen in practice, HCPs other than dietitians would need to be given the time to implement the intervention within their workload. Furthermore, the ONS requires prescribing by a doctor and monitoring for dosage to increase/decrease as required. Therefore, consideration of implementation strategies is required. The implementation of interventions such as

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the one developed here has implications for a range of long-term neurological conditions, where education about and delivery of personalized nutritional support, through collaboration between dietitians, neurologists and the wider multidisciplinary team, may increase and improve the quality of life [33, 34].

5 | Conclusion

We developed a complex nutritional support intervention, underpinned by behavior change theory, with significant contribution from people with ALS, carers and HCPs. The OptiCALS intervention consists of multiple components that were deemed acceptable and usable. The effectiveness of the intervention in changing behavior (to increase calorie intake), and the impact on functional outcomes and speed of disease progression, is being tested in a multi-centre RCT across the UK and Ireland [35].

Author Contributions

Alys Wyn Griffiths: writing – original draft, writing – review and editing, formal analysis. **Sean White:** conceptualization, investigation, writing – original draft, writing – review and editing, formal analysis. **Paul Norman:** conceptualization, investigation, funding acquisition, writing – original draft, methodology, data curation, formal analysis. **Elizabeth Coates:** funding acquisition, conceptualization, writing – review and editing, project administration, supervision. **Hannah Hartley:** formal analysis, investigation, writing – review and editing. **Isobel A. Williams:** investigation, writing – review and editing, formal analysis. **Vanessa Halliday:** conceptualization, investigation, writing – review and editing. **Daniel Beever:** investigation, writing – review and editing, formal analysis. **Gemma Hackney:** supervision, project administration, writing – review and editing. **Theocharis Stavroulakis:** conceptualization, funding acquisition, writing – review and editing. **Christopher McDermott:** conceptualization, investigation, funding acquisition, writing – original draft, methodology, supervision.

Funding

This project is funded by the National Institute for Health Research (NIHR) Programme Grants for Applied Research Programme (Grant Reference Number RP-PG-1016-20006) and supported by the NIHR Sheffield Biomedical Research Centre.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Checklist. **Supporting Information: 1**: Phase 2 participation in Think Aloud interviews. **Supporting Information: 2**: Examples of changes to intervention made in line with MoSCoW prioritization based on participant feedback in each Phase 2 cycle. **Supporting Information: 3:** Overview of participants feedback on acceptability and feasibility of the intervention within Phase 3 Overview of participants feedback on acceptability and feasibility of the intervention within Phase 3. **Supporting Information: 4:** Translation of barriers and facilitators to COM-B components, intervention function and BCTs.

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