Obesity Facts

Position Statement

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The H2020 "NoHoW Project": A Position Statement on Behavioural Approaches to Longer-Term Weight Management

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The NoHoW project is a 5 million Euro project that received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 643309. The project brings together a multidisciplinary team of academic experts in behaviour change, consumer science, weight management interventions (and intervention evaluation), weight management delivery, disease prevention, biomathematics, computer science, personal data tracking and human-computer interactions. The primary focus of the project was to develop and evaluate evidence-based behavioural approaches to weight loss maintenance.

Abstract
There is substantial evidence documenting the effects of behavioural interventions on weight loss (WL). However, behavioural approaches to initial WL are followed by some degree of longer-term weight regain, and large trials focusing on evidence-based approaches to weight loss maintenance (WLM) have generally only demonstrated small beneficial effects. The current state-of-the-art in behavioural interventions for WL and WLM raises questions of (i) how we define the relationship between WL and WLM, (ii) how energy balance (EB) systems respond to WL and influence behaviours that primarily drive weight regain, (iii) how intervention content, mode of delivery and intensity should be targeted to keep weight off, (iv) which mechanisms of action in complex interventions may prevent weight regain and (v) how to de-

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sign studies and interventions to maximise effective longer-term weight management. In considering these issues a writing team within the NoHoW Consortium was convened to elaborate a position statement, and behaviour change and obesity experts were invited to discuss these positions and to refine them. At present the evidence suggests that developing the skills to self-manage EB behaviours leads to more effective WLM. However, the effects of behaviour change interventions for WL and WLM are still relatively modest and our understanding of the factors that disrupt and undermine self-management of eating and physical activity is limited. These factors include physiological resistance to weight loss, gradual compensatory changes in eating and physical activity and reactive processes related to stress, emotions, rewards and desires that meet psychological needs. Better matching of evidence-based intervention content to quantitatively tracked EB behaviours and the specific needs of individuals may improve outcomes. Improving objective longitudinal tracking of energy intake and energy expenditure over time would provide a quantitative framework in which to understand the dynamics of behaviour change, mechanisms of action of behaviour change interventions and user engagement with intervention components to potentially improve weight management intervention design and evaluation.

Introduction

There is now considerable evidence documenting the effects of behavioural interventions on weight loss (WL) [1–3]. Diet and lifestyle interventions in adult populations produce mean WLs of <5 kg after 2–4 years, which is less than pharmacological and surgical approaches [4]. Currently available drugs provide mean WLs of 3–12%, although pharmacotherapy often has some side effects and cannot be used indefinitely [5]. Surgical interventions produce by far the most effective outcomes, but the procedure is not without risk, is often irreversible and generally reserved for treatment of severe obesity [6, 7]. Perioperative morbidity and mortality rates are 5 and 0.3%, respectively [6]. Complications (and percentage frequency) of bariatric surgery include sepsis from anastomotic leak 0.1–5.6%, haemorrhage 1–4%, cardiopulmonary events <1%, thrombosis 0.34%, death 0.1–0.3%. Later complications for gastric band (band slippage, leakage and erosion) range between 1 and 15%. Those for bypass (anastomotic strictures, marginal ulcers, bowel obstructions), range between 1 and 5% [6]. However, almost all approaches to initial WL are followed by some degree of longer-term weight regain [1]. Multicomponent diet, lifestyle, physical activity and behaviour change approaches (which we refer to as behavioural interventions) are the first line of intervention, potentially with the maximum level of scale, that is invoked to help people manage their weight [8]. The focus of this paper is behavioural weight loss maintenance (WLM) interventions in adults and their effectiveness, excluding WL achieved by pharmacotherapy and surgery.

At present, systematic reviews and meta-analyses show the extent to which behaviour change interventions for WLM in adult populations are effective [9]. Generally, per-protocol results show greater WL than intention-to-treat analyses. A number of large trials focusing on evidence-based approaches to WLM have demonstrated effects on weight-related outcomes, generally not exceeding 2 kg by trial end, over time periods ranging between 6 and 12 months. These include the WLM randomised controlled trial [10], DiOGenes [11], PREVIEW [12], NuLevel [13] and NoHoW [14] trials. The Look AHEAD trial produced clinically significant WL (≥5%) after 8 year's intensive lifestyle intervention in 50% of 2,570 adults with type 2 diabetes, a patient population with a strong clinical reason for trying to achieve WLM [15]. The current state-of-the-art in behavioural interventions for WL and WLM raises questions of (i) how do we define the relationship between WL and WLM, (ii) how do energy balance (EB) systems respond to WL and influence behaviours that primarily drive weight regain, (iii) how intervention content, mode of delivery and intensity should be targeted to keep weight off, (iv) which mechanisms of action in complex interventions may prevent weight regain and (v) how do we design studies and interventions to maximise effective longer-term weight management.

In considering these issues a writing team within the NoHoW Consortium was convened to elaborate this position statement. Behaviour change and obesity experts were invited to attend a workshop supported by the European Association for the Study of Obesity (EASO) at the European Congress on Obesity (ECO) conference in May 2019 in Glasgow, UK, to discuss these positions and to refine them. This paper considers six positions that were discussed at that workshop related to current behavioural approaches and directions for longer-term weight management research that can inform practice.

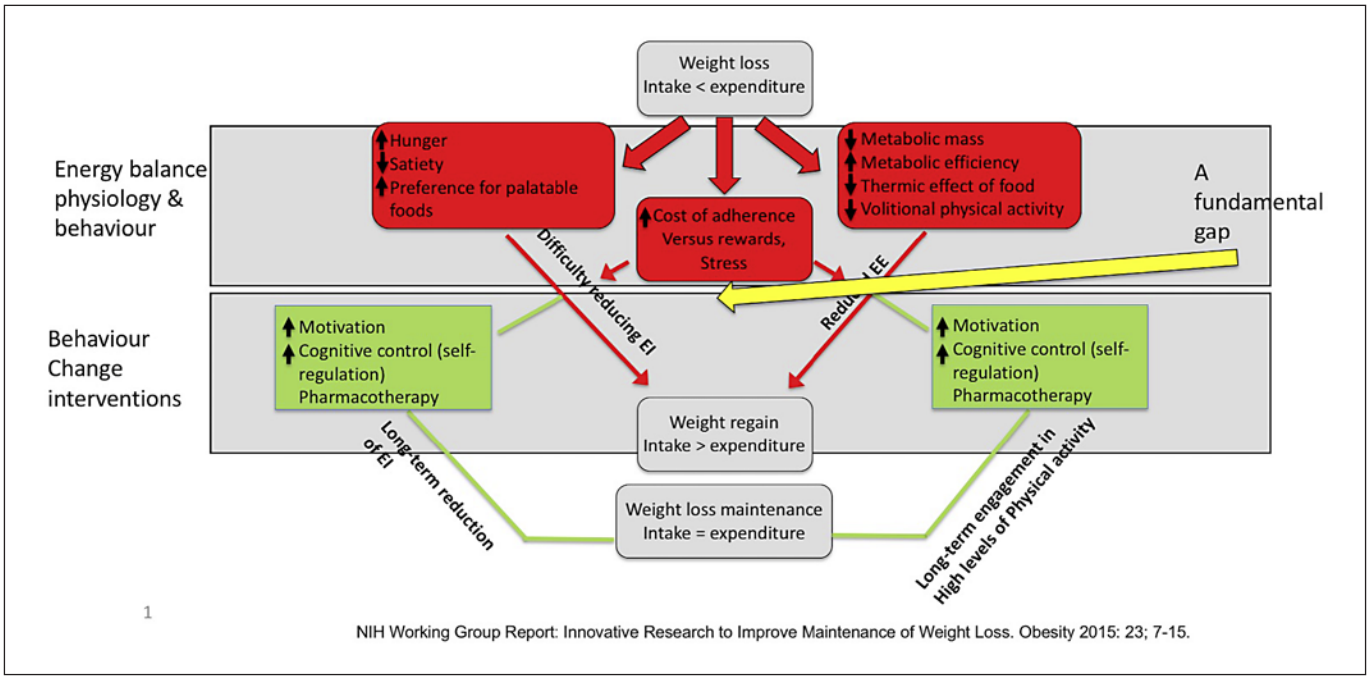

Fig. 1. Adaptation of the NIH Working Group Report framework for maintenance of weight loss (WL) to show how changes in energy balance physiology and behaviour potentially undermine longer-term weight management interventions. The study on weight management tends to be split into small-scale physiological studies of WL and the larger-scale interventions that seek to understand mechanisms of action of behaviour change approaches, and there is an urgent need to integrate these fields of study. EI, energy intake; EE, energy expenditure.

Position 1

WL by intentional weight management attempts can be described as a period of WL and subsequent weight regain prevention (maintenance), but the process of WL attempts usually follows a trajectory of WL followed by weight regain. Behaviour change programmes should take into account the dynamic nature of WL attempts.

Obesity is a complex chronic condition that often involves relapsing cycles of attempted WL and weight regain [16–18]. It can be described using practical and holistic tools for categorizing severity of weight-related health problems such as the Edmonton Obesity Staging System Tool [19] and the classification of obesity as an adiposity-based chronic disease (ABCD) [20]. Even though it is recognised that obesity management can be best achieved through multicomponent behavioural interventions and prevention strategies, to date no set of policies or approaches has made a significant impact on long-term obesity prevalence [21]. Evidence-based interventions and commercial programmes for WL are widely available [1, 2]. However, the evidence for the effective components of behaviour change interventions is limited and weight regain is common, with 80% of individuals who achieve clinically significant WL failing to sustain that WL over a period of 12 months or more [22]. WLM outcomes are similarly modest. In maintenance interventions using behaviour change approaches, the overall mean outcome is about 1.5 kg [9]. Typically, in WLM interventions people have lost about 8–10% of their weight (approx. 8–10 kg) prior to intervention for maintenance. This means that WLM intervention participants on average are keeping off about 15% of the weight they initially lost at 1 year after WL, i.e. they are regaining 80–85% of the weight they lost [9–13, 15].

There is a current debate as to whether WL and WLM involve separate physiological, psychological and behavioural phases or whether the transition from WL to maintenance is a two-stage process [16, 18, 23]. For example, it remains unclear whether maintenance of WL requires a different skills set (from an individual perspective) to that needed to achieve initial WL or whether it involves a continuation of the implementation of the skills developed for initial WL. Some of the behaviours that lead to WL are continued during WLM [24]. Some additional behaviours are also initiated during the period of WLM [23].

The distinction between behavioural strategies for WL and WLM is theory driven (conceptual) [25] but when tested in research trials, few studies have demonstrated this distinction. We do not yet know if the behavioural and psychological mechanisms of action that may be effective for WL are the same as those for WLM. The general course of WL and subsequent outcomes is that maximal WL is achieved at about 6 months of an intervention and body weight gradually increases back to baseline thereafter [1]. Current models of behaviour change include reflective and reactive components [16, 25, 26], but they may not capture changes in the dynamics of compensatory components energy expenditure (EE), eating and physical behaviours that respond to negative EBs over time [18].

It is likely that a dynamic interaction between behavioural strategies to lose and maintain weight on the one hand and the active physiological and passive environmental resistance to WL on the other, account for the patterns of WL and subsequent regain often observed in WL interventions [1] (Fig. 1). The transition from WL to WLM or weight relapse is likely to operate at the environmental, behavioural and physiological levels [18, 27, 28]. Those who lose weight are at high risk of weight regain [1].

Given the limited effectiveness of diet and lifestyle programmes for WL, most people with obesity who have engaged in a successful WL attempt may be actually aiming to lose more weight upon entry to a WLM study rather than maintain the weight lost [24, 29] and many relapse [30]. Many people attempting to maintain their WL therefore experience periods where they re-visit strategies they originally used to lose weight, in order to cope with weight relapse or lose further weight [18]. In this sense the study of WLM would be better described as the study of WL and subsequent regain prevention. Indeed, a greater focus on "why" longer-term WL interventions are subject to the laws of diminishing returns may help us better understand mechanisms that could be more effective for relapse prevention, be it long and slow (as in the case with compensatory EB behaviours) or short and fast (as in the case with drop-out from WL programmes). While we have learned a great deal from studies of weight control registries, these are select samples who are relatively successful at longer-term weight management and may not be representative of the many people who engage in WL attempts [24, 29, 31, 32].

Greaves et al. [16] describe longer-term weight management as generating a tension between existing habits (EB behaviours) and incompatibility of new (weight management) behaviours with the fulfilment of psychological needs. They suggest that this tension can be managed through self-regulation, renewed motivation and managing external influences to change habits, finding non-obesogenic approaches to meet psychological needs and changing self-concept. It is likely that some of the factors that undermine longer-term WL, such as changes in EB physiology affecting EE, food reward-based processes or energy intake (EI), may be outside of conscious recognition and control. There is some evidence that aspects of self-regulation and motivation may improve the odds of changing EB behaviours and if those changes become habitual in the longer term the chances of preventing weight regain may improve [9, 33, 34]. It is possible that changing habits can take 2–5 years [30]. However, it is likely that reactive processes (emotions, desires, impulses resulting from associative learning and physiological resistance to WL) are powerful forces that can undermine relatively transient and fragile attempts at changing EB behaviours during WL (e.g. [35, 36]). It is perhaps in this dynamic transition where we need to better understand the interplay between physiology and behaviour to improve longer-term weight management and the prevention of weight regain [25, 37].

Position 2

Sustained weight management interventions should place greater emphasis on aligning mechanisms of action of behaviour change interventions with the compensatory EB behaviours that undermine those interventions.

Energy deficits alter the physiology of EE in a quantitatively significant manner [38]. In addition, there are a number of changes in compensatory behaviours that oppose or undermine WL [17, 18]. It would appear from mathematical models, that over a period of 12–24 months approximately 25–30% of physiological resistance to WL may be due to compensatory changes in EE, while 70–75% are due to an increased EI [39]. The models [40] that estimate long-term changes in EI from body weight (assuming no change in physical activity EE) during WL interventions suggest compensation in EI is proportionate to WL and appears to be approximately 3–4 times greater than estimated compensation of estimated EE in response to 10–20% WL [39]. If prolonged WL attempts lead to increases in appetite (using estimated EI as a proxy) in proportion to the weight that is lost, it is important to take these changes into account in designing behaviour change interventions for weight management [39, 41].

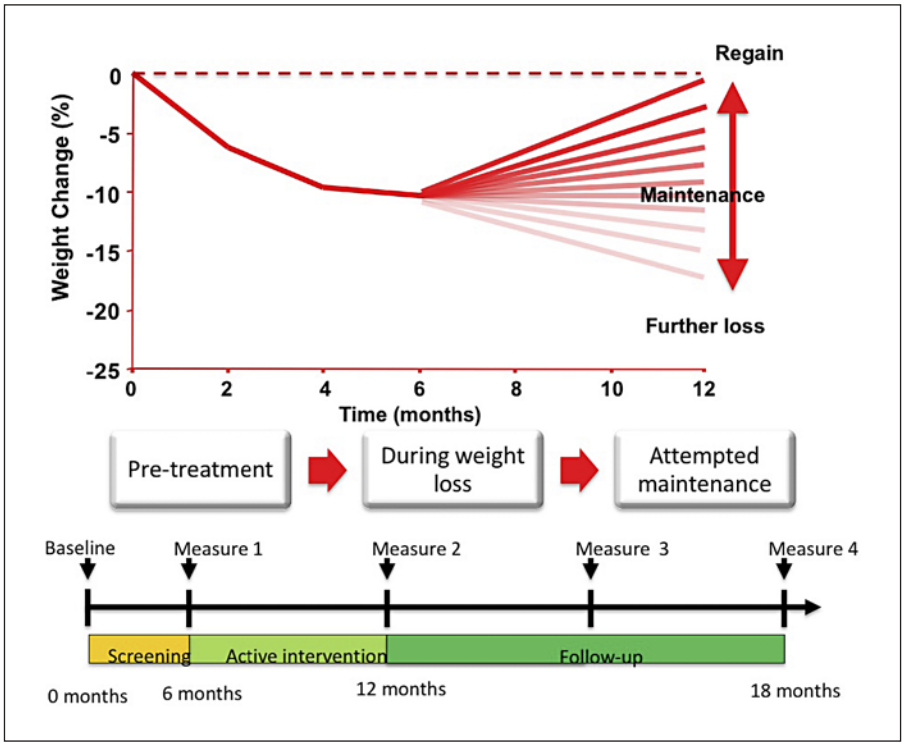

Fig. 2. In many interventions, outcome measures are made during constrained time windows at a small number of regular stages at the beginning, middle and end of the intervention.

WL influences body structure, which in turn affects EB physiology (the composition and distribution of tissues mobilised and EE) and consequently behaviours (physical activity and eating), in a way that attempts to restore body weight to pre-WL levels [18]. Physiological resistance to WL appears to exert a large influence on weight regain through EB behaviours. Current WLM interventions do not appear to be configured to take account of the strength of compensatory behaviours that may undermine longer-term weight management. Researchers should align physiological models of EB regulation and behavioural weight management interventions to account for a number of salient features of the way human EB responds. The asymmetry of EB regulation means that EE behaviours are far less responsive to weight gain than WL [18, 38]. The dynamic physiological responses to energy deficits and their potential impact on behaviour make weight regain a highly probable response to weight management attempts [17, 18].

Thus, while a primary target for WLM should be the maintenance of eating and physical activity behaviours that led to WL in the first place, this should be coupled with an appreciation of how EB systems adjust to WL through lowered energy requirements and compensatory increases in EI over time [18]. These increases are difficult to perceive at the level of the individual and may go undetected by current methods of measurement. Measurement of EI and EE (with the exception of indirect calorimetry including doubly labelled water) usually relies on self-report measures that are known to have several limitations and are arguably unreliable in free-living participants [42]. Furthermore, it is often the case that in many interventions, outcome measures are made during constrained time windows at a small number of regular stages at the beginning, middle and end of the intervention (Fig. 2). Such "snapshot" measures may miss the dynamics of change in mechanisms of action that occur over time and that may be cumulatively important for behavioural outcomes. More sophisticated approaches to tracking EB behaviours in the context of continuously tracked changes in body weight and composition are needed [43] e.g. to identify relapse signatures/trajectories as points for intervention and to provide an empirical framework for tracking psychological and physiological mechanisms.

Position 3

Objective tracking of changes in energy balance behaviours over time may improve prevention of weight regain through personalisation of weight management interventions.

The asymmetry of EB regulation is a major factor that should be considered when designing behavioural interventions for longer-term weight management (i.e., WL and prevention of weight regain). The majority of longer-term WL interventions decrease in intensity as the intervention progresses (i.e., greater intervention intensity is focused on the WL rather than the WLM phase). However, progression of a weight control intervention is associated with decreased adherence, lapse in the control of EB behaviours, increased drop-out and hence weight regain, and as such it is more logical for intervention dose to be maintained or increased, or targeted to critical moments (e.g., lapses) rather than decrease, over time.

Evidence supports an extended care approach, in which obesity is treated as a chronic condition requiring continuous support to prevent weight regain [44]. It has been argued that continuing face-to-face interventions over prolonged periods are resource-intensive strategies that are at high risk of diminishing cost-effectiveness [45].

Objective quantification of EI and EE would help us understand and better use self-reported psychological and behavioural mechanisms by which weight management interventions may work. Significant components of EB behaviours are automatic and therefore extremely difficult to measure using self-report methods [42]. The measurement of eating behaviour in participants of therapeutic WL programmes is remarkably difficult because caloric restriction is often a primary strategy used to lose weight, compliance with such regimes is notoriously poor and self-reported food intake is notoriously unreliable [42]. Given the apparent unreliability of self-report measures of EI and EE, development and application of objective tracking technologies would enable better quantification of EI and EE. Rapid progress is being made in developing machine learning algorithms that improve our ability to estimate EE from physiological and accelerometry data [46–48]. Combining such estimates with tracked body weight (which can now be integrated easily into interventions using WiFi-connected smart scales) would allow approximate estimates of EI changes using validated mathematical models [39–41]. Such developments may provide a major leap forward in longitudinal estimates of EB behaviours and their relative contribution to weight outcomes in behaviour change interventions for weight management. These methodological developments would potentially provide the quantitative framework on which behaviour change interventions for longer-term self-management of body weight could be improved.

Combining detailed digital tracking and feedback of user engagement, with tracking of EB behaviours, body weight and where possible body composition may enable a more targeted approach for focusing delivery of brief interventions at the point of weight relapse or discontinuation of programme engagement. Such targeted strategies may increase cost-effectiveness of next-generation longer-term weight management interventions and improve personalised delivery of intervention content to meet the specific requirements of those experiencing lapses or relapses. In order to achieve more cost-effective and targeted interventions, we need to better understand how to target the content and structure of behaviour change interventions to the changing needs of individuals throughout the course of those interventions. It is important to better understand how the mechanisms of action of behaviour change for weight management operate in different people and how to best apply them [49]. Another relevant approach in recognizing the dynamic nature of WL and regain is to teach WLM skills prior to WL [50]. This approach shows some promise in helping people prevent weight regain [50].

Position 4

There is a need to develop structured, longitudinal assessments of moderators and mediators of objectively tracked EB behaviours and their relative contribution to weight outcomes in longer-term weight management interventions.

Behaviour change approaches for WL and prevention of weight regain should be both theoretically informed and evidence-based in order to understand and target effective intervention components to the needs of specific individuals [3, 51, 52]. Currently there is more theory (117 theories of behaviour change [25]) than clear evidence, and it is important therefore to order both theory and potential mechanisms by which behaviour change interventions exert their effects (or lack of effect). Multicomponent behaviour change interventions are by their nature complex [53]. This requires the development of standardised, shared methods to describe the components of behaviour change interventions [53]. Over the last few years theories of behaviour change have been aggregated into a theoretical domains framework to identify theories relevant to behaviour change and theoretic constructs that may affect changes in behaviour [54]. This has allowed the construction of taxonomies of behaviour change techniques with the intention of mapping behav-

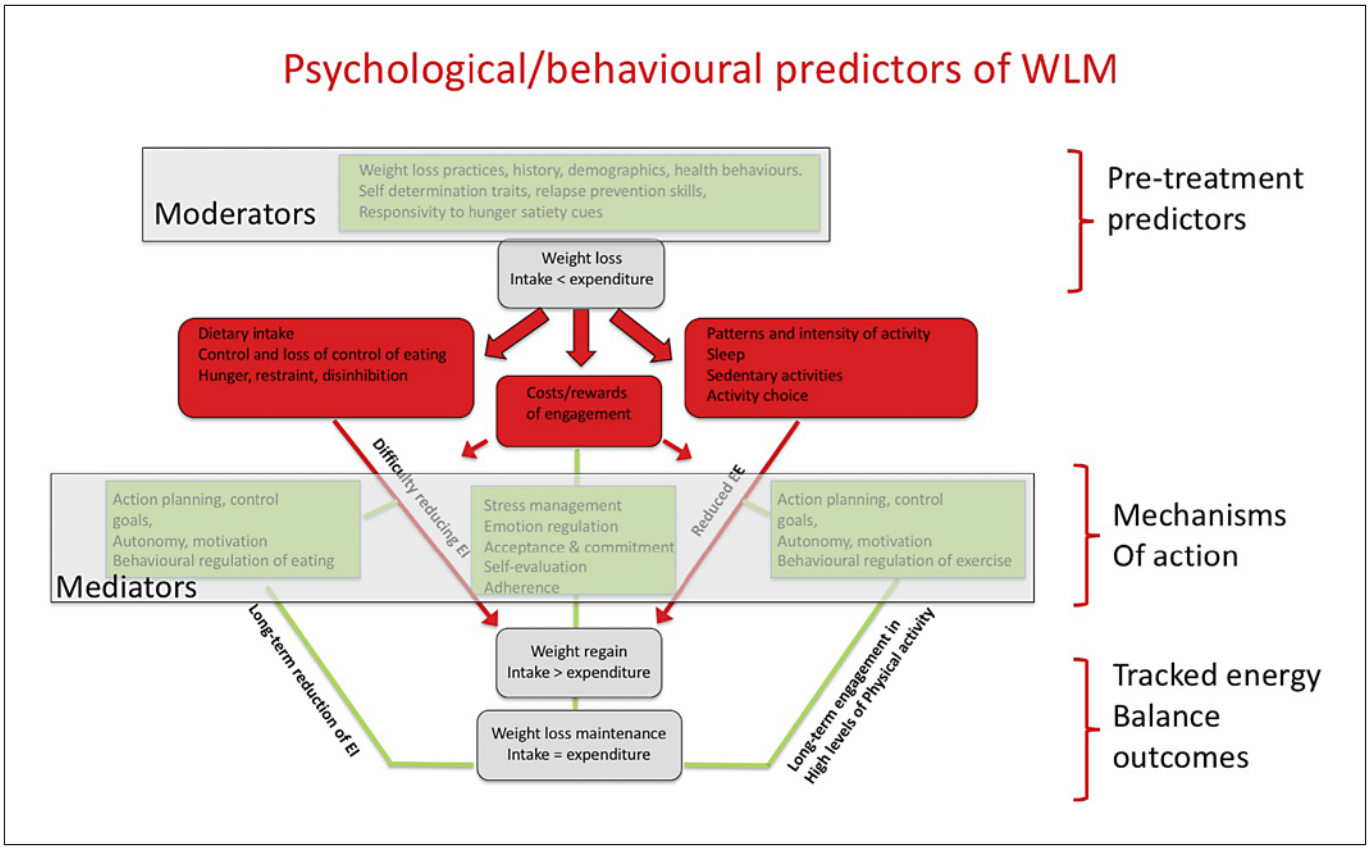

Fig. 3. Schematic adaptation of the NIH Working Group Report framework for maintenance of weight loss illustrating how pre-treatment predictors and mechanisms of action of behaviour change interventions relate to compensatory changes in the components of energy intake (EI) and energy expenditure (EE). At present, moderators, mediators of energy balance behaviours and energy balance behaviours themselves all tend to be assessed using self-report measures. Objective tracking of estimated energy intake, expenditure and balance would provide an empirical framework in which to examine psychosocial predictors of longer-term weight outcomes. WLM, weight loss maintenance.

iour change techniques onto the mechanisms by which they achieve changes in specific behaviours [55, 56]. This approach enables the specified active ingredients of behaviour change interventions (behaviour change techniques) to be related to changes in behaviour through standardised, recognised mechanisms of action, supported by systematic reviews and expert consensus [53]. The COM-B model provides an overarching theoretical framework to understand the barriers and facilitators of behaviour. Specifically, the model suggests that behaviour change requires capability (physiological or physical ability), motivation (reflective and automatic processes to activate or inhibit behaviour) and opportunity (physical and social environment to enable behaviour) [28]. Kwasnicka et al. [25] have systematically reviewed theoretical explanations for the maintenance of behaviour change and identified five overarching theoretical explanations for the maintenance of behaviour change representing motives, self-regulation, psychological and physical resources, habits and environmental/social influences on behaviour. A key question is how such frameworks for reflective and automatic mechanisms of behaviour change interface with the physiology of energy balance compensation in response to attempted or imposed energy deficits. The NIH framework for WLM provides a conceptual model of how compensatory changes in the components of EB oppose WL interventions. Figure 3 shows how this framework can be adapted to assess moderators and mediators of EB behaviours within an objectively tracked EB framework.

Evidence for mechanisms of action that lead to sustained weight management is currently limited [18]. It is unclear what specific behaviour change approaches, delivery, settings and implementation strategies are most

effective for sustained change in EB behaviours. Nevertheless, in the last few years evidence that self-regulation of longer-term weight control and EB behaviours improves longer-term weight outcomes in adults has grown. Dombrowski et al. [9] have found in 45 studies that behavioural interventions targeting both diet and physical activity behaviours for WLM are moderately effective, and not less effective than Orlistat (approx. 1.6 kg difference compared to control/placebo interventions) at promoting WLM over 1 year. There is some evidence of effectiveness over 2 years and limited evidence relating to weight outcomes beyond 2 years [33, 34, 52]. Dombrowski et al. (2014) found no evidence that mode and dose of intervention delivery (number of intervention components or frequency of contact, Internet vs. control or face-to-face vs. remote delivery of the same intervention), for diet, physical activity or nutritional supplements/food replacements have a greater effect when used as interventions alone.

Teixeira et al. [33] have systematically reviewed 42 putative self-regulatory and psychological mechanisms as mediators of longer-term weight outcomes and EB behaviours across 35 behavioural interventions. They identified mediators of successful weight outcomes as higher exercise autonomous motivation, exercise self-efficacy, low perceived barriers to exercise, self-regulatory techniques, flexible eating restraint and positive body image. Mediators of sustained increases in physical activity were autonomous motivation, self-efficacy and use of self-regulatory skills. No mediators of long-term dietary intake were identified, which is perhaps unsurprising given the nature and extent of mis-reporting of EI. Varkevisser et al. [34] have recently systematically reviewed 49 studies and evaluated 5 demographic, 59 behavioural, 51 psychological/cognitive and 9 social and environmental predictors of weight outcomes in observational, long-term WL and maintenance interventions. They found that aspects of self-regulation of eating, activity and weight control behaviours are predictive of WLM, through their impact on change in behaviour during weight management attempts. This is important because pretreatment predictors including sociodemographic background explain very little of the variance in WL [34, 57, 58].

The limited evidence from these meta-analyses suggests that navigating from initial WL to WLM requires long-term self-management of EB behaviours. This occurs in the face of physiological resistance to WL. Avoiding weight regain requires behavioural strategies in which relapse coping and WLM become learned skills of self-regulation, action planning, developing self-efficacy, autonomy and motivation [33, 59–62] as part of a longer-term process. These findings suggest that tracking the dynamics of change in EB behaviours during the course of weight management interventions may be an important approach to improving weight outcomes. Similarly, Rothman's group have articulated the need to track within-person shifts between reactive and reflective systems that may promote or derail effective behaviour change. They also advocate the collection of intensive longitudinal data, electronic tracking of behaviour, ecological momentary assessment and complex modelling approaches, which would help us better understand the factors promoting or undermining longer-term behaviour change [26]. These arguments also apply to EB behaviours and WLM. These are key areas on which next-generation WLM interventions could focus. Core features of WLM interventions that show some effect in adults include behaviour change techniques that improve self-efficacy in self-monitoring (of weight and behaviour), short-term relapse prevention, goal setting, and action plans for diet and physical activity [9, 17, 33, 34, 51, 63, 64]. Autonomous self-regulation and intrinsic motivation may augment self-regulatory goals and self-efficacy [58, 61, 64, 65]. Understanding the tension or conflict between these behaviour change strategies and the factors that undermine WLM is necessary to better target intervention delivery to meet the needs of those who lapse, drop out and/or relapse [18, 27, 28].

Position 5

Intentional WL attempts have the potential to have adverse impact on mental health and well-being, which can in turn impact weight management capability.

It is well documented that people living with obesity experience stigma, have lower self-esteem and a higher risk of experiencing depression and anxiety and perceive a high pressure to lose weight [66–68]. This high pressure to lose weight can result in frequent WL attempts with high personal and financial investments. These efforts are often unsuccessful and when successful, often not sustained. This results in reduced confidence associated with negative emotions; these negative emotions as such become barriers to WLM [69].

Historically, behaviour change models have focused on social cognition (e.g., beliefs, intentions, attitudes and decisions), emphasising pathways of reasoned action in which predecisional motivation leads to the formation of intentions and the implementation of intentions as voli-

tional action [70, 71]. Reactive processes (emotions, desires, habits resulting from associative learning and physiological states) may also have a major impact on behaviour and behaviour change. These processes tend to be relatively rapid, impulsive (less conscious) and habitual in comparison to the slow, deliberative processes of motivation and self-regulation [72, 73]. Furthermore, the development of self-regulatory changes in EB behaviours is effortful, particularly in the face of physiological resistance to WL, while unconscious or reactive components of EB behaviours are rapid and effortless [74]. Physiological mediators of homeostatic and hedonic appetitive drives, and changes in physical activity that are triggered by WL may feed into such a reactive process of behaviour change to undermine self-regulation of EB behaviours.

Another aspect of automaticity (reactivity) potentially affecting EB behaviours is distress tolerance and emotion regulation. Individuals trying to lose weight can experience increased psychosocial stress and weight-related stigma [66–68], which may undermine self-regulatory practices and WL attempts. Repeated attempts at WL followed by weight regain can have a negative emotional impact, leading to perceived stress and negative emotions. For some, eating may be a means of coping with these negative experiences, potentially derailing strategies of planned behaviour [75–79]. There is sufficient evidence to highlight people making WL attempts as a high-risk population for mental health problems [80] and to require that WL interventions make provisions for well-being and self-esteem and to add particular support when participants discontinue the weight management programme as such. Likewise, it is important to strongly recommend that well-being and quality of life need to be considered as an additional important outcome of weight management studies.

While there is increasing evidence for multiple tensions between physiology and behaviour, cognitive strategies and subconscious behaviours, intentions and psychological needs, we are still a long way from articulating these conflicts or strategies for their resolution in the context of behaviour change interventions for longer-term WLM. Recent models emphasise the interplay between reflective and reactive processes and their impact on planned behaviour [16, 25, 26]. Underneath these processes and interfacing with them are compensatory changes in EB physiology and behaviour, which undermine behaviour change interventions for weight management and are likely to escalate as energy deficits increase in magnitude. We hypothesise that compensatory changes in EB physiology and behaviour primarily operate through reactive processes, making them difficult to self-monitor and measure [18]. There is a need to develop more comprehensive and relevant logic models that include the factors likely to both promote and undermine WLM that are perhaps more specific to the personal experiences of those engaged in longer-term weight management attempts. We also need to understand better how different people experience and respond to a WL attempt, throughout the course of that attempt. These insights may help us better articulate the way longer-term weight management interventions could work and why they have not yet achieved the desired effects for the majority of people.

Position 6

Greater standardisation of predictive constructs and outcome measures, in clearly defined study populations, tracked longitudinally would improve cause-effect models that characterise (i) compensation of EB behaviours undermining longer-term weight management, (ii) how and which behaviour change approaches can overcome physiological resistance to WL in various stages of the process of weight management, and (iii) who is likely to maintain weight or relapse.

There is some evidence that aspects of self-regulation and motivation may improve the odds of sustaining changes in EB behaviours and if those changes become automatic in the longer-term, the chances of preventing weight regain may improve. However, reactive processes (emotions, desires, appetitive drives and habits resulting from associative learning and physiological resistance to WL) are powerful forces that can undermine the relatively transient and fragile attempts at changing EB behaviours during WL and maintenance attempts. It is perhaps in this dynamic transition where we need to better understand the interplay between physiology and behaviour to improve longer-term weight management and the prevention of weight regain. Developing interventions that provide ongoing health behaviour support is an important innovation that may improve next-generation interventions [81]. A considerable amount of work is being done in optimising intervention design and establishing mechanisms of action of behavioural interventions [82–85].

Longer-term weight management interventions should be designed around the known compensatory physiological/behavioural responses to WL, and developing approaches to tracking EB behaviours is a critical gap that needs to be addressed in improving future interven-

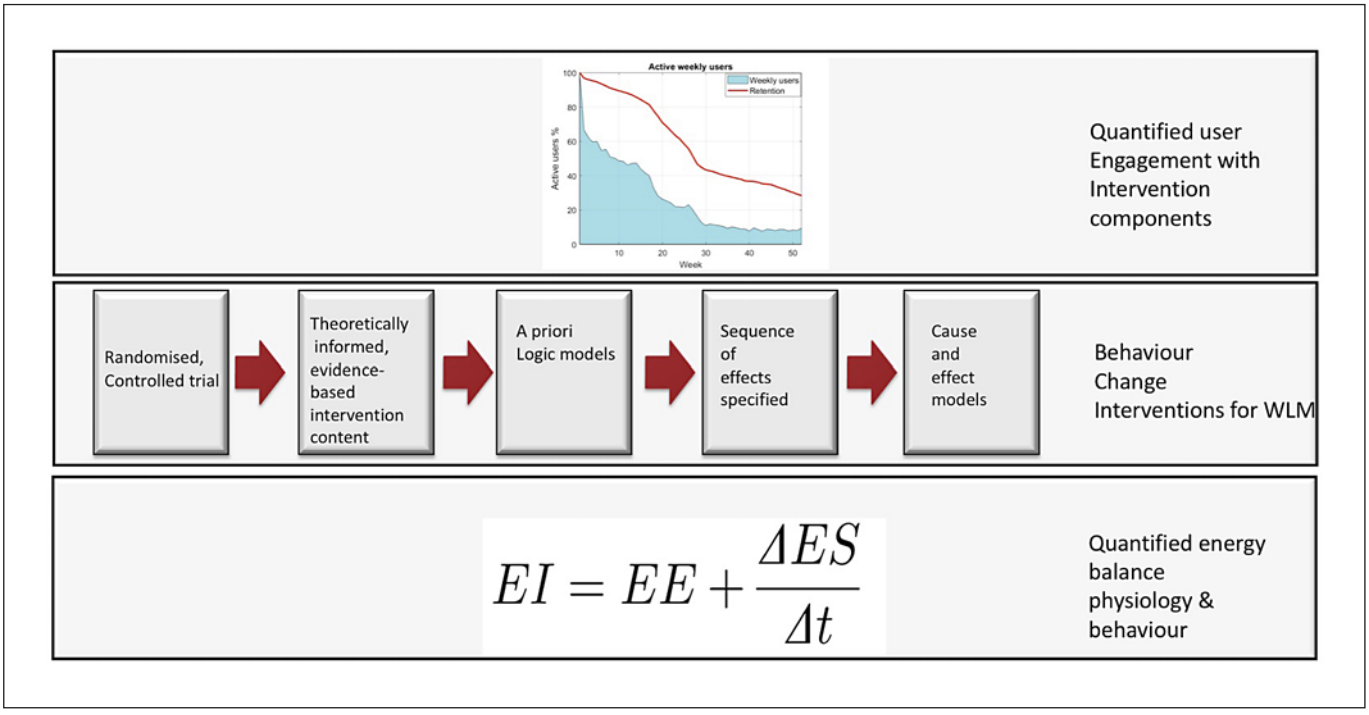

Fig. 4. Schematic diagram illustrating how quantified user engagement with intervention components (using meta-data) can be related to cause-effect models elucidating mechanisms of action of behaviour change interventions in the context of quantified energy balance physiology and behaviour. WLM, weight loss maintenance; EI, energy intake; EE, energy expenditure; ΔES, change in energy stores; Δt, change in time.

tions (Fig. 4). Objective tracking of EB behaviours would provide empirical framework in which behaviour change interventions could be more comprehensively assessed.

There is currently a gap between detailed, small-scale physiological studies of WL and the larger-scale interventions that seek to understand mechanisms of action of behaviour change approaches [18]. Behaviour change interventions for weight management tend to ignore physiological resistance to WL and compensation of EB behaviours, as well as contextual barriers [86]. It is important to improve our understanding of the mechanisms by which WL facilitates subsequent weight regain as a context in which behaviour change interventions attempt to operate. It is equally important for the research community to take stock of why behaviour change interventions for WL and WLM do not yet produce much beyond modest effects. It is probably not the interventions themselves, but the fact that EB physiology and behaviour tend to undermine them that accounts for the high probability of weight regain. It may be useful to consider the key minimum components of WLM interventions as a basis on which to build new approaches and give some thought to the reasons why weight regain is so likely. There is a great deal to learn about why such interventions do not work as well as we hope they would. Considerable insight could be gained from detailed structured analyses of why WLM interventions do not work at the experiential level.

There is a need to develop interventions using ongoing support, that track changes in behaviour, mechanisms of action of behaviour change interventions and user engagement with those interventions, using logic models based on theoretically informed, evidence-based intervention content [82–85]. Employing repeated measures of components of EB (e.g., physical activity, weight) tracked over the course of WL attempts may improve cause-effect relationships between behaviour change approaches and EB behaviours [18, 26]. Such interventions should also, where possible, examine user interactions with and experience of intervention content. Given the evidence reviewed above it is likely that such secondary analyses will yield critical information about who responds to certain intervention components and how those components affect EB behaviours, to inform personalised interventions in the future. If the typical effect sizes produced by multicomponent interventions are small, personalisation of such interventions, by better

matching evidence-based behaviour change content and delivery to the specific needs of individuals may improve longer-term weight outcomes [87, 88].

Improved measurement of EB and associated behaviours may help us bring together research on physiological and behavioural responses to energy deficits, better understand the factors that lead to weight regain and help people navigate more effectively to sustained changes in their weight and health outcomes.

Conclusion

At present the evidence suggests that developing the skills to self-manage EB behaviours leads to more effective WLM. However, the effects of behaviour change interventions for WL and WLM are still relatively modest and our understanding of the factors that disrupt and undermine self-management of eating and physical activity is limited. These factors include physiological resistance to WL, gradual compensatory changes in eating and physical activity, reactive processes related to stress, emotions, rewards and desires that meet psychological needs. Better matching evidence-based intervention content to both the specific needs of individuals and EB behaviours they target may improve outcomes. Improving objective longitudinal tracking of EI and EE over time would provide a quantitative framework in which to understand the dynamics of behaviour change, mechanisms of action of behaviour change interventions and user engagement with intervention components to potentially improve weight management intervention design, evaluation and effectiveness.

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Author Contributions

R.J.S., B.L.H., P.T., F.F.S. and A.L.P. conceived the NoHoW project. R.J.S. was the principal investigator of the NoHoW randomised controlled trial. B.L.H. was the grant coordinator. C.D. was the trial manager. C.D., A.L.P. and S.C.L. were site coordinators. G.H. is the trial statistician and coordinator of the project data management. M.M., I.S. and C.D. coordinated the experts' workshop conducted at ECO to discuss and refine the positions presented in the paper. R.J.S. and C.D. drafted the manuscript, and R.O.D., J.T., D.K., F.F.S., M.M., I.S., J.C.G.H. and B.H. were involved in the experts' discussion and have made substantial contributions to the paper. All authors revised and approved the final version.

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