Self-Weighing and Self-Regulation for Weight Loss

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Abstract

Intentional weight loss requires self-regulation to override externally-driven behaviours. Self-regulation theory hypothesises that individuals automatically self-regulate when they find that their current state is not in line with their goals. In the context of weight management, this process involves self-weighing, contextualising weight measurements, reflecting on and evaluating previous behaviour, and planning and performing weight loss actions. The research presented in this thesis explored barriers to and benefits of self-weighing and self-regulation for weight loss in adults with overweight or obesity. In a think-aloud study, I investigated the extent to which self-regulation occurs naturally. I found that action planning was performed rarely, but was a significant predictor of weight loss. Individuals found self-weighing useful, but fluctuations hindered the interpretation of weight changes. With an observational analysis, I then explored why individuals trying to lose weight stop weighing themselves. I found individuals concurrently reduced their physical activity and gained weight preceding a stop in weight monitoring, suggesting that individuals lost motivation to lose weight and struggled receiving negative weight feedback. An app market review explored user reviews of weight tracking apps, finding that users gained motivation from receiving (graphical) feedback on their progress. Based on the findings from these three studies, I developed a

weight loss intervention guiding individuals through the complete self-regulation process, whilst addressing several identified barriers. To support individuals` interpretation of weight changes, I employed daily weighing and weight tracking, but weekly reflection on weight changes. The intervention additionally encouraged individuals to experiment with weight loss actions on a daily basis, and evaluate their usefulness once a week. A randomised controlled trial (RCT) tested the early effectiveness of the intervention against daily weighing only, finding a significant weight loss effect at 8-week follow-up (-3.20kg, 95% CI=-4.49, -1.92). Participants found the intervention acceptable and feasible. Altogether, my research suggests that self-regulation can be an effective weight loss strategy when individuals are guided through it, supporting further research in this area. The long-term effectiveness of the intervention warrants further testing in a larger RCT.

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Statement of contribution

I declare that this thesis is entirely my own work, completed under the supervision of Professor Paul Aveyard, Professor Susan Jebb and Dr Jamie Hartmann-Boyce at the Nuffield Department of Primary Care Health Sciences, University of Oxford.

I led all aspects of the work presented in this thesis, including the design, conduct, and analysis of all studies, as well as the writing of chapters and related journal articles. All tables and figures contained within this thesis are my own creation. I hereby declare that no part of this thesis has been submitted for any other degree at this or any other university.

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Contents

Chapter 1 Introduction

1.1 Summary

This chapter aims to provide the background to the rest of this thesis. I start by giving an overview of the prevalence, aetiology, and health consequences of overweight and obesity, as well as the benefits of losing excess weight. I consider different treatment approaches to weight loss with a focus on behavioural interventions. Throughout these sections, I discuss the importance of self-regulation in the management of weight and explain my rationale for wanting to investigate how to improve individuals' self-regulation ability. I explore the theoretical background of self-regulation and present research on self-monitoring of weight, the centrepiece of the self-regulation process. Throughout these last sections, I identify gaps in the literature, which lead to the aims and objectives of this thesis.

1.2 Overweight and obesity in adults

1.2.1 Prevalence

The prevalence of overweight and obesity in adults has risen dramatically in recent decades[1]. For 2015-2016, the National Centre for Health Statistics in the U.S. reported an obesity prevalence of 39.6%, an increase of nine percentage points since 1999-2000[2]. The Health Survey for England estimated that obesity prevalence rose from 23% in 2003 to 28% in 2018[3], thus now affecting more than a quarter of the countries' population.

Box 1. Body Mass Index (BMI) Classification

Overweight and obesity are defined by BMI (kg/m^2) ranges; a BMI between 25 to 29.9 is classified as overweight and a BMI above 30 is referred to as obese. Obesity is further split into classes, namely obesity class I (BMI ≥30 to <35), class II (BMI ≥35 to <40), and class III (BMI ≥40)[4].

The Global Burden of Disease Study systematically combined data from more than 185 countries[1, 5]. They reported a dramatic rise in overweight and obesity rates (BMI≥25) worldwide, from 28.8%/29.8% in 1980 to 36.9%/38.0% in 2013, for men and women respectively. These percentages translate into a considerable increase from 921 million to 2.1 billion people across the globe. In 2015, the study authors estimated that there were 603.7 million adults (12.0%) with obesity worldwide.

The prevalence of obesity has increased in high-, middle- and low-income countries over the past decades. Although the proportion of adults affected by overweight and obesity is nowadays still greatest in high-income countries[5], the rate of increase has slowed throughout the last decade, whilst accelerating in low-income countries[1, 6]. It might therefore only be a question of time until the prevalence of obesity is similar across the world. In addition to between-country differences in prevalence rates, research has also revealed that obesity varies by socioeconomic status (SES)[7, 8]. The direction of effects is dependent on the developmental state of the country[5]. Less developed, low-income countries typically exhibit obesity only in the wealthier ranks of society, in which people are able to afford food in quantities necessary to create weight gain[9]. In contrast, in middle- and high-income countries, wealth is

nowadays associated with lower obesity rates[9, 10], meaning that individuals of lower socio-economic background are more likely to be affected by obesity.

Taken together, the epidemiological data shows that prevalence of overweight and obesity is higher than ever before. Considering the health consequences of obesity (see section 1.2.3), this paints an alarming picture. It is therefore not surprising that obesity has been intensively researched in recent years, advancing our knowledge about its aetiology, consequences and treatment options. I will give an overview of these areas in the following sections.

1.2.2 Causes and determinants

On a basic level, overweight and obesity are caused by a mismatch in energy consumption and expenditure. When a person consumes more energy than they expend, the remaining energy is transformed into body fat[11]. But where does this mismatch come from? The Foresight model, published by the UK's Government Office for Science, recognises that a complex system of different interlinked factors underlies the aetiology of obesity[12]. At the core of the model lies the biological system, which tries to maintain homeostasis; that is, a balanced energy budget which keeps weight stable. Genetic, epigenetic, neural and metabolic factors interact with each other and together influence the bodies' ability to maintain energy balance, by affecting energy intake and expenditure. In addition, individuals' dietary and physical activity behaviours are also separately affected by environmental and psychological factors. In the following paragraphs, I briefly explore each area of influence.

I first address the biological factors, including genetic, epigenetic, neural and metabolic influences. The hereditary aspect of obesity is well-illustrated by twin studies. For example, an experimental study investigating weight gain following overfeeding

found that weight gain differed significantly between twin pairs, but was similar within pairs[13]. With advances in genetics, dozens of gene loci have been found to be associated with BMI[14, 15]. When comparing individuals carrying high numbers of BMI-associated alleles at the loci with individuals carrying average numbers of alleles at these loci, the researchers found a difference of 4.6–5.8 kg in weight[14]. The field of genetics is still in the process of unravelling how the differences in genetic composition may take effect to cause weight gain. So far, there is good evidence for the BMI-associated gene loci to affect the central nervous system, most importantly the hypothalamus[14, 16, 17]. The hypothalamus receives information about the nutritional state of the body and reacts by modulating food intake[17]. That is, after a period of fasting, the hypothalamus typically responds by increasing appetite, thus eliciting food intake. Conversely, it decreases appetite in response to satiety cues. Some of the BMI-associated alleles are found to influence this appetite regulation in the hypothalamus. A prominent example is a BMI-associated allele located close to the FTO gene, which is found to affect obesity by causing diminished feelings of satiety after food intake, leading to overconsumption[18]. Recent evidence indicates that the hypothalamus and related brain regions may produce experiences of appetite by eliciting reward signals in response to food cues, thus producing feelings of wanting and hunger[16, 19]. Variants of the BMI-associated loci may also affect this reward response of the appetite regulating system. Findings from neuroimaging studies show that individuals with obesity exhibit stronger activity patterns in the reward circuitry and somatosensory cortex when anticipating the consumption of unhealthy, energy-dense foods[20, 21]. Interestingly, however, the reaction during actual consumption is reduced in individuals with obesity and the act of eating is therefore perceived as less rewarding[20, 21]. This mismatch between expected and actual reward

might cause individuals to seek out more rewarding experiences, leading to overconsumption. The current evidence indicates that interindividual differences in reward circuit activity may be due to a combination of genetic differences and metabolic consequences of obesity itself, since studies in rodents indicate that at least some of the altered reward circuit activity can be reversed through weight loss[22].

In addition to the effects on energy intake, there is also limited evidence suggesting that genetic variations may affect energy expenditure, by influencing the amount of physical activity individuals engage in[23]. Indeed, it is found that spontaneous physical activity, that is non-formal exercise, is a major protector against diet-induced obesity and has a hereditary component to it[24]. The neuropeptide orexin has been debated as the potential molecular basis of these interindividual differences[24-26]. Orexin is expressed in the hypothalamus, and may affect physical activity through its projections to physical activity related brain regions[24, 25]. Further research is necessary to fully understand the ways in which genetic and epigenetic influences affect obesity. The current evidence, however, clearly shows that some people are more predisposed to develop and maintain obesity than others.

Nonetheless, biology is only one part of the big picture. Predispositions to develop obesity have always existed, and while they may explain some of the interindividual differences in obesity occurrence, they cannot explain the vast increases in obesity rates seen over the last decades. To explain this surge, we must turn to other factors. Indeed, environmental changes have been substantial over the last century[27-29]. As countries have become more prosperous and their economies have grown, their food systems have expanded, increasing the supply and affordability of food. As a consequence, people have gained easier access to energy-dense and palatable foods, high in sugar and fat. At the

same time, mechanisation and urbanisation have led to more sedentary and hectic lifestyles. In combination, these changes have created an obesogenic environment, in which underlying genetic susceptibilities to obesity are more likely take effect, leading to the observed rise in obesity prevalence[29, 30]. Societal changes have also been considerable and interact with the other environmental developments. Changes in media consumption and content are a good example here. A century ago, only newspapers and magazines were available to the general public, but nowadays we have access to media through televisions, smartphones and computers as well. Research shows that exposure to media is associated with poorer dietary habits and increased levels of obesity[31]. There are a number of possible explanations. Whilst increasing sedentary time, increased media use has provided individuals with more opportunities for automatic and distracted eating and has led to an increased exposure to advertisements of energy-dense foods[31, 32]. This last point is important since research has shown that the activation of reward circuits in response to food cues occurs mostly outside of conscious awareness and is therefore difficult to control[16]. At the same time, society has become more and more vocal about obesity, with the media often taking an individual-blaming approach to obesity and idolising a slim body image, thus increasing both stigma and body dissatisfaction across society[33, 34]. The dichotomous messages conveyed by the media therefore leave the individual in an ambivalent and difficult-to-navigate environment.

As mentioned earlier, obesity prevalence unequally affects groups of differing socio-economic status. In high-income countries, individuals from lower socio-economic backgrounds are more affected. In this context, it has been consistently found that individuals with low SES have less nutritious diets and engage in less physical activity[35, 36]. Environmental circumstances can provide some explanation here. Research has

found that healthy foods can cost significantly more per 1000kcal than unhealthy foods[37], meaning that individuals from deprived backgrounds may not be able to afford a healthy diet. Moreover, low-income areas have a higher density of fast food restaurants[38], which is associated with greater consumption of high-energy foods[39]. Surveys conducted in low-income areas also reveal that people living there perceive their neighbourhoods as less attractive for physical activity, with less recreational facilities on offer[40]. In combination, the environment of people of low-income backgrounds provides them with less opportunities to live a healthy lifestyle, leading to higher prevalence rates of obesity, and exacerbation of health inequalities.

The above discussion highlights that individuals in developed countries are nowadays confronted with a much more obesogenic environment than several decades ago. However, not every individual in the population is equally affected by the changes in environment. Even though genetic predisposition explains partly why some react more to obesogenic environments than others, they also do not fully predict who develops obesity and who does not. This leads me to the third determinant of obesity: psychological factors. Some examples here include the individuals' attitude regarding their weight[41], their motivational state[42], and their diet- and nutrition-related knowledge[43, 44]. The focus of this thesis lies on one factor in particular: the individual's ability to exert self-control and engage in self-regulation. When high-energy, palatable foods are constantly available, individuals have to be disciplined not to give in to hedonic food pleasures. Staying active despite the advances in transportation methods and the increased availability of rewarding sedentary activities also requires self-control. For some people, these activities may be more difficult to perform given that their biological system predisposes them to seek out a less healthy lifestyle. Healthy lifestyles thus

require more self-control and self-regulation for some than for others. In this context, self-control can be defined as the ability to override automatic responses to external cues, thus allowing for self-regulation, i.e. the actual process of changing automatic behaviour, to occur[45]. Individuals with more self-control are found to have healthier diets, a more active lifestyle and a lower BMI[46]. Moreover, they are more successful at restricting their energy intake and losing weight throughout a weight loss programme[47]. These beneficial effects might be due to the fact that individuals who exert more self-control are more able to act on their healthy intentions. Indeed, executive control, which includes self-control and self-regulation skills, can explain the size of the intention-behaviour gap for healthy dietary behaviours, such that individuals with more executive control implement more of their dietary intentions[48]. The specific regulation of emotions is also of importance as emotional eating, i.e. eating in response to negative feelings, is a common cause for overconsumption. Stress and ineffective emotion regulation are linked to more emotional eating[49, 50], while promoting effective emotion regulation strategies decreases emotional eating[49]. Both emotional and externally driven eating are correlated with impulsiveness and decreased self-discipline[51], i.e. a lack of self-control. Neuroscience has revealed physiological evidence for the effect of interindividual differences in self-control and self-regulatory performance on obesity. Neuroimaging studies have found that the executive control functions of the brain, which enable self-control, seem to be impaired in individuals with obesity, making disinhibition and overeating more likely[52]. For example, there is evidence that in individuals with obesity the dorsolateral prefrontal cortex is more likely to fail at suppressing the brain's positive and rewarding valuation of palatable, high-energy foods[53]. Findings on differences in executive control exist independently of

socioeconomic status, meaning that individuals from both high- and low-income backgrounds exhibit this difference in activity patterns[52]. Taken together, this research reveals the importance of self-control and self-regulation to enable individuals to navigate their obesogenic environment. Research has found that self-control can be trained[54, 55], thus indicating that differences are not (completely) predefined based on genetic differences and individuals can become better at this process. The question therefore is: how can we support individuals in performing better self-control and self-regulation, in order to lose weight? This thesis addresses this particular question. In sections 1.5 and 1.6, I will dive deeper into the self-regulation literature, but before I do, I would like to discuss the physical and mental health consequences of obesity.

1.2.3 Health consequences and costs

Obesity is associated with considerable changes in the body. Unused energy is stored in fat cells, which enlarge and multiply with weight gain. It is both the increase in fat mass, as well as the secretion of free fatty acids and various peptides from the fat cells that cause different diseases[56]. Generally, the health consequences of these bodily changes can be grouped into three categories: metabolic; mechanical; and psychological.

The metabolic consequences of obesity include a range of life-threatening diseases. One of these diseases is type 2 diabetes. Roughly 80-90% of all type 2 diabetes cases are attributable to overweight[57]. Individuals with obesity have an 344% increase in the odds of developing diabetes compared to healthy weight individuals[58]. Another common consequence of obesity is the development of hypertension; the odds are 3.5 times greater in individuals with a BMI≥30 than in healthy weight individuals[58]. Hypertension and type 2 diabetes are common comorbidities in individuals with obesity[59], and together with inflammation, they create a cluster of cardiovascular

disease risk factors, which affect roughly half of all individuals with obesity. This cluster is called the metabolic syndrome[56, 60, 61]. For individuals with the metabolic syndrome, the relative risk of developing cardiovascular disease, including coronary heart disease, heart failure, arterial fibrillation or stroke[62, 63], is 2.35 times higher[64]. Further diseases that have been linked to obesity are certain types of cancer, including colon and breast cancer, as well as gallbladder disease, non-alcoholic fatty liver disease, and Alzheimer's disease[56].

In terms of the mechanical consequences of obesity, it is found that excess body weight causes additional trauma on joints, giving rise to osteoarthritis[58, 65]. The additional weight load has also been associated with an increased risk of developing chronic back pain[66]. Moreover, obesity is linked to obstruction of respiratory function and sleep apnoea[56, 67].

On a psychological level, the literature shows that individuals with obesity are more likely to suffer from some types of mental health issues, including depression and anxiety disorders[68-71]. A prospective cohort analysis found that the baseline obesity status of individuals predicted depression levels at five-year follow-up[72]. Mental health issues such as depression may arise from the strong stigma experienced through mass media and societal attitudes. Observational data shows that individuals who experience more stigmatisation express poorer mental health, including body image dissatisfaction and lower self-esteem[73]. Moreover, the internalisation of weight stigma has been found to predict depression and anxiety levels, as well as overall health[74]. A vicious circle may evolve as there is some evidence from longitudinal studies showing that individuals with depression are more likely to develop obesity[70]. Indeed, a mediation analysis found that the link between experiences of stigmatisation and binge eating

behaviours was to a large part explained by measures of psychological distress[75]. The vicious circle may therefore be established when individuals find it difficult to regulate their emotions in constructive ways.

Considering the wide-ranging health consequences of obesity, several studies have explored the effect of obesity on mortality rates. It is estimated that in 2015, 4 million people died due to consequences of obesity worldwide, representing roughly 7% of all deaths[5]. There seems to be a linear relationship between excess weight and mortality; for every 5 unit increase in BMI, the overall mortality rate increases by roughly 30%[76]. Covering roughly 40% of all obesity-related deaths, cardiovascular diseases are consistently ranked the most common death cause[5, 77, 78]. Diabetes was found to be the second main cause for obesity-related mortality, with an estimated 0.6 million deaths worldwide[5].

Considering the prevalence of overweight and obesity, there is an enormous price tag associated with the treatment of related diseases. In the UK, it was estimated that between 2014-2015, the treatment of obesity-related health issues incurred a cost of £6.1 billion to the NHS[79]. Moreover, it is found that 23% of all drug prescription costs in the UK can be attributed to overweight- and obesity-related illnesses[80]. In light of these costs for society, promoting prevention and treatment of obesity can become a net positive investment. In the next sections, I will review literature on the benefits of obesity treatment and give an overview of the different approaches.

1.3 Treatment of obesity

Weight loss is associated with considerable health benefits. Research has shown that individuals who lose 5-10% of their initial body weight have reduced blood pressure,

better glycaemic control and an improved lipid profile[81, 82]. As a result, individuals are less likely to develop type 2 diabetes and hypertension[83, 84], and other risk factors for cardiovascular disease are also improved[82]. Weight loss has been linked to the reversal of type 2 diabetes, especially if it is achieved soon after the onset of the disease[85, 86]. Mechanical issues such as osteoarthritis can be prevented if weight loss is addressed before significant joint damage has occurred[87]. When joint damage has occurred, weight loss is still associated with significant pain relief[88]. With regards to mental health issues, it is found that weight loss can lead to significant improvements in depressive symptoms[89]. Importantly, individuals do not have to reach their ideal weight in order to reap the benefits of weight loss, as effects (at least for diabetes and hypertension) are already significant at 5-10% weight loss[90] and also appear if individuals remain obese or overweight[91]. A meta-analysis of clinical trials found that premature mortality is reduced by 15% when individuals intentionally lose weight[92], and epidemiological studies reveal that this reduction is mostly explained by decreases in mortality from diabetes, cardiovascular disease and obesity-related cancers[93, 94]. Given the benefits of losing weight, researchers and public institutions have invested considerable effort in developing interventions to tackle obesity. Existing programmes cover medical, surgical, and behavioural approaches on population, community and individual levels. Some of these interventions are more focussed on prevention, while others specifically aim to treat obesity. Given the complexity of the aetiological factors, the Foresight report on obesity highlighted the need for a holistic approach, speaking to the variety of determinants of obesity[12]. Indeed, various areas of influence of the obesity system have been addressed so far. On an environmental level, some countries have tackled food production through policy interventions such as the tax on sugar-

sweetened beverages[95]. Changes to built environments to create more opportunities for physical activity have also been implemented with some effect[96, 97]. With regards to societal influences, regulations aiming to e.g. restrict junk food advertisements to children have been introduced in several countries, including the UK[98]. These three examples show that interventions on a population or community level are well-suited to tackle the prevention of obesity[99].

In contrast, interventions for the treatment of obesity are usually delivered at an individual level. In the surgical and medical realm, the treatment options include bariatric surgery and pharmacotherapy treatment, both of which are effective for weight loss[100-102]. However, due to their cost and concerns surrounding safety and side effects[103, 104], the mainstay of individual treatment for obesity remains behavioural weight management interventions. These interventions aim to improve diet, increase physical activity, or both[105, 106]. The remainder of this thesis is focussed on behavioural treatments for weight loss, so I aim to give a brief overview of the variety of approaches that have been taken. The programmes differ in their format, setting and content. Regarding the format, some are set up as self-help programmes, which are often remotely delivered and aim to help the individual help themselves, typically with modest but significant weight loss effect[107]. The advantage of these programmes is that they are low-cost and scalable, an attractive feature considering the prevalence of obesity. Individual face-to-face programmes provide weight loss support in a one-to-one setting[108], which is more resource intense, as each individual receives separate professional support. Other interventions, including commercial programmes such as Weight Watchers and Slimming World, are set up as group programmes, through which the individual receives lifestyle advice, weight loss guidelines, and social support[109].

The interventions also differ in the setting in which they are provided. Some interventions are provided in a primary care setting[110]. However, a systematic review showed that the effects of these interventions are typically only modest[111]. Hence, many interventions now identify individuals in a primary care setting, but refer them to external weight loss programmes[112]. A specialist clinical setting is also sometimes explored for weight loss treatment, such as a psychotherapy setting for people with obesity eating disorders such as binge eating[113]. Content-wise, behavioural interventions have evolved over time. Traditional interventions have often been simple and prescriptive. Low-calorie-diets, for example, used to only focus on enforcing a daily calorie goal below 1500kcal[114]. Nowadays, behavioural interventions increasingly employ 'behaviour change techniques' (BCTs)[115], which make use of psychological principles to achieve dietary and physical activity goals. These techniques fulfil different functions, such as educating or persuading individuals, restructuring their environment to make the desired behaviour more likely, or modelling the desired behaviour[116]. A group of these behaviour change techniques is also related to self-regulation and self-control. In 1.2.2, I highlighted how self-control and self-regulation are necessary to enable the individual to restrict food intake and reduce sedentary lifestyle. I also discussed research showing interindividual differences in self-regulatory ability. I therefore decided to focus on this specific psychological strategy for my own weight loss research. The next section will explore the theoretical foundation of self-regulation in more detail.

1.4 Self-regulation and control theories

The two most important self-regulation theories are called self-regulation and control theory. In the following section, I briefly outline both theories and discuss similarities and differences.

Self-regulation theory by Kanfer and Karoly was first described and published in the early 1970s[45]. The authors postulated that self-regulation takes place whenever individuals aim to achieve a specific goal. As part of this process, individuals measure their current state, contextualise it with previous states and compare it against the goal state which they strive for. This comparison then triggers an evaluation of previous behaviour. If the evaluation is favourable, i.e. showing that whatever behaviour was performed previously led to progress towards the goal, the previous behaviour is reinforced and repeated in the future. Alternatively, if the evaluation is unfavourable, i.e. the measurement of the current state did not indicate progress towards the goal, individuals perceive a sense of punishment, leading to future inhibition of the unsuccessful behaviour. The theory posits that individuals cycle through this list of behaviours until their current state aligns with their goal.

In parallel, there is also another theory which has been influential in the realm of self-regulation, called control theory. Control theory was published by Carver and Scheier in the early 1980s[117]. As in Kanfer and Karoly's theory, it also posits that individuals measure their current state and compare it against a pre-set goal. Whenever the comparison reveals a discrepancy between the two, the individual performs behaviour in order to get closer to the goal state. The self-regulatory behaviour affects the outcome of interest, thus creating a change in the current state, and allowing for a renewed comparison with the goal. Individuals continue to reduce discrepancy until their current

and goal state are aligned. The cycle of behaviours is thus very similar to self-regulation theory.

Both control and self-regulation theory state that the self-regulation process is triggered by self-monitoring, which can be defined as the continuous measurement and tracking of the current state, allowing for the assessment of progress. Both theories argue that self-regulation should occur naturally without external support once self-monitoring is performed[45, 117, 118]. Control theory is even more explicit, stating that self-regulation in these contexts occurs automatically[117].

The authors of both theories considered what may influence the likelihood of self-regulation success and agree that the expectation of effectiveness regarding the self-regulatory behaviour is an important factor, which is shaped based on previous experience. That is, if individuals think their actions are going to be effective, they are likely to engage in them. If they think their self-regulatory behaviour is not going to be effective, they are likely to withdraw from the process. In addition, Kanfer and Karoly considered that the likelihood of self-regulation is increased when individuals have set themselves a clear and explicit goal, receive support from an external, feel that the aversive consequences of not reaching the goal are stable, perceive themselves to have the ability and skill to make behaviour changes towards goal achievement, and continuously monitor their current state. Carver and Scheier added two more factors. The first factor comprises so-called disturbances from the outside world, which affect the individual's state independently of their own behaviour. For example, being ill may reduce the individuals' physical activity and thus hinder weight loss, even though the individual managed to meet their dietary goals. The second factor is attention. When

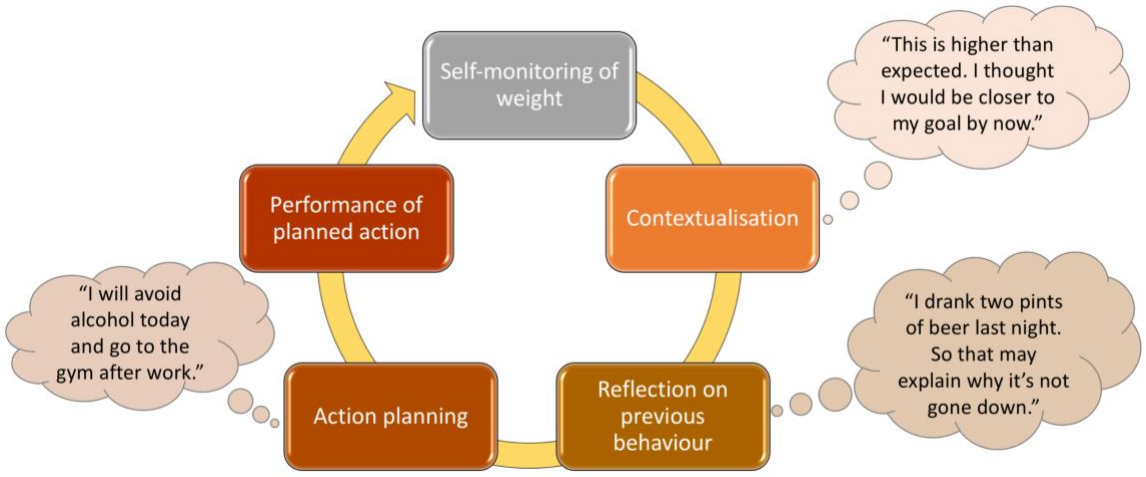
individuals draw attention to their goal, Carver and Scheier theorise that they are more likely to engage in future self-monitoring of the outcome of interest.

Interestingly, self-regulation and control theory have existed in complete parallel for the last decades and are rarely cross-referenced, even though they fundamentally overlap. The reason for this is that the two theories differ in the paradigm which they come from. Self-regulation theory is based on the learning paradigm, which assumes that individuals' responses to the environment are learnt on the principles of reinforcement and punishment. Control theory is based on ideas of cybernetic control and the negative feedback loop. This is why it neglects an evaluation of the behaviour resulting from the self-regulation process and does not consider inhibition of unsuccessful actions and reinforcement of successful behaviours. However, I believe this aspect is important when considering long-term changes such as weight loss. Weight loss is seldom resolved with one simple action; it takes weeks and months of weight loss behaviours to achieve the desired results. Hence, it is important for the individual to evaluate which changes should be continued with and which ones can be discarded. Carver and Scheier reflect on this point in their own paper, stating that control theory is more apt at explaining in-the-moment behaviour, whereas self-regulation theory is better at explaining long-term behaviour change[117]. Because of this, I will mainly focus on self-regulation theory in the following chapters. However, I want to acknowledge here that both theories fundamentally posit the same and my research will therefore have important implications for both (see Chapter 7).

For this thesis, I adapted self-regulation theory to the context of self-weighing and weight loss. In the resulting model, (1) continuous self-monitoring of weight allows for (2) the contextualisation of the current weight with previous measurements and goals, thus

providing (3) an opportunity to reflect on previous behaviours and reinforce successful actions, enabling (4) the planning of actions to reach the goal, followed by (5) the performance of planned actions (see Figure 1.1). I have added a planning stage to the model, which self-regulation theory does not explicitly include. However, one can assume that the process of reinforcement or inhibition of previous behaviour must result in some sort of intention setting. For example, the individual might conclude: “Not eating between meals was really helpful, so I will continue with this today”.

Figure 1.1. Adapted version of the self-regulation cycle, as used in this thesis.



The individual cycles through the self-regulation process in an iterative manner until sufficient weight loss has been reached. The cycle thus allows for experimentation with different weight loss techniques, helping the individual to build a personal portfolio of effective and sustainable strategies[119, 120]. Kanfer and Karoly state that self-monitoring triggers self-regulation, so one can expect that steps 2-4 of the self-regulation process outlined here occur during or immediately after weighing.

The self-regulation process requires a significant amount of self-control, considering that individuals need to override automatic and rewarding behaviours (e.g. eating cake at a birthday party), in order to successfully self-regulate and reach their

weight loss goals. In this context, it is worthwhile discussing research on the concept of ego depletion[121]. This research shows that when self-control is exerted repeatedly, individuals run out of the necessary resources to engage in self-control, leading to a state of ego depletion. Hence, there are not only differences between individuals in the amount of self-control available, but also within individuals over time. The self-control 'resource' described here is currently still a theoretical concept. For a couple of years glucose was handled as a potential biological basis, but this hypothesis has since been disproven[122]. Baumeister and colleagues have extensively studied the ego depletion phenomenon and concluded that self-control works in a similar way to a muscle[121, 123]. In the short-term, whenever the individual exerts control and the resource is depleted, self-control requires some time to recover. Over the longer-term, repeated exertion of self-control leads to an increase in self-control capacity, as though the self-control 'muscle' becomes more efficient. Given the obesogenic environment we live in, self-control resources can easily become depleted, especially when genetic predispositions require the individual to exert more self-control to avoid giving in to temptations.

The aim of this thesis is therefore to find ways in which to support individuals in self-regulation. To do so, I aim to develop and test a self-regulation intervention. To create such an intervention, I need to gain a better understanding of the way and extent to which self-regulation occurs naturally, given that individuals are supposed to be able to self-regulate without external support after self-monitoring but ego depletion might be a hindrance[45, 117]. The literature on self-weighing and weight loss can help in this context. Strictly speaking, self-weighing constitutes only one part of self-monitoring, as it only covers the (continuous) measurement of weight, but not necessarily the recording of

said measurements. However, there seems to be some confusion in the literature concerning the definition of these concepts, as some papers use the two terms interchangeably[124-127]. The literature therefore seems unclear on whether individuals require prompting to keep an overview of their weight measurements or whether this occurs automatically when people self-weigh continuously. I aim to address this gap in the literature with the work presented in this thesis. For the purpose of this thesis, I define self-weighing as the continuous measurement of weight, and self-monitoring as a combination of self-weighing and weight tracking.

1.5 Self-weighing and self-monitoring of weight for weight loss

Self-weighing and self-monitoring of weight have repeatedly been explored as treatment components for weight loss, assuming that this behaviour triggers the self-regulation process described above[128, 129]. In fact, self-monitoring is one of the most common components of behavioural interventions for weight loss[130]. A number of questions have been addressed by the literature: 1) Does self-monitoring of weight achieve weight loss, and if so, in what context? 2) What is the ideal frequency of self-weighing? 3) How good is long-term adherence to self-weighing? 4) Are there any adverse effects of self-weighing? 5) What is the best method to monitor weight measurements? I will review these questions in the following paragraphs, and in doing so identify gaps in the literature, which I aim to address in this thesis.

The first question, regarding the effectiveness of self-monitoring of weight, has been investigated by several researchers. For instance, Steinberg and colleagues assessed the effect of an intervention combining self-monitoring of weight with weekly feedback and lessons on behavioural weight loss strategies. The results showed a significant weight

loss effect in the intervention group[131]. A meta-analysis from 2015 found that self-weighing and self-monitoring of weight, when embedded in a weight loss programme, significantly increased weight loss by 1.7kg (95 % CI -2.6 to -0.8)[124], and another from 2016 showed that self-weighing had a medium-sized weight loss effect[132]. The findings thus indicate that individuals are able to self-regulate when asked to monitor their weight alongside a weight loss programme, despite the obesogenic environment and the associated risks of ego depletion discussed earlier. A randomised controlled trial therefore tested whether self-monitoring may be effective as a stand-alone intervention, hypothesising that it would trigger self-regulation and thus lead to weight loss, as indicated by the previously found effects. Madigan and colleagues asked participants to set themselves a weight loss goal, self-weigh daily and record their weight measurements. Counter to their hypotheses, the trial did not find a significant effect on weight loss[125], bringing into question whether self-monitoring actually naturally triggers self-regulation on its own. Considering that self-weighing and self-monitoring of weight are effective when combined with other weight loss treatment components, the null effect raises the question whether further intervention components, such as feedback on progress or action planning, are necessary to support people in engaging in the whole self-regulation cycle. This is a gap in the literature I aim to address in this thesis.

Regarding the second question, observational data on self-weighing has consistently shown that the frequency of weighing is positively associated with weight loss outcomes[127, 133, 134]. Based on these positive correlations, it is debated whether daily weighing might be the best frequency. A study investigating patterns in self-weighing frequency and body weight measurements found that breaks of more than a

week were linked to weight gain, whilst periods of daily self-weighing were associated with significant weight loss[126]. Another observational study compared participants who weighed daily with participants who weighed less frequently and found that the difference in terms of weight loss was significant (-6.1kg, 95 % CI -10.2 to -2.1)[135]. However, observational studies do not allow for causal inferences, as individuals have not been randomised to different weighing conditions and effects may therefore be due to confounding factors. A meta-analysis from 2015 did not find evidence for the superiority of daily weighing when comparing experimental data from studies employing daily weighing with studies using lower weighing frequencies[124]. However, this analysis compared data from several studies, which used a variety of methods and differed in the intervention components offered alongside self-weighing. This indirect evidence can therefore not rule out confounding factors either. The best test to determine ideal weighing frequency is therefore a direct comparison in a randomised controlled trial. Linde and colleagues did just this by randomising participants of a weight loss programme to a daily or weekly weighing frequency and comparing results against participants randomised to a no-weighing control group[136]. The main results of the trial are not yet published, but the authors reported their findings in conference proceedings, showing that there was a dose-response relationship at 12 months between weighing frequency and weight outcomes. The daily weighing group achieved the largest weight loss (M=-7.97kg), followed by the weekly weighing group (M=-7.69kg) and finally the control (M=-6.77kg)[137]. Significance was not reported but the directionality of the descriptive statistics supports the positive associations found in observational studies, indicating that daily may be better than weekly weighing for weight loss. There are several reasons why daily weighing might be most beneficial. Since consistent repetition of behaviour is key

for the formation of habits[138], daily weighing should most likely result in habitual behaviour. Once daily weighing has become a habit and is an automatic behaviour, adherence to self-weighing should be more likely. Moreover, by weighing daily, individuals may receive more prompts to self-regulate, thus increasing the likelihood of the necessary behaviour change. Studies have rarely tested weighing frequencies exceeding daily, probably because fluctuations in weight due to fluid and food intake would make the interpretation of weight changes throughout the day difficult. For that same reason, it is generally recommended to weigh first thing in the morning, in order to keep weight measurements as comparable as possible across days.

Regarding the third question, research has found that in many people adherence to self-weighing declines long-term. In a weight loss trial, the proportion of participants adherent to self-weighing dropped from roughly 70% in the first week to 20% after 70 weeks[139]. Another study found that 25% of the participants who were asked to weigh daily reduced their weighing frequency significantly across the study, and about 9% stopped weighing themselves altogether after 33 weeks[140]. Steinberg and colleagues saw their participants in the daily weighing intervention group decrease the average frequency of self-weighing from 6.1 to 4.0 days per week within 6 months, and 13% stopped weighing themselves completely after the sixth month[131]. The decline in adherence is of importance considering that the frequency of weighing is a significant predictor of weight loss success[127, 133, 134]. So why do people reduce their weighing frequency, or even stop weighing themselves altogether, even though they are trying to lose weight? Do any specific events trigger a stop? This is another question I will address in this thesis.

Regarding the fourth question, researchers have repeatedly investigated whether frequent weighing has any adverse effects, as a common worry is that it could lead to obsessive behaviour or psychological harm[132, 141]. A meta-analysis revealed that weighing is not associated with negative affect, body-related attitudes, or disordered eating[132]. The researchers did, however, find a small effect indicating that frequent weighing is associated with reduced self-esteem and increased levels of stress. This thesis aims to further explore potential adverse effects of weighing and help understand how these might be reduced.

With regards to the method of keeping track of weight measurements, research suggests that electronic formats are particularly effective[142, 143]. Several studies have revealed significantly higher self-monitoring adherence and retention rates when smartphone applications were used to help individuals track their weight measurements[144]. For instance, in a trial by Carter and colleagues, 93% of the smartphone application users continued to use the intervention at 6-months follow-up, compared to 54% in the control groups[145]. Moreover, the method of tracking seems to influence the effectiveness of self-monitoring. A study by Burke and colleagues tested the effectiveness of a self-monitoring application for a personal digital assistant against a paper diary, and found that the application users achieved more weight loss and a greater reduction of their waist circumference[142]. Researchers argue that an app format is more successful because it allows for more instantaneous feedback, is easy and quick to use, and is mobile and hence accessible most of the day[142, 144, 146, 147]. Interestingly, a review published in 2016 found that 80% of weight management apps on the Google Play and Apple iTunes stores employ self-monitoring strategies, allowing their users to track their weight, physical activity or diet[148]. I therefore decided to explore

what people think of these existing weight tracking solutions as part of my DPhil research.

1.6 Aims and objectives

The overall aim of the work presented in this thesis is to better understand the processes of self-weighing and self-regulation in the context of weight loss. The last sections have identified gaps in the literature, which I will address first using three observational studies. In Chapter 2, I will investigate whether self-regulation indeed occurs naturally after self-weighing. This research will also address barriers to self-weighing and self-regulation. Chapter 3 will then consider why individuals may stop weighing themselves, given that adherence is a key correlate of the effectiveness of self-weighing. Chapter 4 will review existing weight tracking apps in order to identify what users like and dislike about weight tracking. Using the findings of these three studies, and the wider research literature, I will describe the development of a self-regulation intervention which aims to maximise the benefits of this weight loss strategy in Chapter 5. Chapter 6 will then detail the methods and results of a randomised controlled trial testing the early effectiveness of the intervention. Finally, in Chapter 7, I will discuss the main findings and review their implications for both theory and future research.

Chapter 2 Analysing self-regulatory behaviours in response to daily weighing: A think-aloud study

2.1 Summary

This chapter presents an observational study which used a think-aloud method to assess peoples' thoughts and feelings during weighing. The aim was to examine the extent to which people naturally self-regulate in response to self-weighing. The study further investigated barriers to self-regulation. Twenty-four participants with overweight who were trying to lose weight recorded their thoughts and feelings during daily weighing for eight weeks. Semi-structured follow-up interviews assessed participant experiences. Qualitative analysis identified occurrences of the cognitive self-regulation processes, as well as barriers to self-regulation. Exploratory regression analysis assessed the relationship between the performance of the self-regulation steps and weight loss.

On 90% of 498 occasions, participants contextualised their weight measurements with expectations or goals, and on 58% they reflected on previous behaviour. Action planning only occurred on 20% of occasions, and specific action planning was rare (6%). Only specific action planning significantly predicted weight loss (-2.1kg per 1SD increase in the predictor, 95% CI=-3.9kg, -0.3kg). Thematic analysis revealed that barriers to the interpretation of daily weight changes were difficulties in understanding day-to-day fluctuations, losing overview of trends, forgetting to weigh, and forgetting previous measurements.

In conclusion, the study found that self-regulation is rarely completed in a naturalistic setting. Nonetheless, the results revealed that completing the last cognitive

step of the cycle, i.e. specific action planning, is associated with weight loss. Barriers to self-regulation related to negative emotional reactions to weight measurements and problems with the interpretation of weight changes. Moreover, I found that individuals need support in keeping an overview of their weight measurements and are unlikely to start tracking their weight measurements unprompted.

Note: A version of this chapter was published in the journal Psychology & Health[149].

2.2 Introduction

In Chapter 1, I reviewed the literature on self-weighing and self-monitoring of weight, which showed that the frequency of weighing is positively associated with weight loss. Based on this pattern, Madigan and colleagues investigated the effectiveness of self-monitoring as a stand-alone intervention in a randomised controlled trial, but did not find any benefit[125]. As self-monitoring is hypothesised to create weight loss by triggering a self-regulation process (see Chapter 1), the finding by Madigan and colleagues raised the question whether self-regulation is really a natural reaction to self-monitoring, or whether other intervention components are necessary to prompt it. Moreover, it remained unclear whether it is necessary to prompt individuals to track their weight measurements in order to help them keep an overview of their weight loss progress and thus enable them to successfully contextualise their weight.

The purpose of this study was therefore to examine the extent to which self-regulation occurs unprompted after self-weighing in people with overweight who are trying to lose weight. Previous research on implementation intentions has extensively studied the connection between the fourth and fifth component of self-regulation: action planning and action performance (see discussion section 2.5.2). However, to the best of my knowledge, there has been little research looking at the hypothesised predecessors of

action plans and behaviours in the self-regulation process. I therefore decided to restrict this piece of research to the more cognitive elements of the self-regulation process, including contextualisation of weight measurements, reflection on previous behaviour, and planning of weight loss actions.

As a result, I explored the thoughts and feelings people have during and after daily weighing, in order to identify occurrences of the cognitive self-regulation processes. I further examined the relationship between the performance of self-regulation and weight loss outcomes, to investigate which aspects of the process may be driving the weight loss effect found to be associated with self-monitoring. The study additionally explored participant experiences with daily weighing to identify in-the-moment barriers to self-regulation and daily weighing. The insights generated from this piece of research have important implications for the development of my own self-regulation intervention (see Chapter 5).

2.3 Methods

2.3.1 Study design and setting

A single-arm observational study design was employed. In order to allow for the analysis of weight loss effects, I set the length of participation to eight weeks, given that previous studies have been able to detect weight loss effects after two months[150]. The study took place in Oxfordshire, UK, and ran between June and October 2017. I obtained ethical approval for the study pre-recruitment from the Medical Sciences Division's ethics committee of the University of Oxford (reference number R49349/RE001).

2.3.2 Sample size

To estimate the sample size, I followed information power considerations, as described by Malterud and colleagues[151]. In this context, information power describes the richness of information that is expected to result from the data of a recruited sample. If information power is high, only a small sample size is required, and vice versa. Influencing factors in these considerations include the clarity of the research aim, the usage of theory, the specificity of the sample, the quality of data, and the focus of analysis. I considered that this primarily qualitative study had a clearly defined aim, used existing theory (i.e. self-regulation theory), and would sample participants purposefully using prespecified inclusion criteria. Since I could not predict the quality of the data, I decided to acquire a large data set from each participant, comprising daily measures across the whole eight weeks of the study. Cross-case comparison in the analysis meant that a larger sample size than typical for qualitative studies was required. Following these considerations, I deemed a sample size of 24 to be sufficient.

2.3.3 Recruitment and screening

Participants were recruited through advertisements on social media and in public places between May and July, 2017. Individuals contacted me if they were interested in taking part. I arranged a telephone call with them to provide more information about the study and to conduct a screening for eligibility. Criteria for inclusion were a BMI ≥25kg/m^2, the aim to lose weight, sufficient English language skills to ensure that content and depth of think-aloud recordings would not be compromised by language barriers, and age ≥18 years. Individuals were excluded from the study if they already weighed themselves more than once a week, as I wanted to recruit participants for whom daily weighing would be a new behaviour. Individuals were also excluded if they reported having lost more than 5%

of their current body weight in the previous six months to ensure participants were not already following a successful weight loss routine which might influence their engagement with the weight measurements. Individuals were excluded if they were already enrolled in a weight loss programme, were pregnant or planning a pregnancy, if they were taking medication associated with weight gain, or if they had ever had bariatric surgery, as all of these factors could affect weight change. Individuals were excluded if they had a history of eating disorders as daily weighing might cause adverse effects in this group of people[152].

2.3.4 Procedure

After completing the screening, participants were invited to two one-to-one meetings, one at baseline (approximately 45 minutes) and another in the 9th week of the study (approximately 60 minutes). At the first session, I objectively measured participants' height and weight and briefed them on the study tasks. I asked participants to weigh themselves every morning for the next eight weeks. To this end, I provided them with scales equipped with a SIM card (BodyTrace), which automatically synchronised recorded weight measurements with a secure research server via the 3G/4G network. I decided to use such scales as they allowed me to gain access to participant's weight measurements and thus assess adherence to daily weighing. The scales did not require any action from the participant to initiate synchronisation of the weight measurements, which meant that participants could not forget to record their weight. Moreover, by not prompting participants to record their weight measurements, I was able to assess how good participants were at monitoring their weight long-term without prescribed weight tracking. Participants received a demonstration of how to use the scales. To reduce measurement error, I asked participants to place the scales on a hard surface and weigh

themselves first thing in the morning. In addition to daily weighing, I also asked participants to document their thoughts and feelings during weighing using an adapted version of the think-aloud method[153]. That is, I asked them to verbalise all thoughts that came to mind during and right after the weighing process and not to filter the information shared. Before choosing the think-aloud method, I considered other potential methods, such as questionnaires or interviews, to investigate the cognitive processes during weighing. However, these methods would have been reliant on the participant's ability to accurately recall thoughts during weighing. In contrast, the think-aloud method seemed more likely to capture participants' natural thought processes. Typically, think-aloud methods are employed with the researcher being present in the room, thus allowing for prompts[153]. However, since I wanted to capture the natural occurrence of self-regulation without any prompting, and my presence may have provoked thoughts which would not have occurred naturally, I decided it would be best if participants completed this task on their own. This also allowed them to complete the task at home, making the setting more realistic. After explaining the idea of thinking aloud, I made it clear to participants that there were no requirements in terms of the length of the recording. I also asked them not to create content if they had nothing to say. I did not provide them with any information on self-regulation in order not to bias their thought processes. I only asked participants to mention the date and weight measurement on the recording. The method was practised with two brief tasks. I purposefully chose tasks which were unrelated to weighing, in order not to bias participants' future think-aloud recordings. First, I asked participants to imagine standing in the entrance of their home and having misplaced their keys. They were asked to think aloud about the process of their search. Next, I gave participants a menu of a restaurant

and asked them to think aloud about their choice of food. For this second think-aloud task, I asked participants to use their phone to record their talking, in order to practice how to use an audio recorder. Participants stated they felt comfortable with the think-aloud method after these tasks. I encouraged participants to send me their first think-aloud recording to receive feedback on the quality of the recording and the completeness of information (i.e., mentioning of date and weight measurement). Before ending the baseline session, I asked participants to fill in a short baseline questionnaire, capturing their demographic characteristics, their previous experiences with weighing, and their expectations concerning the study. Throughout the study period, participants received text messages every other day to remind them of their daily weigh-in. I called participants every two weeks to ask whether they experienced any problems.

At the second university-based session, I took another weight measurement and ensured that participants had sent me all their think-aloud recordings. For days for which the scale had detected weight measurements but think-aloud recordings had not been sent, I asked participants to check whether they still had a think-aloud recording saved on their phone. I interviewed all participants about their experiences of taking part in the study, as I wanted to ensure that I would be able to capture significant themes, in case the think-aloud recordings were not as fruitful as hoped. In addition, the semi-structured interviews allowed me to collect some information on the weight loss approaches used by my participants and thus put the think-aloud recordings into context. Finally, I debriefed all participants, thanked for their contribution, and gave them a £25 compensation.

2.3.5 Measures

2.3.5.1 Height and weight measurements

Participants' height and weight was measured at baseline and follow-up using a freestanding stadiometer (Tanita Corporation, Leicester Height Measure MkII) and a digital scale (Tanita Corporation, BC-418MA). Height was measured to the nearest 0.1cm and weight was recorded to the nearest 0.1kg.

2.3.5.2 Baseline questionnaire

The baseline questionnaire was presented through the online survey software BOS (Bristol Online Surveys, nowadays JISC Online Surveys). The questionnaire asked participants about their demographic characteristics, including age, gender, ethnicity, educational qualification, and employment status. The questionnaire also asked participants how often they weigh themselves usually, how they feel about weighing themselves, whether they think weighing themselves will be useful for controlling their weight, and whether they expect any barriers to weighing. The exact phrasing of the questions can be found in Appendix 2.1 - Baseline questionnaire.

2.3.5.3 Think-aloud recordings

Participants could choose for themselves whether they preferred to think aloud in audio-recordings or in written diary entries and could switch methods throughout the study. Resources did not allow me to transcribe recordings from all weeks. I therefore restricted my qualitative analysis to data from three weeks of the study. I familiarised myself with several of the recordings from different stages of the study. Based on this, I decided to exclude the first week as I found that participants mostly commented on the functioning of the scales and the audio recorder. I also decided to exclude the eighth week, as many

comments revolved around the upcoming end of the study. In order to consider data from different stages of the study, the 2nd, 4th and 7th week of think-aloud recordings were transcribed. Where think-aloud recordings were missing, the next available day's recording was extracted instead until three complete weeks were included in the analysis. This strategy was successful for 23 participants; for the 24th participant, the last two weeks of data were missing. Thus, I analysed 21 data points for 23 participants, and 15 data points for the 24th participant.

2.3.5.4 Semi-structured interview

In the semi-structured interviews at the end of the second meeting, I explored participants' experiences with self-weighing. I conducted all interviews myself and was trained in qualitative interviewing by a senior qualitative researcher before meeting participants. I asked participants how they felt about self-weighing, and which aspects they liked and disliked, whether they thought weighing was useful for controlling weight, whether they had experienced any barriers to weighing, whether they had tracked their weight measurements throughout the eight weeks, which methods they had used to try to lose weight, and whether they intended to continue weighing. I also asked participants about their experiences with the think-aloud method itself, including whether it had felt natural (see Appendix 2.2 - Semi-structured interview guide). Follow-up questions were asked in response to statements made by the participants, thus allowing flexibility of topic coverage. As participants varied in the detail of their answers, the interviews lasted between 20-60 minutes. All interviews were transcribed and analysed.

2.3.6 Data analysis

Participants' demographics were summarised descriptively. Adherence to the study tasks was calculated for each participant. Adherence was defined as the presence of both a weight measurement and a think-aloud recording for any given day. A correlation assessed whether adherence to weighing and thinking-aloud was associated with weight change.

The content of the think-aloud recordings was analysed using a mixed-methods approach. In order to analyse the extent to which cognitive self-regulation processes occurred during weighing, I conducted a content analysis[154] using the software NVivo (QSR International, Version 11.4.2). This method allowed me to first identify incidences of the different cognitive self-regulation steps and then quantify their occurrence rates. To this end, I created an *a priori* framework, including 1) the contextualisation of the weight measurement with previous measurements or a goal, 2) the reflection on previous behaviour, 3) general action planning, not defining a specific action or time plan (e.g., "I will do some exercise today"), and 4) specific action planning, i.e., defining a concrete action and time plan (e.g., "I will go for a run during my lunch break today"). Action planning was split into two categories, as the literature suggests that concrete action plans are more likely to be implemented than general ones[155]. After familiarisation with the data, coding was performed by me and another independent qualitative researcher for 25% of the participants, reaching good reliability scores (mean κ=.97). I coded and analysed the rest of the think-aloud recordings by myself. Coding was quantified as proportions by calculating per person average occurrences of each self-regulation step over the 21 days analysed. Using the statistical software package SPSS (IBM, Version 24), I examined associations between the occurrence rates of the different

self-regulation steps with Pearson correlations. Exploratory regression analysis assessed the relationship between self-regulation scores and weight loss success.

Additionally, themes related to experiences with daily weighing were identified in the think-aloud recordings using inductive thematic analysis[156]. I chose this method in order to let themes evolve flexibly based on the statements of my participants. Following familiarisation with the data, I generated themes from recurring topics and, where possible, used participants' own words to preserve closeness to the data. No a priori framework or ideas were imposed onto the data. After coding the data of the first six participants, I shared my list of identified themes with an independent qualitative researcher in the department, who then coded the recordings of the same six participants. We discussed discrepancies in our codings at a meeting, further clarifying the definitions of the themes, and adding new themes as they emerged. The resulting codings were sufficiently similar, reaching fair to good reliability scores (mean κ=.93). I coded and analysed the remaining think-aloud recordings by myself. After completing the coding process, I aimed to assess relationships between themes. I used axial coding techniques, lent from the grounded theory approach, to identify overarching themes as well as linkages between themes[157]. That is, I listed all themes in one document and then grouped them according to topics.

The inductive thematic analysis of the think-aloud recordings was very fruitful. Saturation of data was reached as no new themes were generated from the analysis of the last six participants' data. I therefore decided to take a deductive approach with the semi-structured interviews to validate the themes identified previously. To this end, I extracted statements exemplifying the themes from the thematic analysis of the think-aloud interviews. In addition, I also wanted to gain information on participants' weight

tracking behaviour, their perception of the usefulness of daily weighing, and their intention to continue weighing. I therefore extracted and quantified this information from the semi-structured interviews as well.

2.4 Results

2.4.1 Sample characteristics

Of the 94 people who expressed interest in the study, 83 were reachable by phone and screened for eligibility, and 25 were eligible to participate. Twenty-four participants completed the full eight weeks of the study. One male participant was lost to follow-up for unknown reasons and his data was therefore not available for analysis. The final sample consisted of 9 male and 15 female participants; mean age 36.6 years (SD=13.27), mean weight at baseline 85.0kg (SD=17.9kg), mean BMI at baseline 29.60 (SD=4.76). Twenty-two participants had a university degree or equivalent, ethnicity was mixed across White and Asian groups. Eight participants were students. Seven participants weighed themselves once a week before study begin, all others weighed themselves less frequently. For full details on sample characteristics, see Table 2.1. Seventeen participants chose to audio-record their thoughts, two wrote them into a journal, and six used a mixture of both methods.

Table 2.1. Demographic characteristics of the sample.

Characteristic		N (out of 24)
Gender	Male	9 (38%)
	Female	15 (63%)
Ethnicity	White-British	13 (54%)
	White-Other	5 (21%)
	Asian	4 (17%)
	Mixed	2 (8%)
Highest Educational Qualification	Degree or equivalent	22 (92%)
	A-levels, vocational level 3 and above	2 (8%)
Employment Status	Employed or self-employed	16 (67%)
	Looking after home/family	2 (8%)
	Student	8 (33%)
Weighing Frequency Before Study Begin	Less than once a month	7 (29%)
	Once a month	6 (25%)
	Once every other week	4 (17%)
	Once a week	7 (29%)
Liking of Weighing Before Study Begin	Dislike it a great deal	3 (13%)
	Dislike it somewhat	10 (42%)
	Neither like nor dislike it	8 (33%)
	Like it somewhat	3 (13%)

Characteristic	Mean	Standard Deviation
Age	36.6 years	13.3 years
Weight at Baseline	85.0 kg	17.9 kg
BMI at Baseline	29.6 kg/m^2	4.8 kg/m^2

2.4.2 Adherence and weight loss outcome

Participants weighed themselves and thought aloud on 93% (SD=12.2%) of the 56 study days. Average weight change after eight weeks was -0.89kg (SD=3.30). This included one participant who lost 13.6kg. Excluding this outlier, there was a small average change in

weight of -0.33kg (SD=1.93kg). A Pearson correlation showed that adherence to daily weighing and think-aloud recording was not related to weight change (r=-.059, p=.785), this remained unchanged when excluding the outlier (r=.082, p=.711).

2.4.3 Self-regulation occurrence and correlations

The framework analysis revealed considerable differences in the occurrence of the different self-regulation steps (see Table 2.2). On 90% of the 498 occasions, participants compared their current weight to an expectation or goal weight. On slightly more than half (58%) of occasions, participants reflected on previous behaviours that contributed to the weight change observed. However, on only 20% of occasions, participants performed any action planning. Specific action planning was rare (6%).

Table 2.2. Occurrence frequency of the different self-regulation steps in the think-aloud recordings.

Self-Regulation Step	**Example**	**Occurrence Frequency (max. 498)**	**Number of participants**
1. Contextualisation	"I think I'm making progress in the right direction, which is good."	450 (90%)	24
2. Reflection	"I had a restrained calorie intake and a run yesterday, so maybe both of those things contributed to that little bit of weight loss."	287 (58%)	24
3. General Action Planning	"I'm determined to push myself a bit and eat more healthily."	71 (14%)	16
4. Specific Action Planning	"I'll go to the gym tomorrow morning."	30 (6%)	12

Participants who frequently performed the contextualisation step were more likely to reflect on previous behaviours (r=.678, p<.001). Participants who performed the

reflection step were more likely to make general action plans (r=.446, p=.029). There was a marginally significant effect for participants who reflected to make more specific action plans (r=.390, p=.060). See Table 2.3 for all correlation results.

Table 2.3. Correlational analysis investigating the associations of the self-regulation steps.

		1.	2.	3.	4.
1. Contextualisation	r (p)	1 (0)	.678 (.000)	.365 (.079)	-.111 (.605)
2. Reflection	r (p)		1 (0)	.446 (.029)	.390 (.060)
3. General Action Planning	r (p)			1 (0)	.291 (.167)
4. Specific Action Planning	r (p)				1 (0)

2.4.4 Relationship of self-regulation and weight loss

The overall model testing the relationship between the self-regulation steps and weight loss in the complete sample was not significant (F(4, 19)=1.905, p=.151). However, Cohen's effect size f^2 of the model revealed a large effect for the self-regulation steps (f^2=0.406). Post-hoc power analysis using G*Power (Version 3.1) revealed a power of .58 for the model. Only the specific action planning variable significantly predicted weight loss (-2.1kg per 1SD increase in specific action planning, 95% CI=-3.9kg, -0.3kg). When excluding the outlier, the relationship between the self-regulation steps and weight change was statistically significant (F(4, 18)=5.762, p=.004). The effect size for the model further increased (f^2=1.282), and power analysis showed a power of .98. Specific action planning was the only individual component of self-regulation that predicted weight loss significantly (-1.4kg per 1SD increase in specific action planning, 95% CI=-2.3kg, -0.6kg). See Table 2.4 for all results.

Table 2.4. Linear regression predicting weight change from all self-regulation steps; with and without outlier.

		Model					
		With Outlier (N=24)			Without Outlier (N=23)		
		B[a]	p	CI[a]	B[a]	p	CI[a]
Predictor Variables	**Contextualisation**	-1.507	.175	-3.745; 0.731	-0.531	.308	-1.594; 0.532
	Reflection	0.741	.521	-1.628; 3.110	0.871	.113	-0.228; 1.970
	General Action Planning	0.463	.539	-1.084; 2.010	-0.678	.081	-1.449; 0.094
	Specific Action Planning	-2.057	.027	-3.854; -0.261	-1.424	.003	-2.286; -0.563

[a]The coefficients represent the effect of a 1SD increase in the independent variable and show the change in weight in kg that might be expected to ensue.

2.4.5 Experiences with and barriers to daily weighing and self-regulation

The most prominent themes from the thematic analysis are discussed and exemplified with quotes in the following sections, complemented by quotes and quantified information extracted from the follow-up interviews. I provide information on the gender and age of participants quoted, in order to provide some context to the statements.

2.4.5.1 Weighing evokes emotional reactions

Self-weighing evoked an emotional response in participants. Reactions both within and between individuals comprised positive and negative responses, including relief, joy, shame, frustration and guilt. The nature of the reaction depended on whether the weight outcome was higher or lower than expected. Emotional reactions were elicited in both men and women, although women tended to show a stronger emotional response.

> *"It's definitely higher than what I expected, which makes me feel kind of anxious and uncomfortable." (Female, 24)*

> *"I mean obviously I'm cheerful. There is nothing like seeing unexpectedly low numbers on the scale for making a person feel exceedingly jolly." (Female, 52)*

Some female participants stated that they found their emotional response to the weight outcome more intense than they felt was appropriate.

> *"And it is also absurd that my happiness can be so profoundly altered by seeing a number on the scale that's slightly, slightly less than I was expecting, and that - let's face it - is 40 kilos more than it should be." (Female, 52)*

Positive weight changes encouraged participants in their weight loss attempt, while disappointing and frustrating weight measurements led some participants to want to give up on their weight loss attempt since they felt that their efforts were not fruitful anyway. In the debrief interview, one participant noted:

> *"I think I get too upset when it doesn't go down. When I've done a really good day of eating healthily and then I don't see any difference on the scales […] I'm like oh what was the point." (Female, 30)*

Some participants, both male and female, found that their emotional reactions to the weight measurements reduced over time.

> *"[I'm] feeling fewer strong emotions in either direction when getting on the scale." (Male, 34)*

Further support for a habituation process was found in follow-up interviews, where nine participants commented on having noticed that their emotional reactions decreased in intensity throughout the study.

> *"I think I feel better about weighing myself now[…], because you do it so often it's not like a scary number anymore you kind of know what to expect and I think yes it's less kind of horrible." (Female, 29)*

One female participant started the study strongly disliking weighing herself and found that by the end she had developed more positive feelings towards it. In one of her think-aloud recordings she reported:

> *"I'm finding I'm vaguely looking forward to weighing every day. Which is quite a big change about how I feel about the scale." (Female, 52)*

She expressed worry about having to return the scales I lent her by the end of the study, which shows that she had found value in this part of her daily routine.

2.4.5.2 Motivation and influence on daily life

Seeing the daily weight measurement prompted both male and female participants to think about changing their behaviours. This was often paired with statements expressing motivation, but an action plan was rarely made.

> *"Boy oh boy, seven weeks and nothing to show for it. […] But it is good, it is giving me some very strong feedback. I can't fool myself any longer. This must change now." (Male, 36)*

At the follow-up interviews, participants commented that daily weighing over eight weeks helped them realise that their approach to weight loss needed to change in order to lose weight.

> *"It made me realise that I was not only in denial about how quickly I should be losing weight with what I'm doing, but actually probably in denial about what level of effort I'm actually making to lose that weight." (Female, 33)*

Even though participants rarely made action plans in the think-aloud recordings, some noticed while reflecting on past behaviour that the daily weighing had affected their actions throughout the day.

> *"And in fact, yesterday I was at a party in the afternoon and there was quite a lot of cake, I didn't eat any of it […]. And I think that was because of the awareness that I would be weighing." (Female, 52)*

This effect of regular weighing acting as a reminder of the weight loss goal throughout the day was also mentioned by participants in the follow-up interviews.

> *"But, I think the weighing was really mutually supportive. […] At least on a couple of days, I think it really did help me make the right choice in a moment where I might not have made the right choice otherwise, because I knew I was going to read that scale the next day." (Male, 34)*

Hence, even without action planning the weighing process influenced participants' behaviour. This might also explain why 22 participants stated in the interviews that they found weighing useful for controlling their weight.

2.4.5.3 Barriers to interpreting weight measurements

Participants struggled to make sense of their weight changes on a day-to-day basis. They reported in their think-aloud recordings that the daily fluctuations were not always clearly associated with their previous behaviour, making it hard to explain weight changes. This led to frustration as expectations were often not met. This was especially pronounced for female participants; male participants seemed to have fewer unexplainable weight changes and reacted less strongly to them.

> *"My experience in the past is that if you've dieted and had what you think is a very good week about eating and it's not reflected on the scale, very often that can make you miserable and drive you into giving up, or relinquishing a bit of control, or just throwing the towel in because well, you felt deprivation and you're not getting the reward of the scale number." (Female, 52)*

Participants were aware that the daily fluctuations could not only stem from fat loss but also from other changes in their body. Understanding the cause of a weight change was therefore perceived as difficult.

> *"If there is one major thing that is stressing me out about my weight it's that I feel I have no idea if the fluctuations I'm seeing are related to water consumption, fat or muscle loss, amount of food consumed, time I'm weighing myself." (Female, 24)*

Confusion surrounding the interpretation of the weight changes and the meaning of fluctuations was sometimes followed by feelings of helplessness.

> *"I'm not sure what I'm doing wrong, I'm trying to eat healthy, I'm doing exercise classes but the weight just isn't moving. I'm trying all sorts of different things." (Female, 39)*

In the previous theme on emotions I identified that negative emotional reactions sometimes led participants to want to give up on their weight loss attempt. In the context of this theme, one can see that negative emotional reactions were especially a barrier when participants could not explain what they had done wrong or what they should do differently.

Problems with interpreting daily weight changes were further aggravated by unrealistically high expectations about the rate of weight loss. For instance, the following participant expressed her frustration about a lack of weight loss although she was 400g lighter than the previous day:

> *"Still no move, still no change, still not making any difference to everything that I'm doing. Beyond frustrated." (Female, 39)*

Similarly, a participant stated that she realised she had exaggerated expectations about weight changes in the follow-up interview:

> *"Yes, if I eat a pizza one day I'd be expecting it to be like 10 kilos more, which is, I know, silly'. (Female, 26)*

Participants tried to identify trends in their data. However, they reported difficulties in taking this longer-term view.

> *"I guess one of the irritating things about weighing oneself daily is that improvement/weight loss is harder to spot." (Female, 24)*

This mostly had to do with problems with keeping an overview of all measurements taken over time, as participants forgot previous weighing results.

> *"If you weigh yourself every week there's an obvious change and you can remember what you were the week before[…]. When you're doing it daily you lose track of what your weight was the day before." (Female, 39)*

Although 19 participants stated in the follow-up interviews that weight tracking might have facilitated identifying trends in the data, only 11 of the participants actually kept track of their weight throughout the study.

> *"I kind of regretted […] not doing that [weight tracking] as well because […] I have no idea actually what I weighed at the beginning of the study, […] maybe knowing what like each week sort of my progress had been if I was trying, that would have been a better like behavioural mechanism that could have prompted me to certain behaviours." (Female, 24)*

Interpretation of the weight measurements was not helped by the fact that participants sometimes forgot to weigh themselves first thing in the morning, increasing the apparent daily fluctuations. Participants were aware of this problem and preferred weighing themselves in the morning.

> *"I don't like weighing myself last thing at night, want to start first thing again. Maybe I won't stress about it so much then." (Female, 26)*

Overall, continuing problems with the interpretation of weight changes emerged as a barrier to daily weighing and self-regulation.

2.4.5.4 Weighing frequency

Twenty participants stated in the follow-up interviews that daily weighing had become a habit, which they had incorporated in their morning routine. All participants stated they would like to continue weighing themselves regularly, including eleven participants who stated they would like to continue weighing themselves daily. They felt that daily weighing helped them to keep on track with their weight loss goals.

> *"I guess at least now like every day I'm getting the push like you should do something different rather than like every week getting the push you should do something different." (Female, 29)*

However, with daily weighing, participants were more likely to dismiss changes they did not want to see as being part of the natural fluctuations in weight.

> *"It would kind of creep up quite easily, because each day I could just dismiss it […]. So, I was kind of, it was easy to convince myself with oh no that's just, you know, fluctuations." (Female, 29)*

Based on the problems with interpreting daily weight changes, half of the participants specifically stated in the follow-up interviews that they would prefer less regular weighing, although at least weekly. The longer interval between the weight measurements was thought to be helpful to see trends in the data.

> *"Daily it doesn't change very much but weekly I think it does and therefore if you've done well you can see you've done well which motivates you to continue." (Female, 39)*

> *"I think I found the trends between weeks a bit easier to kind of mentally take something from than day to day." (Female, 29)*

Some participants also preferred the weekly weighing as it allowed them to avoid judgement after an unhealthy day.

> *"I think I would prefer to have this kind of longer window where I can say well okay like I ate too much cake yesterday or something so now […] I've got a couple of days where I can undo the damage." (Male, 26)*

Overall, preferences for daily or less frequent weighing depended on how useful the daily weighing was perceived to be. This may explain why more men were willing to continue daily weighing than women (7/9 men vs. 4/15 women), since I found that men had fewer problems interpreting weight changes than did women.

2.5 Discussion

2.5.1 Principal results

The framework analysis revealed important differences in the extent to which self-regulation steps occur naturally after weighing. While participants compared their weight measurement to previous measurements or a goal and reflected on previous behaviour in the majority of cases, it was very rare that participants of either gender spoke of plans to take weight loss actions. Participants who frequently reflected on their behaviour were more likely to perform all other steps of the cognitive part of the self-regulation process.

In the exploratory regression analysis, specific action planning was the only self-regulation step to emerge as a significant predictor for weight loss.

In the thematic analysis, I found that weighing was an emotional topic for most participants, especially women. Weighing was perceived as useful for weight loss by the large majority of participants and helped them realise that they had to make changes to their behaviour in order to lose weight. Some participants also reported that they felt the weighing influenced their behaviours throughout the day, helping them to remain more disciplined.

Difficulties with interpreting weight measurements emerged as a barrier to self-regulation. While for some participants a clear cause and effect relationship of their behaviour and weight was apparent, for others, mostly female participants, the daily fluctuations made it difficult to see the direct impact of their actions and impeded their ability to keep an overview of data trends. When participants were unable to make proper use of the daily feedback, they were more likely to want to continue weighing less frequently. Keeping an overview of the weight loss trends was perceived as difficult by many. However, less than half took the self-initiative to record their measurements.

2.5.2 The role of the cognitive self-regulation processes

The results provide first evidence that contextualisation and reflection processes occur naturally after weighing in the majority of cases. Based on my occurrence and correlation findings, the participants seemed to follow the order of the self-regulation process, although not everyone reached the final stages, as evidenced by decreasing occurrence rates. Reflection on behaviour might be an important intermediate step between contextualisation and action planning, as it was significantly correlated with both, and contextualisation was not directly related to action planning.

Specific action planning emerged as the only significant predictor of weight loss, indicating that this step of the self-regulation process is the key contributor to weight loss effects found in previous studies. This finding aligns well with the literature on implementation intentions. Implementation intentions are similar to specific action planning in that they also specify how, when, and under which circumstances an action is to be performed[158]. A randomised controlled trial by Luszczynska and colleagues showed that adding implementation intentions for diet and exercise behaviours to a weight loss programme significantly increased weight loss success[159]. Similarly, a study by Benyamini et al. found that adding an action planning intervention to a weight loss programme elicited significant additional weight loss[160]. Support for the importance of the specificity of action plans comes from a study aiming to increase exercise, which found that the specificity, rather than quantity of implementation intentions predicted physical activity outcomes[155]. In a meta-analysis of 94 studies investigating the impact of implementation intentions on behaviour performance across a vast range of behaviours, including health behaviours, a significantly positive medium-to-large effect was found[161]. Another review concluded that defining if-then plans, making contingency plans, and incorporating relevant cues for action in the plan play an important role in the success of this strategy[158].

Specific action planning only occurred very rarely in this study. Similarly, de Vet and colleagues found that even when prompting participants to be more specific in their action plans, less than 10% of participants specified the context of all their action plans, and more than 60% did not even form a single specific action plan[155]. This matches the conclusion of Hagger and Luszczynska who recommended that researchers should guide participants in forming implementation intentions in order to increase chances that they

are formed correctly[158]. Hence, the evidence suggests that participants need support in performing this last step of the self-regulation process, but that successful implementation might be a simple, yet effective, approach to weight loss.

2.5.3 Experiences with daily weighing

My qualitative analysis showed that weighing elicited emotional reactions. In line with this, a qualitative study by Carrard and colleagues, which assessed weighing experiences in weight loss maintainers, found that weight loss was related to positive emotions while weight gain led to feelings of guilt and sadness[162]. Moreover, a qualitative study by Zheng and colleagues, investigating experiences with self-weighing in successful participants of a weight loss trial, also found that participants reported feelings of frustration when expected weight loss did not materialise, and positive emotions when weight measurements were lower than expected[163]. Some of my participants expressed that the negative emotions elicited by weighing constituted a barrier to further self-regulation. I will further explore and discuss this finding in Chapter 3.

A positive result of this study was that nine participants reported habituating to weighing, making it a less emotional and stressful task after a while. Similarly, a recent paper examining self-weighing perceptions over the course of a 12-month long weight loss trial reported that participants found weighing more positive and less frustrating by the end of the study[164]. This highlights that people may need support with emotion regulation in early days of regular weighing, but can be reassured that weighing will become a less emotionally upsetting experience over time.

The overwhelming majority of participants in my study reported that they perceived regular weighing as a useful tool for weight management. Many found that weighing provided them with strong feedback about how their behaviour needed to

change in order to lose weight. Several stated that they had been in denial about their weight loss efforts. In line with this, participants in the two other qualitative studies also reported using self-monitoring as a feedback tool to evaluate their actions[162, 163]. Some of my participants stated that regular weighing helped them stay disciplined and make more healthy choices throughout the day. Hence, even though they only rarely engaged in action planning, their behaviour was still influenced by the weighing to some extent. This corresponds to findings by Zheng and colleagues, whose participants stated that the prospect of weight loss and observing weight loss motivated them to continue with weight loss behaviours[163]. Similarly, studies conducted in a laboratory setting have shown that weighing oneself significantly reduces subsequent snack consumption[165].

Although all participants wanted to continue weighing themselves regularly, and hence saw some value in checking in with the scales, the interpretation of daily fluctuations was a barrier to the constructive use of the weight measurements. Many participants felt that the daily weight changes did not always reflect previous behaviours and that timing of the weighing, as well as food and drink intake, influenced the weight measurement. This is similar to the findings of Zheng and colleagues, whose participants also realised that other factors than body fat gain or loss influenced their daily weight change[163]. The resulting unpredictability of weight measurements led to feelings of frustration and helplessness in some participants in my study. Interestingly, women reported more issues with the interpretation due to daily fluctuations than men. This may also explain why I found that the emotional reactions to weighing were especially pronounced in female participants, as inexplicable weight changes may cause more frustration. A recent observational study found that individuals with more variability in

their day-to-day weight measurements are less likely to lose weight[166]. This indicates that frustration with inexplicable fluctuations might cause individuals to reduce their engagement in weight loss efforts.

However, participant responses also highlighted helpful aspects of daily self-weighing, including how it became habitual and helped them keep on track with their goals. It might therefore make sense to separate daily weighing from self-regulation, such that participants weigh daily but are prompted to reflect on behaviour and evaluate their actions on a weekly basis, based on the trend of the week's data. Alternatively, since the day-to-day fluctuations seemed to differ in magnitude across participants and hence impeded them to different extents, future studies might also want to test assigning participants to different weighing frequencies, depending on the magnitude of their day-to-day weight fluctuations.

Although my participants realised the importance of interpreting long-term trends rather than daily weight changes, participants struggled to keep an overview of their weight loss progress and sometimes forgot previous weight measurements. This indicates that a weight tracking component may be beneficial to support long-term self-monitoring. In the Zheng trial, participants specifically stated that they liked the weight tracking element of the intervention as it visualised their weight loss progress[163]. In the present study, fewer than half of the participants tracked their weight, but nearly all stated that it would have been useful to do so. Nonetheless, I found that participants were still able to contextualise their weight measurements 90% of the time, so the lack of weight tracking did not seem to necessarily impair the subsequent self-regulation processes.

Another barrier to self-regulation emerging from the analysis was related to unrealistic expectations. My participants expected to see drastic weight changes after a day of vigilance and similarly expected their weight to increase sharply after a 'cheat day'. Unrealistic expectations have previously been reported in the context of overall weight loss programmes[167-169]. Here, the results show that unrealistic expectations also occur on a day-to-day basis. Although the impact of unrealistic expectations is contested, with some studies indicating that it does not affect weight loss outcomes[167], or even that weight loss outcomes are better for unrealistic goal-setters[170], there is some evidence suggesting that unrealistic expectations may cause attrition from weight loss programmes[171-173]. It is conceivable that continuous regular self-weighing would help participants adjust their daily expectations to more realistic values but further research is needed to explore this possibility.

2.5.4 Strengths and limitations

The study had strong engagement from participants, and hence the data is not much affected by attrition bias. Sending reminders every other day and calling participants every two weeks allowed me to stay in touch and respond to problems. The results of this study are thus based on 498 think-aloud recordings, which were captured in the moment of weighing and provide unfiltered information on participants' thoughts and feelings. This is the first study to have examined thought processes during and right after weighing in this detailed way. Compared to interviews or the standard think-aloud method, data collected using my adapted methodology is less likely to be affected by researcher bias, since I was not present during the think-aloud task. The information gathered from the think-aloud recordings was further supported by elaborations from the participants in over 700 minutes of follow-up interviews. This allowed me to gather reflections on self-

weighing and put the think-aloud data into a broader context without influencing the experience of weighing itself.

One limitation is that it is likely that participation in the study acted as a low intensity intervention[174]. Some participants commented that the knowledge of participating in a research study motivated them to weigh every day and stay disciplined and committed to their goal. Previous research has shown that even control groups receiving no intervention but being followed up lose weight during clinical trials[175]. Furthermore, the think-aloud task might have influenced participants' self-regulation response to weighing. Sixteen participants reported that they felt thinking aloud led to more reflection on the weight outcome than would have naturally occurred. Hence, the occurrence of self-regulation in this study might be an over-estimation of reality, but it is unlikely that thinking aloud distorted the balance between the different self-regulation steps.

Since this study focussed on the cognitive processes following weighing, I cannot make conclusions about the day-to-day performance of weight loss actions. However, the connection between intentions and behaviour has been studied extensively elsewhere[176].

Even though all of my participants were trying to lose weight during the study, only a few of them were successful. It is conceivable that self-regulation occurrences and weighing experiences would have been different in a population which successfully lost weight, especially in relation to the action planning component. Further research is needed to investigate this possibility.

Another limitation is that my sample was small and not representative of the general population in that 22 participants had a university degree or equivalent. As

education is a marker of socioeconomic status[35], it is likely that my sample was restricted to individuals of higher socioeconomic status, thus limiting the generalisability of my results. This may be particularly problematic as research has found that education and socioeconomic status are positively associated with levels of executive functioning, which encompasses self-control and self-regulation[177-181]. Future research conducted in a more diverse sample is therefore needed to improve generalisability to the general population.

Another limitation is that due to the small sample size and the observational design of this study, the results of my exploratory regression analysis, showing an effect for specific action planning, need further investigation to establish causation.

I quantified some of the data collected in the semi-structured interviews. In hindsight, it might have been better to have collected this data in a quantitative way, for example through a questionnaire. However, the interviews allowed me to gain further insights and supported the themes I identified during the inductive thematic analysis of the think-aloud recordings, thus strengthening my qualitative analysis.

2.6 Conclusion

In summary, this study advances the field of self-regulation research by providing the first data on the cognitive processes following self-weighing. The results show that few people complete the self-regulation process, thus countering the hypothesis that self-monitoring automatically triggers self-regulation. Specific action planning was implemented particularly rarely, but it was the only component of the self-regulatory cycle associated with weight loss. The study demonstrated that there are key barriers to self-weighing and self-regulation. These included issues with dealing with negative emotions, difficulties

with interpreting weight changes due to unexplainable fluctuations, problems with remembering previous readings, and unrealistic weight loss expectations. All these barriers constitute potential reasons for why individuals may stop weighing themselves. In Chapter 3, I will present a study which further investigated the causes for breaks in weight monitoring.

Another key finding of this study was that people found it hard to keep track of their weight loss progress when weighing daily. Despite these difficulties, less than half of my participants took the self-initiative to track their weight measurements. This showed that individuals do seem to require support in remembering their weight measurements and may benefit from being prompted to track their weight. I therefore decided to incorporate a weight tracking element in my own self-regulation intervention. In Chapter 4, I review existing weight tracking apps and explore people's likes and dislikes to help design this component. In Chapter 5, I will then describe how I used findings from the think-aloud study and the other chapters to develop a new intervention guiding participants through the complete self-regulation process in order to maximise the potential benefits of this strategy.

Chapter 3 Why do people stop weighing themselves? An observational analysis of weight and physical activity tracking data

3.1 Summary

Self-regulation for weight loss requires regular self-monitoring of weight but the frequency of weight tracking commonly declines over time. The aim of this chapter is to investigate whether it is a halt in weight loss progress or a drop in the motivation to lose weight (using physical activity as a proxy) that may be prompting a stop in weight monitoring. I analysed weight and physical activity data from 1605 Withings Health Mate app users, who had set a weight loss goal and stopped tracking their weight for at least 6 weeks after a minimum of 16 weeks of continuous tracking. Mixed effects models compared weight change, average daily steps, and physical activity tracking frequency between a 4-week period of continuous tracking and a 4-week period preceding the stop in weight tracking. Additional mixed effects models investigated subsequent changes in physical activity data during 4 weeks of the 6-week long stop in weight tracking.

The results showed that users lost weight during continuous tracking (M=-0.47kg, SD=1.73) but gained weight preceding the stop in weight tracking (M=0.25kg, SD=1.62; difference=0.71kg, 95% CI=0.60, 0.81). Both average daily steps (β=-220 daily steps/time period, 95% CI=-320, -120) and physical activity tracking frequency (β =-3.4 days/time period, 95% CI=-3.8, -3.1) significantly declined from the continuous tracking to the pre-stop time period. From pre-stop to post-stop, physical activity tracking frequency further decreased (β=-6.6 days/time period, 95% CI=-7.12, -6.16), while daily step count on the days activity was measured increased (β =110 daily steps/time period, 95% CI=50, 170).

In conclusion, the analysis found that in the weeks before people stop tracking their weight, their physical activity and physical activity tracking frequency decline, while their weight increases. The findings suggest that declining motivation for weight control and difficulties dealing with negative weight feedback might explain why people stop tracking their weight. The increase in daily steps, but decrease in physical activity tracking frequency post-stop might result from selectively measuring more active days.

Note: A version of this chapter was published in the Journal of Medical Internet Research[182].

3.2 Introduction

In Chapter 1, I discussed how self-monitoring of weight is a common component of weight loss interventions; its effectiveness being attributed to a self-regulation process. I also reviewed research showing that the frequency of self-weighing is consistently positively associated with weight loss outcomes. However, adherence rates to weight monitoring seem to decline long-term (see Chapter 1). This could either be due to issues with the tracking devices used, or due to user-internal reasons for no longer wanting to weigh. Research investigating the former suggests that cost, concerns surrounding data sharing, flaws in the design and user experience of technology, issues with data accuracy, as well as mismatches between expectations and needs and the devices' capabilities, deter use of self-monitoring technologies[183-187]. Regarding the user-internal reasons, research has found that users may abandon self-monitoring if they feel they can no longer learn from their data, or if they reached their goals[184, 187]. A limitation of this line of research is that it is based on data collected through questionnaires and interviews and may suffer from participants retrospectively justifying their abandonment. In

contrast, my think-aloud approach (Chapter 2) allowed me to explore in-the-moment barriers to self-weighing. One of the barriers I identified were problems with dealing with frustrating weight measurements. I decided to investigate this further. If receiving frustrating weight measurements can lead to the abandonment of self-weighing, then weight measurements before a stop in weight tracking should reflect a halt in weight loss progress, which could be analysed observationally. I wondered whether the motivation to engage in weight loss efforts might play a role here as well. When motivation declines and individuals perform less weight loss behaviours, their weight loss progress is likely to be impacted. Furthermore, since individuals who stop weighing themselves seem to gain weight[126, 188], I asked myself whether a stop in weight monitoring may lead to a further decline in motivation to engage in weight loss efforts. To investigate these possibilities, I employed a prospective observational design, using actual tracking data from the Withings Health Mate app. The app allows its users to track their weight and physical activity measurements. Since roughly 80% of people increase their physical activity during weight loss[189-191], I considered the physical activity measurements a proxy for the engagement in weight loss behaviours and the motivation to lose weight.

3.2.1 Research questions

My first research question (RQ1) considered whether the pattern of weight and physical activity measurements and physical activity tracking frequency changes before people who are trying to lose weight cease weight monitoring. I tested two competing hypotheses against each other. First, that in the weeks preceding a stop in weight tracking, motivation to lose weight and track behaviour would remain high (i.e. stable levels of physical activity and physical activity tracking), but the user would receive weight readings that show unsatisfying weight loss progress (such as stable weight or

weight gain), leading to frustration and perceived lack of ability to take control over the weight loss progress, making the user stop tracking their weight. The alternative hypothesis was that declining motivation for weight loss would manifest in declining weight loss efforts (as measured through decreasing physical activity). This would lead to unsatisfactory feedback, such as weight stability or gain, and lead to ceasing self-monitoring.

My second research question (RQ2) examined physical activity data after users stopped tracking their weight. My hypothesis was that ceasing self-monitoring of weight would undermine motivation to engage in weight loss behaviours. I therefore expected to see a decrease in physical activity and physical activity tracking frequency after the stop in weight monitoring.

3.3 Methods

3.3.1 Data set

I reached out to the companies Withings S.A. and Fitbit Inc. early on in my DPhil, exploring potential opportunities to collaborate on a project to investigate why people stop weighing themselves. Withings responded positively to my request, so I held Skype meetings with their research team to discuss potential research ideas. In parallel, I also met and discussed the analysis with my supervisors and a statistician in the department. These meetings allowed me to finalise a set of research questions and an analysis plan. In the meantime, a research contract was set up, allowing me to use the Withings data for free as long as I acknowledged Withings on any resulting publication. Withings provided me with a data set comprising weight and physical activity records from 438,688 Withings Health Mate app users from 1st of January 2014 to 19th of January 2018. Withings Health

Mate app users consented to the use of their data for research purposes by accepting the terms and conditions of Withings[192]; ethical approval was therefore not necessary. The data set was restricted to users who were overweight or obese when they started using the app (BMI≥25kg/m^2), and used both the weight and the physical activity tracking features. I also requested to restrict the data set to users who had set themselves a weight loss goal in the app, as I wanted to ensure I only included users who were trying to lose weight. Moreover, as to my request, Withings only included users in the data set who synchronised their weight data from Withings smart scales, as previous research indicates that users may underreport unfavourable weight measurements if done manually[193]. Withings smart scales synchronise weight data to the app via WiFi or Bluetooth. Smart scale owners can set up accounts for up to 8 users and the scale differentiates between users automatically during weighing. Weight measurements are synchronised to the app separately for each user, thus ensuring that the data does not get mixed up. Physical activity is operationalised as daily step counts in the Health Mate app. The data can be synchronised via Bluetooth from Withings physical activity trackers and Apple watches, or via linking to the Google Fit or Samsung Health app. The data set included demographic information about each user, including gender, age, location, self-reported height, initial BMI, and target BMI.

3.3.2 Study design and data screening

Before conducting the analysis, I screened the data set provided by Withings for users whose tracking pattern matched my study design. Only users who stopped tracking their weight for at least six weeks at some point between 2014-2018 were included in the analysis. I chose a period of six weeks to signify a stop to increase the likelihood that the lack of measurements was not due to travel. To be eligible, users also had to have a

preceding 16-week phase of consistent weight and physical activity tracking (≥3 measurements per week) to ensure that only users who monitored their weight and physical activity regularly before the stop were included. I employed a case-crossover design[194] for both research questions. For RQ1, four weeks of data preceding the minimum 6-week long stop in weight tracking were compared to four weeks of data from the same user from the phase of consistent weight and physical activity tracking. I analysed a four-week time period preceding the stop in weight monitoring as I expected that the frequency of weight tracking would change gradually. There were no minimum requirements for monitoring frequency for this pre-stop period. Only users starting both analysis time periods with a BMI of 25kg/m^2 or above were included. For RQ2, the analysis further included a third four-week time period, taken from the 6-week long break in weight monitoring, i.e. post-stop. Figure 3.1 depicts the study design. Where users had several 26-week time periods that fulfilled the above criteria, the first time period was analysed. Previous research has shown that large distances to goal weight are associated with more dissatisfaction with weight loss progress[195], probably because these goal weights are harder to achieve. Hence, if people are far away from their weight loss goal, and receive frustrating weight measurements, they might be more likely to disengage from their weight loss attempt. Here, users may have had significant changes in their weight between the two time periods analysed, thus leading to different distance to goal weight scores. In order to ensure that these differences and their potential impact do not affect my analyses, I decided to control for the distance to goal weight in all analyses.

Figure 3.1. Study design.

3.3.3 Analysis

All analyses were conducted in R (version 3.4.1). I wrote a statistical analysis plan, which was published on the Open Science Framework preceding the analyses[196].

3.3.3.1 Variables

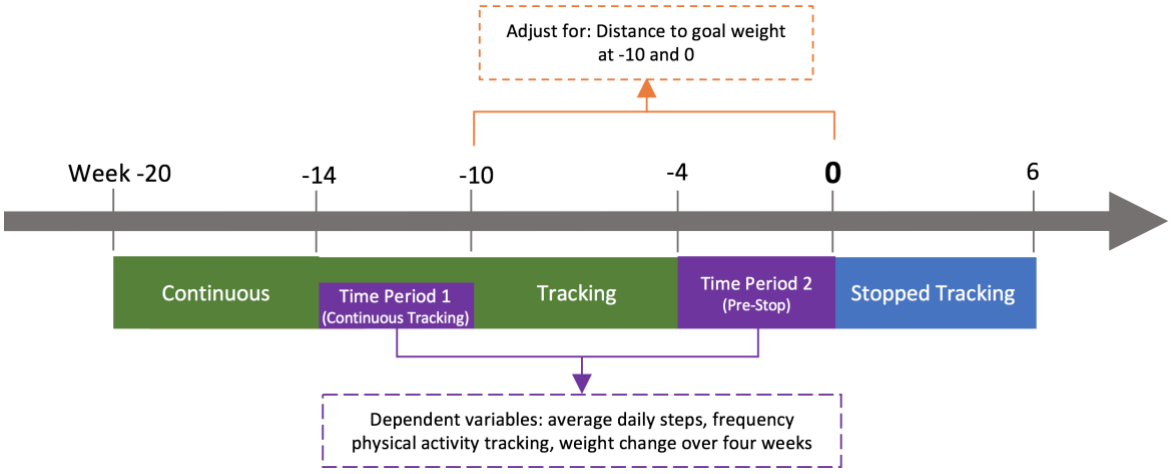
The independent variables in the analyses were called time period, distance to goal weight, date of measurement and user ID. Time period was a factor with two or three levels (continuous tracking, pre-stop and, in RQ2, post-stop), and defined which time period the dependent variable in question originated from. The continuous tracking period was located within the 16-week period of consistent tracking during which users recorded at least three weight and physical activity measurements per week. The pre-stop period was located immediately before the stop in weight tracking. The post-stop tracking period (RQ2 only) was located within the 6-week break in weight tracking. Which weeks the time periods encompassed differed slightly by analysis and is described for each analysis separately below. The distance to goal weight variable was calculated as a difference score between the weight measurement closest to the last date of the time period analysed and goal weight. To set up the analyses as within-subject, I added the variable user ID as a random factor to all analyses. In RQ2 only, I also included date of measurement as an independent variable to specify the date on which the dependent variable analysed was measured.

There were three dependent variables. The first was weight change, calculated as the difference score between the first and last weight measurement of each time period. The second was daily steps. For RQ1, this variable was calculated as the average daily step count across all days of a time period. For RQ2, the individual daily step measurements were used. In both cases, the daily steps variable was divided by 1000 in order to aid interpretation of the coefficients. The third dependent variable was physical activity tracking frequency, which was calculated as a sum score for the number of days for which physical activity measurements were available in each time period. Since physical activity was treated as a proxy measure for motivation to lose weight, increases in daily step counts were interpreted as a strengthened weight loss effort and increased motivation to lose weight. Physical activity tracking frequency was interpreted as motivation to self-monitor weight loss efforts.

3.3.3.2 Research question 1

For RQ1, I assessed whether weight change, average daily steps, and frequency of physical activity tracking differed between the two time periods: continuous tracking (weeks -14 to -10) and pre-stop (weeks -4 to 0, 29 days each). Figure 3.2 depicts an overview of the design.

Figure 3.2. Case-crossover study design to establish linear mixed effects models.



Descriptive analysis examined the demographic characteristics of the analysed sample and unadjusted differences between the two time periods on the dependent variables. Linear mixed effects models, matched by user ID, predicted the dependent variables weight change, average daily steps and frequency of physical activity tracking based on the binary variable time period. All analyses were adjusted for the distance to goal weight. I ran models twice, once using distance to goal weight as a random, another time as a fixed factor. Where a comparative ANOVA revealed a significant difference between the models, the model with the lower Akaike Information Criterion (AIC) was determined to be the best-fitting model. Where no significant difference was found in the ANOVA, the model with the lower degrees of freedom was chosen. Only the best-fitting models are reported here. To assess the sensitivity of my findings to the normality assumption, I compared the outputs with equivalent models fitted using generalised estimating equations (GEE; see Table A of Appendix 3.1 - Results of GEE models).

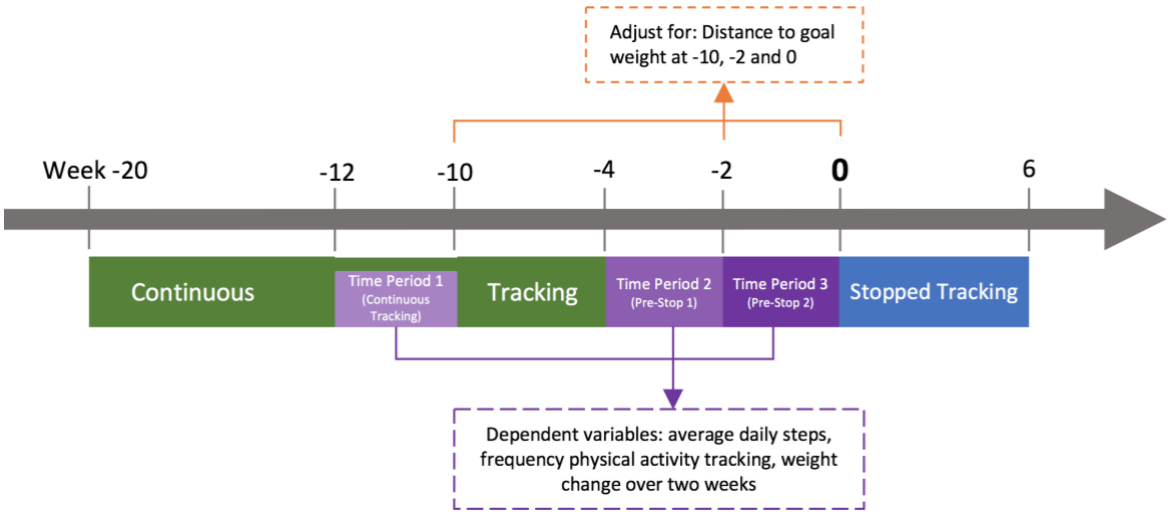
My first hypothesis was that motivation to lose weight and track activity would remain high, but frustrating weight measurements would drive the user to stop weight tracking. Consequently, it follows that there would be no association between the binary

time period variable and average daily steps or physical activity tracking frequency. However, time period would significantly predict weight change, as weight loss would be expected to lessen in the pre-stop time period.

My second hypothesis stated that users would lose motivation for weight loss behaviours and the resulting unsatisfactory weight feedback would lead to a stop in weight tracking. Consequently, it follows that the binary time period variable would significantly predict physical activity levels, such that there would be a decline in average daily steps from the continuous to pre-stop periods. Time period would also significantly predict weight change, as users would be expected to have less satisfactory weight measurements after reducing their weight loss efforts in the pre-stop time period. There was no specific prediction about the pattern of physical activity tracking frequency in this hypothesis.

In order to identify any temporal sequences of the above hypothesised effects, I ran post-hoc analyses splitting the pre-stop time period (weeks -4 to 0) into two two-week time periods (-4 to -2, -2 to 0). I re-ran the analysis above, this time comparing three time periods with each other, namely weeks -12 to -10 (time period 1, continuous tracking) as a baseline, weeks -4 to -2 (time period 2, pre-stop 1) and weeks -2 to 0 (time period 3, pre-stop 2), each 15 days long. All analyses were run twice and adjusted for the distance to goal weight, once set as a random and once as a fixed factor. I report the better fitting models, using the same criteria as for the pre-specified analysis. Tukey-adjusted post-hoc comparisons investigated pairwise comparisons of the three time periods. Again, GEE models were run to assess the sensitivity of my findings to the normality assumption (see Table B of Appendix 3.1 - Results of GEE models). The design of this analysis is depicted in Figure 3.3.

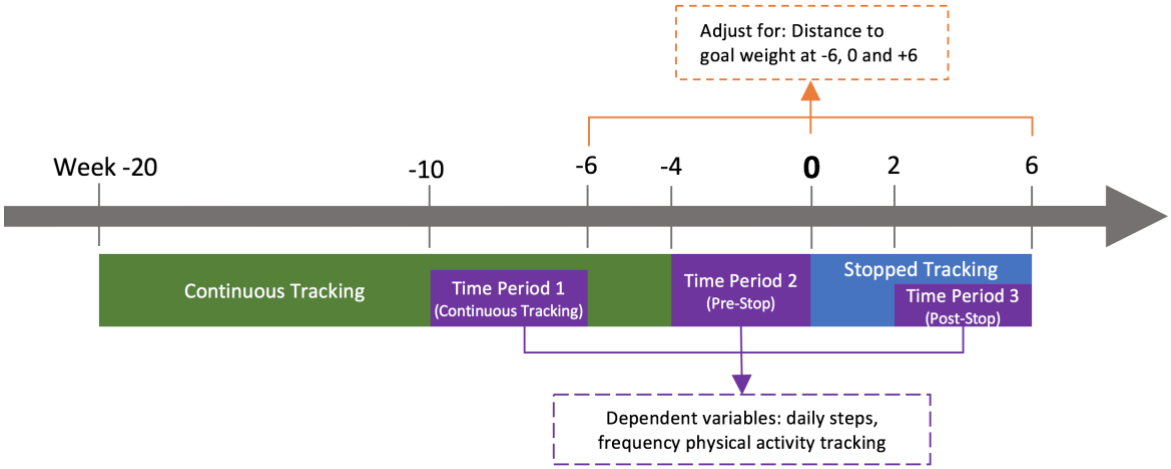
Figure 3.3. Design of the post-hoc analysis, aiming to investigate temporal sequence of effects.



3.3.3.3 Research question 2

For my second research question, I ran analyses to compare daily steps and physical activity tracking frequency before and after the stop in weight tracking. Time period 1 (continuous tracking) for this analysis stemmed from weeks -10 to -6 of the continuous tracking phase, which ensured that users had at least three physical activity measurements per week. This time period was treated as the baseline. Time period 2 (pre-stop) comprised the four weeks preceding the stop in weight tracking (weeks -4 to 0). Time period 3 (post-stop) comprised weeks 2 to 6 of the break in weight tracking (see Figure 3.4 for the design). The analyses were run separately for daily steps and frequency of physical activity tracking using linear mixed effects models. The analyses were adjusted for the distance to goal weight at the end of the three analysis time periods. Tukey-adjusted post-hoc comparisons investigated pairwise comparisons of the three time periods.

Figure 3.4. Case-crossover study design to establish linear mixed effects models.



3.3.3.3.1 Daily steps

Descriptive statistics explored unadjusted differences in daily steps between the three time periods. Linear mixed effects models predicted the dependent variable daily steps from the variables time period and date of measurement. A sequential testing approach was used:

Model 1.) random effect: user ID, fixed effect: time period

Model 2.) random effect: user ID, fixed effects: time period and date of measurement, interaction term: time period*date of measurement

Model 3.) random effect: user ID, fixed effects: time period and date of measurement, interaction term: time period*date of measurement, adjusted for distance to goal weight

The variance inflation factor $GVIF^{(1/(2*df))}$ was calculated at stage 2 of sequential testing to check for multicollinearity of the predictors time period and date of measurement. The third model was run twice, once entering distance to goal weight as a fixed, another time as a random factor. In this paper I only present the results of the best fitting model, which again was identified through an ANOVA and AIC comparison. I also ran GEE on the best fitting model in order to test sensitivity to the normality assumption (see Table C of Appendix 3.1 - Results of GEE models).

The hypothesis predicted a significant main effect for time period, such that daily steps would significantly decrease across all three time periods. I also expected a significant interaction term for time period and date of measurement, as date of measurement should only be a significant negative predictor in the second and third time period. These findings would support the hypothesis that ceasing weight tracking leads to a decline in weight loss efforts.

3.3.3.3.2 Frequency of physical activity tracking

Frequency of physical activity tracking was computed for the same three time periods, i.e. weeks -10 to -6 (continuous tracking), -4 to 0 (pre-stop) and +2 to +6 (post-stop, 29 days each). Descriptive statistics explored unadjusted differences in physical activity tracking frequency between the three time periods. A linear mixed effects model predicted physical activity tracking frequency, with user ID as a random and time period as a fixed effect. The analysis was adjusted for the distance to goal weight at the end of each time period. Again, distance to goal weight was entered once as random and once as fixed factor and only the best fitting model according to the ANOVA results and AIC comparison is reported. For my hypothesis to be correct, I expected to find significant decreases in tracking frequency across the three time periods as this would indicate that the stop in weight tracking signals a stop in wanting to monitor weight loss behaviours.

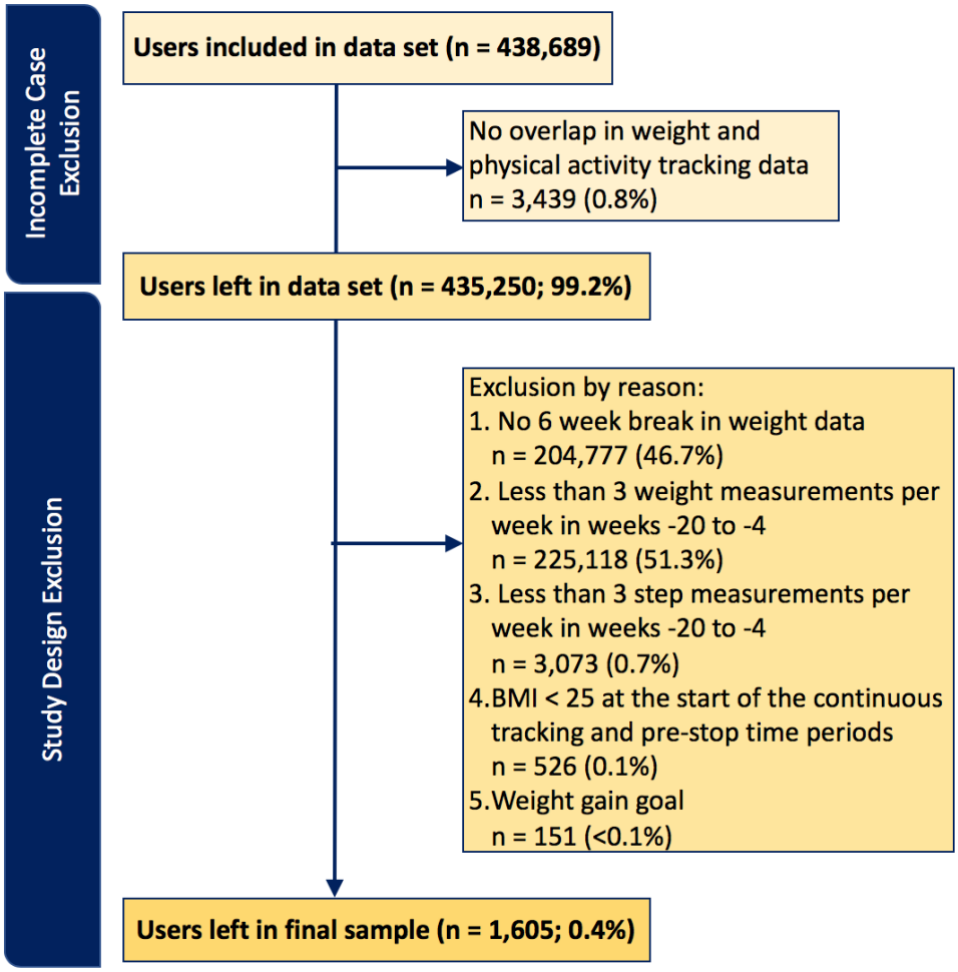
3.4 Results

3.4.1 Sample

The final sample consisted of 1318 male and 287 female users. Average age was 49.0 years (SD=12.5) and average BMI at week -14 was 30.2 (SD=4.7). The reasons for exclusion are shown in Figure 3.5. The final data set covered 221,173 weight and 113,162

physical activity measurements. Nearly half (48.47%, 778/1605) of the users included in the analysis were based in Europe, 36.39% (584/1605) in North America, and the rest split across the other continents.

Figure 3.5. Flow diagram of the exclusion rates at each step.



3.4.2 Research question 1

3.4.2.1 Weight change

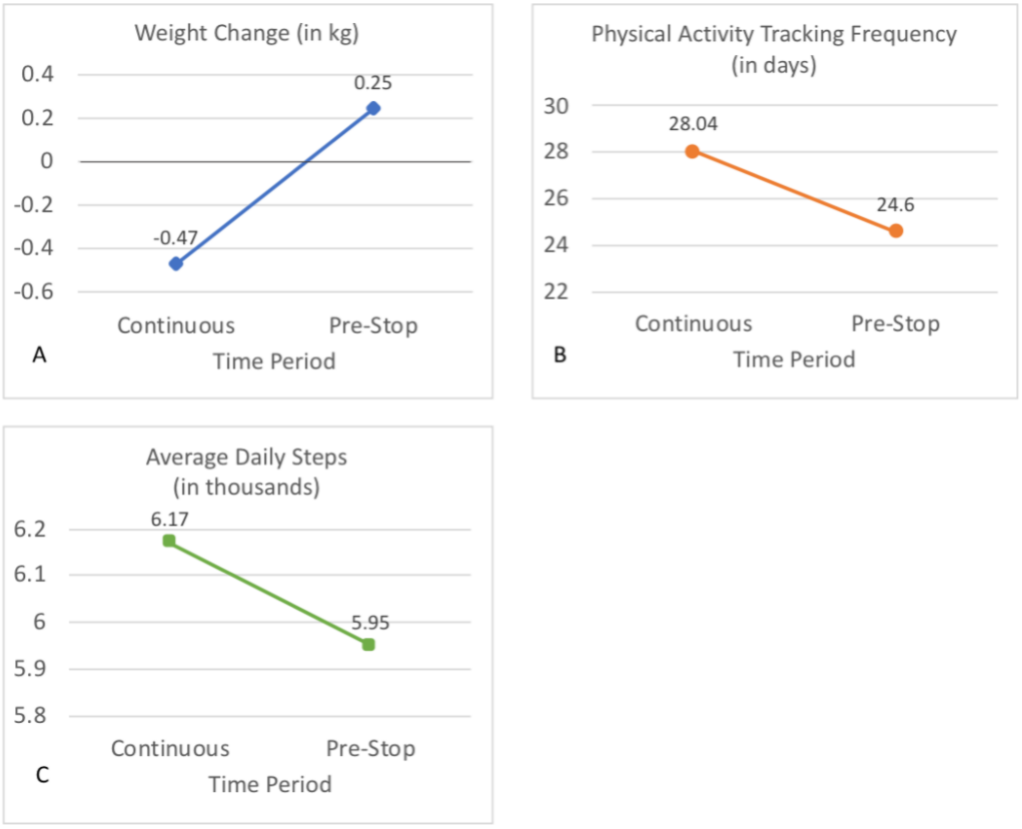
During the continuous tracking period, participants lost weight (M=-0.47kg, SD=1.73), but pre-stop they gained weight (M=0.25kg, SD=1.62). In the mixed effects model the time period significantly predicted weight change, revealing a 0.71kg (95% CI=0.60, 0.81) mean

difference in weight change from the continuous to pre-stop time period. Figure 3.6A depicts the changes in weight change.

3.4.2.2 Physical activity tracking frequency

Participants recorded physical activity on 3.44 (95% CI=-3.78, -3.10) fewer days during the pre-stop compared to the continuous tracking time period. Figure 3.6B depicts the changes in physical activity tracking frequency.

Figure 3.6. Results of the three linear mixed effects models for RQ1.



3.4.2.3 Average daily steps

Nineteen users completely stopped tracking their physical activity during the pre-stop time period, meaning that average daily steps could not be calculated. These users were excluded, leaving 1586 in the analysis. Pre-stop, participants took 220 (95% CI=-320, -210)

fewer steps per day than during continuous tracking. Figure 3.6C depicts the changes in average daily steps.

3.4.2.4 Post-hoc analyses

As in the prespecified analysis, users lost weight during the two weeks of continuous tracking (M=-0.29, SD=1.23), and gained weight in the first and second half of the pre-stop time period (pre-stop 1: M=0.11, SD=1.28; pre-stop 2: M=0.14, SD=1.28). Post-hoc comparisons revealed a 0.40kg (95% CI=0.31, 0.49) and 0.43kg (95% CI=0.34, 0.51) mean increase in weight change between the continuous tracking period and the two periods preceding the stop in weight tracking, respectively. The two pre-stop time periods did not differ significantly from each other (mean increase of 0.03kg, 95% CI=-0.06, 0.11). The results of the model can be found in Table 3.1. Figure 3.7A depicts the changes in weight change.

Physical activity tracking frequency significantly decreased by 1.28 days (95% CI=-1.48, -1.09) between the continuous tracking period and pre-stop 1. It further decreased significantly by 0.96 days (95% CI=-1.16, -0.77) between pre-stop 1 and 2. The results of the model can be found in Table 3.1. Figure 3.7B depicts the changes in physical activity tracking frequency.

One hundred and twenty-six users completely stopped tracking their physical activity during the two pre-stop time periods, meaning that average daily steps could not be calculated. I excluded these users from the analysis, reducing the sample size to 1479 users. Post-hoc comparisons revealed that physical activity significantly decreased by an average 180 steps (95% CI=-290, -70) between the continuous tracking period and pre-stop 1, and another 130 steps (95% CI=-240, -20) between the first and second half of the

pre-stop time period. The results of the best-fitting model can be found in Table 3.1.

Figure 3.7C depicts the changes in average daily steps.

Figure 3.7. Results of the three linear mixed effects models of the post-hoc analysis.

Table 3.1. Best fitting models for the three dependent variables in the post-hoc analyses.

		Weight Change (in kg)	**PA Tracking Frequency**	**Average Steps (in thousands)**
		fixed: time period, random: difference to goal weight, user ID	fixed: time period, difference to goal weight random: user ID	fixed: time period, difference to goal weight random: user ID
Coefficients β (CI)	TP1 to TP2	0.40 (0.31, 0.49)	-1.28 (-1.48, -1.09)	-0.18 (-0.29, -0.07)
	TP1 to TP3	0.43 (0.34, 0.51)	-2.25 (-2.44, -2.05)	-0.31 (-0.42, -0.20)
Tukey-adjusted post-hoc comparisons β (CI)	TP1 to TP2	0.40 (0.31, 0.49)	-1.29 (-1.48, -1.09)	-0.18 (-0.29, -0.07)
	TP1 to TP3	0.43 (0.34, 0.52)	-2.25 (-2.44, -2.05)	-0.31 (-0.42, -0.20)
	TP2 to TP3	0.03 (-0.06, 0.11)	-0.96 (-1.16, -0.77)	-0.13 (-0.24, -0.02)
Please note: Coefficients represent mean differences between the respective time periods				

3.4.3 Research question 2

3.4.3.1 Daily steps

Post-hoc comparisons of the first mixed effects model, entering time period as a fixed and user ID as a random factor, showed a significant decrease of 200 daily steps (95% CI=-250, -150) from the continuous tracking to pre-stop time period, and a significant increase of 120 daily steps (95% CI=60, 180) from the pre-stop to post-stop time period. In the second model, I added the variable date of measurement and the interaction term time period*date of measurement to see whether there were within-time period effects, but the $GVIF^{(1/(2*df))}$ values for the time period variable and interaction term were above 50, indicating strong multicollinearity. I therefore excluded the date of measurement variable from all further analyses. In the final stage of sequential testing, post-hoc comparisons of the mixed effects model adjusting for the

distance to goal weight revealed a significant decrease of 190 steps (95% CI=-240, -130) from the continuous to pre-stop time period. It also revealed a significant increase of 110 steps (95% CI=50, 170) from the pre-stop to post-stop time period. A small but significant decrease of 70 steps (95% CI=-130, -10) was found in the comparison between the continuous tracking and the post-stop period. A summary of all results can be found in Table 3.2. Figure 3.8A depicts the changes in daily steps.

Table 3.2. Results of the daily steps data analysis of RQ2.

		Model 1	**Model 2**	**Model 3**
		fixed: time period random: user ID	fixed: time period, date of measurement, interaction term time period*date of measurement random: user ID	fixed: time period random: difference to goal weight, user ID
Coefficients β (CI)	TP1 to TP2	-0.20 (-0.25, -0.15)	-2.12 (-4.79, 0.54)	-0.19 (-0.24, -0.13)
	TP1 to TP3	-0.08 (-0.14, -0.02)	-6.16 (-9.19, -3.12)	-0.07 (-0.13, -0.01)
	Date of measurement	N/A	-0.00 (-0.00, 0.00)	N/A
	TP1 to TP2*Date of measurement	N/A	-0.00 (-0.00, 0.00)	N/A
	TP1 to TP3*Date of measurement	N/A	-0.00 (-0.00, 0.00)	N/A
Tukey-adjusted post-hoc comparisons β (CI)	TP1 to TP2	-0.20 (-0.25, -0.15)	N/A	-0.18 (-0.24, -0.13)
	TP1 to TP3	-0.08 (-0.14, -0.02)	N/A	-0.07 (-0.13, -0.01)
	TP2 to TP3	0.12 (0.06, 0.18)	N/A	0.11 (0.05, 0.17)
Please note: Coefficients represent mean differences between the respective time periods				

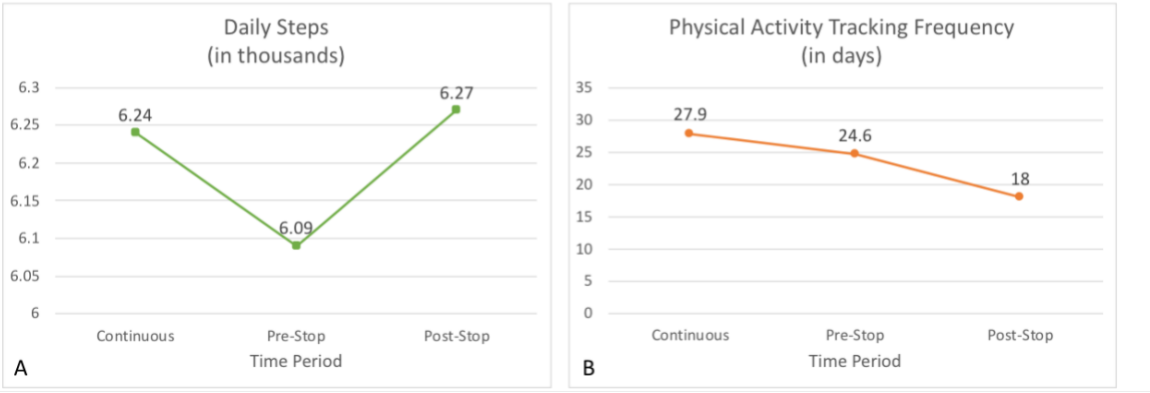
3.4.3.2 Physical activity tracking frequency

Post-hoc comparisons revealed that physical activity tracking frequency significantly decreased by 3.3 days (95% CI=-3.82, -2.85) between the continuous tracking and pre-stop time period, and another 6.6 days (95% CI=-7.12, -6.16) between the pre-stop and post-stop time period. The results of the model can be found in Table 3.3. Figure 3.8B depicts the changes in physical activity tracking frequency.

Table 3.3. Results of the physical activity tracking frequency analysis of RQ2.

		Model
		fixed: time period, difference to goal weight random: user ID
Coefficients	TP1 to TP2	-3.33 (-3.82, -2.85)
β (CI)	TP1 to TP3	-9.98 (-10.50, -9.50)
Tukey-adjusted post-	TP1 to TP2	-3.34 (-3.82, -2.86)
hoc comparisons	TP1 to TP3	-9.98 (-10.50, -9.50)
β (CI)	TP2 to TP3	-6.64 (-7.12, -6.16)
Please note: Coefficients represent mean differences between the respective time periods		

Figure 3.8. Results of the linear mixed effects models for RQ2.



3.5 Discussion

3.5.1 Principal results

The analyses targeting the first research question revealed that a stop in weight tracking is preceded by decreased step counts, lower physical activity tracking frequencies, and weight gain. The findings thus counter my first hypothesis, which had stated that physical activity (i.e. motivation to lose weight) would remain stable, while weight gain would precede the stop in weight tracking. The post-hoc analysis showed that the changes in weight and physical activity developed concurrently, as effects appeared at the same time, in pre-stop 1. The results therefore only partially support my second hypothesis, as they do not reveal the sequential effect theorised: first a decrease in physical activity, followed by weight gain and a stop in weight tracking.

Regarding the second research question, I found a decrease in the frequency of physical activity monitoring but an increase in physical activity on days when activity was recorded after users stopped tracking their weight. My hypothesis, which stated that users would show a decrease in both physical activity levels and tracking frequency, is therefore only partially supported.

3.5.2 Users gain weight before they stop tracking their weight

The literature provides abundant cross-sectional evidence that ceasing regular weighing and weight gain are associated[126, 135, 197-199]. This has been interpreted to indicate that a reduction in tracking frequency leads to weight gain. However, my findings suggest that the relationship may also be reversed: in this analysis, weight gain led to a stop in weight monitoring. My supervisors reached a similar conclusion in their recent review of the qualitative literature of experiences of self-directed weight loss[119]. Further support

also comes from a randomised controlled trial, which found that participants who experienced little progress at the start of the weight loss programme, were more likely to reduce adherence to self-weighing in the following month[134]. This directionality can be explained in terms of the 'Ostrich Problem', which proposes that people avoid outcome information when it shows that progress is poor or it elicits negative emotions[200, 201]. Using this interpretation, the results of the Withings analysis also support my findings from the think-aloud study (Chapter 2), which showed that negative weight feedback can elicit negative emotions, and lead participants to want to give up on their weight loss efforts. Further in line with this, previous research on weight loss has shown that people who anticipate negative feedback from the scales choose not to weigh themselves to avoid negative feelings[184, 202-204]. In a study by Mintz and colleagues, 63% of the female participants reported reacting emotionally to weight measurements, and half felt the weight measurements affected their feelings of self-worth[189]. Taken together, it seems that some people struggle when they receive negative feedback from the scales and therefore stop exposing themselves to the information. The lack of constructive use of weighing feedback hence leads to a stop in engagement with self-monitoring, which is a necessary step for self-regulation. The insights provided by these findings open up avenues for intervention since it is plausible that helping users reframe negative weight measurements as constructive feedback could aid successful self-regulatory processes.

3.5.3 Users reduce weight loss efforts before ceasing weight tracking

Users engaged in less physical activity and reduced the frequency of monitoring physical activity before they stopped tracking their weight. Since attempting to increase energy expenditure through physical activity is a common approach to weight loss[189-191], I interpret these changes as reductions in the motivation to lose weight, leading users to

stop weight tracking. Previous research also supports the notion that levels of motivation might be connected to weight monitoring adherence. One study reported that autonomous motivation predicted adherence to self-monitoring[205]. Two further studies found that measures related to motivation and weight loss behaviours, including goal ownership, weight loss expectations and estimated weight loss skills, were negatively associated with subsequent dropout from weight loss treatment[206, 207].

The question, however, remains why people lost motivation to lose weight. Since the increase in weight and decline of physical activity occurred concurrently, the two aspects may have influenced and reinforced each other. That is, the frustration caused by negative weight feedback might not only have led users to give up on tracking their weight, but also to reduce their motivation for general weight loss efforts, resulting in a decline in physical activity. On the other hand, reduced physical activity might have further reinforced weight gain, leading to a stronger decline in the motivation to track weight, bringing the whole self-regulatory system to a halt. There is some empirical evidence to support this, including a study by Webber and colleagues who found that the positive association between autonomous motivation and adherence to self-monitoring was mediated by weight loss[205].

Another explanation for the decrease in motivation can be found in the 'response to failure' model by Kangovi and colleagues[208]. The model posits that when failure to change behaviour occurs (as measured through weight gain in this context), individuals appraise the situation on a cognitive and emotional level, leading to increases or decreases in motivation. When individuals deem their failure to be due to controllable causes, i.e. they can explain why they gained weight, this increases their motivation to do better. If the failure seems to be uncontrollable, however, their motivation to continue

their weight loss efforts reduces. In the think-aloud study (Chapter 2), fluctuations in daily weight measurements due to changing food and drink intake, time of day, and differences in clothing, made it difficult for some participants to explain weight changes. The experienced uncontrollability of weight changes led to these participants feeling helpless and frustrated, and wanting to reduce their weighing frequency. In the Withings analysis, users tracked their weight measurements at least three times a week, and thus potentially had a similar experience. Other observational research has shown that individuals who experience more fluctuations in their weight are less successful at losing weight, indicating that frustration may lead to reduced motivation for weight loss efforts, in line with the model[166]. The emotional reaction plays an additional important role. The model posits that when individuals feel regret over not having controlled the cause of the weight gain, their motivation to engage in more effort is likely to improve. However, if individuals are not able to tell what caused the weight gain, they cannot regret a specific action and feelings of shame may dominate. According to the model, this leads to a further reduction in the motivation to lose weight. In the context of the Withings data showing a decline in physical activity, it seems possible that users who stopped monitoring their weight indeed felt shame, rather than regret over their weight gain. However, these post-hoc explanations are somewhat speculative as I was not able to measure cognitive or emotional reactions in any way. It could also be the case that individuals were able to attribute the weight gain to controllable causes, but motivation was just not strong enough to overcome issues of ego depletion, leading the individual to give up on their weight loss efforts due to a lack of self-control resources (see Chapter 1). Further research is required to tease apart these possible explanations.

3.5.4 Consequences of stopping weight monitoring

The question arises why users reduced the frequency of physical activity monitoring, but increased their daily step count after stopping weight monitoring? There is some evidence that users are more likely to track favourable weight measurements[193]. It is thus conceivable that users tended to only wear their tracking device on their more active days, leading to less tracking but higher average physical activity on days with data. Also, users may have had less interest in monitoring their physical activity, given that they could no longer put the measurements in context with weight data; a prerequisite to evaluating behaviour and progress for self-regulation. In line with this hypothesis, qualitative studies have reported that people who autonomously track several health parameters do so to identify correlations between the different measures[204, 209], to gain a better understanding of their body, and to experiment with different ideas, e.g. whether more sleep helps with weight loss[204]. Tracking more than one parameter has been associated with better adherence overall, possibly due to mutual reinforcement[210]. Having no longer collected information about their weight, and thus no longer able to complete the self-regulation process, the users in my sample might have perceived less value in their physical activity data, leading to a reduced tracking frequency.

It is notable that even though the frequency of physical activity monitoring declined, users did not stop monitoring their physical activity completely, although they had stopped monitoring their weight. One reason for this discrepancy might be that daily physical activity measurements are independent of each other, while weight measurements are highly autocorrelated. That is, while a weight measurement from one day necessarily predicts the weight measurement of the next day, physical activity

measurements are reset to zero at the start of each day, and the participant might therefore find it easier to start afresh.

3.5.5 Strengths and limitations

One strength of this analysis is that it examines patterns of self-monitoring behaviour in a setting in which users were not aware they were being observed. This reduces biases such as the Hawthorne effect[211], increasing the external validity of my findings. My sample size was considerably larger than most researcher-led studies. Covering 221,173 weight and 113,162 physical activity measurements from 1605 users, the analysis was well-powered to detect pattern changes in the data. Context information for the users was, however, sparse and restricted to basic demographic information. The data set included a high proportion of men, which is rare in the context of weight loss studies, but I lack information regarding socio-economic status and ethnicity, making it difficult to gauge generalisability. However, the spread of users across countries means it is likely to encompass a broader mix of ethnic backgrounds and lifestyles than most single-country studies. I do not know whether the users I analysed participated in any kind of weight loss programme. However, since my analyses were conducted within individuals, confounding differences between individuals were removed and differences in weight change between the pre-stop and its control period are unlikely to be explained solely by starting or stopping weight management programmes. Another disadvantage of using context-restricted app data is that I had no information on users' intentions. For instance, I do not know whether the stop in weight data actually reflects a stop in weight tracking. Users might instead have switched to a different app to track their weight measurements. I designed the study to minimise this possibility. The minimum period of continuous tracking of 16 weeks reduced the chance that the users were just 'trying out' the

app[212]. Only a quarter of downloaded health apps are used long-term and the cut-off lies around the tenth use[213]. As I will show in Chapter 4, users of tracking apps become increasingly bound to their app of choice, as data on past physical activity and weight measurements cannot easily be transferred between apps. I can therefore assume that after 16 weeks of continuous tracking, users who stopped tracking their weight were unlikely to have simply switched apps. It, however, remains possible that users continued weighing themselves without synchronising the data to the app. Nevertheless, since I observed a significant weight gain and decrease in physical activity before the stop in weight tracking, it seems that the stop in weight tracking did occur in the context of waning weight loss efforts.

Unfortunately, I did not have access to matched dietary data, which would have added another useful proxy measure of the motivation to lose weight to the model. I do, however, believe that physical activity should be a good indicator of motivation on its own, since roughly 80% of people report increasing their physical activity as part of their weight loss efforts[189-191].

A necessary feature of my study design is that I restricted my analysis to a group of people who monitored themselves very frequently and were trying to lose weight. High frequency self-monitors are likely to represent a highly motivated population[197], but this limitation also applies to other weight loss studies, where people who choose to take part have intrinsic motivation to make a weight loss attempt.

A final limitation is that since the design of this research is observational, I am unable to make causal inferences from the data. However, it would be difficult to assess my specific research questions experimentally and thus establish causality, as it is unlikely that randomly assigning people to stopping weighing or continuing weighing would

validly recreate what happens before people abandon self-weighing. However, the data of this observational study would have been strengthened if it had been possible to combine it with individual-level data, e.g. from questionnaires assessing momentary motivation, or qualitative methods exploring the individual's thought process. I was able to set the Withings results into context with the findings from my think-aloud study and other pieces of qualitative research, but multi-method data from the same sample would have been preferable. Future research would hence benefit from such a mixed methods approach in order to get deeper and more reliable insights into the mechanisms underlying the patterns I identified.

It is important to note, that I only investigated those users in the Withings analysis, who stopped tracking their weight. It would be interesting to see whether there are also users whose data show the same pattern of an increase in weight, but who manage to uphold their weight loss efforts.

Some of the above highlighted advantages and disadvantages resulted from using data from a third party, commercial company: Withings. Having real-world data was great from an external validity point of view. However, since I did not collect the data myself, I did not have control over its quality. My research is therefore based on the trust that Withings provided me with a valid data set. On the whole, I would say that Withings have been a good partner in this project. They have been flexible and open to my research ideas and delivered their data as promised. However, working with a third-party company still gave rise to some administrative issues. For example, the university had to set up a contract with Withings, delaying the research by several months. Regular changes in personnel on Withings' side also led to delays in communication. Throughout the project, I learnt not to underestimate the time it takes to overcome these hurdles when working

with third party companies. Fortunately, I had started this process early on in my DPhil, allowing me to still complete the project in time.

3.5.6 Conclusion

This observational analysis showed that before people who weighed themselves regularly ceased doing so, their weight increased and their physical activity intensity and tracking frequency declined. This probably indicates that a stop in regular weighing occurs due to a decline in weight loss efforts and individuals struggling with frustrating weight feedback. After ceasing to track weight, there is a decline in the frequency of monitoring physical activity, and an increase in the daily steps taken on the days monitored. The stop in weighing can be interpreted as a halt in self-regulation for weight loss, as progress is no longer monitored and cannot be evaluated. The results indicate that phases of concurrent weight gain and decreases in physical activity may constitute an appropriate time for intervention. Programmes tackling declining motivation and helping with the constructive use of weight measurements may therefore have the potential to help users stay on track with self-regulation and their weight loss efforts. These implications are thus similar to the ones I highlighted in Chapter 2, where I concluded that people may need support in making constructive use of their weight measurements. In Chapter 5, I will describe how I incorporated these findings in the development of the PREVAIL intervention. In the meantime, Chapter 4 will present a piece of research which analysed the content and user reviews of weight tracking apps on the Google Play Store. I did this to identify what users like and dislike about weight tracking tools, and to learn how to best incorporate a weight tracking component in my intervention design.

Chapter 4 Insights from Google Play Store User Reviews for the Development of Weight Tracking Apps: An App Market Review

4.1 Summary

The think-aloud study suggested that individuals could benefit from receiving support in tracking their weight measurements. Based on previous research, mobile apps seem best suited to fulfil this purpose. I therefore conducted a qualitative analysis of user reviews of existing weight tracking apps on the Google Play Store, in order to explore what users like and dislike. The Google Play Store was searched using the search terms "weight loss" and "weight track*". The search results were screened for apps which focus primarily on weight tracking. I identified 15 weight tracking apps and conducted a component analysis on the features they offer. In addition, I sampled 569 of their user reviews from the Google Play Store and conducted a framework and thematic analysis to assess which features users liked or disliked. The component analysis showed that apps varied considerably in the number of features they offered, from as few as 8, to over 40 features (from a list of 64 features overall). All apps allowed users to save their weight measurements, track progress using a graph, and assess their BMI and weight in relation to the healthy range. In the qualitative analysis of weight tracking apps, users expressed preference for simplicity and ease of use. In addition, I noticed that positive reinforcement through detailed feedback fostered users' motivation for further weight loss. Smooth functioning and reliable data storage emerged as critical prerequisites for long-term app usage.

Note: A version of this chapter was published in JMIR mHealth and uHealth[214].

4.2 Introduction

The think-aloud study demonstrated that individuals are not always good at keeping track of their weight measurements when weighing daily (Chapter 2). Participants sometimes forgot their measurements and struggled to see trends in their data. Only half of my participants started to track their weight measurements by themselves, but nearly everyone stated that it would have been helpful to do so at the follow-up interviews. In this context, it became clear to me that my own self-regulation intervention would require a weight tracking component. Previous research, discussed in Chapter 1, found that adherence to tracking is improved when the tracking functionality is delivered in a technological format, such as a mobile app. Moreover, this technological format also seems to improve the effectiveness of the self-monitoring strategy. Given these circumstances, I decided to employ a mobile app for the tracking component of my intervention.

Since several weight tracking apps already exist on the market, I decided to explore what I could learn from them. I was interested in categorising the features existing weight tracking apps offer. I also wanted to know what users thought of these features and what they liked and disliked about weight tracking apps in general, with the hope that these insights would help me with the development of my own weight tracking component. User reviews on app stores offer an opportunity to gain such insights from a large pool of people. Reviews often contain complaints, suggestions of change, and innovative ideas[215, 216], and can therefore help identify the key aspects that affect user satisfaction.

4.3 Methods

4.3.1 Search

In March 2017, I conducted electronic searches of the mobile app market on the Google Play Store using two search terms: *weight loss* and *weight track*.* The searches were performed using an incognito browser in Google Chrome, which was not connected to a Google account. As is standard on the Google Play Store, the searches resulted in the display of 249 mobile apps. The apps displayed are chosen and sorted by an adaptive Google algorithm, which uses a relevance rating based on app engagement and downloads[217]. Due to this, the search results on the Google Play Store change every couple of hours. I used the first search results I received for each search term.

4.3.2 Sampling

I noticed during a first browse through the search results that the apps displayed were quite similar and replicated each other in content. As I was working under time constraints, I therefore made the pragmatic decision to sample apps from each search results list prior to screening against the inclusion criteria.

To make sure I covered a breadth of different features and weight loss approaches, I decided to sample at least the first 100 apps of the search results of each search term. I had a brief look at each app of the top 100 to identify what it offered. I then decided whether saturation was reached, based on whether the last 10 sampled apps provided any novel features or weight loss approaches. If saturation was not yet reached, 10 more apps were sampled from the list. This procedure was repeated until no conceptually new apps were sampled. Where the same app was available in both a free and a paid version, I treated them as two separate apps. Throughout the sampling

procedure, I recorded properties of the mobile apps, such as app and developer name, rating, number of reviews, number of downloads, version of the app, as well as the search term used and the position in the list of each search. The sampling process was conducted over two days, one day per search term.

4.3.3 Screening

Each of the sampled apps was screened against the inclusion criteria. The app had to 1) primarily focus on weight tracking (i.e. have no other main function such as a detailed diet tracker or exercise instructor, but could have additional minor features such as a BMI calculator, counter of glasses of water consumed, etc.); 2) be targeted at people who want to lose or monitor their weight; 3) have stand-alone functionality, meaning that it could be used without a membership subscription or ownership of specific devices; 4) be available in English language. Furthermore, the apps had to 5) have a user rating above 3 stars in order to ensure minimum functionality, and 6) have at least 1,000 user reviews. This last criterion was introduced as most user reviews consist of only a rating without any text attached to it. A minimum of 1,000 reviews therefore increased the chances of a range of text comments being available for analysis.

4.3.4 Component analysis

Characteristics of the included weight tracking apps, including rating, number of reviews and number of downloads, were analysed descriptively through means, standard deviations and ranges. I then conducted a fine-grained analysis of the components available in the weight tracking apps. Each app was downloaded from the Google Play Store to an HTC A9 smartphone (Android 7.0). I created a component list based on the features offered in the first couple of apps and then manually coded their existence for

each app. Throughout coding, when new features were identified, they were added to the list. In the end, the component analysis covered 64 components (see Appendix 4.1 - App components codebook). No paid versions of the apps were purchased. Premium features were coded according to their mentioning in the app description pages on the Google Play Store or in the app itself. I conducted the whole component analysis by myself. Using the resulting data set, I calculated how many components were included in each app and how frequently each component was incorporated in the apps.

4.3.5 User review sampling

In a next step, written user reviews were sampled from each included app's webpages. Only reviews in English language were considered. A sampling to saturation strategy was employed, whereby I extracted the first 30 reviews containing text for each app when the reviews were sorted by helpfulness. If saturation was not reached after 30 reviews (i.e. new aspects were still raised by the users in the last ten reviews), I continued extracting text from further reviews in batches of ten, until no new information was gathered.

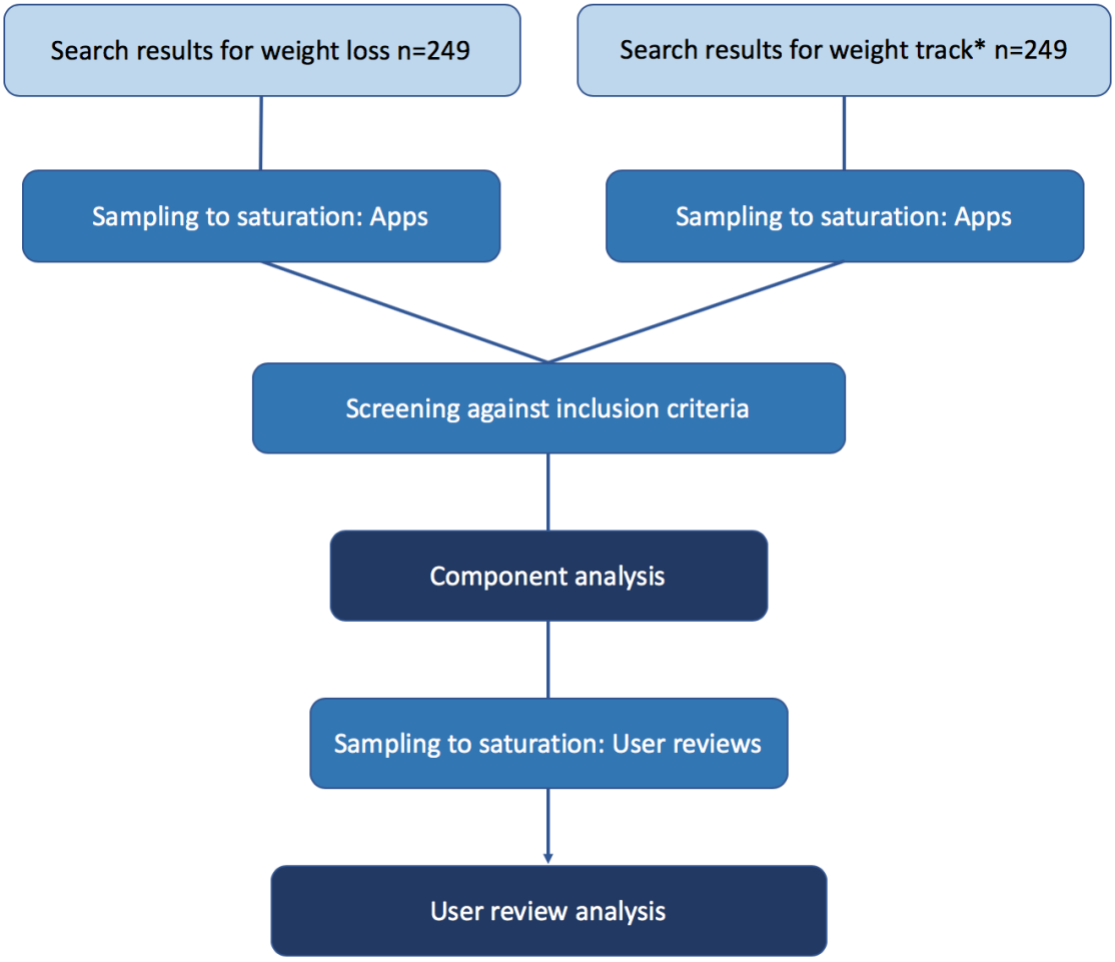
4.3.6 User review analysis

The user reviews were analysed qualitatively in NVivo. A framework analysis according to Ritchie and Spencer[218] was employed to understand what users liked and disliked about the components offered in weight tracking apps. To this end, I set up an a priori framework based on the features identified in the component analysis. Themes linked to specific app components were added inductively as they emerged throughout the analysis. A separate inductive thematic analysis following Braun and Clarke[156] identified additional emerging themes surrounding the general user experience of weight

tracking apps. No a priori framework or ideas were imposed onto the data for this second analysis.

For both analyses, coding was performed by a colleague of mine and me for the first three apps, reaching high interrater reliability (κ=.83). I collapsed the coding structure of our two analyses and then coded the rest of the user reviews by myself. In order to assess linkages between themes, I again used an axial coding approach as in Chapter 2, listing all themes and then grouping them by topics in order to identify overarching themes and categories[157, 219]. I conducted this procedure separately for the framework and inductive thematic analysis. Figure 4.1 gives an overview of the full procedure of the app market review.

Figure 4.1. Procedure of the app market review.



4.4 Results

4.4.1 Sample characteristics

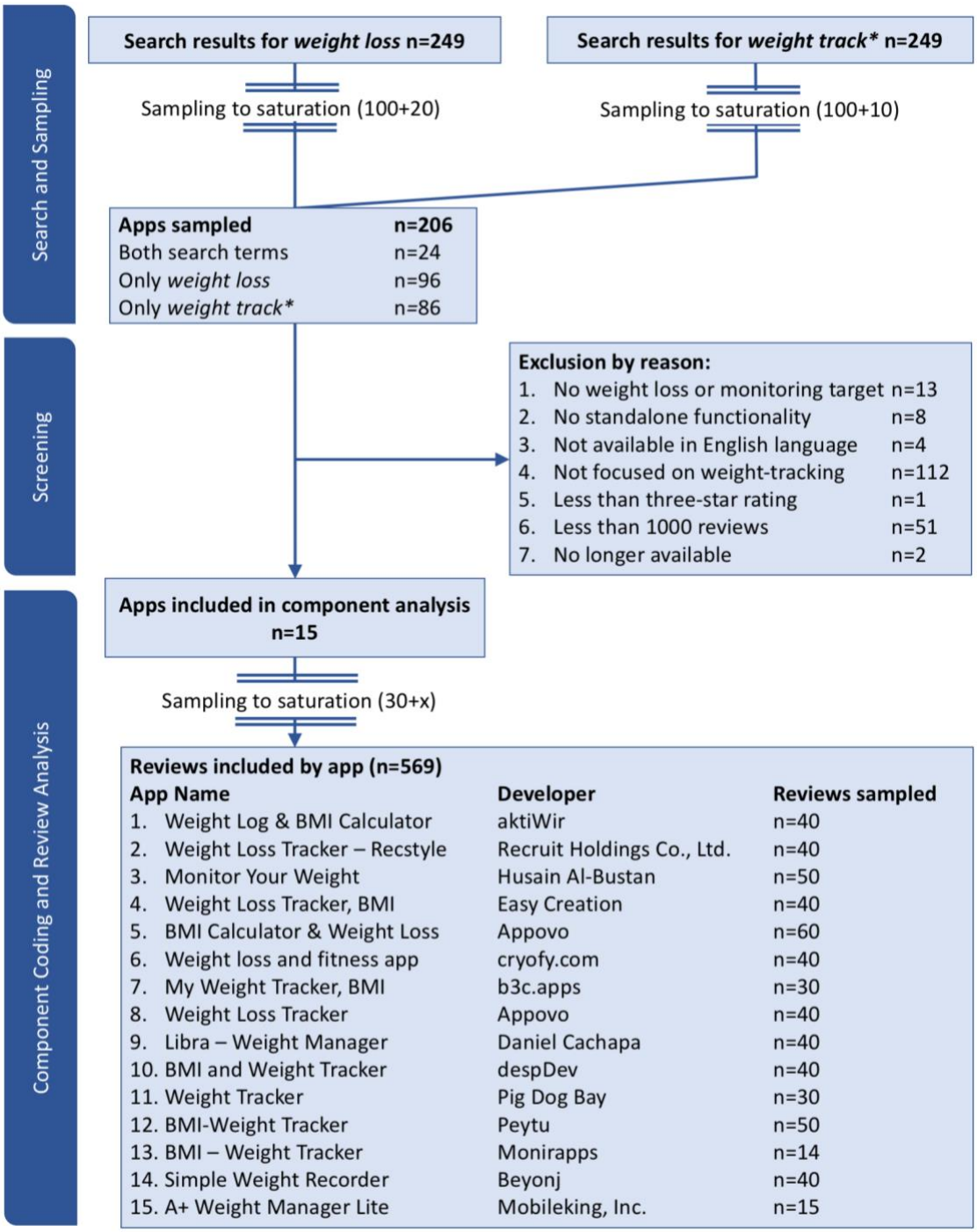
The sampling method resulted in a list of 120 apps for the term *weight loss* and 110 apps for the term *weight track**. The apps on the lists partly overlapped due to the conceptual closeness of the search terms. In combination, 206 unique apps were sampled. The screening resulted in the exclusion of 189 apps. Two further mobile apps were initially recorded but could no longer be found on the Google Play Store at the time of the screening process. The remaining 15 mobile apps (see Table 4.1 for an overview) were included in the component analysis. The included apps' ratings ranged between 3.6 to 4.6 (M=4.2, SD=0.3) on a scale from 1 (low) to 5 (high satisfaction). The number of reviews ranged from 1,196 to 121,871 (M=22,084.3, SD=35,969.9), and the number of downloads ranged from 100,000-500,000 to 10,000,000-50,000,000.

Table 4.1. Basic information about the 15 weight tracking apps.

No	App	Developer	Version	Rating	Reviews	Downloads
1	Weight Log & BMI Calculator	aktiWir	1.44	4.5	31,455	1,000,000-5,000,000
2	Weight Loss Tracker - RecStyle	Recruit Holdings Co.	3.1.8	4.4	17,067	1,000,000-5,000,000
3	Monitor Your Weight	Husain Al-Bustan	4.9.2	4.4	91,617	5,000,000-10,000,000
4	Weight Loss Tracker, BMI	Easy Creation	1.2.11	4.6	1,457	50,000-100,000
5	BMI Calculator & Weight Loss	Appovo	4.2.4	4.0	121,871	10,000,000-50,000,000
6	Weight loss and fitness app	cryofy.com	1.3.6	3.8	13,464	1,000,000-5,000,000
7	My Weight Tracker, BMI	b3c.apps	3.4	4.2	5,276	500,000-1,000,000
8	Weight Loss Tracker	Appovo	1.0.9.8	4.1	1,537	100,000-500,000
9	Libra - Weight Manager	Daniel Cachapa	3.3.3	4.4	19,623	1,000,000-5,000,000
10	BMI and Weight Tracker	despDev	3.4.4	4.4	16,559	1,000,000-5,000,000
11	Weight Tracker	Pig Dog Bay	1.18.05	4.2	1,196	100,000-500,000
12	BMI-Weight Tracker	Peytu	1.97	4.4	3,007	100,000-500,000
13	BMI - Weight Tracker	Monirapps	3.3	4.0	1,560	100,000-500,000
14	Simple Weight Recorder	Beyonj	-	4.2	3,551	1000000-5000000
15	A+ Weight Manager Lite	Mobileking, Inc.	1.6	3.6	2,024	500,000-1,000,000

I sampled 569 user reviews for the qualitative analysis. For two of the 15 apps, less than 30 reviews included text and thus all available reviews with text were included in the analysis. Figure 4.2 displays a flow diagram of the screening and sampling process.

Figure 4.2. Screening and sampling process.



4.4.2 Component analysis weight tracking apps

All apps allowed users to save their weight measurements, view a graphical display of their weight measurements, switch between the metric and imperial system, as well as calculate their BMI and healthy weight range. Other common components included

setting a goal weight, being able to backdate weight entries and viewing weight measurements in a list format. The graphical display of weight measurements also often included a target line showing the users' set goal weight. The "Weight loss and fitness app" by cryofy.com had the most components at 42. The simplest app was "BMI – Weight Tracker" by Monirapps with only 8 components. Many of the weight tracking apps offered additional functions which may support later stages of the self-regulation process. For instance, ten apps provided feedback on the progress to goal weight and five presented a congratulatory note when the user made progress towards the goal, thus contextualising the user's weight with their goal. Similarly, features such as trend lines (six apps) and average weight loss calculations (six apps) contextualised measurements with previous weight records. Some apps also provided support for the reflection process: ten apps allowed the user to take notes for each days' weight measurement, thus offering a space to reflect on reasons for weight changes. A further two apps offered users the option to mark the performance of weight-related behaviours for each day.

Table 4.2 shows the results of the component analysis for all apps, and includes sum scores for each app and each component. To save space, the apps are numbered in line with Table 4.1.

Table 4.2. Component analysis.

	App No.															
Components	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Sum**
Save Weight	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**15**
Weight Graph	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**15**
Metrics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**15**
BMI Calculator	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**15**
Healthy Range	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**15**
Goal Weight	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	**14**
Historic Entries	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	**14**
Weight List View	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	**13**
Weight Target Line	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓	**13**
Feedback Goal Weight	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	×	✓	×	**10**
Notes	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	×	**10**
Export Data	✓	✓	✓	✓	×	✓	✓	×	✓	×	×	✓	×	✓	×	**9**
Weigh-in Time	✓	×	✓	×	×	✓	✓	×	✓	×	✓	✓	×	✓	×	**8**
Save Body Fat	×	✓	✓	×	×	✓	✓	×	✓	✓	×	✓	×	×	×	**7**
Reminder	×	✓	×	✓	✓	✓	×	×	✓	✓	×	✓	×	×	×	**7**
Weight Trend Line	×	×	✓	×	✓	✓	✓	×	✓	×	✓	×	×	×	×	**6**
Average Weight Loss	×	✓	✓	×	×	×	✓	×	✓	×	✓	✓	×	×	×	**6**
Body Fat Calculator	×	×	✓	×	×	✓	✓	×	×	✓	×	✓	✓	×	×	**6**
Body Fat List View	×	×	✓	×	×	✓	✓	×	✓	✓	×	✓	×	×	×	**6**
BMI List View	×	×	×	✓	×	✓	✓	×	×	×	✓	✓	×	✓	×	**6**
Ideal Weight Calculator	×	×	✓	×	×	✓	✓	×	✓	✓	×	✓	×	×	×	**6**
Password	×	✓	✓	×	×	✓	✓	×	×	✓	×	×	×	×	✓	**6**
Import Data	✓	✓	×	✓	×	✓	✓	×	×	×	×	✓	×	×	×	**6**
Google Drive Sync	✓	✓	×	×	✓	✓	×	×	×	✓	✓	×	×	×	×	**6**
Widget	×	×	✓	×	×	✓	✓	×	✓	✓	×	✓	×	×	×	**6**
Prediction Target Date	×	×	✓	×	×	✓	✓	×	✓	×	✓	×	×	×	×	**5**
Body Fat Graph	×	✓	×	×	×	✓	✓	×	✓	×	×	✓	×	×	×	**5**
Save Body Measurements	×	✓	✓	×	×	✓	✓	×	×	×	×	✓	×	×	×	**5**
Congratulatory Note	✓	×	✓	×	×	×	×	×	×	✓	✓	✓	×	×	×	**5**
Personalisation	×	✓	✓	✓	×	×	×	×	×	✓	✓	×	×	×	×	**5**
Body Measurements Graph	×	✓	×	×	×	✓	✓	×	×	×	×	✓	×	×	×	**4**
Body Measurements List View	×	×	✓	×	×	✓	✓	×	×	×	×	✓	×	×	×	**4**
BMI Graph	×	×	×	×	×	✓	✓	×	✓	×	×	✓	×	×	×	**4**
Multiuser	×	×	✓	×	×	✓	×	×	×	×	×	✓	✓	×	×	**4**
Google Fit Sync	×	×	✓	×	✓	×	×	✓	✓	×	×	×	×	×	×	**4**

Table 4.3. Component analysis (continued).

	App No.															
Components	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Sum**
Save Muscle	×	✓	×	×	×	✓	✓	×	×	×	×	×	×	×	×	**3**
Muscle Graph	×	✓	×	×	×	✓	✓	×	×	×	×	×	×	×	×	**3**
Goal BMI	×	×	✓	×	×	✓	×	×	×	×	✓	×	×	×	×	**3**
BMI Trend Line	×	×	×	×	×	✓	✓	×	✓	×	×	×	×	×	×	**3**
Target Date	×	×	✓	×	×	✓	×	×	✓	×	×	×	×	×	×	**3**
Waist-to-Height Ratio Calculator	×	×	×	×	✓	×	×	×	×	✓	×	✓	×	×	×	**3**
Calorie Calculator	×	×	✓	×	✓	×	×	×	×	✓	×	×	×	×	×	**3**
Activity Level	×	×	✓	×	✓	×	×	×	×	✓	×	×	×	×	×	**3**
Body Fat Trend Line	×	×	×	×	×	×	✓	×	✓	×	×	×	×	×	×	**2**
Muscle List View	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	**2**
User-defined Tracking Graph	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	**2**
User-defined Tracking List View	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	**2**
Feedback Goal BMI	×	×	✓	×	×	✓	×	×	×	×	×	×	×	×	×	**2**
Markers Behaviour	×	✓	×	×	×	×	✓	×	×	×	×	×	×	×	×	**2**
Smart Scales Sync	×	×	✓	×	×	×	×	×	✓	×	×	×	×	×	×	**2**
Back-up Cloud	×	×	✓	×	×	×	×	✓	×	×	×	×	×	×	×	**2**
Goal Body Fat	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Body Fat Target Line	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Goal Muscle	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Muscle Trend Line	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	**1**
Muscle Target Line	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Goal Body Measurements	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Body Measurements Trend Line	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	**1**
Body Measurements Target Line	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
BMI Target Line	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×	**1**
Markers in Graph	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	**1**
Body Frame	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Congratulatory Sound	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	**1**
Picture Upload	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×	**1**
Sum of Components	**16**	**29**	**36**	**16**	**18**	**42**	**39**	**12**	**27**	**24**	**19**	**30**	**8**	**13**	**9**	**338**

4.4.3 User review analysis

4.4.3.1 Framework analysis

In the framework analysis of user reviews, I assessed what users thought about the individual features of the weight tracking apps. The components receiving the most positive comments were related to weight tracking and (graphical) feedback. Other components which were often positively rated were related to reliable data storage.

4.4.3.2 Detailed (graphical) feedback

Users frequently highlighted the importance of receiving graphical and non-graphical feedback on their weight loss journey. They appreciated seeing graphs of their weight over time, especially when additional visual cues such as a trend line were given.

> *"I like how it graphs out your weight loss to show your progress. It's very motivating to see how far you have come from where you started."*

> *"The trend line is a neat feature to forecast when I'll reach my goal weight."*

Some mobile apps had a component that predicted the date by which the user would reach their goal. This function was remarked positively by several users.

> *"I like the way it predicts the date for you to reach your goal and the timeline showing your percentage of progress. The graphs are great too! Very motivating."*

Generally, users stated that the feedback provided them with motivation to keep going. Where weight loss success was lacking, users appreciated neutral feedback.

> *"I love the cheering when you lose a bit of weight. That's very sweet and makes you feel good."*

> *"even when you are going through a bad spell it seems non-judgy"*

4.4.3.3 Reliable data storage

Users emphasised the importance of reliable storage of their data which was often collected over a long period of time. When the data was lost through a mal-functioning update or a glitch, it caused frustration.

> *"New update deleted all my data. Horrible. What's the point of making an account if your data doesn't get stored? I'm so mad!"*

> *"Back up doesn't work! I'd been backing up my data weekly to my SD card. Just got my new phone yesterday, went to import database and it says 'database empty' - 3 years of data lost! Fantastic!"*

Following the loss of data, many users stated that they would discontinue their usage of the app and switch to a different one.

> *"Lost all of my tracking history upon update. Even update on 11/16/16 did not correct the issue. All tracking ID just gone. Time to uninstall."*

> *"I was using this [to] track my weight loss over a year. Updated and lost everything. Going to try a different app now"*

Users appreciated mobile apps which allowed them to protect their weight data with a password.

> *"love that can back up data and put password [sic] on it"*

> *"A pin code for privacy on the app would be great"*

4.4.3.4 Inductive thematic analysis

The three most frequently identified themes in the inductive thematic analysis were simplicity and ease of use, smooth functioning, and long-term app usage.

4.4.3.5 Simplicity/ease of use

Users of weight tracking apps expressed a preference for simple apps, equipped with only a few key features. These key features were mostly the saving of weight measurements and graphing. Elaborate additional components were perceived to add unnecessary complexity to the app.

"Just what I needed and nothing more to clutter the screen. I was looking for an app to log my weight and graph it. This got it right."

"I love this app because it is simple and just does exactly what I want instead of a bunch of extra stuff that I'm not going to use and is just going to be in the way"

Reviewers commonly expressed a preference for app designs that were intuitive and easy to use, allowing for efficient app usage.

"I can log data in seconds without navigating through needless steps."

4.4.3.6 Smooth functioning vs. technical issues

The smooth running of the app emerged as a main criterion for user satisfaction and was critical to user retention.

"Been using for a few years, it runs smooth and does what it says it will, which is tough to find sometimes."

Most reports of technical issues reflected problems with an update of the app, suggesting developers were not always able to meet the needs and demands of their users when releasing a new version.

"As seems to be the norm these days, every time a good app is "updated" it gets ruined. Updated on 11/11 and visibility is terrible and takes [sic] ages to display main screen"

"lost all my data after upgrade, behaves really odd, locks up! used to love it..."

4.4.3.7 Long term usage

In 54 of the 569 reviews, people commented on their intention to use the weight tracking app on a long-term basis.

"Has been my Go-To [sic] weight tracking app for several years now, can't fault it :)"

Once users found the app that best fit their needs, they were willing to remain loyal to the app and even downloaded it onto new devices.

"*Every time I change my phone, this app is a must to be downloaded.*"

4.4.3.8 Additional themes

There were several other less prominent themes. Users appreciated it when developers acted mindfully with memory space. Either keeping the size of the app to a minimum or automatically storing the app onto the SD card received positive attention by the users.

> *"As someone who gets annoyed with my tiny phone memory filling up, the fact that this not only can be stored on a SD card but actually automatically saves to it is brilliant."*

Similarly, users appreciated the mindful deployment of advertisements. Inappropriate advertising (such as for a fast food chain) or impairment of app functionality through advertisements were criticised.

> *"What's up with the Duncan donut add [sic] every time I open."*
>
> *"Too many ads. Covers the page so you can't enter stats."*

Inaccuracy of in-app calculators (such as BMI, body fat, etc.) was perceived as frustrating. Users criticised the inaccuracy harshly and expressed disbelief.

> *"Im sevearly [sic] underweight and on and off ive [sic] been hospitalized for it so when I calculated my weight and height I was very shocked to see that apparently im [sic] overweight and my 139 pound friend is obese class 1"*

Providing options to customise the appearance of the app and its functionality was well perceived. Users liked personalising aspects such as background colour, font style, or the amount of measurements to be tracked.

> *"I wish you could customize the widget colours, font size, etc."*
>
> *"love it if I could personalise the colours in the app"*

Finally, I found that when users were satisfied with an app, they stated their willingness to spend money on premium features or blocking of advertisements.

> *"Happily paid the few $ for the pro version after trying the free one for a couple months."*

"but I haaaaate [sic] the update that has now put ads in the app. I totally understand the developer needing to make money, put [sic] I'd rather pay for a premium version to get rid of the ads"

4.5 Discussion

4.5.1 Principal results

The component analysis showed that apps vary considerably in the amount and types of features they offer. The qualitative analysis of user reviews provided insights into which features were particularly important to users looking to self-monitor their weight. I found that components related to feedback on the weight loss journey were of high importance. Receiving positive feedback and visualizing weight loss success provided the user with positive reinforcement, which increased motivation. Furthermore, users emphasised the importance of reliable data storage as they intended to use the app on a long-term basis. Users appreciated mobile apps that were intuitive and easy to use, with few additional components unrelated to weight tracking. Users emphasised that the smooth functioning of the app is of immense importance. When technical issues arose, users appeared likely to discontinue using the app.

4.5.2 What weight tracking apps offer

In my component analysis, I found that the apps all offered basic tracking functionality, including the saving of measurements and presentation of progress in a graphical format. Many of the apps additionally provided features which arguably tie in with the later self-regulation steps contextualisation and reflection. These apps thus support their users in continuing through the self-regulation process. The results of the think-aloud study (Chapter 2) showed that individuals naturally contextualise their weight measurements on 90% of occasions. The extra support in contextualisation may therefore not be

completely necessary for this self-regulation step to occur. Nonetheless, contextualisation may arguably be more effective when the individual has access to better data, as enabled through the different feedback functions of the weight tracking apps. Regarding reflection, the think-aloud study showed that participants engage in this process only slightly more than half of the time. Additional features for reflection, such as allowing users to take notes or to track weight-related behaviours, therefore have the potential to boost the occurrence of this self-regulation process. Moreover, supporting reflection may lead to more action planning, since the frequency of reflection was significantly correlated with the frequency of action planning in the think-aloud study.

In this review, I specifically focused on weight tracking apps. It is therefore not surprising that the apps included in my analysis employed self-monitoring and self-regulation strategies. However, it is interesting that this also matches the findings from weight loss app reviews. For example, Bardus and colleagues assessed behaviour change techniques of weight management apps in 2015, and found that the most prominent ones were based on self-monitoring, goal setting, and feedback[148]. Similarly, two other reviews also found that self-monitoring and goal setting features are employed in the majority of weight management apps[214, 220]. This suggests that self-monitoring features are the core ingredient of most weight loss apps, with additional features added to suit the theme or purpose.

4.5.3 What users find important

My finding that users perceived feedback on and visualisation of their weight loss progress as useful and motivating is consistent with the results of other studies[212, 221]. Users in my sample stated that the feedback kept them on track with their weight loss goal. They liked to receive as much information about their progress as possible, in order

to gain the most reward out of a satisfactory outcome. Improved levels of motivation resulting from app feedback may explain why Burke and colleagues found that electronic tracking with feedback on goal progress helped participants achieve more weight loss than electronic tracking on its own[142]. App feedback may, however, also improve effectiveness of self-monitoring because individuals are enabled to better contextualise their measurements and thus engage in more effective self-regulation.

In a qualitative study by Dennison and colleagues, participants expressed their concern that they might find corrective feedback and lack of success particularly daunting and deterring in weight loss apps[212]. The results of this review do not support these concerns; lack of success was mostly responded to with neutral or no feedback from the app and users did not feel negatively judged for their lack in progress.

Beyond the weight management components, users expected high levels of technical reliability and secure data storage. This is critical because many users intend to use their weight tracking app on a long-term basis, meaning that these apps often cover years of data. The data often assumes an emotional value, since it provides motivation to the user and visualises previous successes and hard work. Losing data that has been collected for several years is perceived as immensely frustrating and can lead to a loss of trust in the app.

In addition, reliable data storage is also important from a user retention perspective: there are many weight tracking apps available on the app store market, so initially users can easily switch from one to another and they often try out several at a time[212]. Barriers to switching are only created once a user starts collecting data in one app over a considerable amount of time, as this data is usually not transferable between

mobile apps. A loss of data eradicates this additional value of the app, making it easier for users to switch to another app.

Reviewers highlighted the importance of an intuitive and simple app design, which is consistent with findings in the literature[221]. A qualitative study by Dennison and colleagues showed that users do not have a lot of patience in dealing with mobile apps and quickly discard them when usage is perceived as complicated[212]. Hence, a simple and straight-forward design is critical.

The user review analysis also indicated that users prefer basic weight tracking apps over more advanced versions. In contrast, the app market review by Bardus and colleagues, which analysed the most popular weight management apps on the market, included several more comprehensive apps[148]; showing that the preference for simplicity is not generalisable to all weight management apps. One possible explanation for this discrepancy could be that complex apps meet the needs of more users. People seeking to download a weight loss app for the first time might settle for a more general and comprehensive app than a specific one in order to be able to test several strategies for weight loss. Once they have found the right features for them, they might download an app that is more specific to their needs. This could explain why I found that for weight tracking apps, less complexity and fewer components were preferred by the users. Further research is needed to examine this.

Many reviews contained complaints about app malfunctions, which were most commonly caused by an update. The topics of the reviews ranged from the emergence of technical issues and the deletion of a previously existing feature, to the disliking of a new user interface design. This suggests that updated versions were premature and not sufficiently tested on users before they were made available to the public. Similarly, a

study analysing complaints in user reviews from the top 20 apps on the iOS App Store found that a substantial number of comments originated from issues with an update[222]. The authors concluded that developers should engage in more rigorous testing and work more closely with users before introducing new versions of an app. They warned that user frustration with an update can lead to bad ratings of an otherwise good app. On the other hand, I found that updates can also lead to positive outcomes. In my review, there were several cases in which users commented on positive changes to issues they had complained. Some users also edited their negative ratings to more positive ones when problems were resolved. Similarly, a recent analysis showed that nearly 50% of user suggestions are implemented in app updates and that this consideration of user opinion is rewarded with higher app ratings[223]. Hence, involving users in the development of an app is highly recommended.

Another approach to enhancing user satisfaction can be to allow users to personalise the design or functionality of the app. In my review, users appreciated the opportunity to adapt the app to their needs and likes, for instance by allowing for the choice of a theme or design. Similarly, Dennison and colleagues found in their study that users liked to be able to make personalised settings, such as deciding when to receive reminders to weigh[212]. Generally, allowing for personalisation enables the developer to cater more needs and preferences and therefore attract more users.

4.5.4 Strengths and limitations

A major strength of this app market review is that I analysed the voices of a large and diverse sample of people. The content of app reviews is influenced by the needs and expectations of the user, as well as the context of usage, and can therefore vary considerably. Asking only a small group of people, such as Dennison and colleagues' focus

group, can restrict the variety and representativeness of the data. With my large sample I was able to analyse which concerns are shared by most users and which ones are more specific. This allowed me to make more reliable conclusions about what users like and dislike in weight tracking apps. Importantly, to the best of my knowledge, I was the first to use this method of qualitatively analysing user reviews of weight loss apps. I found the process to be very fruitful for gaining insights into user experience and opinion.

It is possible that people who write user reviews on the app store are not necessarily representative of the broader population of app users and/or individuals self-monitoring weight. Nevertheless, my approach to reviewing user experience allowed me to capture feedback from a larger number of users and hence provided me with a more diverse sample than would have been achieved through commonly used methods such as qualitative interviews or focus groups.

Another limitation of this review is that I only considered mobile apps from the Google Play Store. This decision was due to a lack of similar indexing methods and the issue that the text of user reviews could not be copy pasted from the iOS store. However, a recent analysis of the mHealth marketplace has concluded that 75% of today's health and fitness app developers produce mobile apps for both the Android and iOS market[224]. The two markets therefore overlap substantially and it is questionable whether I would have found any meaningful differences between the two stores. By searching the app store directly rather than through a search engine, my results are limited because the Google Play Store displays only 249 mobile apps per search term. Several more apps would have been found if I had used a search engine. My approach was, however, guided by the intention to analyse those mobile apps that users of the Google Play Store would find when they search for a weight loss or weight tracking app.

Furthermore, since saturation in features and weight tracking approaches was reached, it seems unlikely that the results would differ had I included more apps.

4.5.5 Conclusion

This review extended the literature by highlighting which facets of weight tracking apps are especially important to users and should be considered in intervention development. First, one should focus on providing appropriate feedback on goal progress, as users responded favourably to detailed feedback on weight loss success and appreciated it when mobile apps remained neutral when success was lacking. Second, I identified that it is important to make sure that data is stored reliably to enable people to use the app on a long-term basis. Third, it is important to keep in mind who the chosen target audience is. A simple and basic app version may be sufficient when speaking to a specifically targeted audience. However, more comprehensive weight loss apps may attract more people as they speak to anyone who is generally looking into weight loss support. Fourth, I recommend incorporating users' opinion in all design and development stages in order to ensure that the app fulfils users' expectations. Furthermore, it is important to perform rigorous testing on an app before making it available to the public, as smooth functioning is critical to user satisfaction and long-term usage. For my own intervention development, I made use of the insights I gained in this review and picked an existing weight tracking app which fulfilled the above criteria. The next chapter details the intervention development, incorporating this weight tracking app as one of the components.

Chapter 5 Intervention Development

5.1 Summary

The findings of my think-aloud study suggested that individuals rarely perform all steps of the self-regulation process naturally, supporting the need for a self-regulation intervention. A brief review of existing self-regulation interventions revealed that they do not sufficiently address all components of the iterative process. This provided me with sufficient evidence to justify the development of a new self-regulation intervention. Using insights from the wider literature, as well as the think-aloud study (Chapter 2), Withings analysis (Chapter 3), and app market review (Chapter 4), I developed intervention components which targeted the needs of users and aimed to overcome barriers to the self-regulation process. For the specifics of the action planning component, I conducted brainstorming sessions with a team of health behaviour experts to identify potential weight loss actions, strengthening the evidence base of this component. An element of co-design was introduced through phone calls and a focus group meeting with PPI panel members, who helped to shape and revise the design of the materials. The result of this work was the PREVAIL intervention, which guided its users through the complete self-regulation process in an iterative manner. To this end, the intervention asked its users to weigh themselves daily, track their weight measurements using an app, plan daily actions for weight loss, and reflect on the effectiveness of these actions on a weekly basis. My aim was that this self-regulation cycle would allow individuals to self-experiment with different weight loss strategies and identify effective actions based on weight loss outcomes.

Note: Parts of this chapter were published as a protocol paper in the BMJ Open[225].

5.2 Introduction

As discussed in Chapter 1, the effectiveness of self-monitoring for weight loss is ascribed to a self-regulation mechanism. However, the results of the think-aloud study showed that people do not naturally perform all self-regulation steps after weighing, with specific action planning being particularly rare (Chapter 2). Interestingly, the frequency of specific action planning was significantly predictive of weight loss. The study thus suggested that people may benefit from support in performing self-regulation, especially action planning. Moreover, the results indicated that self-regulation has the potential to be an effective weight loss strategy. The insights I gained therefore supported the development of an intervention guiding individuals through the self-regulation process.

Several weight loss interventions that include self-regulation components have been developed over the years. Some educate their users about self-regulation theory without providing active support for the key component as identified in the think-aloud study – specific action planning[108, 128, 131, 226]. Others support users in action planning, but fail to imitate the iterative nature of self-regulation, as they do not allow for adaptations to the action plans based on goal progress[160, 227-229], thus disabling self-regulation. Some interventions guide participants through iterative reformulation of action plans following self-monitoring feedback, but are delivered through face-to-face sessions[230, 231], which are resource-intensive and not easily rolled out at large scale. Other interventions incorporating action planning dictate which actions participants are supposed to follow[227, 232, 233], which might reduce goal ownership, a significant predictor of goal engagement and attrition[206, 234]. Notwithstanding these critiques, seven of the eleven studies cited here found significant weight loss effects of the self-regulation interventions compared to their respective control groups, suggesting that

components targeting the self-regulation cycle can enhance weight loss, and encouraging further work in this area. The critiques highlight the need for an intervention that guides users through the whole, iterative self-regulation process in an autonomous, low-cost, and scalable manner.

I decided to address this gap in the literature by developing a new intervention, which I called the PREVAIL intervention (**P**eople **RE**gulating themsel**V**es to **A**chieve we**I**ght **L**oss). This weight loss intervention guided people through the iterative self-regulation process. It encouraged users to self-experiment with different weight loss approaches, and used the self-regulation mechanism to help them find their ideal set of tools.

5.3 Intervention development

My goal was for the intervention components to speak to the first four steps of self-regulation: (1) self-monitoring of weight, (2) contextualisation of weight measurements with goals and expectations, (3) reflection on and evaluation of previous behaviours, and (4) planning of weight loss actions. Based on the research on implementation intentions and my results from the think-aloud study (Chapter 2), I assumed that the action planning component would be sufficient to prompt the performance of weight loss behaviours. I started the intervention development process by collating relevant findings from the think-aloud study (Chapter 2), Withings analysis (Chapter 3), and app market review (Chapter 4). I then put these findings into context with evidence from the wider literature in order to identify how each intervention component could best tackle its purpose. I developed a rationale for each intervention component and then found ways to implement each step, using the input from experts in the department and members of the public.

5.4 Rationale underpinning the intervention components

5.4.1 (1) Self-monitoring of weight

The first component of the intervention aimed to tackle the central component of the self-regulation cycle: self-monitoring of weight. This step constitutes a combination of self-weighing and tracking of weight measurements. I had to decide which frequency of self-weighing would be best for the intervention. As discussed in Chapter 1, research indicates that daily weighing is the most beneficial frequency for weight loss. In the think-aloud study (Chapter 2), I found that adherence to daily weighing was high, indicating that individuals are able to maintain this weighing frequency. Furthermore, in the think-aloud study, most participants found that daily weighing had become a habit by the end of the eight weeks and no major problems were reported regarding the process of daily weighing. I therefore decided to encourage daily weighing as part of the intervention.

Having decided on the approach to the self-weighing aspect of self-monitoring, I turned to the tracking part. In the think-aloud study, participants struggled to memorise daily measurements and keep an overview of their weight loss progress, which impeded their ability to use weight measurements as constructive feedback. Participants stated they would have benefitted from a weight tracking tool to record their weight measurements. I therefore decided to incorporate a weight tracking app in the intervention. A literature review further supported the idea of a weight tracking app, as it revealed that digital tracking devices can significantly increase adherence to self-monitoring[142, 145]. Moreover, a meta-analysis found that actively tracking self-monitored data on goal progress is associated with higher rates of goal attainment[143].

5.4.2 (2) Contextualisation

Following self-monitoring, I aimed to address the second step of the self-regulation process: the contextualisation of weight measurements with previous measurements, expectations, and goals. To make sure individuals had a goal in mind against which to compare their progress, I decided to ask users of the intervention to set themselves a personal weight loss goal at the start of the programme, and recommended 0.5kg per week, as is common in the literature[235]. Regarding the actual contextualisation process, I realised that the weight tracking app introduced for the self-monitoring component already provided users with visualisation of and feedback on their weight loss progress. In the app market review (Chapter 4), these functions kept users on track with their goals. Hence, I considered that the weight tracking app could cover both the tracking and contextualisation functions of the intervention.

5.4.3 (3) Reflection and evaluation

My next aim for the intervention was to prompt reflection on and evaluation of behaviour. Roughly half of the participants in the think-aloud study (Chapter 2) completed this self-regulation step, bringing into question why the other half did not. The think-aloud study and Withings analysis (Chapter 3) indicated that individuals may experience difficulties making constructive use of negative weight feedback, potentially because of emotional barriers. I considered that guiding individuals through constructive reflection on previous behaviour might be a way to overcome these difficulties. As part of this, I wanted to reframe lack of weight loss progress: instead of viewing it as a sign of personal failure, I wanted to encourage users to interpret it as a sign that whatever they had tried out so far had just not been effective enough and that they might have to continue experimenting. The think-aloud study showed that participants struggled to

interpret day-to-day weight changes due to daily fluctuations that were not caused by fat loss or gain. I therefore decided to encourage reflection on a weekly rather than daily basis. In order to be able to reflect on the cause and effect relationship of behaviour and weight loss progress, users needed to know their weekly weight trends. As I knew that the weight tracking app would not cover this functionality, I decided to give users weekly feedback on their weight loss trend myself. The aim of the reflection task was then for users to identify causes for weight trends and to evaluate whether actions taken were effective for weight loss and worth repeating.

5.4.4 (4) Action planning

With the fourth component I targeted the action planning stage of the self-regulation process. In the think-aloud study, participants completed this step in only 1 of 5 occasions. When they did make action plans, these were often vague and generic, and most did not specify a time or action. In Chapter 2, I discussed how important it is for action plans to be specific, as this increases the likelihood of their implementation. Given this background, it seemed crucial to guide users of the intervention through the process of making specific action plans.

I aimed to strike a balance between ensuring that users plan appropriate actions and allowing them to choose actions for themselves. The latter is important because research revealed that participants are more motivated and more likely to achieve their goal if they select the target behaviour themselves[236]. Furthermore, it has been found that lack of goal ownership predicts attrition[206]. I decided to create a list of appropriate weight loss actions from which users could select their own target behaviours. To create the action list, I first identified weight loss actions from effective weight loss interventions in the literature. These were reviewed, adapted, and complemented during

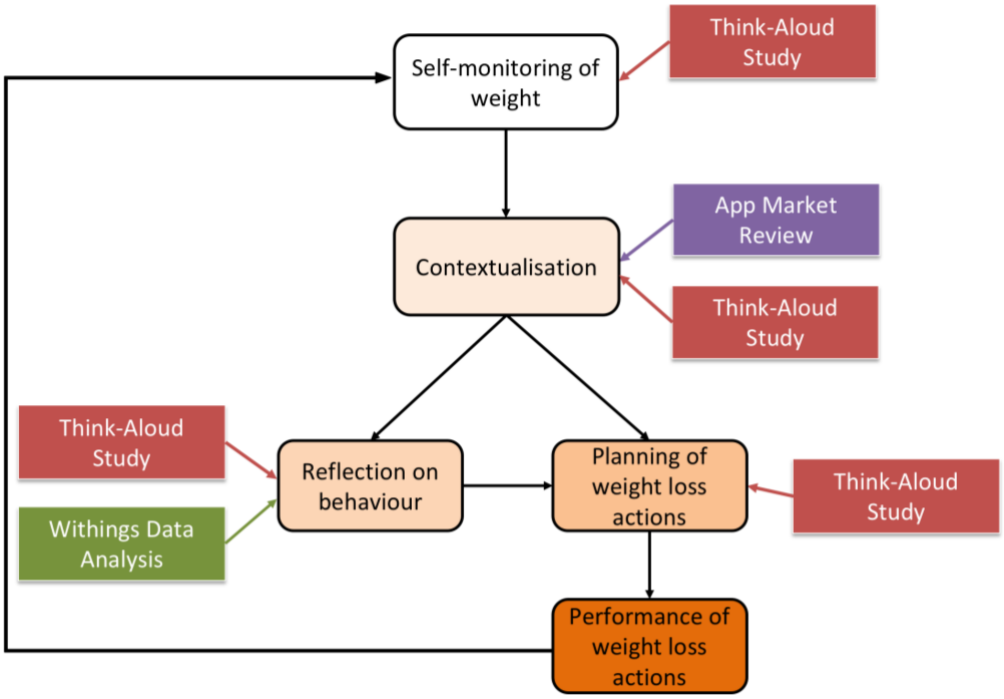
brainstorming sessions with an interdisciplinary expert team. In order to ensure a spread in expertise, I recruited dietitians, general practitioners, and psychologists from the department to this expert team. Initially, I asked the experts to brainstorm specific weight loss actions. I then provided them with the list of weight loss actions I had identified during my literature review. We discussed the evidence base of all gathered weight loss actions and were thus able to refine the list, resulting in a total of 53 weight loss actions.

It remained to decide how often users of the intervention should be prompted to plan actions. Most existing weight loss interventions, which incorporate an iterative action planning component, plan actions for at least a week at a time[230, 237]. However, this does not allow for changing daily schedules. Furthermore, self-regulation enables individuals to self-experiment with different weight loss approaches and use the weight monitoring feedback to evaluate which approaches are effective and useful. Planning actions for a whole week at a time reduces opportunities to self-experiment. Therefore, I decided to adapt a more unconventional frequency: daily action planning. This, however, meant that there was a mismatch in frequencies between daily planning of actions and weekly reflection and evaluation. In order to resolve this, I grouped the 53 weight loss actions conceptually into seven categories, five of which covered diet-related actions and two of which covered physical activity-related actions. This grouping was revised and refined in discussion with my supervisors. I decided that users of the intervention would be asked to choose one category at the beginning of each week, and choose a daily action from this category every morning for the rest of the week. Users were also encouraged to try out several categories throughout the intervention period in order to enable comprehensive experimentation. Weekly behaviour reflection then focused on the effectiveness of an action category. Based on action planning and

implementation intention research, which shows that the specificity of action plans increases likelihood of implementation[155, 158, 161], I decided to ask users to specify where, when, and how they intend to perform chosen actions. The aim of the experimentation with different weight loss approaches was ultimately to allow users of the intervention to identify their personal set of effective and feasible weight loss actions. To increase chances for significant weight loss and the formation of new habits, I decided that users should be prompted from the second week onwards to continue with some of the actions of previous weeks.

To allow users to reflect on action performance and failed attempts, I decided to ask them in the daily action planning questionnaires whether they had managed to complete the planned weight loss action of the previous day. If they had not, I prompted them to reflect on why the implementation had failed and what they could do differently next time. Figure 5.1 depicts how the previous chapters influenced the development of the PREVAIL intervention.

Figure 5.1. Influence of previous studies on intervention development.



5.5 Implementation of the intervention components

Initially, I hoped to be able to use one mode of delivery for all self-regulation components, e.g. a website or a mobile app. Unfortunately, this was not possible due to budget and time constraints. Each component therefore had to be delivered separately using different methods, as described in the following paragraphs.

The combination of the different intervention components resulted in a weekly routine. The self-regulation process started with a self-monitoring task, asking users of the intervention to weigh themselves using standard body scales every morning after waking. I asked users to weigh themselves in a similar state every day, ideally first thing in the morning and without clothes. They were then instructed to track their weight measurements using a weight tracking app. I identified a suitable weight tracking app from the app market review, called “Weight Loss Tracker, BMI” by aktiWir GmbH. The app received positive reviews for its visualisation of and feedback on goal progress, as

well as for its ease of use and smooth functioning. Being available on both the Google Play Store and iOS App store, both Android and Apple smartphone could download it. I made sure the app allowed its users to export their data, enabling me to gain access to the tracking data.

Next, I wanted users to be prompted to complete the action planning task. It seemed easiest to conduct this step through a questionnaire. I therefore set up an account with Qualtrics (Qualtrics LLC, USA), an online survey software, and set up questionnaires that would guide users through action planning. I created four questionnaires: (1) for the first day of week one, (2) for the rest of week one, (3) for the first day of all following weeks, and (4) for the remaining days of all following weeks. All questionnaires started by asking users for their morning weight, in order to capture this information for the weekly trend calculation. Questionnaires (2), (3), and (4) then continued asking users whether they had managed to perform the action they had planned on the previous day and if not, why. Questionnaires on the first day of each week guided users through choosing a category of weight loss actions. All questionnaires asked users to choose an action for the day and specify their action plan by thinking about how they intended to perform the action, what kind of reminders they might use, whether they expected any barriers, and how they might overcome these barriers. Questionnaire (3) additionally prompted users to commit to effective actions from previous weeks. In order to be able to distinguish between users in questionnaire responses, I decided to ask users to enter a unique ID at the start of all questionnaires, consisting of the first and last letter of a user's surname, the first two digits of their date of birth, and the first and last letter of their birth place. To ensure that the final wording of the questionnaires would be appropriate and that questionnaires would be straight-forward to use, I conducted

telephone calls with members of the public in order to gather feedback. My department has a panel of >100 members of the public with an interest in weight management research. Most of the individuals on this panel have personal experiences with weight management issues. I recruited six members of the panel for my phone calls. I used a think-aloud approach to gather feedback. That is, I asked panel members to test the questionnaires and think aloud during the process. This allowed me to identify flaws in the wording and design of the questionnaires. Using this feedback, I was able to revise the questionnaires, thus ensuring the wording was clear and the usage simple and straight-forward. The text of questionnaire (3) can be found in Appendix 5.1 - Daily and weekly questionnaires. I decided that action planning questionnaires should be sent out early in the morning via automated emails from the Qualtrics system. After completing a questionnaire, users would receive a confirmation email reiterating their action choices for the day/week.

I wanted to get in touch with users via email at the end of each intervention week, in order to send them a progress report with feedback on their weekly weight trends. Considering my own schedule, I decided that Mondays would suit me best to send out these emails, meaning that the intervention weeks would start on a Tuesday. For the progress report, I defined trend weight change as the slope of a trend line fitted across all measurements of the week, multiplied by the number of days covered by the measurements. I attached the trend weight change information to a motivational message: if the user lost weight, the email read “that’s great progress”; if the user’s weight remained stable ($\pm$0.2kg), it said “keep up the hard work”; and if the user gained weight, the message was “don’t let this demotivate you, just use the new week to start fresh”. In addition to this written feedback, I decided that the email attachments should

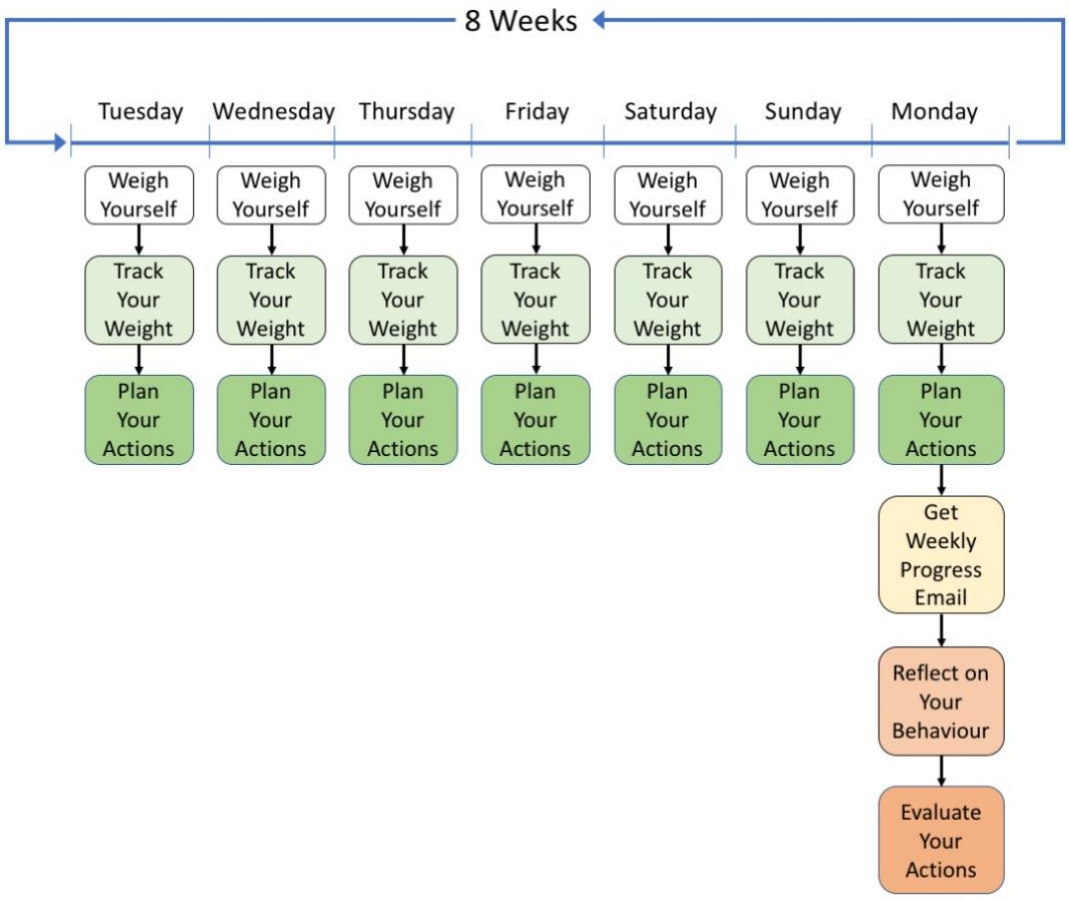
also contain a graph showing the weekly measurements with the trend line. I finished the email by inviting users of the intervention to complete a weekly questionnaire (again using Qualtrics), constituting the weekly reflection and evaluation task. The weekly questionnaire aimed to prompt users to think about why their weight changed the way it had. I decided to ask users to evaluate the category of actions they had chosen for the week, including whether they found the actions useful for weight loss and whether they would repeat any of the actions in the future (for exact phrasing, see Appendix 5.1 - Daily and weekly questionnaires). As with the daily questionnaires, I tested the clarity and usability of the weekly email and questionnaire during my phone calls with the six PPI panel members.

As I wanted to make sure the rationale and procedure of the self-regulation intervention would become clear to users, I decided to write a manual describing the self-regulation idea and all aspects of the intervention (see Appendix 5.2 - Manual). This also included introducing users to the idea that not all weight loss actions might be effective for them, meaning that they would have to self-experiment with different approaches to find their personal set of tools. After creating a first version and revising it using feedback from my supervisors, I held a focus group session with seven members of the weight management PPI panel. The PPI panel members received access to the manual in advance of the focus group session. During the session, I asked the PPI contributors to answer comprehension questions on the intervention tasks to explore whether the self-regulation approach was well-explained. We then discussed the clarity and presentation style of the manual. One of the main points of feedback of this focus group session was that the manual was well explained but too lengthy. As a result, I worked with a professional writer, who also happened to be on the PPI panel, to edit the manual to be

shorter. PPI contributors also stated that they would prefer more graphical elements, in order to make the manual less text-heavy. I therefore also added figures and graphs to present the procedures of the study more visually. The panel helped to revise the explanations of the different action plans. The finalised manual started by explaining the self-regulation approach and prompting the reader to set a weight loss goal. The manual described each step of the intervention tasks in detail. The appendix of the manual covered a detailed overview of all weight loss actions, including information on how to perform each action and why it matters for weight loss. I decided that users of the intervention were to receive this manual at the start of the programme in order to allow for a greater understanding of the self-regulation approach.

During the focus group session with PPI panel members, the idea of an action diary in the format of a table was raised. Weight loss actions could be listed in rows, and the days of the intervention could be shown in columns. Users could tick the boxes of actions they performed on a given day to keep track of their experimentation process. I designed such an action diary in the format of an A3-sized table (see Appendix 5.3 - Action diary), and decided to make it an optional element for users of the intervention. A figure from the manual depicting the intervention procedure is displayed in Figure 5.2.

Figure 5.2. Intervention procedure as depicted in study manual.



5.6 Discussion

To the best of my knowledge, PREVAIL was the first intervention to guide users through complete and iterative self-regulation using daily action planning. The experimentation resulting from this iterative process aimed to provide users with an opportunity to identify their personal set of effective weight loss tools. Moreover, as users of the intervention were prompted to continue with effective weight loss actions, the ultimate aim was for users to identify sustainable strategies which they could continue using beyond the intervention period, thus creating new habits and lasting changes.

The development of this intervention was based on the results of my previous studies, as well as work with experts and members of a PPI panel. I was thus able to

incorporate several perspectives in the development process. First and foremost, I incorporated the users' perspective. By using the insights into weighing experiences gained from the think-aloud study, Withings analysis, and app market review, the intervention pre-emptively addressed potential barriers to self-regulation. My approach therefore incorporated elements of user-centred design, as the experiences of potential users of the intervention were analysed first and the intervention was then developed and adapted to fit their needs[238, 239]. In addition, my work with PPI panel members added an element of co-design to my development process[238]. By working together to shape and revise my intervention materials, we were able to improve the accessibility and acceptability of the intervention for a lay audience. Taken together, my work with members of the public was very valuable in shaping the design of PREVAIL, ensuring that the intervention would be relevant for and usable by its target audience.

In addition to the user perspective, expert perspectives were also present throughout the development of this intervention. I iteratively discussed the design of all components with my supervisors. Moreover, my brainstorming sessions with experts for the action planning component allowed me to include the perspectives and inputs from an even more interdisciplinary team. As a result, the intervention content was shaped by insights from dietetics, psychology, and medicine, increasing its evidence base.

Nearly all components of my self-regulation intervention were delivered remotely through apps, questionnaires, and written resources. The intervention could therefore easily be transformed into a completely remote programme if resources for the development of a comprehensive website or mobile app were available. Such a delivery format would allow for the PREVAIL intervention to become a scalable, self-help treatment for individuals who want to lose weight. However, first evidence for the

effectiveness of PREVAIL is required in order to justify spending research funding on the development of a remote version. In the next chapter, I present the results of a randomised controlled trial, which tested the early effectiveness of the PREVAIL intervention against daily weighing. Since the PREVAIL intervention focussed solely on self-regulation, this RCT allowed me to assess the value of self-regulation as a stand-alone strategy for weight loss, considering that most existing interventions add self-regulation elements to a broader spectrum of weight loss treatment components[136, 159, 160, 226, 240].

Chapter 6 The early effectiveness of the PREVAIL intervention for weight loss

6.1 Summary

The aim of the randomised controlled trial was to compare short-term weight loss outcomes between the PREVAIL intervention and self-weighing only. I recruited adult participants with a BMI≥30 kg/m^2 and randomised them to either control (n=51) or intervention (n=49) group. Both groups were asked to weigh themselves daily for eight weeks. The intervention group was asked to use a weight tracking app to help contextualise weight measurements, and to complete daily and weekly questionnaires to prompt action planning, reflection, and evaluation of actions. Weight was measured at baseline and 8-week follow-up. At follow-up, 20 participants in the intervention group were interviewed regarding their experiences in the study. A mixed effects linear regression assessed the effect of the intervention on weight at follow-up, adjusting for baseline weight and general practice. Moderators and mediators of the effect were investigated. I assessed feasibility and acceptability of the self-regulation intervention through qualitative analysis of follow-up interviews and quantitative analysis of adherence rates and responses to a final questionnaire.

I followed up 98% of participants at 8 weeks with no difference between groups. Mean weight loss was -4.18kg (SD=3.84) in the intervention group compared to -1.01kg (SD=2.67) in the control group, the adjusted difference was -3.20kg (95% CI=-4.49, -1.92). Averaged across all self-regulatory tasks, intervention group participants were adherent to instructions on 77% of days. There was no evidence of a difference between groups in

the mean percentage of days participants weighed themselves (mean difference=3.1%, 95% CI=-6.5, 12.8). Adherence was an independent predictor of weight loss success in both groups (-1.54kg per one SD increase in adherence, 95% CI=-2.16, -0.93). On a scale from 1 (not useful) to 10 (very useful), participants rated the intervention's usefulness for weight loss as 8.25 (SD=2.04). The rating was positively associated with weight loss success (β=-1.11kg, 95% CI=-1.56, -0.65). In follow-up interviews, participants reported that the intervention enabled them to experiment with and identify effective weight loss actions.

The PREVAIL intervention, guiding participants through the self-regulation process, was effective, feasible and acceptable. It supported participants in identifying helpful personal weight loss actions through a process of self-experimentation.

6.2 Introduction

In Chapter 5, I detailed how I developed a new weight loss intervention guiding people through an iterative self-regulation process, which I called the PREVAIL intervention (**P**eople **RE**gulating themsel**V**es to **A**chieve we**I**ght **L**oss). The intervention encourages users to self-experiment with different weight loss approaches and use the self-regulation mechanism to find their ideal set of strategies. To test the early effectiveness of this novel intervention, I conducted a randomised controlled trial comparing the PREVAIL intervention against daily weighing, without further support. A secondary objective of the trial was to conduct a process evaluation of the PREVAIL intervention to assess acceptability and feasibility. I wanted to gain insights into the experiences of my participants in order to identify facilitators, barriers and unmet needs related to PREVAIL. Moreover, I aimed to investigate potential moderators and mediators of the

intervention's effectiveness, as well as independent predictors of weight change. One of the potential moderators was education, a significant predictor of measures of executive control[178-181]. Since the self-regulation approach requires self-control and self-regulatory abilities, both of which are functions of executive control, I hypothesised that individuals with a higher educational qualification would achieve better weight loss in this trial. Since education is a proxy measure of socio-economic status[35], this analysis also allowed me to assess the impact of SES on the intervention effect. Another potential moderator related to the participant's liking of self-weighing at baseline. I hypothesised that individuals who liked self-weighing would gain more benefit from the PREVAIL intervention. I also decided to investigate the potential mediating effect of adherence, since it is a common predictor of the success of weight loss interventions[205, 241]. I theorised that individuals who follow the intervention more diligently would have better weight loss outcomes. Finally, I wanted to test whether individuals in the PREVAIL intervention group achieved more weight loss if they liked the intervention.

6.3 Methods

6.3.1 Study design and setting

An individually randomised, two arm, parallel group design was employed, assessing superiority of the self-regulation intervention over daily self-weighing alone. Participation lasted eight weeks from baseline to follow-up. The cost of running of a longer-term trial was not justified without evidence of early effectiveness. Nonetheless, previous research has shown that weight loss at four weeks significantly predicts long-term weight loss success[242, 243]. Weight loss effects found at eight weeks should therefore provide good indication of the effectiveness of the intervention. Participants attended two study

visits with me, one at baseline and one after the end of the eighth week of the intervention. The primary outcome was weight change. The study took place in Oxfordshire, UK, and ran between April to October 2019. The trial was reviewed and approved by the NHS National Research Ethics Committee (REC) and the Health Research Authority (HRA, reference number: 18/SC/0482). A protocol of the trial was registered prospectively on ISRCTN[244] and published with BMJ Open[225].

6.3.2 Recruitment

Four general practices around Oxford, UK, functioned as participant identification centres and searched their health records to identify suitable patients for the trial (age ≥18 years, BMI ≥30kg/m^2). The general practitioners (GPs) screened the search lists and excluded patients who would be inappropriate to invite, such as patients who were violent or terminally ill. Suitable patients were sent an invitation letter from their GP. They were encouraged to contact me if they were interested in taking part. GPs also identified suitable patients during routine consultations. I asked general practices not to refer patients to commercial weight loss programmes, other obesity clinics or bariatric surgery, whilst they were enrolled as participants in this trial.

6.3.3 Eligibility criteria

Participants had to be willing and able to give informed consent, be aged 18 years or above, have a BMI ≥30kg/m^2, and own an Apple or Android smartphone in order to be able to download the weight tracking app used in the PREVAIL intervention.

As in the think-aloud study (Chapter 2), participants were excluded if they were unable to understand English, were currently weighing themselves more than once a week, had taken part in a weight management programme or other weight loss study in

the last three months, or had lost more than 5% of their current body weight in the last six months, had ever had bariatric surgery or were scheduled for bariatric surgery, were pregnant or planning to become pregnant during the course of the study, or had ever been diagnosed with an eating disorder. They were also excluded if they had an electronic medical implant such as a pacemaker, as the weighing scales I employed would not have been safe to use. Individuals could also not take part if they foresaw that they would be unable to follow all intervention procedures for a period of more than 4 consecutive days (e.g. due to a holiday).

6.3.4 Sample size

Based on an assumed difference of 1.5kg between groups, 90% power, a 5% type I error rate, and a 20% drop-out rate, a sample size of 100 participants was required. The variance of weight change used for this calculation was based on results of a similar length trial[150], which reported a standard deviation of 2.13kg at 2 months follow-up.

6.3.5 Randomisation

All eligible participants were randomised with an allocation ratio of 1:1 to the intervention or control group. A randomisation sequence, stratified by GP and using block randomisation with randomly varying block sizes of 2 and 4 was generated by another researcher in the department using a computer algorithm (www.randomization.com). She concealed the allocations in numbered, sealed, opaque envelopes for the baseline visits.

6.3.6 Intervention and control

6.3.6.1 Intervention

Participants were asked to weigh themselves every morning after waking using standard body scales (Etekcity Corporation, California). In addition, they followed the PREVAIL intervention as described in detail in Chapter 5. Briefly, the intervention consisted of daily weight tracking using an app called "Weight Loss Tracker, BMI" by aktiWir GmbH, as well as daily and weekly questionnaires (using Qualtrics, USA). The daily action planning questionnaire asked participants to choose between one of seven action categories at the start of each week, and then plan one action within this category on each day for the rest of the week. A weekly progress report email gave information about the weekly weight loss trend, and prompted participants to complete the weekly questionnaire to reflect on and evaluate the category of actions they had experimented with. An optional A3-sized action diary helped participants track their implementation of action plans. I called participants at the end of the 1st and 4th week to ask about and solve technical problems that may have arisen (e.g. with the functioning of the scales or the receiving of questionnaires).

6.3.6.2 Control

Participants in the control group were asked to self-weigh daily. I explained to participants that I wanted to find out whether seeing their weight on a daily basis would motivate them to engage in any weight loss behaviours. I chose this comparator task in order to test whether the self-regulation process could enhance self-weighing to be an effective weight loss tool. I provided participants with smart scales (BodyTrace, Inc., New York), which were equipped with a SIM card and automatically transferred weight

measurements to a secure server via the 3G/4G network. This allowed me to assess adherence to daily weighing in the control group.

6.3.7 Participant flow

6.3.7.1 Screening

People who were interested in taking part contacted me by email or telephone. I first discussed study participation and then undertook screening via telephone using a questionnaire covering the inclusion and exclusion criteria. If the person appeared to be eligible according to their responses and was interested in attending a baseline visit, I scheduled an appointment with them for a local venue. I emailed participants the participant information sheet (see Appendix 6.1 - Participant information sheet) and details of our baseline appointment.

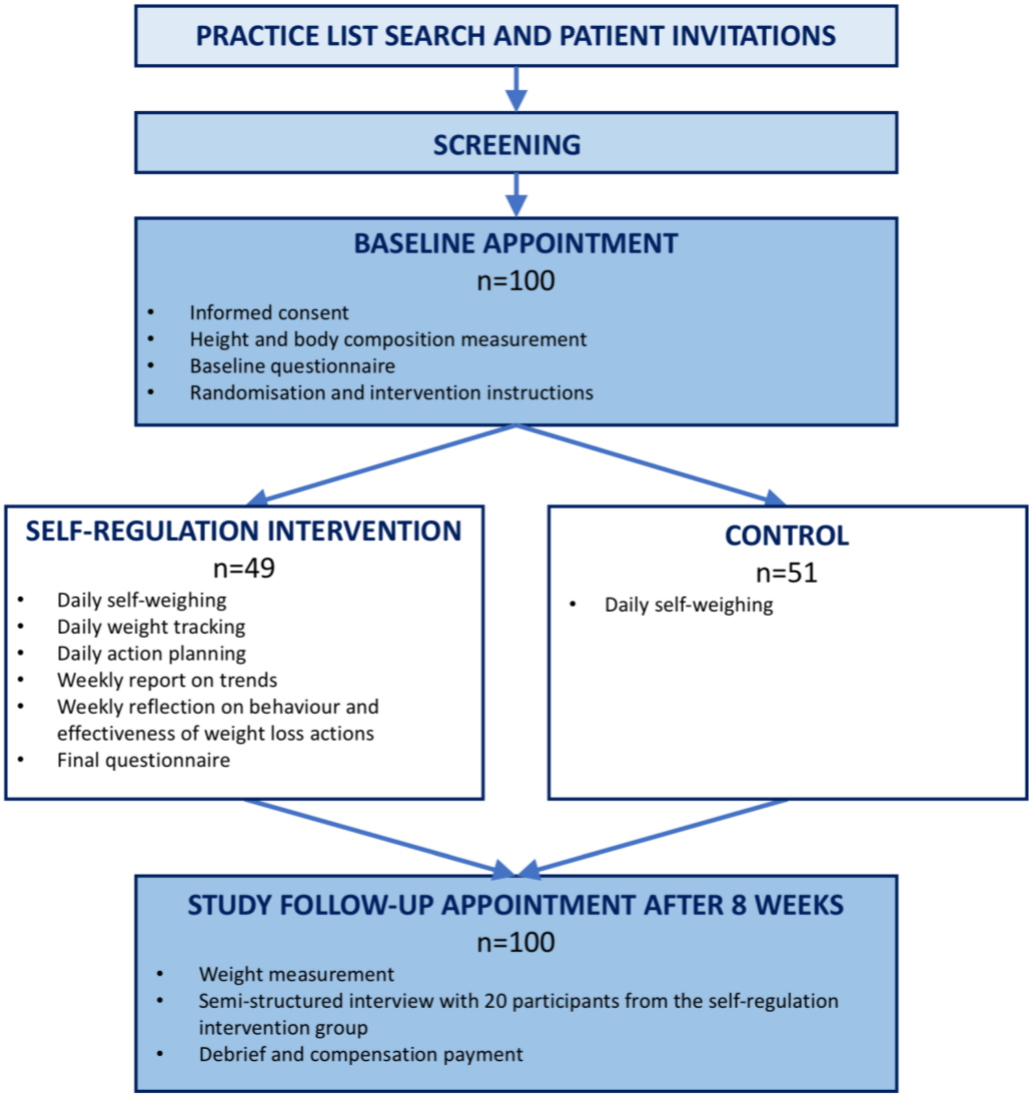
6.3.7.2 Baseline

At the baseline appointment, I sought informed consent from participants and double-checked eligibility for inclusion in the study by measuring height and weight and calculating the BMI. Eligible participants were asked to complete an online questionnaire capturing demographics (i.e., age, gender, ethnicity) and previous experiences with self-weighing. I randomised participants and provided instructions for the assigned interventions. In the control group, I followed a written instruction guide (see Appendix 6.2 - Control group intervention description), and in the intervention group the PREVAIL manual (see Appendix 5.2 - Manual), in order to ensure that all participants received the same instructions. I provided participants with a body scale for the duration of the trial. I scheduled a follow-up appointment for after the completion of the intervention period of eight weeks.

6.3.7.3 Follow-up

I emailed participants a week in advance to remind them of the follow-up meeting. In the intervention group, this email also contained a final questionnaire, asking participants about the usefulness of the intervention. The appointment took place at a local venue. Participants were asked to return the weighing scales, and in the intervention group also the action diary. I measured participants' weight in order to assess weight change. Afterwards, I discussed with participants about their experiences in the study. For 20 participants in the intervention group, this was a formal qualitative interview. I purposefully sampled the interviewees with the aim to reflect different levels of adherence, weight change, and responses to the final questionnaire. The interviews were recorded, transcribed and analysed. Before ending the meeting, I asked participants two questions to assess blinding: what they thought the aim of the trial was and what task they thought the parallel group had followed. Afterwards, I debriefed participants about the aim of the study and the programme which the other group had followed, thanked them for their participation and provided them with a £35 voucher as compensation for their time and effort. The procedure is displayed in Figure 6.1.

Figure 6.1. Procedure of the PREVAIL trial.



6.3.8 Blinding

Due to the nature of this trial, it was difficult to blind participants to treatment allocation. I aimed to make the particular behavioural mechanisms I was testing as opaque as possible by presenting daily weighing as an intervention to control group participants, as done in previous trials[124]. As the researcher who conducted baseline and follow-up visits and data analysis, I was not blinded to treatment allocation. The primary outcome, weight change, was measured objectively. Adherence to intervention tasks was measured objectively through the frequency of weight logs and completed daily and

weekly questionnaires in control and intervention group. The evaluations of intervention components in the final questionnaire was measured without researchers' input and analysed quantitatively. As the researcher who conducted the semi-structured interviews with intervention group participants, I was not blinded during qualitative analysis.

6.3.9 Retention

The daily questionnaire and weekly report emails acted as prompts for the participants to engage with the intervention. There were no criteria for withdrawal other than participants' request to withdraw. I asked participants wishing to withdraw whether they were willing to attend the final follow-up. Some of these participants in the intervention group I also interviewed using the above described semi-structured interview in order to understand their reasons for discontinuation.

6.3.10 Patients and public involvement

Members of the public were involved in the design of the study at several stages. After creating the invitation letter, participant information sheet, informed consent form, as well as baseline and follow-up questionnaires, I asked members of the weight management PPI panel of my department for feedback. Based on phone calls with these members, I was able to make the materials and questionnaires clearer and more concise.

I conducted a test run of the intervention procedures for four weeks with five members of the department who were not otherwise involved in this study. They provided feedback on the running of the intervention, which, amongst other outcomes, led to the creation of a reminder email which was sent out to participants before the start of the intervention. No members of the public were involved in conducting or analysing the study.

6.3.11 Outcomes

6.3.11.1 Primary outcome

The primary outcome was weight change between baseline and follow-up.

6.3.11.2 Secondary outcomes

I quantitatively investigated adherence rates and intervention ratings across all intervention components. Semi-structured interviews qualitatively investigated the acceptability and feasibility of the intervention, and identified barriers and unmet needs.

Using quantitative methods, I investigated moderators, mediators and independent predictors of weight loss effectiveness. I assessed whether education or liking of self-weighing at baseline moderated the weight loss effectiveness of the PREVAIL intervention. Moreover, I assessed whether adherence to the intervention tasks mediated the effect of the intervention on weight change. For the intervention group only, I also assessed whether liking of the PREVAIL intervention at follow-up predicted weight change.

6.3.12 Measurements

A schedule of measurements can be found in Table 6.1.

6.3.12.1 Physical measurements

Participants' height was measured at baseline to the nearest 0.1cm using a stadiometer. Weight was measured both at baseline and follow-up using a digital scale (SC-240 MA, Tanita Japan). Weight was recorded to the nearest 0.1kg.

6.3.12.2 Adherence measures

For the control group, adherence to daily weighing was measured as the proportion of days for which a weight was recorded on the BodyTrace scales server or for which a

written record was provided by the participant. Where synchronisation issues with the scales disrupted saving of measurements on the server and participants did not keep a written record, the proportion of days adherent to weighing before the issues with synchronisation arose were calculated.

For the intervention group, adherence to daily weighing was assessed by calculating the proportion of days for which a weight was recorded in the weight tracking app or in the daily action planning questionnaire. Adherence to weight tracking was calculated as the proportion of days for which a weight measurement was recorded in the app. Where participants did not use the weight tracking app or the app data was faulty, self-reported written records of weight measurements were accepted. Where the weight tracking data was incomplete due to technical reasons (e.g. switching of mobile phones), the proportion of days adherent to weight tracking were calculated for the time frame covered by the existing data. Adherence to action planning and reflection/evaluation was measured by calculating the proportion of days for which the respective questionnaires were completed. A composite adherence score was calculated by averaging the adherence measures for daily weighing, weight tracking, action planning and reflection/evaluation. In the control group, this composite adherence score was equal to daily weighing adherence.

6.3.12.3 Baseline questionnaire

A baseline questionnaire measured demographic characteristics such age, gender, ethnicity, highest educational degree and employment status. Since the majority of participants in the sample had a university degree or equivalent, and the rest were distributed in small quantities across the other qualification levels, I created a binary variable (in the following called university degree) coded as 0=no university degree or

equivalent and 1=university degree or equivalent. The questionnaire asked participants how often they weighed themselves usually, whether they liked weighing themselves on a scale from 1 (dislike it a great deal) to 5 (like it a great deal), and whether they thought daily weighing would be useful for controlling weight on a scale from 1 (definitely not) to 5 (definitely yes).

6.3.12.4 Final questionnaire

Participants in the intervention group completed a final questionnaire which collected ratings on a scale from 1 (not useful) to 10 (very useful) for each intervention component, as well as for the intervention overall.

6.3.12.5 Semi-structured interview

In the interview I asked participants about their experiences with self-weighing and the intervention components, with the aim to collect feedback on acceptability and feasibility, alongside identifying barriers and unmet needs (see Appendix 6.3 - Semi-structured interview guide).

Table 6.1. Schedule of measurements.

	Screening	Baseline visit	Intervention Period	Completion email	Follow-up visit (after 8 weeks)
Length	10 mins	30mins-1h	10 mins per day	5 mins	45 mins
Location for participants	Home	Local venue	Home	Home	Local venue
Eligibility assessment	☑	☑ (BMI)			
Enrolment		☑			
Baseline questionnaire		☑			
Weight		☑	☑		☑
Height		☑			
Allocation		☑			
Weight tracking (only intervention)			☑		
Daily questionnaire (only intervention)			☑		
Weekly report and questionnaire (only intervention)			☑		
Final questionnaire (only intervention)				☑	
Semi-structured interview (20 participants in intervention group)					☑

6.3.13 Statistical analyses

A statistical analysis plan was published on ISRCTN preceding the analyses[244].

Quantitative analysis was carried out using SPSS, version 24, and R Studio, version 1.0.153. All of the analyses were conducted at a 5% two-sided significance level.

6.3.13.1 Primary outcome

The statistical analysis of the primary outcome, effectiveness of the intervention for weight loss, was carried out both on the basis of intention-to-treat (ITT) and per-protocol (PP). For the ITT analysis, participants were analysed according to their allocated

intervention group. I endeavoured to obtain full follow-up data on every participant to allow full ITT analysis. Where I was unable to meet participants for follow-up, I tried to record self-reported weight at eight-week follow-up by telephone or email. Where this was not possible, baseline observations were carried forward (BOCF). I assessed the sensitivity of the analysis to assumptions about missing data by also running an analysis imputing the last home-measured weight (last observation carried forward, LOCF) for people who did not attend the final meeting and did not self-report their weight at eight-week follow-up, as well as an analysis restricted to participants completing follow-up or self-reporting weight at follow-up (in the following called completer analysis). For the PP analysis, I excluded participants who stopped following their allocated intervention at some point throughout the study.

For both ITT and PP analysis, a linear mixed effects model, predicting weight at follow-up while adjusting for baseline weight (fixed effect) and GP practice (random effect), assessed the effect of condition (fixed effect). I assessed normality of all model residuals using histograms, QQ-plots and other diagnostic plots. Where the normality assumption was violated, I ran additional sensitivity analyses using semi-parametric generalized estimating equations.

6.3.13.2 Secondary outcomes

Means and standard deviations of intervention ratings from the final questionnaire and adherence rates to the different intervention components were calculated. Adherence rates for daily weighing in the control and intervention group were compared using independent samples t-tests. Means and standard deviations of final questionnaire ratings were calculated.

I ran linear mixed effects models to assess potential moderators, mediators and independent predictors of effectiveness. Missing data on the moderator, mediator and predictor variables was not imputed for these analyses, BOCF values for the weight change variable were employed. The first model using the same parameters as in the primary analysis, and adding the binary variable university degree, as well as the interaction term university degree*condition, tested for a moderation of the interventions' effect on weight change. Estimated marginal means (EMMs) of follow-up weight were calculated for each group of the 2x2 interaction.

Similarly, a linear mixed effects model tested the moderating effect of liking of weighing on the interventions' effectiveness, adjusting for the same parameters as in the primary analysis. Liking of weighing was added both as an independent parameter, as well as in an interaction term with condition. Estimated marginal means of follow-up weight were calculated for control and intervention groups, at M-1SD and M+1SD of the liking of weighing variable.

Third, a linear mixed effects model tested the predictive value of the overall intervention rating (intervention group only) for weight change, adjusting for both baseline weight and GP practice.

Finally, a mediation analysis following Baron and Kenny[245] tested whether adherence mediated the effect of condition on weight change[1]. For step 1 of the mediation analysis, I re-ran the primary analysis excluding participants for whom adherence data was not available. Step 2 of the mediation analysis constituted a linear

[1] In the statistical analysis plan, I stated that I would run a moderator analysis on the adherence measures. However, it makes more theoretical sense to assess whether adherence was a mediator of treatment effectiveness, as engaging with the intervention could be a necessary precursor for it to be effective.

mixed effects model on the same subsample, testing whether condition significantly predicted composite adherence while adjusting for GP practice. For steps 3 and 4, I re-ran the linear mixed effects model of step 1, this time adding the composite adherence score as a predictor to assess whether adherence significantly predicted weight change and whether the effect of condition turned non-significant in the presence of the adherence measure.

6.3.14 Qualitative analyses

All interview audio-recordings were transcribed and entered into the NVivo software package (QSR International, version 11.4.2) for qualitative data analysis. I performed the analysis of all interviews by myself. Framework analysis according to Ritchie and Spencer[218] assessed the participants' experiences and perceptions of the intervention. To this end, I created an a priori framework covering the different intervention components, i.e. weighing, weight tracking, action planning, weekly progress reports, reflection, and evaluation. Emerging themes surrounding the intervention components were added inductively throughout the coding process. Inductive thematic analysis following Braun and Clarke[156] explored additional themes, including acceptability, barriers and unmet needs. No a priori framework or ideas were imposed onto the data for this second analysis and I only recorded themes that emerged directly from the data. After completing this first phase of analysis, I aimed to assess relationships between themes, thus combining the framework and thematic analysis. Axial coding techniques, lent from the grounded theory approach, were employed to identify overarching themes and linkages between themes[157]. To this end, I started by listing all themes in one document and then grouped them according to topics (see Appendix 6.4 - Mind map qualitative analysis).

6.3.15 Trial management

I ran all the day-to-day management of the study myself. A Trial Management Group (TMG), consisting of my supervisors and me, had oversight of the trial procedures. We were responsible for the monitoring of all aspects of the trial's conduct and progress and ensured that the protocol was adhered to and that appropriate action was taken to safeguard participants and the quality of the trial itself. My supervisors and I met regularly throughout the course of the trial.

It seemed implausible that the intervention would lead to an increased occurrence of adverse events. My supervisors and I therefore decided that recording adverse events would be an inappropriate burden to participants. Being a short trial with no adverse event monitoring or stopping rules, we deemed that a trial steering committee and a data monitoring committee were unnecessary.

6.4 Results

6.4.1 Sample

Two hundred and sixty-one people contacted me between April to August, 2019, to express their interest in the study. Of these, I was unable to reach 19 and turned away 14 who contacted me after recruitment had closed. I screened the remaining 228 for eligibility, 128 of whom were excluded due to various exclusion criteria, especially BMI<30kg/m^2 and pre-existing regular self-weighing habits (see Figure 6.2 for CONSORT flow diagram).

One hundred participants were recruited to the trial and randomised to the control (n=51) and intervention condition (n=49). The average BMI at baseline was 35.1kg/m^2, 62.6% of participants were female and mean age was 53.2 years. Further

baseline demographic characteristics and quantified measures of experiences with self-weighing at baseline are presented in Table 6.2 and Table 6.3. Participants did not differ significantly between groups on baseline demographic characteristics (all $p>.05$). At follow-up, 13 participants in the control and 5 in the intervention group indicated that they were aware of being in the control or intervention group. The rest expressed not knowing what the parallel group might have done.

Table 6.2. Baseline demographic characteristics.

N(%), unless otherwise specified	**Control (n=51)**	**Intervention (n=49)**	**Total (n=100)**
Age, years, mean (SD)	52.1 (15.0)	54.4 (15.7)	53.2 (15.3)
Gender, % female[a]	31, 60.8%	31, 63.3%	62, 62.6%
BMI, kg/m^2, mean (SD)	35.1 (4.8)	35.1 (3.4)	35.1 (4.1)
Ethnicity			
White	44 (86.3%)	45 (91.8%)	89
Asian or Asian British	4 (7.8%)	2 (4.1%)	6
Black of Black British	2 (3.9%)	1 (2.0%)	3
Mixed/Other	1 (2.0%)	1 (2.0%)	2
Highest educational qualification			
No formal qualifications	2 (3.9%)	4 (8.2%)	6
Vocational/work-related qualifications	2 (3.9%)	1 (2.0%)	3
GCSE, NVQ level 1	6 (11.8%)	6 (12.2%)	12
Apprenticeship	3 (5.9%)	1 (2.0%)	4
A-levels, NVQ level 2-3	5 (9.8%)	6 (12.2%)	11
Other post-high school qualifications	2 (3.9%)	1 (2.0%)	3
University degree, NVQ level 4+	31 (60.8%)	30 (61.2%)	61
Employment status[b]			
Employed	34 (66.7%)	25 (51.0%)	59
Self-employed	8 (15.7%)	5 (10.2%)	13
Unemployed	1 (2.0%)	1 (2.0%)	2
Looking after home and family	2 (3.9%)	2 (4.1%)	4
Student	1 (2.0%)	1 (2.0%)	2
Retired	9 (17.6%)	16 (32.7%)	25
Long-term sick or disabled	1 (2.0%)	0 (0.0%)	1

[a]One participant in the control group preferred not to indicate their gender, the percentage for female gender is therefore based on 99 participants in total.

[b]Participants were able to select several if applicable.

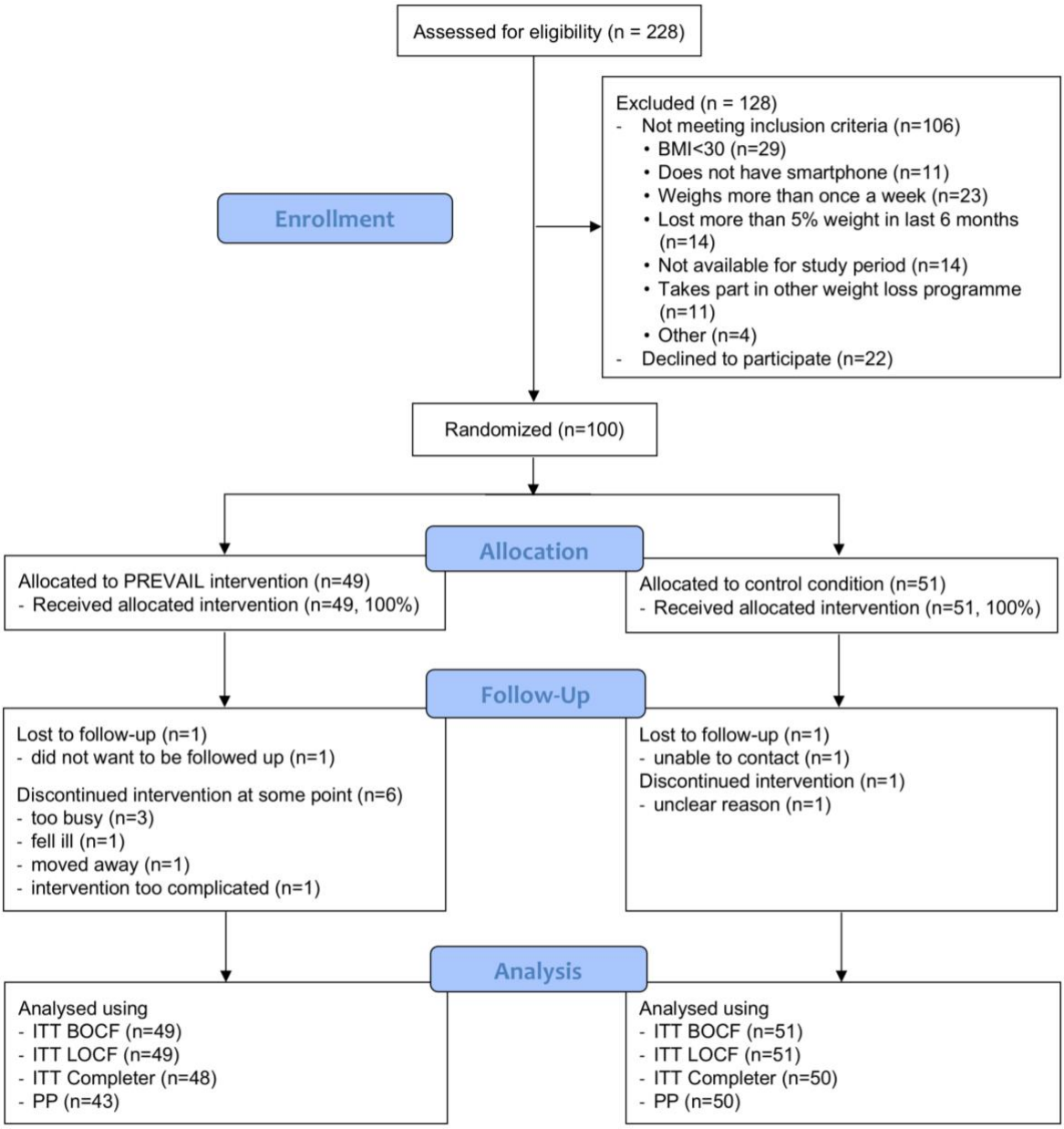
Table 6.3. Baseline characteristics self-weighing.

N(%), unless otherwise specified	**Control (n=51)**	**Intervention (n=49)**	**Total (n=100)**
Weighing frequency			
Less than once a month	21 (41.2%)	30 (61.2%)	51
Once a month	12 (23.5%)	8 (16.3%)	20
Every other week	6 (11.8%)	2 (4.1%)	8
Once a week	12 (23.5%)	9 (18.4%)	21
Liking of weighing			
Dislike it a great deal	7 (13.7%)	7 (14.3%)	14
Dislike it somewhat	16 (31.4%)	13 (26.5%)	29
Neither like nor dislike it	24 (47.1%)	23 (46.9%)	47
Like it somewhat	4 (7.8%)	6 (12.2%)	10
Like it a great deal	0 (0.0%)	0 (0.0%)	0
Usefulness of weighing to control weight			
Definitely not	1 (2.0%)	3 (6.1%)	4
Probably not	15 (29.4%)	9 (18.4%)	24
I don't know	8 (15.7%)	19 (38.8%)	27
Probably yes	20 (39.2%)	13 (26.5%)	33
Definitely yes	7 (13.7%)	5 (10.2%)	12

6.4.2 Retention

96% of participants were followed up in person at eight weeks, n=47 in the intervention and n=49 in the control group. One additional participant in the intervention, and one in the control group provided their self-reported weight at follow-up, resulting in a sample of n=98 for the completer analysis. Forty-three participants in the intervention and 50 in the control group completed the allocated intervention and were therefore included in the PP analysis. The complete participant flow is depicted in Figure 6.2.

Figure 6.2. CONSORT flow diagram.



6.4.3 Primary outcome

The linear mixed effects model testing the ITT analysis using BOCF imputation revealed that participants in the intervention group lost 3.2kg more weight than participants in the control group (95% CI=-4.49, -1.92). These statistically significant results were replicated in the LOCF and completer analysis (for full results, see Table 6.4). The PP analysis also revealed a statistically significant -3.65kg difference between the two groups

(95% CI=-4.98, -2.33). Model residuals were not normally distributed. GEE sensitivity analyses replicated the statistically significant effect of condition on weight change for all imputation and analysis methods (Table 6.5).

Table 6.4. Results of the linear mixed effects models of the primary analysis.

		Mean (SD) weight change from baseline		Adjusted difference (95% CI)	p
		Intervention	Control		
ITT	**BOCF (N=100)**	-4.18 (3.84) (n=49)	-1.01 (2.67) (n=51)	-3.20 (-4.49, -1.92)	<.001
	LOCF (N=100)	-4.18 (3.84) (n=49)	-1.03 (2.67) (n=51)	-3.18 (-4.47, -1.90)	<.001
	Completer (N=98)	-4.26 (3.84) (n=48)	-1.03 (2.69) (n=50)	-3.27 (-4.57, -1.97)	<.001
PP (N=93)		-4.70 (3.81) (n=43)	-1.03 (2.69) (n=50)	-3.65 (-4.98, -2.33)	<.001
Adjusted for: GP practice (random effect), baseline weight (fixed effect)					

Table 6.5. Results of the GEE sensitivity analysis of the primary analysis.

		Adjusted difference (95% CI)	*p*
ITT	**BOCF (N=100)**	-3.20 (-4.93, -1.47)	<.001
	LOCF (N=100)	-3.18 (-4.93, -1.43)	<.001
	Completer (N=98)	-3.27 (-5.04, -1.50)	<.001
PP (N=93)		-3.65 (-5.39, -1.92)	<.001
Adjusted for: GP practice (random effect), baseline weight (fixed effect)			

6.4.4 Secondary outcomes

6.4.4.1 Adherence rates

Average adherence rates could be calculated for all 49 participants in the intervention and 46 participants in the control group. Data from five participants in the control group

was lost due to technical issues with synchronisation of the scales. Average adherence rates to the different intervention components can be found in Table 6.6. Adherence to daily weighing did not differ significantly between the control (M=84.9%, SD=14.8%) and intervention group (M=81.7%, SD=30.1%; mean difference=3.1%, t(70.8)=0.65, 95% CI=-6.5%, 12.8%).

Table 6.6. Adherence to intervention components.

	Intervention Component	**Mean % (SD)**
Control	Daily Weighing (n=46)	84.9% (14.8)
Intervention	Daily Weighing (n=49)	81.7% (30.1)
	Weight Tracking (n=40)	75.0% (36.3)
	Daily Action Planning Questionnaires (n=49)	79.9% (30.4)
	Weekly Reflection/Evaluation Questionnaires (n=49)	70.4% (35.8)
	Composite Adherence (n=49)	76.6% (30.7)
	Action Diary (optional, n=47)	47.9% (41.3)

6.4.4.2 Intervention Component Rating

Forty-five intervention group participants completed the final questionnaire. The average overall rating of the intervention was 8.25 on a scale from 1 (not useful) to 10 (very useful). The ratings of the individual intervention components were on average positive, with action planning being rated the most (M=8.11, SD=1.89) and weekly evaluation the least useful (M=6.89, SD=2.17). All average ratings with standard deviations can be found in Table 6.7.

Table 6.7. Average ratings of the intervention components in the final questionnaire.

Question	Mean (SD)
How do you feel about weighing yourself overall? (n=45)	7.56 (2.57)
How useful did you find the intervention for controlling your weight overall? (n=44)	8.25 (2.04)
How useful did you find tracking your weight for controlling your weight? (n=45)	7.96 (2.74)
How useful did you find planning weight loss actions for controlling your weight? (n=45)	8.11 (1.89)
How useful did you find reflecting on the reasons for weight changes for controlling your weight? (n=45)	7.11 (2.31)
How useful did you find the weekly action evaluation for controlling your weight? (n=45)	6.89 (2.17)
Please note: Questions were completed by participants in the intervention group who followed the intervention for at least one week and attended the follow-up meeting. The first question was rated on a scale from 1 (very negative) to 10 (very positive). The other questions were rated on a scale from 1 (not useful) to 10 (very useful).	

6.4.4.3 Moderators, mediators and independent predictors of effectiveness

6.4.4.3.1 University degree

The linear mixed effects model revealed that there was no moderation of the treatment effect by university degree and also no main effect for university degree (all p>.1, see Table 6.8). As it may be possible that the study was underpowered to detect moderation, I calculated EMMs of follow-up weight at the different levels of the university degree and condition factors. In the control group, participants with a university degree lost 0.4kg more than participants without, whereas in the intervention group participants with a university degree lost 0.9kg less than those without one. There was hence no consistent effect of the university degree variable.

6.4.4.3.2 Liking of weighing

There was neither a significant moderation, nor main effect of liking of weighing at baseline on weight change (all p>.1, see Table 6.8). The EMMs of the control group showed that follow-up weight decreased with increased liking of weighing (M-1SD=98.3kg, M+1SD=97.3kg). The same pattern was apparent in the intervention group (M-1SD=95.1kg, M+1SD=94.4kg), thus revealing that participants of both conditions achieved slightly more (although non-significant) weight loss at follow-up if they liked weighing themselves at baseline.

6.4.4.3.3 Overall intervention rating

The overall intervention rating had a significant effect on weight change, such that participants in the intervention group lost 1.1kg more per one-unit increase (on a scale from 1 to 10) on the overall intervention rating (95% CI=-1.56, -0.65, see Table 6.8).

Table 6.8. Linear mixed effects models exploring moderators and predictors of effectiveness.

		Adjusted Difference (95% CI); p		
		Condition	**Additional Variable**	**Additional Variable* Condition**
Moderators and Predictors	**University degree (N=100)**	-5.69(-10.13, -1.24) p=.01	-2.01(-6.15, 2.14) p=.35	1.54(-1.10, 4.19) p=.25
	Liking of weighing (N=100)[a]	-3.71(-7.77, 0.35) p=.08	-0.84(-3.29, 1.61) p=.50	0.22(-1.31, 1.74) p=.78
	Overall intervention rating (N=44)[b]	-	-1.11(-1.56, -0.65) p<.001	-
Outcome: Weight Change (BOCF); adjusted for: GP practice (random effect), baseline weight (fixed effect)				

[a] Scale from 1 (dislike it a great deal) to 5 (like it a great deal)

[b] Scale from 1 (not useful) to 10 (very useful)

6.4.4.3.4 Mediation analysis adherence

For step 1 of the mediation analysis, the linear mixed effects model using the subset of participants for which adherence data was available (n=95) replicated the significant effect of condition on weight change (adjusted difference=-3.30kg, 95% CI=-4.626, -1.980). Step 2 of the mediation analysis revealed that condition did not significantly predict adherence in a linear mixed effects model adjusted for GP practice (adjusted difference=-0.083, 95% CI=- 0.181, 0.015). However, since the p-value (p=.10) indicated there might be a marginal effect lacking power, I continued with steps 3 and 4 of the mediation analysis. The resulting linear mixed effects model, adjusted for baseline weight and GP practice, showed that adherence affected weight change independently of condition. For each 1SD increase in adherence[2], participants in both groups lost 1.54kg more weight (95% CI=-2.16, -0.93). At the same time, there was still a significant main effect of condition, as intervention group participants lost 3.81kg more than participants in the control group (95% CI=-5.01, -2.61). As condition did not predict adherence in step 2, and condition remained a significant predictor of weight change in the presence of the adherence variable in step 4, mediation could be ruled out.

6.4.4.4 Qualitative analysis

Twenty participants in the intervention group were interviewed at the follow-up meeting. Thirteen of them were female, their composite adherence varied between 21% to 100%, and their average weight loss was -4.6kg (ranging from -18.7kg to +0.9kg, SD=4.9). The overall intervention rating ranged between 3 to 10 points on a 10-point scale (M=7.9,

[2] The coefficient and confidence intervals were multiplied with the standard deviation of adherence (0.25). The coefficient therefore reflects changes in weight per 1SD increase in adherence.

SD=2.31). Throughout the following sections, I give information on the gender and age of the participants quoted, in order to provide some context to the statements.

6.4.4.4.1 The intervention was a success

The qualitative analysis mirrored the positive quantitative evaluations of the intervention. Fourteen participants specifically commented on how the intervention had been a success for them.

> *"It's the first time I've lost weight systematically in my life other than a few kilos here and there so the programme worked wonders for me." (Male, 48)*

Participants positively differentiated the intervention from typical diets, saying that the self-regulation approach was less restrictive, allowed for more flexibility and more active involvement.

> *"The attractiveness of it was that it wasn't a prohibited diet. It wasn't, you mustn't do this, you mustn't do this, you have to do this, you know. […] It was, you know, much more about choosing what you want to do that worked for you. I'm sure I'm not the only person who's said, going to be saying this to you. It's just a different way, […] less nanny-ish I suppose really." (Female, 51)*

Many went on to recommend the programme to friends or family, thinking that it would benefit them as well.

> *"I've sold it to everybody at work, everybody at work thinks it's really good." (Female, 55)*

Reasons for success were plentiful. Several participants commented that the intervention helped them take control over thoughtless eating behaviour. The daily activities helped participants refresh their motivation and focus on their goal.

> *"My thing is emotional eating or I'm bored or something like that. So my attention goes to food and I'm like oh no I'm not doing that because I'm not eating either after this time or in between meals. And that was really helpful just to kind of have that commitment." (Female, 60)*

Increased control and discipline were achieved through the structured approach to self-regulation, which nudged participants to confront their weight and commit to a weight loss action every day. Participants expressed that they liked the degree of structure, as it allowed them to flexibly make their own decisions, while holding them accountable to an overarching goal.

> *"Yeah and it works for me it was a nice blend of self-regulating and structure. Because only self-regulating can get too, can get too anarchic without any parameters. Over self-regulating gets too controlling and rubs people up the wrong way but I think the balance between self-regulating and structure was very good." (Male, 48)*

Another common reason for weight loss success was that participants had gained important insights into how their body works and how their actions affect their weight.

> *"I've worked out what works best for me and what, sort of helps but doesn't give the good results." (Female, 55)*

> *"It was educational to say the least and there are a lot of things in there that I didn't know about and surprised me to be perfectly honest. And it's been a bit of a revelation" (Male, 64)*

A few participants expressed that they had been sceptical at first when starting the programme, as the structure and number of tasks seemed daunting. However, most found that the daily intervention tasks quickly became part of their morning routine and soon did not struggle juggling them.

> *"When I started I thought 'Oh my God this is gonna be a nightmare' sort of thing, you know, but all of a sudden you get in the little rota." (Female, 80)*

After the intervention had stopped, some participants stated that it had felt odd not to perform the intervention tasks anymore, as they had become part of their daily routine.

> *"I'd got in such a routine […] the habit has been there now for…and this morning I was like this felt really strange not having to do it." (Female, 55)*

6.4.4.4.2 Weighing and weight tracking were useful, but the optimal frequency depended on the participant

Most participants stated that weighing themselves was an important part of the programme, whether they enjoyed the process or not. Regular weighing helped participants to keep track of their weight loss progress.

> *"Thinking about it now I'm starting to feel as though it was absolutely essential, weighing myself and monitoring it with an App, otherwise I would have been in the dark regarding my progress." (Male, 48)*

Some participants expressed that the daily frequency of weighing was helpful and necessary, because it kept them focused and motivated them to continue with their weight loss efforts.

> *"It sort of gave you a kick start of like weighing every morning because […] if you saw that it went slightly up it would make you think differently. So I think it was a good idea of weighing each morning" (Female, 49)*

Participants explained that the combination of weighing and action planning enhanced the usefulness of weighing, as it gave context to the weight measurement and enabled reflection on cause and effect. The study therefore changed how participants approached and made use of weight measurements.

> *"But because it's so structured then it did make a difference because […] it wasn't just weighing myself, it was weighing myself and deciding what I'm going to do for the rest of the day, […] in the context of why I lost or why I gained, so that was pretty good." (Female, 40)*

> *"I've probably used it [the weighing] now more as a sort of actual guide to what works. […] if you track it you go 'oh actually I spiked and then I lost weight the last three days. Those few days, what did I do then?'" (Male, 26)*

However, participants in the PREVAIL trial differed in their ability to interpret day-to-day changes and some commented on problems with making sense of fluctuations.

> *"I did feel it was a bit discouraging when […] I'd been really good and then your weight would like go up and, I mean I know that's because of like fluid and things […] it just changes so much doesn't it?" (Female, 39)*

A few participants talked about experiencing emotional reactions to weighing. When the weight measurements indicated a lack of progress, emotions were negative, and could constitute a barrier to further progress.

> *"Because once I started putting on a little bit of weight then my motivation just really plummeted and I kind of got into a familiar place of oh this never works, nothing will work for me." (Female, 60)*

Furthermore, one participant expressed that facing their weight on a daily basis was detrimental because it triggered mental health issues.

> *"I suffer with depression and anxiety and for me the daily act of weighing myself was just a constant reminder of how fat I am. Which doesn't help when a lot of my issues revolve around my weight anyway" (Female, 34)*

In these contexts, wanting to weigh less often than daily was discussed. These participants did not want to stop weighing themselves completely, as they still saw value in checking in with their weight on a regular basis. However, they considered that the detrimental effects of daily fluctuations and resulting emotions might be avoidable by weighing on a less frequent basis.

> *"Maybe on a sort of every two days or every three days kind of basis to keep track. But also, to not always have these day-to-day differences because you do find that that can be a bit demotivating as you, when you don't see the sort of direct cause and effect relationship." (Female, 49)*

Other participants identified that specific events, such as their period, negatively affected their weight and decided not to weigh during those times to avoid having to see frustrating weight measurements.

> *"And probably I will not do it when I'm having my period, I would just avoid it because […] it's just painful when you know that you've done all this hard work." (Female, 33)*

Tracking weight measurements using the app was well received. Participants spoke about how seeing their weight loss progress in a graph was motivating. They appreciated that the app was simple and easy to use.

> *"I just like looking at the graph, I send pictures of it to my sister. That's worked really well for me. […] That tracking aspect, it's been really motivating." (Female, 45)*

> *"I thought it was very effective and, and easy to use and nicely set out." (Female, 51)*

Since participants enjoyed tracking their weight, they also wanted to continue using the app to record their weight measurements in the future.

> *"I'm going to continue with the app I've got on my phone because I like it. That actually helps keep me focussed." (Female, 55)*

Nonetheless, participants also expressed some barriers to weight tracking. Some had trouble remembering their weight measurement for long enough to type it into the app. An automatic synchronisation of the weight measurement was perceived as a good solution to this issue.

> *"You could create a set of scales which synced to your mobile phone rather than having to actually go through the whole process of […] remembering what it was." (Female, 34)*

Others did not want to track frustrating weight measurements, because this would ruin their weight loss trend in the app.

> *"I was like I've put nearly 1 kilo, a quarter of, I'm not going to put this on. It's just going to damage my results." (Female, 33)*

6.4.4.4.3 Action planning enabled experimentation and identification of the ideal set of weight loss tools

Participants commented positively on the fact that the action planning task provided them with choices so they could experiment with several different approaches.

> *"It was quite fun like 'Oh what am I going to do today.' And from an experimenting point of view as well it was, it was good to be able to try different things and to see which […] small things […] are likely to have an impact and basically focus on those." (Female, 34)*

Which actions were relevant differed per person, and participants actively pre-selected which actions and categories they wished to try. Criteria for this decision were whether the action seemed feasible, whether participants trusted the likely effectiveness of the action and whether adopting the action would make a change to their usual behaviour.

> *"I looked at all the categories […] and the actions within them, I knew whether they were good for me to choose. One of them was about drinking. […] I only ever drink either water or unsweetened squash, I never have anything with sugar in, I don't drink alcohol, there was nothing in there that would actually [make a difference]. So I'm like forget that category" (Female, 55)*

Participants used different approaches to daily action planning. Most chose actions that would fit well into their schedule to increase feasibility. Some specifically chose those actions that were going to have the most impact on their weight. Finally, there was a group of participants who specifically chose "easy" actions. Of the 20 participants whom I interviewed, seven had achieved only a little weight loss (<1.5kg). Of these seven, five reported that they had chosen their actions because they were easy, which might partly explain why they achieved lesser weight loss than other participants.

> *"So where it [the action] was easy to be honest. […] Fasting and things I didn't, I didn't try. Again, I think it's trying to just not get over focussed on it, tackle the realistic things." (Female, 51)*

Most participants expressed that they experimented with several actions, at least at the start of the intervention period, and used the reflection and evaluation tasks to identify which actions worked for them. As participants realised which actions were most useful, experimentation decreased and participants repeatedly stuck to their tried and tested set of tools.

"That suited me so I felt there was no need to change. […] My aim was .02 a day off sort of thing if I could, so as long as I was achieving that I was quite happy." (Female, 80)

Some participants therefore expressed that they did not need the full eight weeks of experimentation.

"Six weeks would have done it for me. […] I just felt that I had tried everything I wanted to." (Female, 45)

Experimenting with weight loss strategies allowed some participants to overcome barriers to weight loss behaviours, which had seemed daunting before. The experimentation therefore encouraged participants to identify new weight loss actions.

"Only having three meals […] was a breakthrough because I thought I can't possibly do that. […] So it was really useful, it kind of showed me that I could do it." (Female, 60)

The fact that participants only had to commit to actions for one day seemed to help with overcoming barriers.

"Even the ones that seemed difficult, knowing that they were only for a day really helped me to stay on track." (Female, 31)

The daily aspect of action planning was generally appreciated. Participants reported that it helped them stay focussed each day and made the task more exciting as they could switch actions every day. It also provided participants with a sense of reward when they managed to complete their daily task.

"It did make me focus more and really think about how I was going to tackle the daily task." (Female, 55)

"And I think actually giving yourself small daily goals to achieve was like it, it kind of gave you a little bit of sense of achievement towards the end of the day." (Female, 34)

Some participants contrasted daily action planning against weekly action planning, and expressed that the daily planning made it more likely for them to adhere to their self-set

plans. It also meant that participants could fit their actions flexibly around their daily schedule, which was appreciated.

> *"Because I think if you'd have asked me to plan it or plan a week in one go and then leave it alone then I, I may well have done the first two days and then I would have forgotten I think." (Male, 26)*

> *"Which was good, better than saying I'm not going to eat after 8 'o' clock for the whole week. So it did fit in with your daily life." (Female, 72)*

Some participants raised the point that they appreciated being asked to specify their action plan, as they felt that this strengthened their commitment to the task.

> *"It sort of focussed your mind for the day. And that you actually sort of thought about what you're going to do and then how you might go about it. So you're congruously thinking about things instead of just picking one and going I'll do that and then forget about it." (Male, 26)*

However, the questions I employed for the specification task also annoyed quite a few of the participants, as they felt they were often irrelevant and participants did not have much to say about them.

> *"But then to be asked about what happens if you don't or can't do it and you think well I don't know I'll just deal with it if it comes up. I can't predict what, what might happen that will force me not be able to do it." (Female, 72)*

A few participants struggled with the daily planning frequency, as the morning time was stressful and they felt the planning just added another thing to their busy morning routine.

> *"But for me actually doing, the morning is the worst possible time. Because I don't have time and I have so many e-mails as well. So any e-mail that comes through that's not a priority, you know, something doesn't happen" (Female, 51)*

However, other participants thought the morning time was best, so the ideal timing of the daily action planning task might be subjective.

6.4.4.4.4 Weekly progress report was helpful but on the wrong day

Participants liked the weekly progress report they received from me via email on Mondays. The attached graph with the weekly weight loss trend was rewarding and motivating, and gave a better overview of the progress.

> *"It was good to actually see it there, you know. […] the majority of the time it was losses I was having so it was like what I aim to do I seem to be achieving." (Female, 49)*

However, a major issue was the timing of the progress report. Weight gains over the weekend upset the participants' weekly trends, causing more negative feedback than necessary. In future trials, progress reporting should therefore be done towards the end of the week, not at the start.

> *"I really had a very definite trend which is drop, drop, drop, ping up at the weekend. It always made […] my weight loss look much flatter than it was." (Female, 45)*

6.4.4.4.5 Reflection and evaluation enabled identification of useful actions in the first weeks of the study

Insight into which actions were effective was enabled by reflecting on weight loss progress. Some participants also considered how feasible actions were and whether they had made a difference to behaviour in order to decide which actions worked for them.

> *"Weighing myself daily plus knowing what I had done the day before and was doing that day, I think it actually made me realise what worked instead of just going I think that worked or I think that worked. It was actually, there were facts to back it up so to speak." (Male, 26)*

As participants went through the programme, they started to combine weight loss actions that they had found to be useful. By doing this, they built up a set of actions that they continuously performed every day. This allowed them to build new and healthy habits.

"It was interesting how it helped me to build, the doing, performing the actions had helped me build habits into my life and because I'd seen a positive change I felt quite positive about continuing with those habits."
(Female, 31)

Since they increasingly stuck to the weight loss actions they had identified as useful, participants found it more and more unnecessary to reflect and evaluate. Therefore, the value of the reflection and evaluation task reduced over time. This might also explain why adherence to the evaluation task was the lowest at 70.4%.

"Once I'd established what, what was working, yeah, it didn't seem like I needed to reflect so much." (Male, 57)

6.4.4.4.6 The intervention was a "good start to weight loss"

Having identified their set of tools, participants expressed wanting to continue with these new behaviours to achieve further weight loss. In this context, the intervention was described as a good starter to the weight loss journey.

"It is very easy, structured [um] it's a good way of starting your way into weight loss if you really want to do it. It's, it's a great beginning" (Female, 33)

6.4.4.4.7 Overall barriers and unmet needs

One of the main barriers to following the intervention was social life and leisure time. Participants expressed that, especially on weekends, they often felt their food consumption was out of their control. They struggled to forgo fun activities in order to follow their diet.

"You've got to live and I've got a family and I've got friends and I want to do nice things and I don't want to have to say no all the time."
(Female, 45)

"At the weekend when I'm going to a friend's anything could happen, you know. And I'd feel that I wasn't in control." (Female, 72)

The same feeling of being out of control also applied to travelling, which was common as the study took place over the summer holiday period.

> *"It was to do with being travelling and away and not in a, not in a controllable environment." (Female, 60)*

Another barrier related to simply forgetting to perform planned actions. This was usually because participants were busy and lost focus.

> *"I was just forgetful I had stuff on and forgot that I was supposed to be mindful while I was eating my food or whatever because I was just hungry." (Female, 31)*

Although many participants felt like they got into a routine with the study tasks, a few struggled with managing the multiple aspects of the programme and would have liked something simpler.

> *"For me it was just a little bit too complicated […] just less, generally less things." (Female, 51)*

A couple of participants mentioned that they would have appreciated the opportunity to reflect on the feasibility and experience of performing planned actions on a daily basis. They envisaged this could be combined with the daily action planning task.

> *"Being able to think about why that action that I performed was successful I think could have been really helpful with thinking about how to make other actions that are similar successful in that way. Or for me being able to reflect on 'Oh yeah that was actually quite good maybe I'll, maybe I should carry that one on.'" (Female, 31)*

Participants felt responsible to the study and wanted the research to go well. While this is not necessarily a barrier to the intervention throughout the study period, it might affect how well participants carry on with their new habits after the study is over.

> *"You don't want to let the person down who's giving you a chance to get your wellbeing and it's, and I want your research to go well." (Male, 48)*

6.5 Discussion

6.5.1 Principal results

Participants in the PREVAIL intervention group lost significantly more weight than participants in the daily weighing group. Similar to previous studies[175], control group participants in this study lost on average 1kg. Adherence in both conditions was high and did not differ between groups. Adherence was an independent, positive predictor of weight loss, but did not mediate the intervention's effectiveness. On average, participants in the PREVAIL group rated the intervention favourably, which was reflected in positive comments about the interventions' success and the usefulness of its components in the interviews. Participants specifically highlighted that the intervention had allowed them to identify their personal set of effective weight loss actions and take control over their weight loss progress. The interviews revealed that temptations during social and leisure time activities, as well as frustration with weight measurements, were barriers to the intervention's success. The higher participants rated the intervention in the final questionnaire, the better their weight loss was at 8-week follow-up.

6.5.2 Self-regulation is effective for weight loss

The results of this trial provided first evidence that the iterative, daily self-regulation approach taken by the PREVAIL intervention can lead to significant weight loss. Indeed, the weight loss effect I detected for the intervention was of similar size as the one found in a 12-week-long trial for the Weight Watchers programme (4.43kg weight loss, SD=4.3)[109]. The results of the PREVAIL trial are therefore in line with previous studies employing self-regulation components in their interventions and finding significant weight loss effects[108, 128, 131, 160, 226, 227, 229, 233]. Since the PREVAIL

intervention employed components addressing all hypothesised processes of self-regulation theory, and because I kept additional aspects to a minimum, the results of this trial also provide evidence for the value of self-regulation theory for weight loss.

Viewed in context with the think-aloud study, the PREVAIL trial results underline the importance of guiding users through the self-regulation approach, as not every individual seems likely to complete all steps by themselves. The importance of guiding individuals is also in line with findings of a meta-regression by Michie and colleagues, which assessed the self-regulation strategies employed in diet and physical activity interventions. They found that interventions combining self-monitoring with at least one other component of the self-regulatory cycle, including goal setting, specific action planning, feedback on the effect of actions and the evaluation of actions, were significantly more effective[246]. Similarly, a meta-analysis on the effectiveness of monitoring goal progress found that larger effects were elicited when the technique was combined with the explicit goal setting, feedback on goal progress and the planning of actions[143]. In combination, these studies show that self-monitoring techniques should be provided in context with other self-regulation components in order to elicit the full potential of self-regulation.

The mediation analysis showed no evidence that adherence to the intervention tasks mediated the effect on weight loss, which could be interpreted such that self-regulation did not drive the weight loss effect. However, I would argue that the null-effect is rather attributable to the fact that adherence assessed different tasks in the control and intervention arm. To properly test whether the intervention leads to weight loss success by facilitating performance of self-regulation, adherence to all self-regulation steps would have had to been measured in both groups. However, in the control group,

the only variable I could measure was adherence to self-weighing. A previous study has shown that self-weighing on its own does not lead to complete self-regulation [149]. Hence, self-weighing adherence in this study was likely not a good indicator of whether individuals actually performed self-regulation. Thus, the data should not be interpreted as showing that self-regulatory activities do not explain the success of the PREVAIL intervention. In support of this, adherence to the self-regulation steps in the intervention arm was still associated with weight loss success. I found that adherence to self-weighing was a significant predictor of weight loss success in the control arm too, and this matches other observational data [127, 133, 134], showing an association between frequency of self-weighing and weight loss. Adherence to self-weighing may hence reflect persistence in weight loss efforts.

In the secondary analysis, I found that participants who rated the intervention as more useful, were more successful at losing weight. The directionality of this effect is, however, unclear. Did participants who expected the intervention to be more useful engage more in intervention tasks and hence achieve more weight loss, or did they rate the intervention as more useful after they had been successful throughout the intervention period? Since I asked participants about the usefulness of the intervention at the end of the trial, the latter seems more likely. However, further research is needed to disentangle the directionality of the effect.

6.5.3 Action planning was key to weight loss success

The PREVAIL intervention rigorously guided participants through specific action planning. As hypothesised, this led to the implementation of weight loss behaviours and resulted in weight loss effects. The qualitative analysis showed that the combination of self-weighing and action planning led to a constructive use of weight measurements, as participants

put their weight into context with behaviour changes and used it to reflect on and evaluate their actions. The participants hence engaged in active self-regulation, using a feedback loop to experiment with and reinforce successful weight loss behaviours.

A novel aspect of the PREVAIL intervention was the daily frequency of action planning. Typically, weight loss studies including an action planning component help participants create one action plan for the whole duration of the intervention[227-229], or even dictate which actions are to be performed[227, 232, 233]. Few allow for the iterative reformulation of personally chosen action plans, and when they do, the action plans are usually set for at least a week at a time[160, 237]. Planning the actions daily was feasible, acceptable and seemed beneficial to participants. The adherence to action planning was nearly 80% and action planning had the highest rating of all intervention components at 8.1/10 points. Daily planning allowed participants to adapt their action flexibly to the schedule of their day and many participants indicated that they felt a heightened sense of commitment to the weight loss effort due to this daily refocussing. Arguably, this will have also increased goal ownership, a significant predictor of goal engagement and attrition[206, 234]. By dividing actions into categories and asking participants to stick to one category per week, participants were able to evaluate the effectiveness of actions on the basis of weekly weight trends, thus overcoming the problem of daily fluctuations. The resulting balance between daily flexibility and weekly evaluation seems to have proven successful for most participants.

The trial foresaw eight weeks of experimentation. However, I only provided participants with seven action categories and participants typically did not find all actions relevant, thereby further reducing their choices. It is thus not surprising that some participants completed experimentation before the end of the eight weeks. Some

participants indicated that the weekly evaluation task reduced in value after experimentation was completed. Further development of the PREVAIL intervention may explore whether allowing participants to enter into a post-experimentation phase, in which they continue to plan daily actions, but do not have to evaluate actions on a weekly basis and can switch between categories day-to-day, might be a better strategy.

6.5.4 Barriers to the PREVAIL intervention

In Chapter 1, I discussed how the obesogenic environment makes it difficult for individuals to consistently stick to their weight loss behaviour goals and break unhealthy habits. Those participants who successfully lost weight in the PREVAIL trial therefore showed strong self-control skills. However, it is also worthwhile discussing those participants who followed the self-regulation approach and did not lose weight successfully. What hindered them? In my qualitative analysis, some of the participants who were less successful conceded that they had not tried their hardest. I also identified barriers to self-regulation. For one, participants reported that external circumstances, such as holidays or leisure time activities with friends or family, created temptations or hindered the performance of planned actions. Indeed, previous research shows that holidays are consistently linked to weight gain[247, 248]. Moreover, other qualitative research has also found that the social circumstances of food consumption can constitute a barrier to healthy eating[249, 250]. Potentially, participants who did not successfully lose weight in the PREVAIL trial encountered more of these hindering events or were not able to overcome them. It is conceivable that the provision of social support could prove useful in these contexts. When an individual follows a weight loss programme together with close others, it should be easier for the group to forgo temptations during joint social activities, as they share a common goal and can hold each other accountable,

thereby potentially changing social norms[251]. Indeed, it is found that when individuals start a weight loss programme together with friends or family, they are more likely to complete the programme and achieve greater weight loss[252, 253]. Even social support from strangers has shown to increase weight loss effects[254, 255]. There thus seems to be a general beneficial effect of receiving support, which enables individuals to engage in more self-control.

Other barriers I identified were problems dealing with frustrating weight measurements or inexplicable weight changes. Statements relating to these barriers were less prominent than in the think-aloud study. Nonetheless, these findings still replicate the results of the think-aloud study and Withings analysis and thus align themselves with the literature discussed in the previous chapters. I will discuss potential approaches to these issues in the implications section of Chapter 7.

One of my participants in the trial explicitly stated that having to confront her weight was counterproductive, as she struggled with mental health issues related to her weight and emotional eating. This fits with research I highlighted in Chapter 1, which shows that ineffective emotion regulation may cause a vicious circle to form, leading to further weight gain[70, 75]. This indicates that some individuals may require interventions tackling deeper psychological issues and causes of obesity, rather than just implementing superficial behaviour change. Combining self-regulation with cognitive behavioural therapy may be a suitable and effective approach in these cases[256, 257].

6.5.5 Potential effects on self-efficacy and locus of control

Participants were excited to have identified a set of weight loss actions that worked for them. They felt confident to be able to achieve further weight loss by continuing with these actions. I would argue that these findings reflect an increase in self-efficacy. Self-

efficacy refers to a person's belief in being able to achieve a certain outcome[258]. The concept has been widely examined in the context of health behaviours and is repeatedly found to be a significant predictor of successful behaviour change[259]. Research has shown that self-efficacy can be increased through experiences of success[258, 259], which my participants had since they identified which weight loss actions worked successfully for them. A meta-analysis examining the relationship between behaviour change techniques (BCTs) and self-efficacy in the context of physical activity interventions in individuals with obesity found that the techniques "action planning", "time management", "prompt self-monitoring of behavioural outcome", and "plan social support/social change" were all significantly associated with increases in self-efficacy[260]. In the PREVAIL intervention, participants were prompted to self-monitor their weight and plan weight loss actions every day, which also required them to manage their time. Hence, the PREVAIL intervention arguably covered three of the four BCTs associated with increases in self-efficacy. A next phase RCT could explore whether self-efficacy mediates the interventions' effectiveness.

Participants took active control of their weight loss progress, which was also reflected in their comments on feeling focussed and more in control. This suggests that the intervention increased participant's internal locus of control, a psychological construct describing a person's belief that their own actions can affect changes for a given outcome[259]. An internal locus of control for health behaviours has repeatedly been associated with better weight loss outcomes[261, 262]. Links between the PREVAIL intervention and locus of control could also be further explored in a next phase RCT.

6.5.6 Strengths and limitations

This trial provides first evidence for the early effectiveness of the PREVAIL intervention. The randomised controlled trial followed best practice standards and is therefore a trustworthy source of evidence. Nearly 40% of the participants in this trial were male, which is a higher proportion than typically present in weight loss studies[263]. Moreover, follow-up in both groups was very high, at 98%. The follow-up interviews were conducted with more than a third of the intervention participants, and the spread in adherence rates, weight loss success and intervention rating ensured that a variety of experiences was analysed.

The main limitation to this trial is that the follow-up was only two months and did not include a post-intervention maintenance phase. Furthermore, a sample size of 100 participants, even though sufficient to detect an effect, was small for a randomised controlled trial. A longer-term and larger trial is therefore needed to properly assess the value of the PREVAIL intervention for the treatment of obesity.

Another limitation is that I conducted all aspects of the study myself, apart from creating the randomisation sequence. Because of that, I was the only person to be in touch with participants throughout the study, which might have created an increased sense of accountability. Indeed, in the follow-up interviews, participants expressed that they wanted to do well for the research and for me. However, since I was the sole contact of participants in both groups, it is unlikely that this drove the weight loss effect found in the primary analyses. Nonetheless, this circumstance might have affected participants' responses in the follow-up interviews, as participants might have aimed to please me with their comments about the intervention. To try to prevent this kind of bias, I made it clear to participants that the PREVAIL intervention was in its early testing stages, and

their honest feedback would be appreciated as it would help me to improve the intervention for the future. Another issue created by being the sole researcher conducting the study was that I was not blinded to condition during the qualitative and quantitative analysis. I further discuss these issues in my reflexivity statement in Chapter 7.

I was initially worried that participants in the control group might quickly realise they were in the 'placebo' group. However, the probing questions at the end of the follow-up meeting indicated that 82 participants were unaware of the aim of the study, indicating that blinding was achieved for most participants.

At the follow-up interviews, some of the intervention group participants stated that they did not want to track weight measurements in the weight tracking app when these were going to have a negative effect on their weight loss trend. This is in line with my own assumptions from the Withings analysis (Chapter 3), where I purposefully selected users who automatically synchronised their weight measurements to the Withings Health Mate app, in order to overcome potential biases due to selective tracking. The finding is of relevance here as it could mean that my adherence measures for self-weighing in the intervention group are biased. However, since I pooled information from both the weight tracking app and the daily questionnaires to assess adherence to daily weighing, I hope I was able to overcome this issue. Nonetheless, there is a small risk that participants also did not fill out the daily questionnaire when they wanted to avoid entering frustrating weight measurements, thus leading to an underestimation of self-weighing adherence.

In section 6.5.2, I mention that, as the PREVAIL intervention is based on self-regulation theory, this trial allowed me to test the effectiveness of the theory for weight

loss. However, the delivery method of the intervention components arguably introduced some additional BCTs, potentially diluting clean effects. For instance, in order to enable participants to reflect on the effectiveness of their weight loss actions once a week, I needed to provide them with an overview of their weight loss trend. Since the weight tracking app did not have such functionality and I did not have enough budget to create a weight tracking app with this feature, I decided to calculate weekly weight trends myself and provide them to participants via email. By doing this, however, I reminded participants every week that someone was monitoring their progress. Research shows that this can increase the effectiveness of self-monitoring[143]. Furthermore, the email gave feedback on the participant's progress, by e.g. stating "that's great progress" whenever participants lost weight. It is found that providing external feedback on progress can improve weight loss outcomes[142], potentially because verbal praise increases intrinsic motivation[264]. The weekly feedback is therefore arguably also a behaviour change technique. Generally, the weekly contact via email and the two phone calls throughout the intervention period may have reinforced feelings of accountability discussed above. However, since these additional aspects were arguably only minor, the results of this trial still provide support to the notion that self-regulation programmes based on self-regulation theory can produce effective results for weight loss.

A final limitation is that the sample was quite homogenous in terms of educational status and ethnicity, reducing generalisability to the general population. However, education had no moderating effect, thus indicating that the intervention effect was independent of educational background. Nonetheless, I further discuss the generalisability issue in the limitations section of Chapter 7.

6.5.7 Next steps

The next step is to test the long-term effectiveness of the PREVAIL intervention in a larger randomised controlled trial, using a more heterogeneous sample. Throughout the results and discussion sections of this chapter, I have identified several opportunities for minor changes to the PREVAIL approach, which could be implemented in a next-stage trial. For instance, the daily action planning task could incorporate a daily reflection task, allowing users to evaluate the feasibility and usefulness of performed weight loss actions. Moreover, it could be tested whether providing feedback on weight loss progress on Fridays leads to more satisfaction with weight loss trends. A post-experimentation phase could also be included, prompting individuals to continue with effective weight loss actions. Finally, a larger RCT could assess the directionality of the intervention rating effect found in the present study, as well as potential mediating effects of the concepts self-efficacy and locus of control.

The self-regulation approach has the advantage that it can be delivered as a remote self-help intervention. Considering the prevalence of obesity, there is a strong need for more scalable weight loss solutions which can be self-managed by the individual[107]. The self-regulation approach can therefore be used to address an important need in society. As mentioned in Chapter 5, one could create a mobile app which incorporated the PREVAIL intervention components, including weight and weight trend tracking, action planning and reflection/evaluation. A web-based randomised controlled trial could test the mobile app against unsupported daily weighing. As well as making the intervention scalable, the app delivery format would also minimise the researchers' contact with participants and could therefore provide an even better opportunity to test the value of

self-regulation theory for weight loss. If successful, this self-help, self-regulation intervention could be made publicly available.

6.6 Conclusion

This trial provided evidence for the early effectiveness of the PREVAIL intervention, supporting the idea that helping people perform self-regulation is effective for weight loss. The positive evaluation of the intervention and high adherence rates showed that this approach is both feasible and acceptable to participants. Investigation of long-term effectiveness of the PREVAIL intervention is warranted. A longer-term and larger randomised controlled trial could further help alleviate biases and address research questions raised by my findings.

Chapter 7 Discussion

7.1 Summary

Here, I summarise and discuss the main findings of my DPhil research. I present how the results of the think-aloud study, Withings analysis, and app market review culminated in the development of the PREVAIL intervention, and discuss how the findings of my four studies fit with each other and the wider literature. As strengths of this DPhil project, I highlight my multimethodological and theory-testing approach, as well as the scalability and novelty of the PREVAIL intervention. As general limitations, I discuss not having addressed the issue of lacking motivation identified in Chapter 3, as well as the limited generalisability of my findings. I reflect on potential sources of bias in my research, and discuss how I addressed them. I discuss the implications of the findings for self-regulation theory and future research. I highlight that self-regulation does not occur as naturally as assumed and make recommendations for how the self-regulation approach could be employed more effectively in future interventions.

7.2 Contributions of this thesis

In the introduction (Chapter 1), I presented literature claiming that the effectiveness of self-weighing in the context of a weight loss programme is attributable to a self-regulation process. Previous research, however, showed that daily weighing on its own is not effective for weight loss. I identified a lack of understanding of whether self-regulation occurs naturally when people weigh themselves, or whether other weight loss treatment components are necessary for this process to occur. I therefore conducted a think-aloud study (Chapter 2), in which I asked 24 individuals with obesity to weigh

themselves daily and audio-record their thoughts and feelings during weighing. The study showed that individuals mostly put their weight into context with previous measurements and reflected on previous behaviour half of the time, but rarely planned actions to advance their weight loss progress. The frequency of specific action planning, specifying a time and weight loss action, significantly predicted weight loss at eight-week follow-up. I discussed in Chapter 2 how this finding is in line with implementation intention research, which shows that forming a specific plan helps to bridge the intention-behaviour gap[159-161]. In the inductive thematic analysis of the think-aloud study, I found that participants struggled to keep an overview of their weight loss progress when weighing daily. This indicated that individuals may benefit from support in tracking their weight measurements. The analysis further revealed that weighing elicited emotional reactions in participants. When weight changes were positive, participants generally reported feeling motivated and joyful, while negative weight measurements led to feelings of guilt, shame and frustration. I showed how these emotional reactions to weighing are supported by findings from other qualitative research on self-weighing experiences[162, 163]. Feelings of frustration were especially elicited when participants in my study could not see a cause and effect relationship between their behaviour and weight changes, due to daily fluctuations. This was not helped by the fact that they struggled to take a longer-term view and see trends in their weight data. Generally, emotional reactions to negative weight measurements acted as a barrier to further self-regulation in the think-aloud study. I was interested to investigate this further – could problems dealing with negative weight changes be a cause for stopping self-weighing and weight loss efforts?

In the introduction, I showed that there is a lack of knowledge about why people stop monitoring their weight. I therefore analysed patterns in the weight and physical activity data of 1605 users of the Withings Health Mate app, before these users stopped tracking their weight for at least six weeks (Chapter 3). The results showed that users gain weight and reduce their physical activity and physical activity tracking frequency before they stop tracking their weight. Since these effects occurred concurrently, the findings pointed to two mechanisms. On the one side, the findings indicated that users engaged in less weight loss efforts, and wanted to avoid seeing resulting negative weight changes. On the other side, the findings also indicated that in light of receiving negative weight feedback, users lost the motivation to continue with their weight loss efforts and thus reduced physical activity. The latter explanation is in line with my hypothesis based on the think-aloud study findings: individuals may struggle with making constructive use of negative weight feedback and therefore give up on their weight loss attempt. Either way, the results match other findings in the literature, indicating that when people expect negative feedback, they stop monitoring the outcome, which has been termed the 'Ostrich Problem'[200, 201]. Taken together, the findings therefore indicated that some people may benefit from receiving support in making constructive use of negative weight feedback.

I also discussed the findings of the Withings analysis in context with the 'response to failure' model[208], which posits that when negative weight changes are not attributable to controllable causes, and the individual does not feel guilt or regret, their motivation for weight loss efforts declines. Since the think-aloud study indicated that inexplicable negative weight changes lead to feelings of frustration, and the Withings analysis revealed a decline in weight loss motivation following weight gain, the

combination of the two studies fits well with the assumptions of the model. Further support is provided by observational research, showing that greater fluctuations in day-to-day weight measurements are associated with less weight loss success[166]. Since daily fluctuations thus seem to be a barrier to self-regulation, the findings suggest that individuals could benefit from support in overcoming daily fluctuations and focussing on trends in their weight data.

Given the results of the think-aloud study and Withings analysis, as well as my review of existing self-regulation interventions (Chapter 5), which showed that these weight loss programmes do not optimally harness the potential of the self-regulation strategy, I decided to develop a new weight loss intervention, PREVAIL, to support individuals through the self-regulation process. This included guiding individuals through self-weighing, weight tracking, the planning of weight loss actions, and the evaluation of the usefulness of said actions. Previous research showed that electronic approaches are more effective when it comes to self-monitoring[142, 145]. I therefore decided to use a mobile app for the weight tracking component. To identify what users like and dislike about existing weight tracking apps, I qualitatively analysed user reviews from 15 apps on the Google Play Store (Chapter 4). I found that users gained motivation from seeing their weight loss progress in the form of a graph. They also rated it a prerequisite that the app functions smoothly. Through the app market review, I discovered a weight tracking app that was very popular and fulfilled all requirements. I therefore used this app for the weight tracking component of the PREVAIL intervention. In order to foster constructive use of negative weight measurements, I decided that the intervention should guide individuals through a reflection task and frame self-regulation as a process of

experimentation. In order to help individuals overcome issues with daily fluctuations in their weight, I set the reflection task to a weekly frequency.

In Chapter 6, I described the methods and results of an eight-week randomised controlled trial testing the early effectiveness of the PREVAIL intervention against daily weighing. I found that participants in the PREVAIL intervention group lost 3.2kg more than those in the control group. Intervention ratings and follow-up interviews revealed that users of the intervention found the tasks feasible and acceptable. Daily action planning was the highest rated individual component in terms of usefulness, showing that this new action planning frequency made sense to participants. In combination, the findings indicated that the PREVAIL intervention constitutes a promising weight loss programme which warrants further testing over a longer period. In context with my previous studies, the PREVAIL trial also showed that guiding people through self-regulation beyond just self-monitoring of weight is necessary to elicit the full benefits for weight loss. In Chapter 6, I discussed how this last point is in line with other research, finding that the effectiveness of self-monitoring is boosted when the technique is combined with other self-regulation components[143, 265].

The thematic analysis of the PREVAIL trial replicated and thus supported findings from previous chapters. With regards to the weight tracking component, the PREVAIL trial also showed that participants found the graphical visualisation of their weight loss progress motivating. Moreover, PREVAIL replicated the finding of the app market review that people appreciate ease and simplicity in a weight tracking tool. In the think-aloud study, there were several participants who disliked the daily weighing frequency, as they found daily weight fluctuations irritating and experienced negative emotional reactions to their weight measurements. These findings were replicated in the PREVAIL study,

although to a lesser extent. By implementing evaluation on a weekly frequency, I might have reduced issues with daily fluctuations hindering reflection. Nonetheless, concerns about weight fluctuations persisted to some degree in the PREVAIL trial, despite the instructed focus on weekly weight trends, rather than daily measurements. It hence seems that some people struggled taking this long-term view. The finding that emotional reactions to daily weight changes persisted could be explained by the fact that basic emotions are elicited through an automatic appraisal system[266], so the instructed long-term focus may not have prevented feelings of anger or sadness. Furthermore, when emotional reactions were linked to the weight itself, and not a change in weight, focusing on long-term trends may have been irrelevant. Further research is needed to explore how these barriers to self-regulation could be addressed (see section 7.5.2).

The think-aloud study indicated that specific action planning may be the key aspect of self-regulation, since it was the only component to be significantly associated with weight loss. Guiding participants through this process raised the occurrence of action planning from 20% in the think-aloud study to 80% in the PREVAIL intervention. Participants of the PREVAIL intervention reported that the experimentation with different weight loss approaches in combination with feedback from the scales allowed them to identify which weight loss tools were effective for them. In contrast, participants in the think-aloud study did not comment on learning much from putting behaviour and weight change into context. The daily action planning therefore seems to have enabled participants of the PREVAIL intervention to better interpret weight changes, by providing them with a focus for their reflection.

7.3 Strengths and limitations

In the following paragraphs, I would like to address overall strengths and limitations of the work presented in this thesis. Strengths and limitations of specific studies were discussed in their respective chapters.

7.3.1 Strengths

To the best of my knowledge, PREVAIL was the first intervention to employ iterative self-regulation with daily action planning. I chose to develop a self-regulation intervention, as I wanted to support individuals in succeeding with their weight loss attempts despite the obesogenic environment. An advantage of the self-regulation approach is that it has the potential to translate into a self-help intervention, which individuals with obesity could follow without intensive support. Such an intervention would be more scalable and potentially cheaper than labour-intensive, and current gold standard treatments, such as Weight Watchers or Slimming World.

Another strength of my work is that I examined the self-regulation approach from multiple angles, using both experimental and real-world data and employing qualitative and quantitative methods. My studies replicated each other's findings, thus strengthening my conclusions. Since the PREVAIL development was based on the findings of my previous studies, it pre-emptively addressed several barriers to self-regulation.

A final strength of my DPhil work is that the PREVAIL intervention is based on self-regulation theory. Several researchers have called for intervention development to be more theory-based[267-269]. Research on theory usage has shown that up to 89% of all health behaviour change interventions are not based on theory, and of those that are, many do not fully apply it or add components that do not align with the theory[270]. Moreover, Noar and Zimmermann made the important point that assumptions of

theories are seldom tested[269]. While it is unclear whether theory-based interventions are actually more effective than non-theory-based interventions, this issue leads to the problem that results from such interventions cannot be used to refine and improve the theory at hand[270, 271]. With the work presented in this thesis, I aimed to counter this situation. I designed an intervention incorporating all components of self-regulation theory and keeping the use of unrelated behaviour change techniques to a minimum. The trial results therefore provide evidence for the effectiveness of not only the PREVAIL intervention, but also self-regulation theory for weight loss. Furthermore, having tested assumptions of the theories, my studies have several implications for self-regulation and control theory, which I will discuss in section 7.5.1.

7.3.2 Limitations

One of the strengths I highlighted is that the PREVAIL intervention pre-emptively addressed barriers to self-regulation. However, one barrier I identified and did not address directly, is the drop in motivation for weight loss efforts observed in the Withings analysis. I assumed that the loss in motivation might have been caused by problems with making constructive use of frustrating weight measurements. This I aimed to address by guiding individuals through constructive reflection and evaluation on a weekly basis in PREVAIL. I considered incorporating specific motivational components in the intervention, but decided against this, because I did not want to add components which could wash out the stand-alone effect of self-regulation I was trying to evaluate. Also, adding more components would have increased the burden of the intervention, which was already considerable given the number of tasks participants were asked to complete. Interestingly, even though none of the components specifically addressed motivation, participants following the PREVAIL intervention expressed that they felt the programme

motivated them to engage time and effort into their weight loss. As discussed in Chapter 6, the verbal feedback I provided on a weekly basis might have had such a motivational side-effect. Hence, the PREVAIL intervention might have incorporated more motivation-enhancing aspects than intended. In section 7.5.2 on implications for research, I discuss further ideas on how to tackle signs of declining motivation.

One general limitation of both the think-aloud study and the PREVAIL trial is that the generalisability of results is restricted. Both studies were conducted in the same city, and overrepresented highly educated people, indicating high socio-economic status[35]. The self-regulatory approach relies on executive functions such as self-control and reflection. Studies have found that individuals with a lower socio-economic status tend to score lower on executive function tests than individuals with a higher SES[272-274]. Moreover, higher educational achievement has also been directly linked to better executive functioning skills[178-181]. Hence, my sample of highly educated people might have overrepresented individuals who were more likely to benefit from the self-regulation approach. The obesity prevalence in high-income countries is higher in groups of low socio-economic status[9, 10], and these groups are less likely to receive or access weight loss programmes in the first place[275, 276]. Differences in treatment effects would therefore further exacerbate disparities in obesity burden. Interestingly, the PREVAIL trial did not find evidence of a difference in effect by educational status. This is in line with other trials testing self-regulation strategies[160, 226, 228]. The findings thus indicate that education and, by proxy, socio-economic status may play a less important role in a person's self-regulation skills than the literature on executive control may suggest. However, due to the restricted variability in educational levels, I could only compare individuals with a university degree against individuals without a university

degree. A larger RCT, with a focus on broadening exposure across different SES and educational achievement groups, is therefore necessary to properly test for differences in treatment effects of the PREVAIL intervention.

The generalisability limitation also extends to the Withings analysis and app market review. Although the analyses covered a larger sample, which was spread across different countries, there may have been limited SES representation, as the purchase of expensive and non-essential devices such as smart scales, physical activity trackers and smartphones may not be affordable for individuals of low-income backgrounds. Indeed, statistics from 2019 show that the proportion of high-income people owning a smart watch or fitness tracker in the US is double that of people from low-income backgrounds[277]. Nonetheless, at the time of my app market review, more than half of the UK's and US' low SES population used a smartphone[278, 279]. It is therefore possible that my sample for the review included some breadth in socioeconomic status, even though there might have been an overrepresentation of individuals of middle or high SES. Access to smartphones is constantly rising. In the UK, smartphone usage in low SES groups increased from roughly 40% in 2012 to 67% in 2018[278]. Assuming that this trend will continue, future studies using data collected through smartphones may be less affected by this limitation. Whether this positive development will also extend to other luxury products, such as smart scales or physical activity trackers, remains, however, questionable.

7.4 Reflexivity statement

I would like to use this opportunity to reflect on how outcomes of the studies presented in this thesis might be biased, and what I did to improve the validity and credibility of my

results. I would argue that for the objectively measured outcomes, such as weight, risk of bias is low. The scales I used in the think-aloud study and PREVAIL trial were calibrated and measurements took place on a hard, wooden or linoleum surface. Even though the times of measurements ranged from morning to evening for both baseline and follow-up meetings, these differences constitute random error and are unlikely to introduce a systematic bias. In the Withings analysis, I only included synchronised data from smart scales and step trackers. The data was therefore also objectively measured, decreasing risk of bias.

The Withings and app market review analyses both used data from individuals who were unaware that they were taking part in research. Typical biases, such as demand characteristics[280] or the Hawthorne effect[211], can therefore be ruled out. In contrast, in the think-aloud study and PREVAIL trial, participants knew that they were being observed and that the aim of the studies was to foster weight loss. Moreover, I was the sole contact for participants and across the several meetings and phone calls, participants may have developed a more personal connection and sense of responsibility to me. These factors might have created demand characteristics such that participants might have changed their responses in questionnaires and interviews to please my hypotheses that weighing and self-regulation are helpful for weight loss. To counter this, I aimed to achieve "empathic neutrality" in both studies[281], meaning that I told participants that I was interested in their personal experiences, that there was no right or wrong, and that it was unclear whether self-weighing or the self-regulation techniques were effective, and I therefore relied on their honest responses to evaluate and improve these approaches. Trustworthiness in the results is increased by the fact that the findings of the covert observational Withings and app market review analyses supported some of

the results of the think-aloud study and the PREVAIL trial. This triangulation across different methodologies and settings is indeed a recommended strategy to enhance credibility[281].

With specific focus on my qualitative research, bias may have been introduced through observer effects, inconsistent methods (i.e., instrumentation bias), my own expectations, biases and subjective perceptions, as well as my qualitative research competencies[281]. Observer effects are particularly relevant to the audio recordings of the think-aloud study. Participants were aware that I was going to listen to their recordings, which might have affected the content or length. I kept participants in the dark regarding my hypotheses on self-regulation theory, but it is possible that participants highlighted more thoughts and feelings than would have occurred otherwise, potentially leading to an overestimation of the occurrence rates of the different self-regulation steps. However, as discussed in Chapter 2, I would expect that such biases would affect all self-regulation components equally, and therefore not distort the relative differences. Moreover, I tried to alleviate this issue altogether by telling participants that I was interested in knowing what came to their mind during weighing, and asked them not to create more content than developed naturally.

Biases related to consistency of data collection methods apply to the interviews I ran in the think-aloud and PREVAIL trial. I created and used interview guides, which pre-specified open questions, thus increasing consistency across all interviews. As recommended in the literature on addressing instrumentation bias[282, 283], I also piloted the interviews with volunteers in the department in order to see whether the questions were effective at raising a range of insights and whether they made sense to the interviewees. Despite these precautions, the qualitative analyses may have been

affected by biases introduced by my own expectations and subjective perceptions. For instance, being the same person to develop and conduct the evaluation of the PREVAIL intervention may have led me to favour positive feedback on the intervention and dismiss criticism. Being aware of this kind of bias, I made sure to pay attention to negative cases, i.e. cases which were not in line with my expectations[281]. Moreover, in the think-aloud study, I recruited an independent second coder for parts of the analysis. Using this method of analyst triangulation[281], I was able to compare themes and check for reliability. Cronbach's alpha results showed that our qualitative analyses were very similar, thus strengthening the trustworthiness of my results. In the PREVAIL trial, I conducted all analyses by myself due to time constraints. Nonetheless, a validity check was present in both the PREVAIL and think-aloud interviews as I used a respondent validation method[284, 285]. That is, I summarised my account of the participants' responses at the end of the interviews and asked participants to honestly feedback whether this account seemed valid or whether they would like to correct or add anything. By doing so, I was able to ensure that my interpretation of participant's statements was in line with their account. Furthermore, I tried to keep true to participant's comments as much as possible throughout the analysis stages by coding verbatim and using rich quotes throughout the results sections to support my conclusions[285].

Nonetheless, it is important to note that the quality and validity of the analysis output is limited and predicted by the quality of the input. That is, while I was cautious to control for my subjective biases throughout the analysis, I am aware that the data I collected might have been biased in the first place. Biased sampling strategies, which limit the range of views represented in the analysis, are one source of such issues[284]. In the think-aloud study, all participants took part in the semi-structured interviews, thus

maximising the range of available views. For the PREVAIL trial, I used the technique of fair dealing[284]. I purposefully sampled participants with both high and low adherence, little and much weight loss, who gave good and bad ratings to the intervention. I therefore hope to have alleviated biases caused by sampling techniques. Another source of bias may be, however, the fact that as a young academic female researcher with a BMI in the healthy weight range, I differed from my participants on key variables, which might have created distance during the interviews. It is conceivable that this might have affected what participants felt comfortable sharing with me. Through open body language and my approach of empathic neutrality, I tried to overcome these biases. Nonetheless, I must acknowledge that if the study were replicated with other qualitative researchers, different feedback might be collected.

The final potential source of bias mentioned above refers to my qualitative research competencies. Since my training before this DPhil was solely quantitative, the app market review was the first piece of qualitative research I ever did, and the interviews I conducted for the think-aloud study were the first I ever ran. My qualitative research experience across the last three years has therefore been a steep learning curve. In order to prepare myself, I read textbooks on qualitative research and received one-to-one training with an experienced qualitative researcher in the department. The piloting phases of the interviews were also conducted with an experienced qualitative researcher in order to test and improve the quality of my interviewing skills. By the time I analysed real data for the thesis and interacted with participants, I had understood the fundamental basics of qualitative research. However, some of the aspects of qualitative interviewing did not come naturally to me, as I initially found it difficult not to overinterpret participants' statements or ask suggestive questions. It was the repeated

process of running interviews and conducting analyses, sometimes alongside qualitatively trained second coders, that taught me the value of good interviewing skills and enabled me to overcome these problems. I have learnt how to ask more open questions and I have trained myself in being more patient in interview settings to give participants time to formulate their answers. Taken together, my qualitative research experiences across the DPhil have allowed me to more fully understand, appreciate and conduct good quality qualitative research.

7.5 Implications for research

The research conducted in this thesis was theory-testing and provided proof-of-concept evidence for the PREVAIL intervention. Here I discuss implications for theory and future research.

7.5.1 Implications for self-regulation and control theory

Generally speaking, the findings of my studies provide support to the application of self-regulation theories to weight loss research. In the think-aloud study, I found evidence for the natural occurrence of each of the cognitive steps of the self-regulation process. Moreover, the results of the PREVAIL trial indicate that the self-regulation approach, as hypothesised by control[117] and self-regulation theory[45, 118], is effective for weight loss.

In Chapter 1, I presented the main assumptions of the two theories. The results of my studies support some of these assumptions, but negate others. For instance, the theories describe self-regulation as a natural process following self-monitoring, but my think-aloud study showed that self-regulation is not triggered by self-weighing in everyone; and the action planning component requires support in particular. From my

point of view, there are three potential explanations for this finding. First, it could be that participants did not pay proper attention to their weight measurements in the think-aloud study. This explanation seems unlikely though considering that participants were prompted to think aloud during weighing and the results show that the weight measurements evoked emotional reactions. A second explanation could be that participants were unable to interpret weight measurements and therefore the comparison to expectations step failed to trigger a discrepancy-reducing process. This argument finds some support in the think-aloud study, as participants reported difficulties interpreting daily weight changes knowing that they might be due to random fluctuations. A third reason could be that individuals were able to identify discrepancies between their current status and expectation, but did not know how to approach their weight loss attempt. This hypothesis actually aligns with self-regulation theory[45], as Kanfer and Karoly also state that individuals require the necessary skills and expertise to be able to make behaviour changes. Participants in the think-aloud study seldom planned weight loss actions, indicating that they did not have a plan for how to carry out their weight loss attempt. Moreover, in the PREVAIL trial, participants stated that experimenting with different weight loss actions taught them important lessons about which strategies worked for them. My findings thus provide support to this third hypothesis.

In the think-aloud and PREVAIL studies, participants expressed that their social life and leisure time activities hindered them from implementing weight loss actions. In control theory, this idea maps on to the disturbance component, which posits that changes in the environment can positively or negatively affect self-regulation[117]. However, control theory assumes that the disturbance component affects the outcome

of interest independently of self-regulatory behaviours. This view matches a situation in which, e.g., an individual skips breakfast, but attends a dinner with lots of high-calorie foods in the evening, leading to weight gain regardless of the successful implementation of weight loss behaviour. However, it does not explain those situations in which the individual is hindered from performing the weight loss behaviour due to disturbances in the first place. I would therefore argue that it would make sense to redefine the disturbance component as an influencer of both the outcome, as well as the behaviour. In contrast to control theory, the disturbance aspect remains completely unaddressed in Kanfer and Karoly's model of self-regulation[45]. One argument for both models, however, could be that, since individuals have many competing goals at the same time, the disturbance could be seen as a trigger of attention to another goal, for example wanting to be a social person. Actions that are performed following the disturbance would therefore be discrepancy-reducing to the goal that is most salient in the moment. As a consequence, interventions aiming to avoid the effect of disturbances would have to constantly keep the goal of losing weight at the forefront of individuals' minds.

The think-aloud study revealed that even though participants did not necessarily verbalise action plans immediately during or after weighing, participants reported feeling like the weighing influenced their actions throughout the day. It is possible that there is an active and a passive route to self-regulation. In the active route, individuals actively make plans to achieve the desired change. In the passive route, individuals are only prompted to amend behaviour when specific situations return attention to their goal of losing weight. In this context, it is important to note that I interpreted self-regulation and control theory such that the authors posit an immediate action (or at least action planning) to occur following the comparison of the current status to the reference goal. I

therefore assumed that self-regulation would be measurable immediately during or after weighing in the think-aloud study. However, neither theories are explicit about the timeliness of the process, and it is possible that the self-regulation process is more dispersed in time, with action planning occurring after some reflection or in any case later in the day, which would align with what I have termed passive self-regulation. Qualitative research may be able to address this possibility.

In the think-aloud study and PREVAIL trial, I found that dissatisfactory weight changes led to frustration and, in some cases, feelings of helplessness. The Withings analysis further revealed that these frustrating weight changes may lead to disengagement from weight loss efforts. This supports the role of the expectancy component, which is discussed for both control and self-regulation theory: when individuals expect that their planned behaviour is not going to achieve the desired change, they are hypothesised to disengage.

7.5.2 Implications for future self-regulation interventions

Since my DPhil research supports further usage of the self-regulation approach for weight loss, I would like to highlight important implications of my findings for future intervention development in this area. First and foremost, it seems important to guide individuals through the action planning component of self-regulation, as people are unlikely to complete this process by themselves. Guided action planning also allows individuals to explore a variety of weight loss actions, which they might not have encountered before and thus broadens their horizon. In combination with reflection and evaluation, it enables individuals to identify their personal set of effective weight loss tools. The daily frequency of action planning was well received as it allowed individuals to fit their plans more flexibly to their day. My findings therefore support further usage of daily action planning.

Regarding self-weighing, I would recommend employing a daily frequency, since the literature indicates that it is most effective for weight loss[137], and I found that daily weighing provides at least some individuals with extra motivation, and is quickly incorporated into a daily routine. The think-aloud study indicated that many individuals struggle to interpret day-to-day changes in their weight due to fluctuations. I would therefore recommend that reflection and evaluation tasks occur on a less frequent basis. Indeed, in the PREVAIL trial, the weekly frequency allowed participants to make more constructive use of weight feedback and resulted in fewer occurrences of complaints about fluctuations. Where daily weight measurements are available, I would recommend the reflection and evaluation task take place on the basis of weekly weight trends, which are more likely to be representative than a single weekly measurement.

When giving feedback to individuals on their weight loss progress, I would suggest choosing a day towards the end of the week, ideally Friday. It is the weekends where individuals are more likely to 'fall off the waggon', so giving them feedback before the weekend will likely reflect better weight loss trends. Moreover, receiving this feedback just before the weekend begins might help to keep up discipline throughout Saturday and Sunday, since I found that positive feedback increases motivation for further weight loss efforts.

My participants' experiences with the weight tracking component were very positive; they liked seeing their weight measurements in a graph and the tracking helped them to keep an overview of their weight loss progress. I would therefore recommend incorporating a tracking component in self-weighing-based interventions. The app market review showed that users liked to receive as much feedback on their progress as possible,

including trend lines, predictions of finish dates and weight trend calculations. Providing this additional information can be rewarding to the user and keep up motivation.

Future research may want to explore how to address the barriers to self-regulation I identified. In the PREVAIL trial, individuals were sometimes hindered in implementing their action plans due to outside disturbances, as discussed in 7.5.1. In Chapter 6, I suggested that individuals may benefit from a social support element to self-regulation interventions, as this could help overcome barriers caused by social leisure time activities. In line with this, research shows that social support elements improve adherence to and weight loss effects of interventions[252, 253].

In the PREVAIL trial, even though I asked participants to interpret weekly, and not daily weight changes, some participants still found seeing their daily weight fluctuations irritating. Future research may want to explore how this issue with daily self-weighing could be overcome. For example, it could be tested whether presenting individuals with daily calculated weight trends, based on measurements of the last 7 days and thus averaging out fluctuations, would be less frustrating. Some smart scales such as the Withings Body+ provide this information on the scales' screen[286] and could be used to test such an approach. Another barrier to daily weighing was dealing with emotions elicited by weight measurements. I initially thought that this issue could be overcome by guiding individuals through constructive reflection and evaluation on a weekly basis. Moreover, I tried to instil the idea of experimentation in participants, i.e. that lack of progress was simply an indicator of not having found the right weight loss tools yet. However, although being less of a concern in the PREVAIL trial than in the think-aloud study, some participants still struggled with this barrier. Since emotions are elicited rather automatically[266], the most useful way to overcome this barrier might be to

include training of emotion regulation strategies in self-regulation interventions[287]. One such approach may be to include a 'self-regulation writing task'. This strategy, developed by Cameron and Nicholls, asks individuals to write about distressing experiences and develop a more positive outlook by creating an in-depth understanding of the causes of and potential solutions to the situation[288]. Although not tested in the context of weight loss research, previous research indicates that this strategy may lead to more effective emotion regulation[289].

In the limitations section 7.3.2, I discussed how my findings from the Withings analysis indicate that declining motivation is a marker of impending abandonment of a weight loss attempt. Indeed, as motivation is necessary to uphold self-control, declining motivation indicates that self-regulation failure is imminent[290]. This suggests that, as researchers, we need to think about how to intervene to keep individuals on track. One option is to use a motivation-enhancing intervention, such as motivational interviewing[291, 292]. However, this kind of intervention is only going to be effective, if the measured motivational decline is not actually caused by ego depletion. Gollwitzer and Sheeran concluded in their meta-analysis on implementation intentions that individuals can get derailed from their action plans when they are overwhelmed by temptations and exhausted from exerting constant self-control[161]. Under these circumstances, normal levels of motivation are no longer sufficient to drive self-control and self-regulation failure occurs. Even though high levels of motivation may allow individuals to overcome ego-depletion for a while, this effect only lasts until the last reserves of self-control are exerted[121, 290]. Given this background, I see two additional approaches for dealing with signs of declining motivation or ego depletion. One solution might be to allow these individuals to temporarily switch to a maintenance phase, during which they stick to a

less strict regime and have a chance to replenish their self-control and motivational resources. This might also be a sensible approach when weight loss efforts are interrupted due to major, uncontrollable disturbances, e.g. when the individual suddenly befalls a family emergency. In these contexts, taking a planned break might decrease chances of complete withdrawal from the weight loss effort. Wing and colleagues found that taking prescribed breaks from a weight loss programme was not associated with reduced weight loss success[293]. Their results therefore indicate that breaks from a weight loss effort may not be harmful to overall weight loss progress, thus supporting this approach. The second option is to examine ways in which the weight loss behaviours could become less effortful, thus requiring less motivation and avoiding ego-depletion in the first place. The formation of habits might be a useful approach to this. Habits are automatic behavioural responses to environmental cues, which have become ingrained in an individual's behavioural repertoire[138]. Following habits is relatively effortless, whilst inhibiting them is effortful. Hence, weight loss behaviours should become easier to perform once they have become habits. To form new habits, behaviours have to be repeatedly performed in similar contexts. The duration of this process varies greatly between people, but can take from as little as a few weeks to several months[294]. Lally and colleagues tried to capitalise on habit formation of weight loss actions in a weight loss trial[150]. Participants were given a list of ten weight loss actions and were asked to start performing these actions daily. At the 32-week follow-up, participant's weight loss success was associated with the degree of automaticity of the new learned behaviours. Furthermore, the majority of participants indicated that performing the new weight loss actions had become habitual. Habit formation may thus be a promising strategy to avoid declining motivation and ego depletion. The question, however, remains how this could

be combined with the self-regulation approach, as the self-experimentation strategy runs counter to repetition. In the PREVAIL trial, I prompted participants to experiment with as many weight loss actions as relevant to them from a list of 53. The resulting constant changes made it difficult for habits to form. However, I found that towards the end of the study, participants stopped experimenting and repeatedly stuck to the same set of actions. In addition, I was successful in prompting participants to continue with actions they had previously evaluated as useful. In combination, the PREVAIL intervention might have supported first steps in habit formation, although the short period of the trial was probably not sufficient for proper development. It might therefore be sensible to extend self-experimentation interventions such as PREVAIL to include a habit formation phase, during which participants are asked to continuously engage with the weight loss behaviours identified throughout the experimentation phase. By reducing chances for future ego depletion, this habit formation phase might make the continuation of weight loss behaviours beyond the study period more likely.

7.6 Conclusion

Taken together, the research presented in this thesis has helped to advance the field of self-regulation in the context of weight loss management. I conclude that guiding individuals through a process of self-weighing, weight tracking, action planning and reflection is feasible, acceptable, and effective for weight loss. Being split across four studies, my research triangulated findings using different methods, samples and settings, thus strengthening the trustworthiness of my results. My findings have significant implications for self-regulation and control theory, most importantly that self-regulation does not occur as naturally after self-weighing as had been assumed. Self-regulation

components are common in weight loss research, so by providing clear pointers to further research opportunities, I hope that this thesis helps to further the development of effective interventions supporting weight loss.

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Appendices

Appendix 2.1 - Baseline questionnaire

Before we start, please enter your participant ID:

It helps our study to find out a bit more about the people who are taking part. We would be grateful if you could answer the following questions.

1. Please tell us how old you are.
2. Are you male or female?
    a. Male
    b. Female
3. How would you describe your ethnic group?
    a. White-British
    b. White-Irish
    c. White-Other
    d. White & Black Caribbean
    e. White & Black African
    f. White & Asian
    g. Mixed-Other
    h. Indian
    i. Pakistani
    j. Bangladeshi
    k. Asian-Other
    l. Black-Caribbean
    m. Black-African
    n. Black-Other
    o. Chinese
    p. Other
    q. Prefer not to say
4. What is your highest educational qualification?
    a. Degree, or equivalent, and above
    b. A-levels, vocational level 3 and above
    c. Other qualifications below 'A-level or below vocational level 3
    d. Other qualifications (e.g. foreign)
5. Are you: (you can select multiple answers)
    a. Employed
    b. Unemployed
    c. Looking after home or family
    d. Student
    e. Retired
    f. Long-term sick or disabled
    g. Other

The next questions are about your previous experiences with weighing yourself.

6. How often do you weigh yourself usually?
    a. Less than once a month
    b. Once a month
    c. Once every other week
    d. Once a week
    e. More than once a week
7. How do you feel about weighing yourself?
    a. Dislike it a great deal
    b. Dislike it somewhat
    c. Neither like nor dislike it
    d. Like it somewhat
    e. Like it a great deal
8. Do you think weighing yourself daily will help you control your weight?
    a. Definitely not
    b. Probably not
    c. I don't know
    d. Probably yes
    e. Definitely yes
9. What do you think might you find difficult about weighing yourself daily?
    a. Open text response

You have completed the baseline questionnaire. Thank you very much.

Appendix 2.2 - Semi-structured interview guide

Further spontaneous questions were asked in response to the participants' answers.

1. How would you explain your experiences in this study to a friend?
    a. Is there anything in particular that you liked?
    b. Is there anything in particular that you disliked?
2. How regularly have you weighed yourself in the last eight weeks?
    a. *If answer is once a day:*
        a. Not everyone finds it easy to remember weighing oneself daily. Do you have any tips for these people?
    b. *If answer is less than once a day:*
        a. Are there any particular reasons why you have not weighed yourself daily?
        b. Do you have any ideas about what would help you to weigh yourself every day?
        (if you did this study again)
3. Have you tracked your weight measurements throughout the eight weeks?
    a. Have you tracked anything else additionally?
4. How do you feel about weighing yourself overall?
    a. Do you think this has changed over the course of the study?
        i. *If answer is yes:* Do you have any ideas why this has changed?
5. Did weighing yourself every day present any challenges?
    a. *If any challenges are named:* Have you found any strategies to overcome these challenges in the last eight weeks?
6. How useful did you find weighing yourself daily for controlling your weight?
    a. Do you think your opinion on this has changed over the course of the study?
        i. *If answer is yes:* Do you have any ideas why you find it more/less useful now?
7. Do you think that weighing yourself daily has become a habit over the last eight weeks?

8. Do you think you will continue to weigh yourself regularly in the future?
    a. *If answer is yes:*
        i. Do you think you will continue to think aloud during weighing?
        ii. Do you think you will keep a diary or record about your weight measurements?
9. Did you do anything to try to lose weight in the last eight weeks (e.g. dieting)?
        i. *If any measure was taken*: Do you think weighing yourself daily affected this?
10. Have you been more or less physically active than usual in the last eight weeks?
    a. If yes: What do you think caused this change?
11. How much time have you spent exercising each week in the last eight weeks? (including yoga, cycling for >30 min, tennis, etc.)
12. Have you been dieting more or less than usual in the last eight weeks?
    a. If yes: What do you think caused this change?
13. What have you been doing to change your diet in the last eight weeks?
    a. Have you been doing this on a daily basis?
    b. Have you introduced any 'cheat days'?
14. We asked you to weigh yourself every day, which isn't something you normally do. And we asked you to think aloud about your thoughts and feelings. Do you think the thinking aloud bit made a difference to how you felt or thought about weighing yourself?
    a. *If yes*:
        i. In what way have your thoughts and feelings changed?
        ii. Can you give some examples of thoughts or feelings that were triggered specifically by thinking aloud during weighing?
15. Do you think knowing that someone else will hear/read your thoughts and feelings made a difference?
16. How natural has it felt for you to think aloud on the scales?
    a. Do you think this has changed over the course of the study?
        i. *If answer is yes:* Do you have any ideas why you find it more/less natural now?

17. Have you used both methods of recording your thoughts and feelings?
    a. *If answer is yes:* Which method of recording your thoughts and feelings did you find more natural?
    b. *If answer is no:*
        i. Which method did you use?
        ii. Why did you choose this method?

Appendix 3.1 - Results of GEE models

Research Question 1

Table A. Results of the GEE models testing sensitivity to the normality assumption for pre-specified analyses of RQ1.

Variable	**β**	**p**
Weight Change	0.73	<.001
Physical Activity Tracking Frequency	-3.4	<.001
Average Daily Steps	-0.22	.059
Fixed effects: time period, difference to goal weight; random effects: user ID		

Table B. Results of the GEE models testing sensitivity to the normality assumption for post-hoc analyses of RQ1.

Variable		**β**	**p**
Weight Change	TP1 to TP2	0.40	<.001
	TP1 to TP3	0.43	<.001
	TP2 to TP3	0.03	.85
Physical Activity Tracking Frequency	TP1 to TP2	-1.3	<.001
	TP1 to TP3	-2.3	<.001
	TP2 to TP3	-1.0	<.001
Average Daily Steps	TP1 to TP2	-0.18	.007
	TP1 to TP3	-0.31	<.001
	TP2 to TP3	-0.13	.014
Fixed effects: time period, difference to goal weight; random effects: user ID			

Research Question 2

Table C. Results of the GEE models testing sensitivity to the normality assumption for pre-specified analyses of RQ2.

Variable		**β**	**p**
Physical Activity Tracking Frequency	TP1 to TP2	-3.3	<.001
	TP1 to TP3	-10.0	<.001
	TP2 to TP3	-6.6	<.001
Average Daily Steps	TP1 to TP2	-0.14	.011
	TP1 to TP3	0.04	.879
	TP2 to TP3	0.18	.060
Fixed effects: time period, difference to goal weight; random effects: user ID			

Appendix 4.1 - App components codebook

Table A. Codebook with definitions of all app components.

Component	Definition
1. Save weight	Possibility to save weight measurements manually
2. Weight graph	Graph showing weight measurements over time
3. Metrics	Option to switch between metrics of measurements
4. BMI calculator	Option to calculate BMI
5. Healthy range	Information on healthy range of weight/BMI
6. Goal weight	Possibility to set a target weight
7. Historic entries	Option to enter measurements for dates in the past
8. Weight list view	List of weight measurements
9. Weight target line	Target line in the weight graph
10. Feedback goal weight	Feedback on progress to the target weight
11. Notes	Option to add notes to measurement entries
12. Export data	Option to export measurement data from the app
13. Weigh-in Time	Option to save time of weighing with the measurement
14. Save body fat	Possibility to save body fat measurements manually
15. Reminder	Option to set reminder for weighing/related behaviours
16. Weight trend line	Trend line in the weight graph
17. Average weight loss	Statistic showing average weight loss (day/week/year)
18. Body fat calculator	Option to calculate body fat percentage
19. Body fat list view	List of body fat percentage measurements over time
20. BMI list view	List of BMI measurements over time
21. Ideal weight calculator	Option to calculate ideal weight
22. Password	Possibility to set a password for the app
23. Import data	Option to import data to the app
24. Google drive synchronisation	Option for automatic synchronisation with Google Drive
25. Widget	Widget available for the app
26. Prediction target date	Predicted date of reaching target based on trend
27. Body fat graph	Graph showing body fat percentage over time
28. Save body measurements	Possibility to save body measurements manually
29. Congratulatory note	App displays congratulatory note after weight loss
30. Personalisation	Option to personalise colour/design of the app
31. Body measurements graph	Graph showing body measurements over time
32. Body measurements list view	List view of body measurements over time
33. BMI graph	Graph showing BMI over time
34. Multiuser	Possibility to use the app with several user profiles
35. Google fit synchronisation	Option for automatic synchronisation with Google Fit
36. Save muscle	Possibility to save muscle % measurements manually

Table B. Codebook with definitions of all app components (continued).

Component	Definition
37. Muscle graph	Graph showing muscle percentage over time
38. Goal BMI	Possibility to set a target for BMI
39. BMI trend line	Trend line in graph of body fat percentage over time
40. Target date	Option to set target date for goal, e.g. weight, muscle %
41. Waist-to-height ratio calculator	Option to calculate waist-to-height ratio
42. Calorie calculator	Calculates energy expenditure and ideal caloric intake
43. Activity level	Calorie calculator considers activity level of user
44. Body fat trend line	Trend line in graph of body fat percentage over time
45. Muscle list view	List of muscle percentage measurements over time
46. User-defined tracking graph	Option to track user-defined measurements, graph view
47. User-defined tracking list view	Option to track user-defined measurements, list view
48. Feedback goal BMI	Feedback on progress to the target BMI
49. Markers behaviour	Option to mark relevant behaviours, e.g. exercise
50. Smart scales synchronisation	Option for automatic synchronisation from smart scales
51. Back-up cloud	Option to back-up data in the cloud
52. Goal body fat	Possibility to set a target for body fat percentage
53. Body fat target line	Target line in graph of body fat percentage over time
54. Goal muscle	Possibility to set a target for muscle percentage
55. Muscle trend line	Trend line in graph of muscle percentage over time
56. Muscle target line	Target line in graph of muscle percentage over time
57. Goal body measurements	Possibility to set a target for body measurements
58. Body measurements trend line	Trend line in graph of body measurements over time
59. Body measurements target line	Target line in graph of body measurements over time
60. BMI target line	Target line in graph of body fat percentage over time
61. Markers in Graph	Markers included in graph of weight measurements
62. Body frame	Option to indicate size of body frame
63. Congratulatory sound	App plays jingle or sound when weight loss is achieved
64. Picture upload	Option to upload pictures, e.g. of self

Appendix 5.1 - Daily and weekly questionnaires

Questionnaire (3) – First day of all following weeks

Good morning,

We hope your weigh-in went well this morning. If you haven't weighed yourself yet, please do so before you fill out this questionnaire.

To get started, please enter your participant ID:

What was your weight this morning? If you forgot to weigh yourself, please enter NA.

Did you manage to perform your planned weight loss action yesterday?

If no: Why were you unable to perform your planned weight loss action? Will you be doing anything differently next time you choose this action?

It's time to decide which category of weight loss actions you would like to focus on this week. Please choose from the following options:

- Red: Eating in a structured way
- Orange: Avoiding or swapping specific foods
- Yellow: Changing what you drink
- Green: Creating a healthier diet
- Blue: Meal-time tactics
- Purple: Burn more calories
- Pink: Be more active as part of your daily life

Please choose a weight loss action to perform today.

-- Drop-down menu of actions— *(only the chosen category will be shown)*

Please think about how you are going to perform this action. Where and when exactly are you going to do the chosen behaviour? What kinds of strategies and tools are you going

to use to help you (e.g. reading nutrition labels, wearing a fitness tracker)? Please be as specific as possible as this will help you actually perform the action today.

What cues are you going to use to remind yourself of the task (e.g. setting a reminder on your phone)?
What might make it difficult for you to perform the action today? What will you do to overcome these problems?

The more different weight loss actions you perform on a daily basis, the better your chances of losing weight. We therefore encourage you to stick to the daily actions that you have found helpful so far in addition to the weight loss actions you are focussing on this week. Of the actions you have tried so far, please select the ones you plan to continue this week.
-- Drop-down menu of all actions— *(see above)*

Thank you for making your action plan. You can now close this tab. We hope you achieve your aims today.

Reflection & Strategy Evaluation Questionnaire

Welcome to your weekly reflection and evaluation questionnaire. You are going to return to this questionnaire every week to reflect on your activities and rate the action plans you tried out throughout the week.

To get started, please enter your participant ID:

WEEK 1:

How did your weight change over the course of this week (in kg)? Please use the cleaned weight change we've sent you in the weekly progress email. If you lost weight, put a

minus sign in front of the weight, e.g. -0.5. If you gained weight, put a plus sign in front of the number: e.g. +0.5.

Why do you think your weight went up/your weight went down/your weight stayed the same this week? *(depending on answer to last question)*

Please take a moment to evaluate the weight loss actions you focussed on this week.

Category focussed on this week: *drop-down list*

Do you think the actions you chose this week helped you to lose weight? Yes, all; Yes, some; No; Don't know

Will you reuse any of them in the future? Yes; No; Maybe

Comments (e.g. which actions in this category were especially useful?)

Below, you can find an overview of your evaluations so far. Think about which actions you want to continue doing over the course of the next week.

Table displaying summary of the evaluations so far

Thank you for completing the evaluation for week 1. Good luck starting week 2.

You can now close this tab. The system has saved your entries. You can come back to this overview any time throughout the week by clicking on the link we sent you via email. We will send you this same link again next week so you can continue with the reflection and evaluation task for week 2.

WEEK 2:

Please click on the forward button below to continue with the evaluation for week 2.

Welcome to the second week's reflection and evaluation task.

How did your weight change over the course of this week (in kg)? Please use the cleaned weight change we've sent you in the weekly progress email. If you lost weight, put a minus sign in front of the weight, e.g. -0.5. If you gained weight, put a plus sign in front of the number: e.g. +0.5.

Why do you think your weight went up/your weight went down/your weight stayed the same this week? *(depending on answer to last question)*

Please take a moment to evaluate the weight loss actions you focussed on this week.

Category focussed on this week: *drop-down list*

Do you think the actions you chose this week helped you to lose weight? Yes, all; Yes, some; No; Don't know

Will you reuse any of them in the future? Yes; No; Maybe

Comments (e.g. which actions in this category were especially useful?)

What other actions did you do throughout this week?

Below, you can find an overview of your evaluations so far. Think about which actions you want to continue doing over the course of the next week.

Table displaying summary of the first two evaluations

Thank you for completing the evaluation for week 2. Good luck starting week 3. You can now close this tab. The system has saved your entries. You can come back to this overview any time throughout the week by clicking on the link we sent you via email. We will send you this same link again next week so you can continue with the reflection and evaluation task for week 3.

Repeats for all following weeks.

End of intervention period:

Thank you for completing the final evaluation. Please click the continue button to submit all the data you have entered. We thank you for your contribution to this research.

You can now close this tab.

Study Manual

NUFFIELD DEPARTMENT OF PRIMARY CARE HEALTH SCIENCES

UNIVERSITY OF OXFORD

Funded & supported by NHS National Institute for Health Research

1

PREVAIL TRIAL MANUAL

Foreword

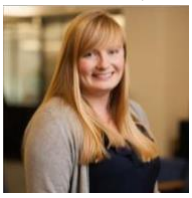
Welcome to the Prevail trial - it's great to have you onboard. Your participation helps our research, and we hope that it will help you lose weight.

Before we introduce you to the intervention, we would like to tell you about ourselves. We are four researchers at the University of Oxford who are trying to find out how to help people become more successful at losing weight:

Kerstin Frie

Kerstin studied psychology at university for four years before coming to Oxford as a researcher. For the last two years she has studied the self-regulation process. Her work has led to the development of this intervention. She will be your primary contact throughout the study.

Jamie Hartmann-Boyce



Jamie is a senior researcher at the university. Her previous research examined how people who are successful at losing weight do so. We'll be testing some of the strategies she found in this new study. Jamie has been closely involved in the intervention's development and the design of this study.

Susan Jebb

Susan is an Oxford University professor and one of the UK's leading nutrition scientists. Her research has helped show which interventions are effective in helping people to lose weight. She advises the government on food and obesity policy and appears on BBC programmes like Horizon to inform l people about diet and health.

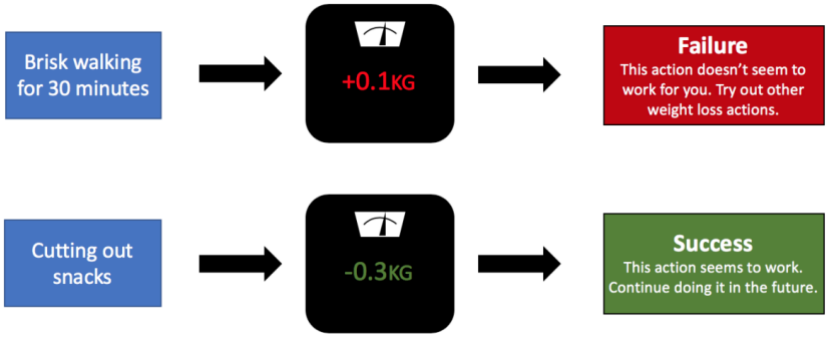
Paul Aveyard

Paul is a professor at Oxford University and a GP. His research looks at creating simple interventions that help people lose weight. As Kerstin's supervisor, Paul helped develop the intervention and design of this study. Paul appears regularly on the BBC discussing weight-related public health issues.

We have put all our knowledge into developing the intervention and hope it will help you. This manual is designed to provide all the information you'll need during your participation. If you have any questions - or get stuck at any point - please get in touch via email (prevail@phc.ox.ac.uk) or phone (01865) 289317.

The Idea Behind the Intervention

There is rarely a 'one size fits all' solution to weight loss. We know from previous research that different approaches work for different people. The idea of this study is to help you try out several weight loss actions (e.g. brisk walking or cutting out snacks) and learn from your successes and failures. It's like you're experimenting on yourself! Every time you try out a new action, you can monitor your weight and gain a clue about whether the action works for **you**. You can then use this information to decide whether you want to continue doing this action or try another. Here's an example:



Often people find a combination of actions is most effective. We will encourage you to build a set of actions that you have tested for yourself and that work for you. We call this combination of self-monitoring (i.e. weighing yourself), reflection (i.e. thinking about whether your actions led to weight change) and action-planning (i.e. choosing what actions to do next to aid weight loss) the self-regulation process.

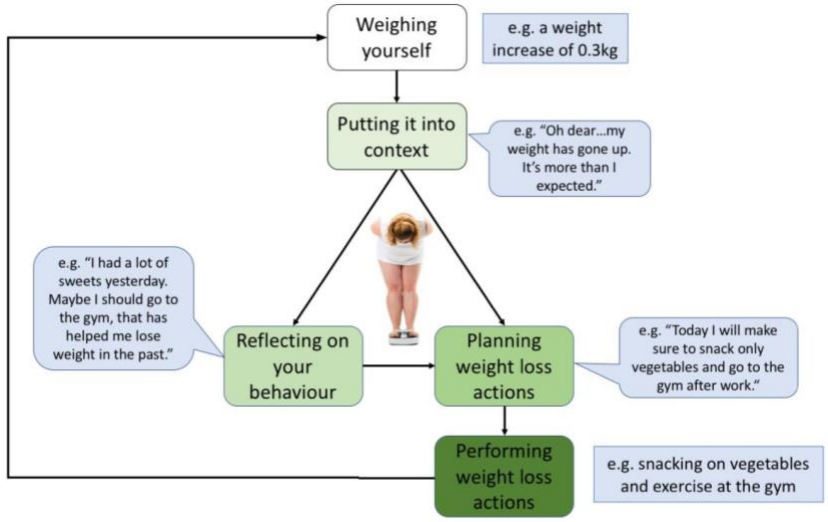
Science can tell us what works, but we often learn best from others. We've talked to many people who've adopted the self-regulation approach to help them lose weight. We'll tell you their stories throughout this manual. We call them "the successful self-regulators".

What does the self-regulation process look like?

Self-regulation is a cycle of steps that we suggest you go through to help you lose weight. It includes:

- Weighing yourself: stand on the scales and discover your current weight.
- Putting it into context: how has your weight changed since yesterday? How does where you are match up with where you want to be?
- Reflecting on your behaviour: how has what you've done in the last couple of days affected your weight? Has it helped you lose weight?
- Planning actions: what are you going to do today to lose weight?

The Self-Regulation Process:



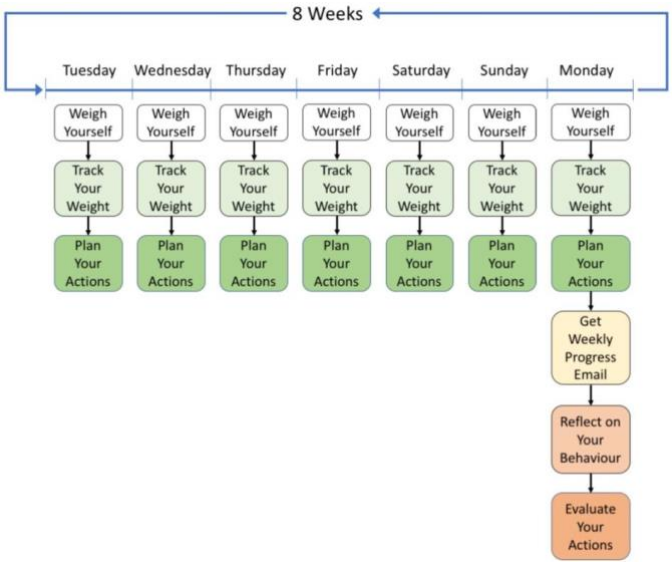
Successful self-regulators: meet Linda

Linda is 36 years old and was able to maintain a healthy weight until she had her two children (now aged 3 and 5). Kept busy by her children and her job, Linda has put on over a stone. Although she'd like to return to the weight she was in her 20's, she thinks that's not on the cards right now. For the moment, she's set herself the goal of losing 5kg for her holiday. The holiday is only 10 weeks away and Linda weighs herself every day. Today, she discovers her weight has increased by 300g – more than she had expected – prompting her to explain this weight gain. She realises that she ate lots of sweets at work yesterday, to distract her from a boring task. She has to work on this same task again today, which might cause her to eat more sweets. She therefore decides to get rid of the sweets and bring vegetables to work instead. Recalling that going to the gym helped her lose weight previously, she decides to visit the gym after work. Linda will weigh herself in the next few days to check whether her plans are working out. Stepping on the scales every day helps her focus on her goal.

How self-regulation will work for you

You will start the intervention next Tuesday. We'll ask you to weigh yourself once every day in the morning before breakfast. To support you in keeping track of your previous weight measurements, we will ask you to track your weight loss progress with a simple weight tracking phone app. We will send you a link to an online questionnaire every morning to help you plan weight loss actions for the day. Every Monday we'll send a weekly report on your weight loss progress by email with a link to an online reflection questionnaire, which will help you think back on what you did over the week that might have influenced your weight. Over time, this will build into a collection of actions that you can use to control your weight - your personal roadmap for success.

Here is a diagram of what to do on each day of the week:



Setting yourself a goal

When you self-regulate, it is key to have a goal in mind about how much weight you want to lose. Therefore, we'll ask you to decide on a weight loss goal you want to reach by the end of the study. Science shows that it's better to set a realistic, rather than an overly ambitious, goal. We suggest you choose a weight loss goal around 4kg/8lb for the next 8 weeks.

My goal is to lose:	
My goal weight is:	

1) Daily Weighing - Doing it Right

What you should know about daily weighing

Over the next eight weeks please weigh yourself once every morning. To get the most from this, please follow our advice:

- Put the scales in the right place (see box)
- Weigh yourself at the same point in your morning routine every day (see box)

The **right place** for scales

Scales work best when they are placed on an even and hard surface, such as tiles or a wooden floor. Try not to keep them on carpet. If you only have carpet at home, try to find a piece of wood or other hard surface that you can put under the scales. Whenever you move the scales, give them a chance to recalibrate. To do this, wake up the scales by tapping on them with your foot and wait for the display to return to 0.0kg before stepping on.

The **right time** to weigh yourself

When you start weighing yourself every day, you will notice that your weight can fluctuate quite a bit throughout the day and from one day to another, which often does not mean you have lost weight or gained fat. The fluctuation mostly relates to how much food or drink you've consumed, the clothes you're wearing or whether you've been to the loo. As well as that, you lose weight overnight because your body carries on burning energy (calories) but you (hopefully!) aren't eating. We are looking at small changes from day to day, so give yourself the best chance to see them. We recommend you weigh yourself each morning after visiting the toilet. If you take a shower in the morning, do this after weighing yourself. This way you'll be wearing your night clothes or nothing at all, and be in the same condition every day. Once you start eating and drinking this will affect the reading. To help you remember to weigh yourself at the same point of your morning routine every day, we ask you to set an alarm on your phone. If you forget to weigh at your usual time, don't do it later in the day. Please still complete the other steps of the intervention and set yourself an extra reminder to weigh yourself the next day.

Successful self-regulators: meet Peter

Peter is a 19-year-old university student. He read about the benefits of monitoring yourself in a magazine and wanted to try monitoring his weight. At first, he was really into it and weighed himself twice a day. He was frustrated to find that his weight went up in the evening even though he'd hardly eaten anything and sometimes he'd been to the gym too. He kept missing readings and weighed himself at random times throughout the day. Peter used a weight tracking app to record his weight, but the record made no sense. Talking to his friend Matt, he learned that his weight naturally fluctuates throughout the day and that it is therefore important to weigh yourself at the same time every day. He asked his family's permission to move the scales to his bathroom. Now the first thing he does when he wakes up is go to the toilet and then on the scales. His weight fluctuates less and Peter finds it easier to interpret his weight changes. Peter has also learned to look at the trend and does not get blown off course by small changes in his weight.

2) Daily Weight Tracking

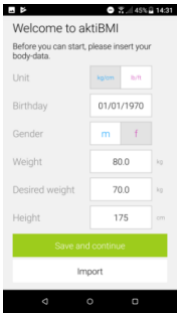
Why you should track your weight

It is easy to lose the overview of your weight measurements when you weigh yourself every day. By tracking your weight, you will be better able to put your measurements into context. This is why we advise you to use a simple weight tracking app called *Weight Loss Tracker, BMI* by AktiWir GmbH, to keep a record of your weight measurements. The app displays your weight loss progress in a graph and a list. It gives you feedback on your weight change, which can be very motivating. Here are some screenshots and explanations on how to use the app.

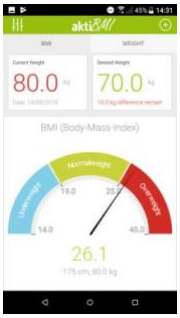
How to use the *Weight Loss Tracker, BMI* by AktiWir GmbH

The following screenshots were taken using an Android phone. The interface may look slightly different on iPhone.

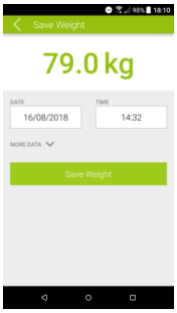
Getting started:



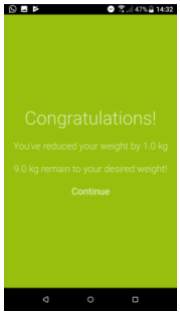
a) When you open the app for the first time, it will ask for information about yourself. After completing all fields, click on "Save and continue" to save the data.
b) The app opens the main screen, which has two tabs: *BMI* and *Weight*. The *BMI* tab shows your current weight, your desired weight and your BMI (2).



Enter a weight measurement:



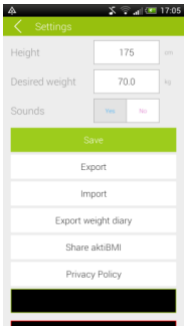
c) After weighing yourself, tap the plus symbol in the top right corner of the main screen to access the weight entry page. You can set the date, time and weight measurement (3).
d) If you have lost weight or stayed the same, the app will give feedback on how our weight has changed. When you tap the screen, the app will return to the main screen (4). If you gained weight, the app will go straight back to the main screen.



View your weight measurements in a graph or list:

d) Swiping right or tapping on the tab *Weight* will reveal a graph showing your weight measurements (5). When you scroll down within the *Weight* tab you'll find a list of all your weight measurements.

Export your data and send it to us every Monday:



e) Tap on the settings button. Scroll down to find the *Export* function (6). When you select it you should be given the opportunity to share the exported data via email. Please send it to prevail@phc.ox.ac.uk every Monday. We will remind you of this in the weekly progress email.

Successful self-regulators: meet Richard and Steve

Richard is a 46-year old plumber who is shocked to discover from his GP that his blood sugar is high. His Dad had diabetes and he doesn't want that to happen to him. His GP tells him that losing weight would help him to prevent diabetes. Richard decides to try losing weight and asks his friends for tips. His friend Steve tells him that he weighs himself every day. Richard is surprised and wants to learn more. Steve explains he uses a weight tracking app. This app helps him to keep an overview of his weight and see trends in the data. Steve explains that the trends are more important than the daily weight changes because fluctuations can be caused by other things than weight loss.
Steve tells Richard that he found weighing frustrating at first because he ate healthy foods yet his weight stayed the same. He felt judged by the scales and didn't enjoy weighing himself, which nearly made him stop. But he realised that not facing his weight would not help him either. The scales just reflected the reality and gave important information about whether his weight loss strategy was working. Now he tries to be less emotional about weighing himself and take his weight measurements as constructive feedback. He has learned that just eating healthily doesn't help him to lose weight, he must also reduce portion size. Steve tells Richard that he's learnt two really valuable things from this: 1. not to get downhearted, whatever the scales are telling you will help you in the long run, so stay positive. 2. 'Nearly always the scales are telling me something I need to know'.

3) Daily Action Planning

We will prompt you to plan a weight loss action every day to help you make progress. We have come up with a list of 53 weight loss actions that you can choose from. We have clustered them into 7 groups:

- Eating in a structured way
- Avoiding or swapping specific foods
- Changing what you drink
- Creating a healthier diet
- Meal-time tactics
- Burn more calories
- Be more active as part of your daily life

Your weight will fluctuate from day to day and the helpfulness of a weight loss action will only become apparent over time. If you switch between very different weight loss actions every day, it will be difficult for you to know which one caused the weight change. Therefore, it's best you stick to one category of actions every week so that you do similar things over a longer period of time. At the end of the week, it will be easier to judge whether the approach you have chosen helped you lose weight and whether it's something you want to keep on doing.

Weight Loss Actions Overview

Category Red: Eating in a structured way
1. Plan all meals for the day in advance (what and when)
2. Eat no more than three times
3. Skip a meal
4. No calories after 8pm
5. Check the calorie count of everything you want to eat or drink
6. Set yourself a calorie goal and stick to it
7. Have a "fasting" day with less than 800kcal
8. Keep a diary of what you eat and how you feel
9. Check your portion size
10. Only eat when sitting at a table

Category Orange: Avoiding or swapping specific foods
1. Don't eat between meals
2. Cut out crisps, biscuits, cakes and sweets
3. Cut out fried food
4. Have only one course at meal-times
5. Cut out carbs
6. Swap unhealthy snacks for fruits and vegetables
7. Swap rice/potatoes/pasta for extra vegetables
8. Use meal replacement products
9. Swap unhealthy snacks with 6-8 individual nuts

Category Yellow: Changing what you drink
1. Drink only water or unsweetened coffee or tea
2. Swap sugary soft drinks with diet or no sugar versions
3. Do not drink alcohol
4. Drink a pint of water before each meal
5. Swap juices or smoothies with whole fruit and vegetables

Category Green: Creating a healthier diet
1. Eat at least 5 portions of fruit or vegetables each day
2. Snack only on vegetables
3. Eat only foods with a green nutrition label for total fat
4. Eat only foods with a green nutrition label for sugar
5. Make sure half of your main meal of the day is a salad or vegetables
6. Swap rice/potatoes/pasta with extra vegetables
7. Swap fatty meats with lean meats

Category Blue: Meal-time tactics
1. Eat slowly or 20 chews per bite
2. Focus on your food while eating
3. Stop eating before you feel full
4. Use smaller plates and bowls
5. Cut food into smaller pieces
6. Eat for less than 20 minutes at a time

Category Purple: Burn more calories
1. Walk up and down a flight of stairs for as long as you can
2. Go cycling for as long as you can
3. Go swimming for as long as you can
4. Stretching Exercises
5. Attend an exercise class
6. Play a group sport
7. Go to the gym
8. Exercise at home with the 21-minutes NHS Choices workout
9. Brisk walking for as long as you can

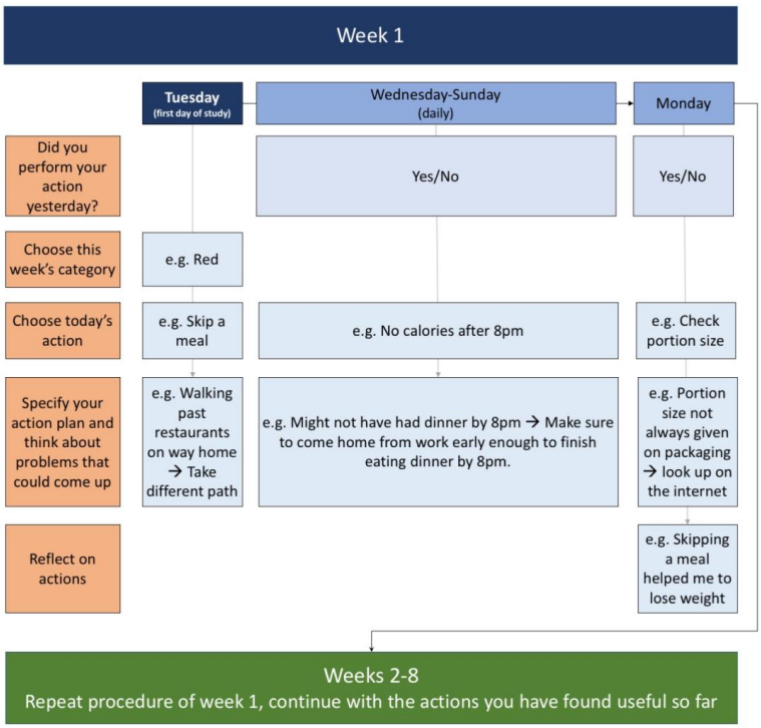
Category Pink: Be more active as part of your daily life
1. Walk 10,000 steps
2. Walk/cycle instead of taking the bus or car
3. Go for a walk with your friend(s)
4. Stand up while working
5. Take the stairs whenever you can
6. Have an active day with your family or friends
7. Stand up while watching TV

How it works

Every morning we will send you an email with a link to an online questionnaire. Start by entering today's weight. If you have forgotten to weigh yourself, please enter NA. We will then guide you through planning today's weight loss actions:

1. At the start of the week, we will ask you to choose a **category** of actions, e.g. "Meal-time tactics" or "Burn more calories".
2. Each day we will ask you to choose a **specific action** within that category. This way you will be able to try out several similar, but different, weight loss actions throughout the week. We will ask you to specify where and when you are going to perform the chosen action. Science shows that doing this makes it much more likely you'll stick to your plans. For actions that go on throughout the day, such as cutting out snacks, please plan the action for the whole day. We will ask you to think about what problems or situations may stop you from performing the action, and to think about possible solutions. Science shows that thinking through 'if something happens, then I will…' is key to success. You can find some tips on what to do when you encounter typical problems on pages 31-33.
3. Give your chosen action a good go. If you slip up, don't worry, but think through your action plan again and try to do it the next time the opportunity arises. Try not to let a small lapse hinder your efforts for the rest of the day.
4. The next day, we will ask you whether you did what you planned.
5. At the end of the week, we will help you to look back and work out which specific actions worked for you, and which didn't. We tell you more about this step on p. 16.
6. From the second week onwards, you'll be able to carry on doing things that are helping and drop things that aren't. We'll ask you to commit to the helpful actions. We know that making a firm commitment helps people stay on track. Remember, the idea is that you gradually build up a **collection of weight loss actions** that work for you.

Here's a diagram to illustrate the action-planning process:



Successful self-regulators: meet Danielle

Danielle is 55 years old. Her children have just moved out so she finds herself with more free time. Having gained two stone over the last twenty years, she decides some weight loss might do her good. Danielle has done some research and decided she should tackle her eating behaviours. Every day she sets herself a similar but slightly different action goal to keep it interesting. She knows how important it is to be specific about your action plan and to plan for when something goes wrong. She decides today should be a fasting day with less than 800 calories. She plans to check the labels of all foods before she eats them to ensure she stays within the limit. As some foods don't have a nutrition label she is worried she might lose track of the calories she consumes, so she downloads a calorie counting app to help her track her intake throughout the day. Worried that she might give up on her plan if she feels really hungry, she plans to chew gum whenever she is about to give in. In the evening, Danielle feels good about herself because her action plan worked out.

Some tips on making the right action plans

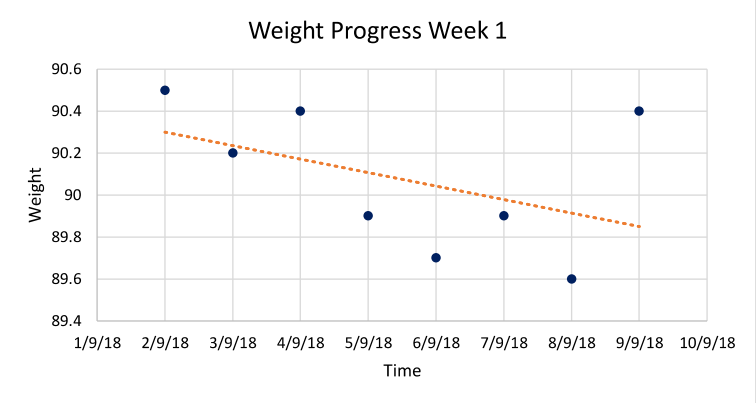
1. **Choose actions that change your behaviour:** Committing to an action that you already perform every day won't help you to lose weight. For example, if you don't consume sugary soft drinks, don't chose the action "Swap sugary soft drinks with diet soft drinks".
2. **Changes to your diet are more effective for weight loss than changes to your physical activity:** Start with a diet category so you're already committed to some dietary actions that work for you when you start to take on categories focused on physical activity such as "Burn more calories" and "Be more active as part of your daily life".
3. **Plan ahead:** For some actions, you're going to need to plan ahead. For example, if you're restricting yourself to certain foods, you'll need to buy them beforehand. When choosing a category at the beginning of the week, have a look through all the actions in that category and plan which action you could do on which day.
4. **Experiment with as many different actions as possible:** The aim of this programme is to try out lots of different approaches and work out which ones work for you. So allow yourself to experiment with unfamiliar categories and actions. Doing so will help you to find the greatest number of actions that work for you.

There's an overview of all weight loss actions in the next section. Some on the list are repeated. This is because they fit into several categories of actions. Others may seem to contradict each other, such as "Don't eat between meals" and "Swap unhealthy snacks for fruits and vegetables". While no snacking is more effective for weight loss than healthy snacking, there might be some days where no snacking at all just doesn't seem doable to you. Therefore, we've included both options in our list. On pages 19-30 you can find detailed descriptions of all weight loss actions.

If you miss a day, get back on track the very next day. Don't let a minor lapse become a major collapse.

4) Weekly Progress Reports

Once a week we'll email you a brief report on your weeks' progress. We'll use the weights you submit as part of the daily questionnaires to calculate a 'cleaned' weight change. This process removes the influence of daily fluctuations. This number should give you a better idea of the trend of the weeks' progress. For example, if you started the week at 90.5kg and your weight changes each day were –0.3kg, +0.2kg, -0.5kg, -0.2kg, +0.2kg, -0.3kg and +0.8kg, you will have ended your week at 90.4kg and might be uncertain whether you were successful at losing weight. However, in this scenario, your 'clean' weight change would be -0.45kg, which shows much more clearly that you have lost weight. We will also send you a graph with the weeks' measurements, which will provide a picture of your progress.



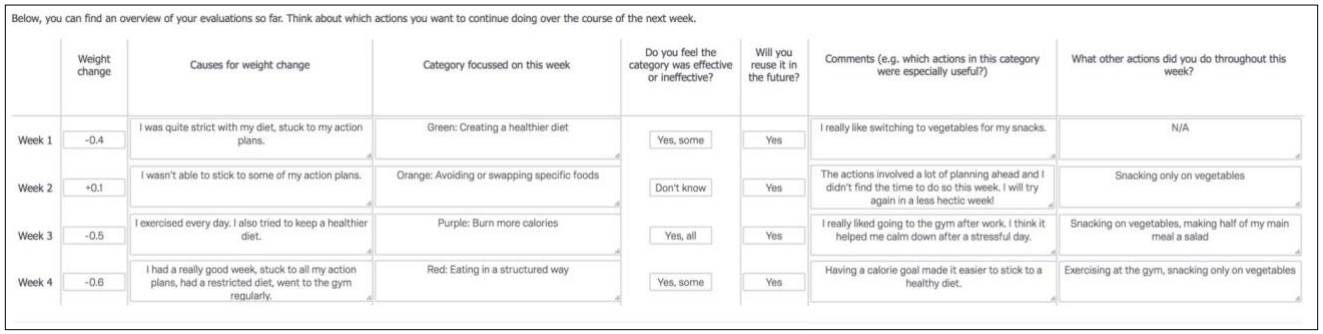
5) Behaviour Reflection

In the weekly progress report email, we'll send a link to an online questionnaire. This will be the same questionnaire every week. You will be asked to complete the questions related to your week and then close the questionnaire. The system will save your entries automatically. The following week, the link we send will bring you back to the page where you left off so you can progress with next week's questions.

The first set of questions each week will help you reflect on your behaviour. This is an important part of the self-regulatory process. We'll ask you to think about what you did that might have affected your weight. Reflection may help you explain the weight changes you have seen.

6) Action Evaluation

The next set of questions in the weekly questionnaire will ask you to evaluate your chosen actions for this week. This includes whether you think the actions helped you to lose weight, whether you plan to re-use them and any comments you'd like to make. The next page shows an overview of all your responses so far. Use these weekly evaluations to decide whether your chosen actions this week were helpful. Which actions do you want to keep? We'll ask you to commit to continuing these actions in the next action-planning questionnaire.
This is what the weekly action overview evaluation will look like after the 4th week:



Below, you can find an overview of your evaluations so far. Think about which actions you want to continue doing over the course of the next week.

	Weight change	Causes for weight change	Category focussed on this week	Do you feel the category was effective or ineffective?	Will you reuse it in the future?	Comments (e.g. which actions in this category were especially useful?)	What other actions did you do throughout this week?
Week 1	-0.4	I was quite strict with my diet, stuck to my action plans.	Green: Creating a healthier diet	Yes, some	Yes	I really like switching to vegetables for my snacks.	N/A
Week 2	+0.1	I wasn't able to stick to some of my action plans.	Orange: Avoiding or swapping specific foods	Don't know	Yes	The actions involved a lot of planning ahead and I didn't find the time to do so this week. I will try again in a less hectic week!	Snacking only on vegetables
Week 3	-0.5	I exercised every day. I also tried to keep a healthier diet.	Purple: Burn more calories	Yes, all	Yes	I really liked going to the gym after work. I think it helped me calm down after a stressful day.	Snacking on vegetables, making half of my main meal a salad
Week 4	-0.6	I had a really good week, stuck to all my action plans, had a restricted diet, went to the gym regularly.	Red: Eating in a structured way	Yes, some	Yes	Having a calorie goal made it easier to stick to a healthy diet.	Exercising at the gym, snacking only on vegetables

Successful self-regulators: meet Natasha

Natasha is 62 and recently developed diabetes. She wants to lose weight as she's heard this can help with her diabetes. Natasha is not sure yet which weight loss approach will work for her. She decides to start by avoiding certain food groups. After one week she finds this approach has helped her to lose 0.8kg. Satisfied with this result, Natasha considers her actions throughout the week. She thinks cutting out sweets and biscuits was the most significant behavioural change as she used to nibble on them all the time. Natasha decides to continue avoiding them next week. Additionally, she wants to try going for a run – she used to run regularly in her youth.

FAQ

1. What is my participant ID?
   - ➔ Your participant ID is a combination of letters and numbers unique to you. It consists of the first and last letters of your surname, your day of birth (regardless of month or year) expressed as two digits, and the first and last letters of your birthplace. For instance, Sam Smith who was born on the 09.05.1982 in Oxford would receive the ID SH09OD.
     We use a participant ID to anonymise your data. That is, instead of using your name on study documents, we use your participant ID. That way, the researchers involved won't know whose data they are working with.
2. The scales you gave me don't work. What should I do?
   - ➔ If you have problems with the scales, please get in touch with us. We will try to help or provide you with another set of scales.
3. Why do I have to weigh myself in kg?
   - ➔ We are using a collection of different scales in this study. Some measure weight only in kg. We therefore decided that all study materials refer to weight in kg. We thank you for your understanding.
4. I forgot to weigh myself this morning and now I'm no longer at home. Should I still complete the daily action-planning questionnaire?
   - ➔ Yes, please complete the action-planning questionnaire. For the question about today's weight change, please enter "NA". Set yourself an alarm on your phone to remember weighing yourself in the morning.
5. I wasn't able to perform my action plan today. What shall I do?
   - ➔ Life can get in the way of our plans; just start fresh tomorrow. Tomorrow's action planning questionnaire provide an option to say you weren't able to perform your planned action. It will ask you to reflect on why you were unable to do it and what you could do differently next time.
6. I'm doing everything right but I'm not losing weight. Why is that?
   - ➔ It might be that you haven't yet found the actions that work for you. Try out different approaches over the next days and weeks. One action per day will most probably not be enough to lose weight. Therefore, we encourage you to build up a set of actions over the weeks. So stay patient and keep at it.
7. I find the intervention hard to use. Why are there so many different materials?
   - ➔ Although we think the intervention will be helpful for weight loss, we don't know yet for sure. That's why we are doing this study. If we find that the intervention is helping with weight loss, we will be able to apply for funding to create a phone app with all the functions of the intervention. With this study we also want to see what people think about the intervention in order to improve it before creating the app.

Thank you for reading this manual. You are now ready to get started!

Detailed Overview of All Action Plans

Version 1.0, 7th of December, 2018

Weight Loss Actions Category Red: Eating in a structured way

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Plan all meals for the day in advance (what and when)	Take the time to plan what you will eat over the next 24 hours. Make it quite detailed – when will you eat, what will you cook, will you take something prepared if you're going out? If you know you are eating out, look up their menu in advance and plan your order. Then make sure that you stick to your plan and don't eat more.	A lot of calories are added to our diet from impulsive snacks or poor food choices. Committing to a food plan in the morning, when you are mindful of your goals and not exposed to temptations, can help you eat healthily throughout the day.	A, B, C, D, H
2	Eat no more than three times	Make sure that you have no more than three eating occasions throughout the day. You can have a breakfast, lunch and dinner, but no snacks in between or after.	Impulsive snacks can add lots of calories. Cutting out snacks will reduce your daily energy intake.	A, B, C, D
3	Skip a meal	Skip either breakfast, lunch or dinner. Make sure you don't compensate for the loss by snacking instead.	By skipping a meal, you are saving a lot of calories, which means your body will use its fat reserves instead.	A, B, C, D
4	No calories after 8pm	Don't eat any food after 8pm and ensure any drinks you consume after 8pm have zero or very few calories (e.g. tea without sugar, water).	Food and drink consumed in the late evening are often unhealthy and high in calories (e.g. crisps, beer). Cutting out all foods and calorie-rich drinks in the evening can help reduce your calorie consumption.	A, B, C, D
5	Check the calorie count of everything you want to eat or drink	Use nutrition labels, websites or apps to check the calorie content of foods before you eat. Make sure you consider how the calories are presented as they sometimes refer to a portion size or per 100g. Reflect on whether consuming the food or drink is worth the calories you're adding to your daily intake. Compare the calorie content with that of similar items and see if there is a lower calorie alternative.	Many people don't know how many calories their foods and snacks contain. You might realise that a lower calorie alternative will be just as satisfying.	A, B, C, D, E

No	Action	What to do	Why does it matter?	Tips (see p. 31)
6	Set yourself a calorie goal and stick to it	Go to the following website to find out how many calories you need per day: https://www.bbc.com/food/diets/how_many_calories_do_you_need. Subtract 600 calories and set the resulting figure as your goal for the day. Then keep track of the calorie content of everything you eat throughout the day. Ensure you do not exceed your target. You can use free calorie counting mobile phone apps, such as MyFitnessPal.	Research shows that setting calorie goals can help you lose weight. It makes your goal for the day more tangible and helps you think about how to spread your daily calorie intake.	A, B, C, D, E
7	Have a "fasting" day with less than 800kcal	Have a day of "fasting" where you consume less than 800kcal. You can find some low calorie recipes to help you here: https://www.bbc.com/food/collections/intermittent_dieting_recipes https://www.bbc.com/food/diets/low-calorie_diet Make sure you drink at least 2 litres of low calorie fluids to avoid dehydration. You can use free calorie counting apps, such as MyFitnessPal, to help you keep track.	Eating only 800 calories means cutting out more than half of the calories you consume on a normal day. Your body will have to source half to two-thirds of the energy you need from fat reserves, giving a boost to your weight loss.	A, B, C, D, E
8	Keep a diary of what you eat and how you feel	Keep a record of all the foods and drinks you consume throughout the day. Make a note of the time when you consume and also the reason e.g. whether you were craving this kind of food, wanted to reward yourself or were hungry. Write down how you felt after consuming the food or drink. Go through your food diary in the evening and see which foods or drinks you could have avoided.	Keeping a psychological diary will make you think more about how you use food not only to feed yourself but also to provide comfort or reduce boredom. You can then think of other strategies to handle these emotions that do not include food.	C, D3

No	Action	What to do	Why does it matter?	Tips (see p. 31)
9	Check your portion size	Weigh everything before you eat it and check your portion against the recommended serving size on the packet or by using this general guide: https://blog.myfitnesspal.com/essential-guide-portion-sizes/	Most people are unaware of recommended serving sizes. Checking portion sizes will help prevent overeating.	A, B, C
10	Only eat when sitting at a table	Only eat while you are sitting at a table. Don't eat while you're on the go or when working.	When you eat while doing other tasks, it is easy to overeat. Sitting down at a dining table will help you focus on your food and boost feelings of fulness. By committing to only eating while sitting at the table, you will reduce snacking.	A, B, C, D

Weight Loss Actions Category Orange: Avoiding or swapping specific foods

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Don't eat between meals	Do not eat any snacks between meals. Stick to your three main meals, breakfast, lunch and dinner.	Snacks increase your daily calorie intake. So cutting snacks will reduce the calories you consume.	A, B, C, D
2	Cut out crisps, biscuits, cakes and sweets	Do not eat any crisps, biscuits, cakes, chocolates and sweets throughout the day.	These foods are very 'energy dense' and contain a lot of calories in every bite, so it's easy to overeat.	A, B, C, D
3	Cut out fried food	Do not consume any fried foods today. This includes fries or chips, onion rings, poppadoms, battered fish, etc.	Fried foods contain lots of calories. Cutting them out will reduce your calorie intake.	A, B, C, D, E
4	Have only one course at meal-time	Do not consume any starters or desserts with your lunch and dinner. For breakfast, consume just one type of food (i.e. only toast or cereal, etc.).	Starters and desserts add to your calorie intake. Cutting them out will reduce your consumed calories.	A, B, C, D
5	Cut out carbs	Avoid carbohydrates, including potatoes, rice, pasta, bread, breakfast cereals, beans, and sugary foods such as pastries, cakes, biscuits, confectionery or chocolates. Fruit and dairy are allowed.	Carbohydrates account for around 40% of all the calories we eat. When you cut out carbohydrates, you will tend to reduce your overall energy intake.	A, B, C, D, E
6	Swap unhealthy snacks for fruits and vegetables	Swap unhealthy snacks with fruits and vegetables, such as apples, carrots, celery, or peppers.	Unhealthy snacks are rich in calories. Swapping them with fruits and vegetables will reduce your calorie intake.	A, B, C, D
7	Swap rice/potatoes/ pasta for extra vegetables	Avoid rice, potatoes or pasta as a side to your main course. Instead swap them with boiled or steamed vegetables, including broccoli, carrots, or cabbage.	Rice, potatoes and pasta contain far more calories than vegetables. Replacing starchy carbs with vegetables will help you stay full while eating fewer calories.	C, D, E

No	Action	What to do	Why does it matter?	Tips (see p. 31)
8	Use meal replacement products	Try swapping breakfast, lunch and/or dinner for a meal replacement product such as a specially formulated meal bar, shake or soup. You can buy them online or in your local pharmacy.	Specially formulated bars, shakes or soup shakes contain all the nutrients you need and are usually much lower in calories than a typical meal.	A, B, C, D
9	Swap unhealthy snacks with 6-8 individual nuts	Replace all unhealthy snacks with 6-8 nuts.	Nuts are high in protein and fibre which will help you to feel fuller.	A, B, C, D

Weight Loss Actions Category Yellow: Changing what you drink

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Drink only water or unsweetened coffee or tea	Drink only water, coffee and tea today. Your tea or coffee may include a small amount of milk, but no sugar, honey or syrups.	High calorie drinks can quickly increase your calorie intake without increasing your sense of fulness. Switching to low-calorie drinks will help you lose weight.	C, D4, D7, E1
2	Swap sugary soft drinks with diet or no sugar versions	Swap your sugary soft drinks for the zero or low-sugar versions. You might have to experiment with different brands to discover your preferred taste.	A typical can of sugary drink contains about 100 calories. Switching to zero or low-sugar versions of soft drinks can help reduce your calorie intake.	C
3	Do not drink alcohol	Refrain from drinking any alcohol today.	Alcohol contains a lot of calories. A pint of beer contains about 250 calories, 150ml of red wine contain 125 calories. By avoiding drinking alcohol, you can save calories.	C, D7
4	Drink a pint of water before each meal	Drink a pint of water before you choose your meal and decide on the portion size.	Drinking a pint of water will help fill up your stomach. That way you will feel less hungry when making meal decisions, helping you to make healthier choices and choose smaller portion sizes.	C, E1
5	Swap juices or smoothies with whole fruit and vegetables	Avoid juices or smoothies and eat a piece of whole fruit or vegetable instead.	Swapping juice with intact fruits and vegetables has the advantage that you benefit from the fibres they contain. Fibres are good for digestion and cholesterol levels. They slow the breakdown of sugars from the fruit or vegetable, making it less likely that you experience peaks in your blood sugar levels. Eating whole fruits and vegetables rather than drinking a smoothie slows down the rate of eating and increases feelings of fullness.	C

Weight Loss Actions Category Green: Creating a healthier diet

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Eat at least 5 portions of fruit or vegetables each day	Eat at least five portions of different fruits and vegetables.	Fruits and vegetables bulk out a meal, helping you to feel fuller on fewer calories.	C, H
2	Snack only on vegetables	Tempted to snack outside of your three main meals? Then snack on vegetables, such as carrots, peppers or celery.	Vegetables are low in calories and consuming them as a snack won't add too many calories to your daily intake.	A, B, C, D
3	Eat only foods with a green nutrition label for total fat	Only eat foods with low total fat (3g or less per 100g). This is often indicated by a green colour-coding for total fat on the nutrition label.	Fat contains a lot of calories. Eating low-fat foods will therefore reduce your calorie intake.	A, B, C, D, E
4	Eat only foods with a green nutrition label for sugar	Only eat foods with low sugar content (5g or less per 100g). This is often indicated by a green colour-coding for sugars on the nutrition label.	Sugary foods contain a lot of calories. Eating low-sugar foods will reduce your calorie intake.	A, B, C, D, E
5	Make sure half of your main meal of the day is a salad or vegetables	Make sure that half of your main meal of the day – lunch or dinner – consists of boiled or steamed vegetables or a salad. Potatoes do not count as vegetables. Salad dressings should be low fat, such as lemon juice, balsamic vinegar, or yoghurt dressing.	Vegetables provide you with many important nutrients and are low in calories. Salads and steamed or boiled vegetables are a great side to your main meal. They add bulk to a meal so you feel fuller and satisfied.	C, D, E
6	Swap rice/ potatoes/pasta with extra vegetables	Avoid rice, potatoes or pasta. Instead swap for boiled or steamed vegetables, including greens, carrots or parsnips.	Rice, potatoes and pasta contain far more calories than vegetables. Replacing starchy carbs with vegetables will help you stay full while eating fewer calories.	C, D, E
7	Swap fatty meats with lean meats	Avoid fatty meats, including salamis, sausages, steaks, pork belly or mince. Swap them with lean cuts of meat which have a relatively low-fat content. Remove all visible fat from meat, including the skin from chicken. Choose extra lean mince or ask your butcher for a leaner cut. Or choose fish instead.	Fatty meats contain many calories. You can reduce your calorie intake by switching to lean meats.	B, C, D

Weight Loss Actions Category Blue: Meal-time tactics

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Eat slowly or 20 chews per bite	Slow down how quickly you eat. You can achieve this by chewing each bite twenty times, decreasing your chewing speed or putting your cutlery down between bites.	Reducing your eating speed will help you notice feelings of fullness before you have overeaten.	C, H
2	Focus on your food while eating	Have a quiet meal without distractions. Be mindful about eating and your feelings of satisfaction and fullness. Concentrate on the feel of the food in your mouth, the smells, taste, and how your feelings change during the meal.	Being mindful can help you identify feelings of fullness and support you in avoiding overeating.	C, D
3	Stop eating before you feel full	Stop eating before you feel full. Instead look out for the moment when you stop feeling hungry. You can freeze leftovers or keep them in the fridge for another time.	It takes a while for feelings of fulness to set in. Therefore it's easy to overeat.	B, C, D
4	Use smaller plates and bowls	Use smaller plates or bowls and smaller serving spoons to help with your portion control.	Using smaller crockery and utensils will help you eat smaller portions and reduce your calorie intake.	C, D
5	Cut food into smaller pieces	Cut your food into smaller pieces when eating.	Reducing the bite size will increase the time you need to eat and help your gut hormones increase. These tell your brain you are full, meaning you can feel satisfied before you have overeaten. It will also give you the feeling of having had a larger meal.	C, H
6	Eat for less than 20 minutes at a time	Don't spend more than 20 minutes eating each meal. Eat at a normal pace. You can freeze your leftovers or keep them in the fridge.	Restricting the time you spend consuming your food will automatically restrict your calorie consumption.	B, C

Weight Loss Actions Category Purple: Burn more calories

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Walk up and down a flight of stairs for as long as you can	Walk up and down a flight of stairs until you are out of breath and can no longer sustain a conversation. Take a rest and then go again.	Engaging in exercise burns calories and helps you lose body fat.	C, F
2	Go cycling for as long as you can	Go cycling outdoors or at the gym. Take breaks if necessary.	Engaging in exercise burns calories and helps you lose body fat.	C, F, G
3	Go swimming for as long as you can	Swim until you are out of breath and can no longer sustain a conversation. Take a rest and then go again.	Engaging in exercise burns calories and helps you lose body fat.	C, F, G
4	Stretching Exercises	Do stretching exercises at home. There are many online tutorials available, like this one: https://www.youtube.com/watch?v=9jAyRP0bqKA	Stretching exercises help develop flexibility. This may enable you to engage in more physical activities. Any extra exercise burns calories.	C, F
5	Attend an exercise class	Attend a structured group exercise or sports class. This may be a class at a gym or sports club led by a trainer, e.g. a dance class.	Engaging in exercise burns calories and helps lose body fat. Doing exercise in a group can be especially motivating.	C, F
6	Play a group sport	Play a group sport such as badminton, tennis, or football. This might either be formal training or a game between friends.	Engaging in exercise burns calories and helps you lose body fat. Doing exercise in a group can be especially motivating.	C, F, G
7	Go to the gym	Go to the gym for a workout. A good way to structure your training is to start with a warm-up on a cardio machine, followed by strength training and cardio exercise to finish. Make sure to ask the trainers to explain any unfamiliar machines so you don't hurt yourself while using them.	The suggested gym routine will help you strengthen several muscles in your body, which helps boost your long-term metabolic rate. The cardio routine will get your heart-rate going and burn calories.	C, F, G

No	Action	What to do	Why does it matter?	Tips (see p. 31)
8	Exercise at home with the 21-minutes NHS Choices workout: https://www.nhs.uk/live-well/exercise/10-minute-workouts/	Try one of the NHS Choices website 21-minute workouts that you can perform easily at home. They include: 6-minute warm-up, 10-minute workout of your choice and 5-minute cool-down. You can find them here: https://www.nhs.uk/live-well/exercise/10-minute-workouts/	The NHS Choices workouts will strengthen several body muscles. Building muscle mass will help boost your long- term metabolic rate. Plus, engaging in exercise burns calories.	C, F
9	Brisk walking for as long as you can	Go for a brisk walk until you are out of breath and can no longer sustain a conversation.	Engaging in exercise burns calories and helps you lose body fat.	C, F, G

Weight Loss Actions Category Pink: Be more active as part of your daily life

No	Action	What to do	Why does it matter?	Tips (see p. 31)
1	Walk 10,000 steps	Set yourself the goal of walking at least 10,000 steps. You can count your steps using a pedometer or fitness tracker. There are many free apps that have pedometer functionality as well. They record the number of steps you made on your phone.	Walking 10000 steps in one day burns around 500 calories, which helps you lose body fat.	C, F
2	Walk/cycle instead of taking the bus or car	If going somewhere, cycle or walk some or all of the way to get more active.	Engaging in physical activity burns calories and helps you lose body fat.	C, F
3	Go for a walk with your friend(s)	Meet your friends for a walk instead of sitting down somewhere.	You burn more calories while walking than sitting. Sitting down with friends often leads to eating, which you can avoid by making it a walking meeting.	C, F, G
4	Stand up while working	Stand up while you're working. If your work place does not have a height adjustable desk, try to find a cupboard or cabinet that has a good height to work on. Try to have standing or walking meetings with your colleagues.	You burn more calories standing than sitting.	C, F
5	Take the stairs whenever you can	Always choose the stairs over the lift.	Engaging in physical activity burns calories and helps you lose body fat.	C, F
6	Have an active day with your family or friends	Have an active day with family or friends. For example, go for a hike or play sports such as football, frisbee, or badminton.	Engaging in physical activity burns calories and helps you lose body fat. Doing this together with family or friends makes it more enjoyable.	C, F, G
7	Stand up while watching TV	Stand up while watching TV.	You burn more calories standing than sitting.	C, F

Tips and Tricks: What to do to succeed

If you are experiencing difficulties completing your planned action today, have a look at the tips below (check the right-side column of the action plan list to discover which tips are relevant).

A) Dealing with cravings

1. Make a bargain with yourself to wait a minute to see if the craving passes. Then see if you can last another.
2. Eat chewing gum or brush your teeth instead. You might not feel like chocolate after that!
3. Distract yourself e.g. by walking up and down the stairs or phoning a friend.
4. Think about how it will be once you have lost weight. Really try to imagine what it will feel like.
5. Acknowledge the feeling of craving, think about how it feels. Don't wrestle with it and don't stress about it. You don't need to worry about what it means or what will happen, just notice the feeling. Be mindful.
6. Drink a glass of water. If you dislike the taste of plain water, try infusing it with lemon, cucumber, ginger, or mint leaves.

B) Dealing with temptation

1. Avoid places with food temptations, such as fast food restaurants or ice cream parlours.
2. Do not go shopping when you are hungry.
3. Make a shopping list and stick to it.
4. If you have food or drinks in your house that aren't part of your eating plan, give them to a local food bank or your friends/neighbours.
5. Don't bring unhealthy foods/drinks into the house.
6. If you're having an unhealthy snack (e.g. a piece of chocolate), take only a small amount and return the rest to the fridge/cupboard.
7. Make sure you have healthy snacks at home and with you when you're out.
8. When you are going to eat out, check the menu beforehand and choose what you will eat. Restaurants are required by law to provide nutritional information about their dishes, including calorie content. If the information is not included on the menu, ask the waiter. In chain restaurants the nutritional information might also be available online.
9. If you tend to reward yourself by eating food, try to find a reward in something else, e.g. going to the cinema or taking a hot bath.
10. If you think you might struggle to find healthy foods in your lunch break, prepare your lunch at home and bring it with you to work.

C) Dealing with drops in motivation

1. Imagine how you will feel once you have lost weight: What will you look like? What will you be able to do? What will it mean to you?
2. Plan a (non-food) reward for yourself once you have lost a certain amount of weight.
3. Write down a list of reasons why you want to lose weight and stick it on your wall.
4. Stick a photo on your wall from a time when you were happy with your weight.
5. Review your progress so far in the weight tracking app. What does it mean to you? Where would you like to see the graph go?
6. Go through your wardrobe and find clothes that currently don't fit. Imagine wearing them again.

D) Staying strong despite social influences

1. Learn to say "no". Practice saying "thanks, but no" until it becomes a habit.
2. If you feel uncomfortable using a written food diary in public, make notes on your phone. Or take a photo and write it down later.
3. Explain to family and friends why losing weight is important to you and ask for their support.
4. Ask those around you to keep unhealthy foods and drinks out of your sight.
5. If you are attending a social gathering, make sure you bring yourself some healthy food options.
6. If people around you are drinking alcohol, arrange for your low-calorie beverage to be served in a wine glass to feel like you are participating.

E) If you're not sure about the food and drink alternatives

1. If you struggle drinking plain water, try infusing it. Perhaps with slices of lemon, orange, cucumber, ginger, or mint leaves. Or try sparkling water.
2. If you're not a fan of cooked/boiled vegetables, eat them raw instead.
3. If you don't like green vegetables, try mashing them together with other vegetables to create a combined flavour.
4. If you dislike the taste of boiled or steamed vegetables, add lemon juice, herbs or spices.

F) Dealing with barriers to exercise

1. If you are feeling stiff or sore, try exercising a different part of the body. Also try stretching the sore bits and you will feel better. Fitness exercises that are not focussed on building muscles, such as walking, swimming, cycling or jogging, will help muscle soreness go away.
2. Find an exercise buddy. Having someone to exercise with is more fun and you won't want to let them down by not showing up.
3. If you find exercising boring, listen to music or watch television while working out.
4. If you feel uncomfortable exercising around people you don't know, choose a time when it's less crowded, go with a friend, or exercise at home.

G) Dealing with bad weather

1. Put on rainproof clothes.
2. Check the weather forecast. If the weather is going to improve, move your action to a later time of the day.
3. Find an indoor exercise. For instance, if you planned to go for a run, go running on a treadmill instead.

H) Time and cost issues

1. Prepare your meals in advance as this will be cheaper than eating out.
2. Look out for special offers on fruits and vegetables.
3. Prepare meals in bulk and freeze them for when you don't have much time.
4. Have healthy ready meals in the freezer for when time is short.
5. Buy healthy prepared foods such as a green salad or a lean soup for when you're busy.
6. If gym membership is too expensive, find things to do without a gym, such as going for a run or following an exercise video on YouTube.

Categories	Actions	Week 1							Week 2							Week 3							Week 4						
		Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo
Red: Eating in a structured way	1: Plan all meals for the day in advance (what and when)																												
	2: Eat no more than three times																												
	3: Skip a meal																												
	4: No calories after 8pm																												
	5: Check the calorie count of everything you eat or drink																												
	6: Set yourself a calorie goal and stick to it																												
	7: Have a "fasting" day with less than 800kcal																												
	8: Keep a diary of what you eat and how you feel																												
	9: Check your portion size																												
	10: Only eat when sitting at a table																												
Orange: Avoiding or swapping specific foods	1: Don't eat between meals																												
	2: Cut out crisps, biscuits, cakes and sweets																												
	3: Cut out fried food																												
	4: Have only one course at meal-times																												
	5: Cut out carbs																												
	6: Swap unhealthy snacks for fruits and vegetables																												
	7: Swap rice/potatoes/pasta for extra vegetables																												
	8: Use meal replacement products																												
	9: Swap unhealthy snacks with 6-8 individual nuts																												
Yellow: Changing what you drink	1: Drink only water or unsweetened coffee or tea																												
	2: Swap sugary soft drinks with diet or no sugar versions																												
	3: Do not drink alcohol																												
	4: Drink a pint of water before each meal																												
	5: Swap juices or smoothies with whole fruit and vegetables																												
Green: Creating a healthier diet	1: Eat at least 5 portions of fruit or vegetables each day																												
	2: Snack only on vegetables																												
	3: Eat only foods with a green nutrition label for total fat																												
	4: Eat only foods with a green nutrition label for sugar																												
	5: Make sure half of your main meal is a salad or vegetables																												
	6: Swap rice/potatoes/pasta with extra vegetables																												
	7: Swap fatty meats with lean meats																												
Blue: Meal-time tactics	1: Eat slowly or 20 chews per bite																												
	2: Focus on your food while eating																												
	3: Stop eating before you feel full																												
	4: Use smaller plates and bowls																												
	5: Cut food into smaller pieces																												
	6: Eat for less than 20 minutes at a time																												
Purple: Burn more calories	1: Walk up and down a flight of stairs for as long as you can																												
	2: Go cycling for as long as you can																												
	3: Go swimming for as long as you can																												
	4: Stretching Exercises																												
	5: Attend an exercise class																												
	6: Play a group sport																												
	7: Go to the gym																												
	8: Exercise at home with the 21-min NHS Choices workout																												
	9: Brisk walking for as long as you can																												
Pink: Be more active as part of your daily life	1: Walk 10,000 steps																												
	2: Walk/cycle instead of taking the bus or car																												
	3: Go for a walk with your friend(s)																												
	4: Stand up while working																												
	5: Take the stairs whenever you can																												
	6: Have an active day with your family or friends																												
	7: Stand up while watching TV																												

Appendix 6.1 - Participant information sheet

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IRAS ID: 247681
Version 1.1
07/12/2018

PARTICIPANT INFORMATION SHEET

We would like to invite you to take part in this research study, which may help you to lose weight. Joining the study is entirely up to you, before you decide we would like you to understand why the research is being done and what it would involve for you. Please take the time to read this information and discuss it with others if you wish. If anything is unclear, or if you would like more information, please ask the researcher.

1. ***Purpose of the Research***

The aim of this study is to compare two brief weight loss interventions and find out whether they help people lose weight. The study will take eight weeks to complete and is run in Oxford, UK.

2. ***Why have I been invited?***

We are looking for 100 participants whose body mass index (BMI) is above 30, and may therefore benefit from losing weight. You have confirmed that you fulfil the inclusion criteria when you first got in touch with us. This study is therefore suitable for you and we would like to invite you to participate.

3. ***Do I have to take part?***

No. Taking part is entirely voluntary. You can ask questions about the study before deciding whether or not to participate. Taking part in the study will not affect the usual care you receive from your GP. Your GP will be notified about whether you participate in the study or not. If you do agree to participate, you may withdraw yourself and your data from the study at any time, without giving a reason and without penalty, by advising the researchers of this decision.

4. *What would taking part involve?*

We will invite you to two meetings at a venue close to you: one at the beginning and the next, two months later, at the end of the study. At the first meeting, you will be randomly allocated to one of the two study groups by chance, like tossing a coin. We cannot predict which group you will be in and we unfortunately cannot take your preference into consideration. We will explain the details of what we ask you to do for the next eight weeks. We will measure your height, weight and body fat. We will give you a set of body scales for the duration of the study, as you will be asked to weigh yourself regularly for the next eight weeks. Please be prepared to take the scales home with you, they weigh around 2kg. You might find it useful to bring a bag for the scales with you. Finally, we will ask you to fill in a short questionnaire. You will have the opportunity to ask any questions. This first meeting will take no more than one hour.

We will ask you to follow the instructions you have received for the next eight weeks. We anticipate that you will spend 10 minutes a day to complete all tasks of the intervention. The study team may call you on the phone during the intervention period to ask about your experiences as a participant and to resolve any issues.

After you have completed the eight weeks of the intervention period, we may send you a short online questionnaire via email to find out how you liked the intervention. We will then invite you back to a second meeting. We will ask you to return the body scales. We will take another weight and body fat measurement in order to see whether your weight or body fat changed throughout the study. We may ask you to discuss your experiences in the study with us. With your consent, we will audio record this discussion. This second meeting should take no more than 45 minutes.

5. *What we will expect from you*

If you agree to take part in the study we would expect you to:

- Attend two appointments with the study team
- Follow your allocated intervention to the best of your ability
- Return the scales we lend you at the end of the study

Taking part in this study will not affect any other treatment you are receiving. You may continue to take your regular medication or other prescribed or over-the-counter medicines during the study.

6. *What are the possible benefits of taking part?*

Everyone taking part in the study will receive an intervention that has the potential to help with losing weight. Everybody will also receive information about how to weigh themselves in the best way to achieve reliable results. Once the analyses of the results are finished, you

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will get an email explaining our findings. The knowledge gained in this study will help our research and, in the future, may help you and other people to lose weight.

7. *Will I be reimbursed for taking part?*

After completion of the study, you will receive a One4all gift card worth £35, to compensate you for any costs or inconvenience in attending appointments related to the study.

8. *What are the potential disadvantages and risks of taking part?*

There are no known risks from taking part. Some people worry that weighing oneself regularly may cause undue concern about weight. However, research suggests that there are no long-term consequences of regular weighing for your mental health.

9. *What happens if I don't want to continue with the study after I consent?*

If you change your mind, you can of course stop taking part in the study. You will be able to decide whether you just want to stop participating or whether you also want to withdraw the data we collected from you from the study. Your future medical care will not be affected. You do not need to come back to the second meeting to explain why you want to withdraw. However, if you want to stop participating in this study and are happy to tell us about the reasons, it would be helpful for us to hear from you as your experience is valuable to us. Whether you want to tell us about your experiences or not, we would ask you to please return the weighing scales so we can use them in other research studies.

10. *How will my information be kept confidential?*

When the study is finished, your responses will be anonymised. This means it won't be possible to know that the data came from you, as you will only be identified by a code. Any information that is collected about you during the course of the research will be kept strictly confidential. The data will be stored on the University's secure research server and will only be accessible to the study team. The audio recordings of our discussion about your experiences in the study will be transcribed. The original audio recording files and the transcriptions will be stored with the rest of the anonymised data. The data will not be copied onto any other storage medium.

At the end of the study, all personally identifiable data, with exception of the participant consent form, will be destroyed. All other research data and records will be stored for a minimum retention period of five years after publication or public release of the work of the research, in accordance with the University of Oxford's Policy on the Management of Research Data & Records. We may retain the anonymised data from this study for future secondary analyses beyond this time period.

Responsible members of the University of Oxford may be given access to data for monitoring and/or audit of the study to ensure that the research is complying with applicable regulations.

11. *What will happen to my data?*

Research is a task that we perform in the public interest. The University of Oxford, as sponsor, is the data controller. This means that we, as University of Oxford researchers, are responsible for looking after your information and using it properly. We will be using information about you in order to undertake this study. We will use the minimum personally-identifiable information possible. We will destroy your personally identifiable data with exception of the participant consent form after the study has finished. We will store the anonymised research data and research documents, including the consent form, securely at the University of Oxford for five years after the end of the study.

Your rights to access, change, or move your personal information may be limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. Further information about your rights with respect to your personal data is available at http://www.admin.ox.ac.uk/councilsec/compliance/gdpr/individualrights/.
You can find out more about how we use your information by contacting Kerstin Frie at prevail@phc.ox.ac.uk.

12. *What will happen to the results of this study?*

The overall study results may be presented at scientific meetings or published in a scientific journal. This research will also contribute to a doctoral thesis at the University of Oxford. On successful submission of the thesis, it will also be deposited in the University archives, and available to the public. You will not be identified in the presentations and publications.
We will send you a summary of the study results.

13. *Who is organising and funding the research?*

This study is being carried out by Kerstin Frie (phone: 01865 289317; email: prevail@phc.ox.ac.uk) and sponsored by the University of Oxford.
The research is funded by the National Institute for Health Research Collaborations for Leadership in Applied Health Research and Care (NIHR CLAHRC) Oxford.

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14. *Who has reviewed this study?*

All research in the NHS is looked at by an independent group of people, called a Research Ethics Committee, to protect participants' interests. This particular study was reviewed and approved by the NHS national Research Ethics Committee and the Health Research Authority (reference number: 18/SC/0482).

15. *Who do I contact if I have a concern about the study or I wish to complain?*

If you wish to complain about any aspect of the way in which you have been approached or treated during the course of this study, or if you have a concern about any aspect of this study, please contact Ms Kerstin Frie (phone: 01865 289317; email: prevail@phc.ox.ac.uk), or the University of Oxford Clinical Trials and Research Governance (CTRG) office (phone: 01865 616480, email: ctrg@admin.ox.ac.uk), who will seek to resolve the matter in a reasonably expeditious manner.

The University of Oxford, as Sponsor, has appropriate insurance in place in the unlikely event that you suffer any harm as a direct consequence of your participation in this study.

If you have any complaints or queries regarding the care you receive as an NHS patient, you can contact Patient Services for Oxfordshire Clinical Commissioning Group at patient.services@oxfordshireccg.nhs.uk or phone 0800 052 6088. You can also contact the NHS Patient Advice and Liaison Services (PALS) via email PALS@ouh.nhs.uk or phone 01865 221473. Patient Services is unable to provide information about this research study.

Thank you for taking the time to read this information sheet.

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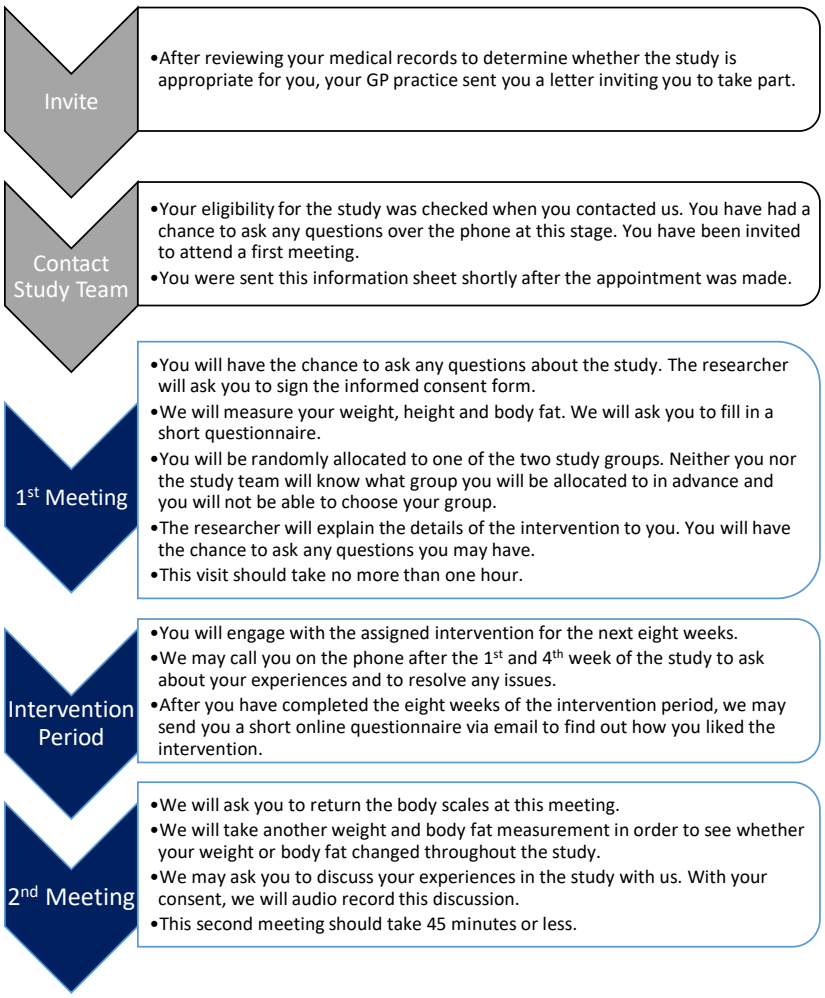
Figure 1. Study Participation



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Appendix 6.2 - Control group intervention description

- Weighing frequency seems to be associated with weight loss and weight loss maintenance
- We want to find out whether weighing on its own helps with weight loss
- We would like to ask you to weigh yourself on a daily basis, want to find out what kind of weight loss behaviours this triggers for you
- Up to you to decide what kind of diet or physical activity related changes you would like to make – we do not prescribe anything
- Fluctuations in daily weight measurements: weight is dependent on food and drink intake, time of day, etc. In order to give yourself the best possible chance of detecting actual weight loss, we recommend you weigh yourself at the same point in your morning routine, ideally after you've gotten up and been to the loo, before you have had breakfast. Does not have to be the same time every day
- Can sometimes take 2-3 days to see effects from lifestyle changes, therefore mostly interested in data trends, look at weight measurements across a week to determine whether it overall goes down/stays the same/goes up
- Find the right place for the scales: need a hard surface such as wood, linoleum or tiles, carpet is not ideal
- Scales are special, have a SIM card inside them which transmits weight measurements automatically to a research server. You therefore do not need to take note of your weight measurements for us
- Try out scales together

Appendix 6.3 - Semi-structured interview guide

Further spontaneous questions were asked in response to the participants' answers.

General questions

1. How would you explain your experiences in this study to a friend?
    a. Is there anything in particular that you liked?
    b. Is there anything in particular that you disliked?
2. How do you feel about weighing yourself overall?
    a. Do you think how you feel about weighing changed over the course of the study?
3. Do you think you will continue to weigh yourself regularly in the future?
    a. If answer is yes:
        i. How regularly will you continue weighing yourself?
        ii. Do you think you will continue keeping a record about your weight measurements?
        iii. Do you think you will continue to reflect on weight changes?
        iv. Do you think you will continue to make action plans?

Intervention components

4. How useful did you find the intervention for controlling your weight overall?
5. Weight tracking
    a. Was there anything you particularly liked about tracking your weight?
    b. Was there anything you particularly disliked about tracking your weight?
    c. What did you think about the frequency of the weight tracking task?
6. Action planning
    a. Was there anything you particularly liked about the action planning task?
    b. Was there anything you particularly disliked about the action planning task?
    c. Tell me about the actions you tried out throughout the study, how did you choose them?
    d. How often did you complete the planned actions?
    e. Were there any barriers to completing the planned actions?
    f. How easy or hard did you find it to stick to one category of actions per week?

g. What did you think about the frequency of the action planning task?

7. Reflection and action evaluation
    a. Was there anything you particularly liked about the reflection task?
    b. Was there anything you particularly disliked about the reflection task?
    c. How easy or hard did you find it to evaluate the effectiveness of a category of actions at the end of the week?
    d. Which category of actions was the most effective for you and why?
    e. Which category of actions was the least effective for you and why?
    f. How useful was the weekly evaluation in keeping an overview of the strategies you tried out?
    g. What did you think about the frequency of the reflection and evaluation task?
    h. How useful did you find the action diary?
8. Was the intervention missing anything that would have helped you lose weight?
9. How would you like it if the intervention you followed throughout this study were translated into an app?
    a. What features would you like to see in the app?
    b. Would you make use of such an app?

Appendix 6.4 - Mind map qualitative analysis