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FULL-LENGTH REPORT

Sugar Habit Hacker: Initial evidence that a planning intervention reduces sugar intake

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ABSTRACT

Background and aims: Sugar is a potentially addictive substance that is consumed in such high levels the World Health Organisation has set recommended consumption limits. To date there are no empirically tested brief interventions for reducing sugar consumption in adult populations. The current study aimed to preliminarily assess the feasibility of recruitment, retention, and intervention engagement and impact of a brief intervention. *Methods:* This pre-post study recruited 128 adults from New Zealand to complete a 30-day internet-delivered intervention with in-person and email coaching. The intervention components were derived from implementation intention principles whereby the gap between intention and behaviour was targeted. Participants selected sugar consumption goals aligned with WHO recommendations by gender. To meet these goals, participants developed action plans and coping plans and engaged in self-monitoring. Facilitation was provided by a coach to maintain retention and treatment adherence over the 30 days. *Results:* Intervention materials were rated as very useful and participants were mostly satisfied with the program. The total median amount of sugar consumed at baseline was 1,662.5 g (396 teaspoons per week) which was reduced to 362.5 g (86 teaspoons) at post-intervention evaluation (d = 0.83). The intervention was associated with large effects on reducing cravings (d = 0.59) and psychological distress (d = 0.68) and increasing situational self-efficacy (d = 0.92) and well-being (d = 0.68) with a reduction in BMI (d = 0.51). *Conclusion:* This feasibility study indicates that a brief intervention delivering goal setting, implementation planning, and self-monitoring may assist people to reduce sugar intake to within WHO recommendations.

KEYWORDS

sugar, addiction, self-help, treatment, implementation planning, self-regulation

INTRODUCTION

High sugar consumption is associated with an increased risk of a number of health conditions including childhood and adult obesity, Crohn's disease, metabolic disease, type 2 diabetes, depression, cognitive decline, hypertension, high cholesterol, colon cancer, and dental cavities (Aeberli et al., 2011; Bostick et al., 1994; Burt & Pai, 2001; Knüppel, Shipley, Llewellyn, & Brunner, 2017; Lustig, Schmidt, & Brindis, 2012; Mayberry, Rhodes, & Newcombe, 1980; Ouyang et al., 2008; Pan et al., 2014; Stanhope, 2016). The World Health Organisation (WHO) recommends maximum daily sugar intake is no more than 10% of dietary intake with a maximum of 5% associated with better health (World Health Organization, 2015). Ten percent of daily intake equates to around 50 g (12 teaspoons) of sugar per day.

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Drawing on several research areas, it appears sugar consumption may provoke a psychological and physical response like that seen in substance use disorders (SUDs). SUDs are characterised in the DSM-5 under a set of four main characteristics, that is, impaired control (e.g., using larger quantities of the substance than intended), social impairment (e.g., neglecting relationships due to usage), risky use (e.g., continued usage despite physical and mental health consequences), and pharmacological indicators (e.g., tolerance and withdrawal) (American Psychiatric Association, 2013). The DSM-5 criteria provides a useful lens to examine how sugar is similar (or different) to other drugs of addiction. In terms of impaired control, it may be that often people are unaware of the amounts of sugar they ingest. For example, they may acknowledge that a given product contains sugar, but underestimate the amount. In other cases, they may be simply unaware that a product contains sugar (e.g., savoury products, such as sauces). In that sense, sugar may differ from other addictive substances where the person has some awareness of what is being consumed. In terms of dependence, sugar may have a similar response to other drugs as it affects the brain through activating reward pathways (e.g., dopamine and opioid production) (Avena, Rada, & Hoebel, 2008; Garber & Lustig, 2011). Over time, this activation may cause the individual to crave sugar and experience withdrawal-like symptoms, such as headaches, when reducing intake (Colantuoni et al., 2002; Falbe, Thompson, Patel, & Madsen, 2019). Opioid and dopamine processes have been implicated as a mechanism for addiction as they can activate the brain's reward circuity, for example, opioid release can produce a euphoric state (Gianoulakis, 2004).

Despite the ubiquity of sugar across various food and beverages, the processes that determine sugar intake (or reduction) remain unclear. Recently, a social-cognitive and motivational model of sugar consumption incorporating aspects of the Self-Determination Theory, the Theory of Planned Behaviour, and the Health Action Planning Approach (HAPA) has been developed (Hagger, Trost, Keech, Chan, & Hamilton, 2017). Empirically, however, the variance explained by this model has thus far been small and, based on a single time-point (i.e., static model of decision-making), the planning element did not mediate the "gap" between intentions and behaviour (i.e., the difference between intending to do something and actually doing it), as reported in other health behaviour change studies (Hagger et al., 2017).

Despite intentions to change behaviours, a high proportion of individuals fail to do so. The HAPA model (Schwarzer, Lippke, & Luszczynska, 2011) addressed this issue by identifying motivational and volitional phases of behaviour change where activation of behavioural intentions can be supported by planning in the volitional phase. Action planning and coping planning (also referred to as implementation intentions) is a promising method used across a broad range of health conditions for reducing the intention-behaviour gap (Gollwitzer, 1999; Sniehotta, Scholz, & Schwarzer, 2005; Sniehotta, Schwarzer, Scholz, & Schüz, 2005). According to action planning, linking a goal intention (such as 'I want to stick to my sugar limits') with an action plan specifying how to respond (i.e., when, where and how) can assist in closing the intention-behaviour gap (Sniehotta, Schwarzer, et al., 2005). Research indicates that action planning is strengthened when accompanied by a coping plan (or back-up plan) that pre-empts obstacles and identifies opportunities to act (i.e., if X happens, then I will do Y) (Hagger & Luszczynska, 2014). To guide the identification of barriers and solutions, researchers have developed brief volitional help sheets (Arden & Armitage, 2012; Armitage & Arden, 2012). These 1–2 page guides provide a list of around 20 common barriers and solutions and have been used to expedite the planning process where participants choose a barrier and a solution for their own use (Kwasnicka, Presseau, White, & Sniehotta, 2013). Recent research has extended the concept of the volitional help sheet by developing detailed descriptions of barriers and solutions which were based on lived experience mined from hundreds of online forums and websites (Park, Booth, Bagot, & Rodda, 2020). Results from feasibility testing indicated the guidelines were perceived as helpful and easy to use and understand (Park et al., 2020).

Despite sugar consumption being related to a range of harms and a potentially addictive substance, there have been no targeted psychological interventions specifically aimed at reducing it. People in New Zealand consume sugar at levels in excess of the WHO guidelines with one study indicating 58% of adults consume more than 10% of daily calories from free sugar and 88% consuming more than the WHO conditional recommendation of 5% (Kibblewhite et al., 2017). Therefore, the aim of the current study was to assess the preliminary feasibility of a brief intervention for the reduction of free sugar consumption in the New Zealand general population. Implementation planning has demonstrated efficacy to support behaviour change for a range of health conditions but has not previously been delivered for sugar reduction. The intervention delivers implementation planning (action and coping planning) with goal setting and self-monitoring. Because internet interventions are associated with high attrition and low treatment adherence (Christensen, Griffiths, & Farrer, 2009; Linardon & Fuller-Tyszkiewicz, 2020), we included in-person and email support via a coach. The specific aims for this study were to: (a) determine whether a brief internet-delivered intervention with in-person and email coaching is feasible for sugar reduction in terms of recruitment, retention, and intervention engagement, (b) determine the program's acceptability in terms of satisfaction and usability, and (c) preliminarily assess if this intervention is associated with reduced sugar consumption, reduced sugar addiction, sugar cravings, psychological distress, BMI and improved wellbeing.

METHODS

Participants

A total of 128 participants aged 18–78 years were recruited from the greater Auckland region using a combination of

flyers and online advertisements (social media, university and health promotion websites). The eligibility criteria required participants to be aged 18 years or older and have a desire to reduce their sugar consumption. Volitional state was an inclusion criteria as the intervention targeted those ready to enact change and was not expected to influence those who were not intending to change their quantity of sugar consumed. Participants were excluded if they had received treatment for a mental health disorder including eating disorder or clinical depression in the previous 12 months, had a current diagnosis of Type 1 or Type 2 diabetes, or had previously sought professional advice (e.g., from a psychologist, dietician, or other health professional) to reduce sugar intake.

Intervention

Sugar Habit Hacker is an internet-delivered intervention with in-person and email coaching designed to support people wanting to reduce their free sugar consumption. The intervention is a theoretically- (behaviour change techniques: BCT) and empirically- (lived experience) based intervention. As indicated in Table 1, the core BCT components of the intervention were goal setting, action planning, coping planning, and self-monitoring. The intervention incorporated these BCTs to strengthen the relationship between participants' intentions to reduce sugar consumption and subsequent behaviour.

To support participants' development of action and coping plans, we developed an extended volitional help sheet (i.e., guideline) which details a range of barriers and potential solutions. Building on our previous work in internet gaming disorder (Park et al., 2020), the sugar implementation guidelines were almost entirely informed by lived experience which was mined from hundreds of websites and discussion forums (Rodda, Booth, Brittain, McKean, & Thornley, 2020). The resultant 64-page guideline presented 16 broad strategies for sugar reduction inclusive of strategies to remove or reduce access to sugar products (i.e., avoidance, environmental restructuring, consumption planning); direct reduction of sugar (i.e., tapering, substance substitution); goal-consistent response in high-risk situations (i.e., consumption control, urge management, withdrawal management); support (i.e., social network, professional support); maintaining change over the longer term (i.e., self-monitoring, underlying issues, maintain readiness); and general improvement of mental and physical health (i.e., alternative activities, healthy eating, wellbeing). Each of the 16 broad strategies contained tips and information for implementation as well as a section presenting the available academic evidence.

In-person and email coaching was provided to increase retention and ensure participant comprehension of the intervention. At the baseline in-person interview, the coach prompted a further discussion on reasons for change and reasons for entry into the study. This discussion was based on participants' responses to open text questions in the online survey. At this time, participants were also provided with an overview on how to use the online planning tool and how to navigate the hard copy of implementation guidelines containing tips and strategies for reduction. Participants were asked to choose two strategies to focus on. The coach provided email feedback on the participants' action and coping plans. For example, the coach checked that action plans contained how, when, and where new behaviour will take place. For coping plans, the coach checked that barriers were related to the action plan, and where solutions were brief or incomplete, the coach linked participants to specific sections of the implementation guidelines. At 14 days post baseline, the coach checked in by email to remind participants to stick to their action plans and to enact coping plans as needed. All interactions were based on a motivational interviewing approach that valued individual autonomy and decision making.

Measures

Measures included participant demographics (age, gender, education, ethnicity, and annual income, with weight and height for BMI calculations). The New Zealand index of deprivation (NZiDep) was administered which was a brief eight-question index used to measure participants' social economic status (SES) (Salmond, Crampton, King, & Waldegrave, 2006).

Primary outcome. Sugar consumption was measured using a modified food frequency questionnaire (FFQ), adapted for sugar consumption in the local context (Cade, Thompson, Burley, & Warm, 2002). The validated FFQ (Food4Me FFQ) (Forster et al., 2014) was used with products derived from a variety of sources, including popular sugars purchased in New Zealand supermarkets (Hamilton, Mhurchu, & Priest, 2007), list of sugar products used in a paper which assesses the marketing of unhealthy foods to NZ children (Mhurchu, Mackenzie, & Vandevijvere, 2016), and a New Zealand list of frequently consumed foods high in sugar content (Kibblewhite et al., 2017). The list contained 22 broad categories of products with examples of common types and portion sizes listed under each category. Participants selected the amount and frequency with which they had consumed items in that category. Results were aggregated across all categories into an overall sugar quantity as measured in grams and teaspoons.

Secondary outcome measures:

- Kessler 6 Psychological Distress Scale (K6) is a 6-item measure indexing current and non-specific psychological distress in the past four weeks (Kessler et al., 2002). Baseline alpha was $\alpha = 0.812$.
- World Health Organisation Well-Being Index (WHO-5) is a 5-item measure assessing well-being over the preceding 30 days (World Health Organization: Regional Office for Europe, 1998). The internal consistency in the current sample was acceptable. Baseline alpha was $\alpha = 0.798$.

Table 1. Intervention components of *Sugar Habit Hacker*

Component	Activity	Delivery method
Goal setting	• Self-assessment and writing about reasons for and importance of change. • Set goal for males (<28 g – 7 tsp or <36 g – 9 tsp per day) and females (<16 g – 4 tsp or <24 g – 6 tsp per day). • Set a start date 2–3 days after development of plans.	Reasons via open text field. Goal setting with coach and then recorded in Qualtrics.
Action planning	• Identify two behaviour change strategies from a menu of options. The menu of options included a summary of 16 different approaches for sugar reduction. • Prepare two action plans detailing how the strategy can be put into action. Complete template starting with the statement *I will* . . . Prompts include what, when, where, and how.	Qualtrics drop-down list plus open text fields.
Coping planning	• Identify up to three obstacles or barriers (if) to each action plan and a solution to address each barrier (then).	Three open text fields for barriers & solutions.
Implementation guidelines	• Review implementation guidelines for 16 different categories of behaviour change strategies. These were based on lived experience and what worked for other people who had attempted to implement the strategy.	64-page hard copy booklet provided at baseline assessment.
Self-monitoring	• Participants recorded sugar consumed with a hard copy self-monitoring sheet.	Paper copy
Goal coach*	• Firm up reasons for change. Discuss triggers for sugar and challenges to self-control. Assist with goal selection for sugar reduction. • Discuss program overview and explain role of the coach. • Provide email feedback on action and coping plans at baseline and their alignment with program materials. • Provide email support at 14 days to link participants to strategies and provide support for continued implementation and solutions for barriers. A second email at post-treatment prompted participants to complete online measures.	Sessions conducted face-to-face (baseline and post evaluation) and via email (all other interactions).

Note: * Delivered at baseline, 14-days and 30-days post baseline.

- The Brief Substance Craving Scale (BSCS) measures subjective desire for alcohol (Mezinskis, Honos-Webb, Kropp, & Somoza, 2001; Somoza et al., 1999) and was adapted to measure sugar cravings. Baseline alpha was $\alpha = 0.868$. For a fourth item (which is reported separately), participants were asked to estimate the number of times they had craving for sugar over the past 24 h.
- The 13-item Yale Food Addiction Scale (mYFAS2.0) measured sugar addiction (11 items for addiction criterion, 2 items for clinical significance). The scale was originally developed from the DSM-IV-TR substance use criteria and recently updated to align with the new criteria in the DSM-5 (Schulte & Gearhardt, 2017). Baseline alpha was $\alpha = 0.837$.
- The 8-item Weight Efficacy Lifestyle Questionnaire Short Form (Ames, Heckman, Grothe, & Clark, 2012) assessed situational self-efficacy in relation to overeating. The current study adapted the scale by replacing "overeating" with "sugar." Baseline alpha was $\alpha = 0.906$.

Programme evaluation measures.

- Planning propensity was measured with an adapted question from Hagger et al. (2017). The stem of "Over the past 30 days I have . . ." was followed by three items each for action planning (e.g., planned in detail how I would reduce my sugar use) and coping planning (e.g., I planned in advance what to do if something got in the way of my plans). Self-monitoring was measured with a three-item scale (e.g., I had a system in place on how I would track my sugar each every day). Each question was measured on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree. Baseline alphas were $\alpha = 0.83$, 0.88 and 0.89, respectively.
- The 15-item internet evaluation and utility questionnaire (Ritterband et al., 2008; Thorndike et al., 2008) was adapted to evaluate the programme for sugar reduction. Four items were selected which included (i) satisfaction, (ii) usefulness, (iii) ease of comprehension, and (iv) the likelihood of participants returning to the program if difficulties continued or returned. Higher scores on these

items indicate good perceptions of the program. Baseline alpha was $\alpha = 0.76$. Two open-ended items related to the most and least helpful parts of the *Sugar Habit Hacker*.

Procedure

Baseline assessment was undertaken in Qualtrics survey software as well as face-to-face (weight and height). Once baseline assessment was completed, participants were provided a hard copy of the implementation guidelines as well as verbal information on the study procedures and how to use the online planning tool. A link to the intervention was provided by email to participants. Participants received personalised feedback (coaching) via email on their plans from a post-graduate psychology student within 2–3 days of plan submission. Participants also received an additional coaching email at day 14 and a prompt to complete the 30-day follow-up evaluation at the conclusion of the intervention. The coach undertook fidelity checks to ensure participants had understood and read the materials. This process occurred at baseline interview where information was presented in-person via a didactic exchange. The coach also provided email feedback on the alignment between participant action and coping plans and programme materials (e.g., that the plans were aligned with a chosen strategy) and that the planning tools were used correctly (e.g., confirm that plans followed the if-then structure).

Statistical analyses

Analyses were conducted within SPSS (version 25). Missing data for outcome variables were replaced with last observation carried forward (i.e., baseline scores). Descriptive statistics (means, standard deviations for continuous variables; median, 25% and 75% interquartile ranges (IQRs) for sugar consumption as open-ended distribution; frequencies for categorical data) were used to describe the sample. To understand recruitment, retention, and engagement, participant demographics were compared for those who (i) completed versus dropped-out at baseline, (ii) completed versus did not complete the intervention (goal setting and plan development), and (iii) completed versus did not complete post-treatment evaluation. Comparisons were undertaken using *t*-tests (e.g., age) or χ^2 (e.g., gender), as relevant to data type.

To understand the impact of the intervention, completers (those who completed baseline and commenced 30-day follow-up) and intention-to-treat (ITT; those who completed baseline) analyses were conducted; results were the same, therefore completer results are presented, unless otherwise noted. Paired sample analyses (*t*-tests for means, Wilcoxon signed rank for medians, McNemar's test for dichotomous variables) were conducted for completers and ITT samples. For interpretability, grams of sugar are converted to teaspoons using 4.2 g per teaspoon. Clinical significance change in sugar consumption at post-intervention was determined "healthy" if levels were within gender-relevant WHO guidelines (i.e., ≤6 teaspoons per day for females, ≤9 teaspoons per day for males). Reliable change was not assessed or incorporated when determining clinical significance as the newly developed sugar consumption measure does not yet have psychometric information (i.e., measurement reliability). Intervention engagement (yes/no) was defined as setting a goal, completing at least one action plan (participants could set two action plans) and one coping plan (at least one barrier and solution identified).

Partial correlations with age, gender, income, intervention engagement, follow-up food addiction symptoms, situational efficacy, craving total, craving frequency, psychological distress, wellbeing (controlling for baseline sugar consumption, addictive symptoms, situational efficacy, craving total, craving frequency, psychological distress, wellbeing) with follow-up sugar consumption were examined. Significant correlations were entered into a hierarchical regression analysis and used to predict changes on sugar consumption (DV sugar consumption at follow-up, step 1 baseline variables including sugar consumption for control, step 2 follow-up variables, step 3 engaged with intervention). Initial regression indicated multicollinearity with BMI (VIF > 10, Tolerance < 0.2), which was subsequently removed and the regression re-run. Parametric analyses (*t*-tests, partial correlations, hierarchical regressions) were run with 1,000 sample bootstrapping. Effect sizes were assessed with Cohen's $d = M_A - M_B/SD$: 0.2 = small, 0.5 = medium, 0.8 = large; Wilcoxon signed rank effect size $r = Z/\sqrt{N}$; 0.1 = small, 0.3 = medium, 0.5 = large; and $f^2 = R^2_{AB} - R^2_A/1 - R^2_{AB}$ (where A is one group of IVs and AB is an additional group of variables): 0.1 = small, 0.25 = medium, 0.4 = large.

Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. The Institutional Review Board of the University of Auckland approved the study. All participants were informed about the study and all provided informed consent.

RESULTS

Aim 1 – Participant characteristics and intervention engagement

A total of 186 participants completed part of the baseline survey with 58 not completing the physical measures resulting in a total of 128 participants at baseline. At post-treatment, 97 participants were retained in the study (76%). There were no differences between completion of baseline (yes/no) on gender, food addiction (number of symptoms, addiction category), situational efficacy, cravings, distress, wellbeing, or levels of sugar consumption. However, compared to those who did not complete baseline, completing participants were older ($M = 41$ years, SD = 15 versus $M = 32$, SD = 11), more likely to be in part-time (22% vs. 5%) but less likely to be in full-time employment (43% vs. 66%). It took 53 days to

Table 2. Sugar Habit Hacker baseline participant characteristics and comparisons for baseline completion

Demographic and baseline measurement scores	Did not complete baseline $n = 58$ (n, %)	Completed baseline $n = 128$ (n, %)	Group comparisons
Gender, Male	10 (17.2)	16 (12.5)	$\chi^2(1) = 0.75$, $P = 0.39$
Age, years (M, SD)	32.17 (10.81)	40.46 (15.13)	$t(184) = -3.76$, $P < 0.001$
Ethnicity			$\chi^2(3) = 4.03$, $P = 0.26$
White European	42 (72.4)	98 (76.6)	
Asian	13 (22.4)	18 (14.1)	
Māori	3 (5.2)	7 (5.5)	
Pasifika	0 (0)	5 (3.9)	
Employment			$\chi^2(3) = 11.26$, $P = 0.01$
Employed full time	38 (65.5)	55 (43.0)	
Employed part time	3 (5.2)	28 (21.9)	
Unemployed	6 (10.3)	18 (14.1)	
Student	11 (19.0)	27 (21.1)	
Income			$\chi^2(4) = 8.42$, $P = 0.08$
Less than $20,000	3 (5.2)	14 (10.9)	
$20,001–$40,000	3 (5.2)	14 (10.9)	
$40,001–$70,000	20 (34.5)	24 (18.8)	
$70,001–$100,000	9 (15.5)	30 (23.4)	
$100,001+	23 (39.7)	46 (35.9)	
NZ index of deprivation (M, SD)	1.72 (0.93)	1.91 (1.20)	$t(184) = -1.02$, $P = 0.31$
Sugar consumption (g)			
Total for 30 days (median, IQRs)	1,560.5 (1,014.0, 2,325.3)	1,662.5 (1,017.0, 2,602.0)	$\chi^2(1) = 0.40$, $P = 0.53$
Daily average (median, IQRs)	52.0 (33.8, 77.5)	55.4 (33.9, 86.7)	$\chi^2(1) = 0.40$, $P = 0.53$
Yale Food Addiction symptoms (M, SD)	1.8 (2.64)	2.6 (2.9)	$t(184) = -1.68$, $P = 0.09$
Yale Food Addiction categories			$\chi^2(3) = 4.19$, $P = 0.24$
No food addiction	48 (82.8)	98 (76.6)	
Mild food addiction	3 (5.2)	2 (1.6)	
Moderate food addiction	3 (5.2)	11 (8.6)	
Severe food addiction	4 (6.9)	17 (13.3)	
Situational efficacy (M, SD)	36.8 (16.8)	36.5 (18.7)	$t(184) = 0.10$, $P = 0.92$
Brief Substance Craving (M, SD)	6.1 (2.3)	6.0 (2.1)	$t(184) = 0.39$, $P = 0.69$
Craving in past 24 h (M, SD)	5.7 (12.8)	3.6 (2.5)	$t(184) = 1.75$, $P = 0.08$
Kessler 6 Psychological Distress (M, SD)	12.7 (4.7)	12.3 (3.9)	$t(184) = 0.50$, $P = 0.62$
WHO Wellbeing Index (M, SD)	50.4 (16.7)	52.4 (18.0)	$t(184) = -0.73$, $P = 0.47$
BMI score (M, SD)	*Did not complete*	28.0 (6.6)	–

recruit 128 participants (11 April to 3 June, 2019), with half the sample recruited within 20 days.

As indicated in Table 2, participants were predominantly female (87%), aged 41 years on average, white European (77%), and approximately 60% earning more than $70,000 NZD per annum. The majority (77%) did not have a sugar addiction, and approximately 20% reported moderate or severe food addiction. On average, participants reported 2.6 addiction symptoms (range 0–11) and 59.4% had a BMI score indicating that they were overweight or obese.

Baseline sugar consumption

Participants consumed sugar from an average of 13.4 different sources (SD = 4.23; range 2–22). The highest sugar consumption was associated with sweets and lollies (e.g., candies, marshmallow; 14%), cakes, muffins, cupcakes, and deserts (13%), and plain chocolate including milk or dark chocolate (11%; driven by females 12% vs. males 4% of total sugar consumed). A list of all sugar sources, by gender and total baseline participants is provided in Supplementary Table 1. On average (median), females consumed 54 g of sugar a day (IQRs: 33, 88) and males 66 g (IQRs: 50, 86). These figures translate to twice the daily recommendation for women (i.e., 12.8 teaspoons vs. recommended 6 teaspoons) and almost twice the daily recommendation for men (i.e., 15.7 teaspoons vs. recommended 9 teaspoons). There were 17 (13%) participants who were eating within recommended limits.

Intervention engagement

Across the sample, 94 (73%) participants adhered to the treatment protocol which required participants to set a goal and develop two action plans with a minimum of one coping plan each. In terms of the engagement with individual intervention components 97 (76%) selected from

one of predefined sugar reduction goals and a similar proportion set a start date (n = 91, 71%). Female consumption goals were 4 teaspoons/16 g (n = 63, 56%) or 6 teaspoons/24 g (n = 24, 21%) and for males 7 teaspoons/28 g (n = 10, 63%). The majority (n = 78, 81%) completed two action plans as per protocol and developed more than one coping plan for each. A further 16 participants (17%) developed 2 action plans with one coping plan for each. Two participants (3%) developed only one action plan although developed more than one coping plan. Participants agreed that over the 30-day intervention, they had planned in detail how to manage their sugar reduction (M = 3.97, SD = 0.70), had established coping plans to address barriers (M = 3.81, SD = 0.82), and had engaged in self-monitoring of sugar consumption (M = 3.59, SD = 0.91). Interaction with the goal coach was offered at baseline, 14-days, and post-baseline. All participants attended the in-person baseline assessment with 74 (77%) of completers also attending a second in-person assessment. Across demographics and outcome measures, there were no differences between those who did and did not adhere to the protocol (see Supplementary Table 2). Of those who completed post treatment evaluation 86/96 (90%) adhered to the treatment protocol.

Aim 2 – Acceptability of Sugar Habit Hacker

Overall, participants (n = 96) reported the program materials and information to be very useful with mean scores significantly higher than the scale mid-point (M = 4.00, SD = 0.68; $t(95)$ = 21.43, P < 0.001). Specifically, participants (n = 96) were mostly satisfied with the program materials (M = 4.09, SD = 0.82; $t(95)$ = 19.00, P < 0.001), found the information in them mostly useful (M = 3.88, SD = 0.92; $t(95)$ = 14.64, P < 0.001), very easy to understand (M = 4.51, SD = 0.67; $t(95)$ = 29.63, P < 0.001), and would somewhat to mostly return to the materials if difficulties continued or returned (M = 3.50, SD = 1.11; $t(95)$ = 8.79, P < 0.001).

Aim 3 – Impact of intervention

Comparisons between those who did and did not complete post-treatment evaluation indicated no differences by gender, age, ethnicity, employment or income, but completers were more likely to report a severe food addiction and less likely to have a moderate food addiction. There were no other differences across measures for those who did or did not complete the post-treatment evaluation (see Supplementary Table 3). Pre- and post-intervention scores and comparisons are presented in Table 3. There was a statistically significant reduction in sugar consumption (primary outcome) with a large effect size. There were significant improvements for all secondary outcomes with medium to large effect sizes: fewer addiction symptoms, cravings, and psychological distress as well as improved situational efficacy well-being. Regarding the clinical significance of changes in sugar consumption, at baseline only 17 participants (18%) were eating within gender-based WHO recommendations. This proportion increased to 81% (n = 78) at post-intervention (χ^2 = 77.53, P < 0.001). Of the 17 participants who were eating within WHO guidelines pre-intervention, 11 further reduced their sugar consumption by more than 50%, a further two reduced by 8% and 24%, and four increased their sugar consumption. There were eight participants who improved by 50% (cut their sugar consumption in half) but remained outside the guidelines.

To maximise sample size to meet regression assumptions, the ITT group was used to predict change in sugar consumption. Partial correlations (see Supplementary Table 4) showed no association between reductions in sugar consumption and age, gender, income, or craving frequency. After controlling for baseline measures [R^2 change = 0.36, $F(5, 122)$ = 13.57, P < 0.001], follow-up situational self-efficacy (B = −0.60, P = 0.02) and total craving (B = 3.37, P = 0.01) predicted follow-up sugar consumption [R^2 change = 0.25, $F(4, 118)$ = 18.28, P < 0.001]. At Step 3, completing the intervention (B = −16.87, P = 0.02) also predicted sugar consumption [R^2 change = 0.03, $F(1, 117)$ = 8.15,

Table 3. Pre-post evaluation comparisons for completers (n = 96)

Variables	Baseline	Follow-up	Comparison statistics		Effect size
Primary outcome (Median, IQRs)					
Sugar consumption			Z	*P*	*r*
Total grams of sugar	1,662.5 (1,017.0, 2,602.0)	362.5 (182.0, 617.0)	−8.15	<0.001	0.83
Daily grams of sugar	55.4 (33.9, 86.7)	12.1 (6.1, 20.6)	−8.15	<0.001	0.83
Secondary outcomes (M, SD)			*T*	*P*	Cohen's *d*
Yale Food Addiction Symptoms	2.71 (3.0)	0.70 (1.49)	−6.86	<0.001	0.70
Situational Efficacy	37.22 (19.81)	55.27 (16.72)	9.02	<0.001	0.92
Brief Substance Craving	5.97 (2.23)	3.56 (2.17)	−5.82	<0.001	0.59
Craving in past 24 h	3.56 (2.38)	2.05 (1.97)	−8.86	<0.001	0.90
Kessler 6 Psychological Distress	12.46 (3.95)	9.60 (3.83)	−6.74	<0.001	0.68
WHO Wellbeing Index	52.13 (18.5)	64.88 (16.89)	6.67	<0.001	0.68
BMI score	28.15 (6.54)	27.87 (6.38)	−5.01	<0.001	0.51

Note: WHO = World Health Organisation. Effect size values: r 0.1 = small, 0.3 = medium, 0.5 = large, Cohen's d 0.2 = small, 0.5 = medium, 0.8 = large.

Table 4. Hierarchical regression predicting change in daily sugar consumption (n = 128; bootstrap)

Independent Variable (IV)	*B*	Std Error	95% CI (lower, upper)	Sig
Control variables (entered at Step 1)				
Baseline sugar consumption	0.50	0.93	0.30, 0.67	<0.001
Baseline situational efficacy	0.24	0.22	−0.18, 0.71	0.285
Baseline craving total	−2.71	1.33	−5.45, −0.11	0.047
Baseline psychological distress	−0.33	1.05	−2.46, 1.71	0.794
Baseline wellbeing	0.02	0.19	−0.32, 0.44	0.887
(entered at Step 2)				
Follow-up situational efficacy	−0.60	0.23	−1.03, −0.14	0.017
Follow-up craving total	3.37	1.36	0.84, 6.37	0.014
Follow-up psychological distress	1.90	1.66	−0.09, 5.21	0.274
Follow-up wellbeing	0.08	0.24	−0.47, 0.51	0.712
(entered at Step 3)				
Engaged with intervention (0 = no)	−16.87	6.15	−28.77, −3.92	0.018

Note: Results reported are values for Step 3. See Supplementary Table 5 for results for each individual step. Control variables: sugar consumption at baseline, baseline situational efficacy, craving total, psychological distress, and wellbeing. 10 IVs requires sample size of n = 130.

P = 0.005], although the effect size was f^2 = 0.06 (<small). Key predictors for reduced sugar consumption were therefore improvement in situational efficacy, reductions in craving, and participating in the intervention (Table 4).

DISCUSSION

This study was designed to preliminarily assess whether a brief intervention with in-person and email coaching was feasible for sugar reduction in terms of recruitment, retention, and intervention engagement as well as whether the intervention had an impact on sugar consumption. This feasibility study was the first to examine important features of developing an intervention to reduce sugar consumption to within levels recommended by health organisations. Uptake was strong with 100 participants meeting eligibility criteria recruited within four weeks and completing a baseline assessment that was delivered online and in a face-to-face setting. Using a blended approach of internet-delivered and coaching support in-person and by email, we were able to retain 75% of participants without any remuneration for completion of post-treatment surveys. This rate of retention is similar to post-treatment rates for internet interventions more broadly (Christensen et al., 2009; Linardon & Fuller-Tyszkiewicz, 2020) and our previous study delivering action and coping planning with implementation support (Park et al., 2020). Engagement with the action (could complete one or two action plans) and coping (could complete up to three coping plans for each action plan) planning components of the intervention was excellent. Almost three-quarters of participants completed a combination of at least one action and coping plan, with most completing both action plans and detailing multiple (>1) coping plans for each. Our findings suggest that blended online and hard-copy delivery of sugar interventions supported by in-person and email coaching support is promising. Future research might consider variations of intervention delivery and support (online, face-to-face, or phone) as well as remuneration to increase the rate of retention in internet interventions.

Across the sample, baseline sugar consumption was high, with participants consuming twice the WHO recommended limit (Johnson et al., 2009; World Health Organization, 2015). Improvements were reported for the primary outcome of sugar quantity and all secondary outcomes. Increases in participants' situational efficacy and decreases in craving levels were associated with follow-up sugar consumption reduction. Key predictors for reduced sugar consumption were improvements in situational self-efficacy, reductions in craving, and participation in the intervention. Intervention engagement was a significant predictor suggesting that an additional aspect other than those indexed by secondary outcomes facilitated the reduction in sugar consumption. Similar to the cross-sectional study by Hagger et al. (2017), we found no correlations between gender, age, or BMI with sugar consumption. Taken together, particularly the improved situational self-efficacy, these findings suggest that the majority of participants were able to improve their competency in sugar reduction.

This study had a number of strengths including a focus on an understudied global public health issue, theoretically based intervention content, identification of methodological aspects for recruitment considerations, intervention feasibility and acceptability, and preliminary impact of the intervention. There are also a number of limitations should also be noted. First, short term follow-up indicated the intervention had a positive effect on the short term but longer follow-up is needed to determine if sugar consumption remains low in the time following the intervention. It is recommended in future studies that a longer follow-up period is conducted to determine the long-term impacts of the intervention and whether these remain stable over time. Second, the intervention content was aligned with the volitional phase of behaviour change and therefore targeted towards those who were in a state of readiness to change their sugar consumption. As such, the eligibility criteria were

that participants should have "a desire to reduce their sugar consumption". Given this state of readiness, it is possible that some change would have occurred without the intervention and there was the possibility of social desirability effects. Future studies should apply a randomised controlled trial design to determine whether the specific intervention is more effective than no treatment. It would also be useful to test the intervention with and without coaching so as to determine the relative contribution of each intervention component. This intervention focused on volitional strategies, however, our previous work identified strategies for behaviour change that were motivational (e.g., coming to a realisation, examining the pros and cons of change, and seeking information and knowledge) (Rodda et al., 2020). Future research might consider interventions for sugar that target motivational enhancement and this could be tested with or without the intervention targeting volitional phase.

Third, participants were recruited from the greater Auckland area through community advertising but the sample may not have been representative of people who need help to reduce sugar consumption. Participants represented a convenience sample that contained a high proportion of participants not employed full-time. This may reflect limited after-hours availability of face-to-face appointments as well as the study being conducted in a central city location that was not easy to access. Participants were also most frequently female with almost 60% reporting a high BMI. It is unclear whether the sample was reflective of a sub-population that want to reduce sugar consumption and/or who are willing to take part in a study involving a blended in-person and online approach. Fourth, the intervention was delivered via Qualtrics survey software which is necessarily limited in its functionality and capacity to provide a platform for self-monitoring. Future research should investigate the feasibility of delivering the same content via a smartphone application that can integrate each of the intervention components. Our primary outcome measure required retrospective recall on a group of sugar products that were identified specifically for the current study. Future research should consider real-time tracking of sugar consumption using ecological momentary assessment designs so as to avoid issues such as recall bias (Shiffman, Stone, & Hufford, 2008).

Fifth, several of the measures used in the current study were not validated specifically for sugar. Unfortunately, measures suited to assessing the psychological processes indexing the addictive properties of sugar consumption were not available, hence we adapted measures from substance use research (e.g., brief craving substance questionnaire). We administered three items taken from a 20-item scale indexing craving to minimise participant burden. Although the three items performed well (internal consistency), cravings proved to be an important factor in influencing sugar reduction. The full scale with multiple items capturing different aspects of craving (e.g., intensity, frequency, duration) separately could be considered for future studies. Because most measures were administered online and all items were forced choice, there were minimal missing data. Where there were missing data, last observation carried forward was used rather than imputation for outcome variables. This conservative approach has less power to detect significance.

Sixth, we identified a number of issues with the planning measure selected. Although it had been previously used in a cross-sectional sugar consumption study (Hagger et al., 2017), we only deployed it at post-intervention, thereby not identifying any changes in participants' planning behaviours. Future research would do well to consider using an *if-then* planning measure which assesses participants' identification of opportunities and risks. Furthermore, for our measures, we retained the original wording of the item (e.g., stick to my intention), which was different from the plain language used within our study (e.g., goal). This approach may have not supported participants' understanding what the item was targeting and appropriate responses. Lastly, for this feasibility study, the assessment of clinical significance must be cautiously considered. Our study was focused on feasibility, rather than efficacy and so was clearly limited by our single sample and sugar consumption measure without normative and measurement reliability data. Future work can examine more nuanced clinical change by incorporating reliability of change indices (Jacobson & Truax, 1991) and consider participants who may have improved but not reduced to within guideline recommendations.

Overconsumption of sugar is a global health issue with short- and long-term ramifications on health at an individual- and population-level. This work is an important step towards addressing this global health issue.

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Authors' contribution: SR conceived the study and obtained funding. NC and SR supervised the project. MB delivered the intervention and collected the data. KB and NB prepared the first draft of the paper and conducted the data analysis. All authors reviewed and approved the final paper.

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SUPPLEMENTARY MATERIAL

Supplementary data to this article can be found online at https://doi.org/10.1556/2006.2021.00054.

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