Martin, J. S., Chater, A. & Lorencatto, F. (2013). Effective behaviour change techniques in the prevention and management of childhood obesity. International Journal of Obesity, 37(10), pp. 1287-1294. doi: 10.1038/ijo.2013.107

CITY UNIVERSITY LONDON

EST 1894

City Research Online

1   Effective behaviour change techniques in the prevention and management of childhood

2   obesity

3

4

5   Jilly Martin, PhD

6   Department of Psychology, University of Sheffield

7

8   Angel Chater, PhD

9   School of Pharmacy, University College London

10

11   Fabiana Lorencatto, MSc

12   Department of Clinical, Educational & Health Psychology, University College London

13

14   Address for correspondence:

15   Dr Jilly Martin

16   Department of Psychology

17   University of Sheffield

18   Western Bank

19   Sheffield

20   S10 2TN

21   Email. jilly.martin@sheffield.ac.uk

22   Tel. (+0044) 114 2226513

23

24

1

25   Abstract

26   Rates of childhood obesity are increasing, and it is essential to identify the active components

27   of interventions aiming to prevent and manage obesity in children. A systematic review of

28   behaviour change interventions was conducted to find evidence of behaviour change

29   techniques (BCTs) that are most effective in changing physical activity and/or eating

30   behaviour for the prevention or management of childhood obesity. An electronic search was

31   conducted for Randomised Controlled Trials (RCTs) published between January 1990 and

32   December 2009. Of 4,309 titles and abstracts screened, full texts of 135 articles were

33   assessed, of which 17 published articles were included in this review. Intervention

34   descriptions were coded according to the behaviour-specific CALO-RE taxonomy of BCTs

35   (1). BCTs were identified and compared across obesity management ($n = 9$) vs. prevention (n

36     $= 8$) trials. To assess the effectiveness of individual BCTs, trials were further divided into

37   those that were effective (defined as either a group reduction of at least 0.13 BMI units or a

38   significant difference in BMI between intervention and control groups at follow-up) vs. non-

39   effective (reported no significant differences between groups).

40   We reliably identified BCTs utilised in effective and non-effective prevention and

41   management trials. To illustrate the relative effectiveness of each BCT, effectiveness ratios

42   were calculated as the ratio of the number of times each BCT was a component of an

43   intervention in an effective trial divided by the number of times they were a component of all

44   trials. Results indicated six BCTs that may be effective components of future management

45   interventions (provide information on the consequences of behaviour to the individual,

46   environmental restructuring, prompt practice, prompt identification as role model/position

47   advocate, stress management/emotional control training, and general communication skills

48   training), and one that may be effective in prevention interventions (prompting generalisation

49   of a target behaviour). We identified that for management trials, providing information on the

2

50   consequences of behaviour in general was a feature of non-effective interventions and for

51   prevention trials, providing information on the consequences of behaviour in general,

52   providing rewards contingent on successful behaviour and facilitating social comparison

53   were non-effective.

54   　　　To design effective behaviour change programmes for the prevention and

55   management of childhood obesity, we would recommend utilising the BCTs identified as

56   effective in this review. The impact on intervention effectiveness of combining BCTs should

57   be the topic of further research.

58

59 *Key words*

60 Childhood Obesity

61 Prevention

62 Management

63 Behaviour Change Techniques

64 Taxonomy

65 Effectiveness

4

66   Effective behaviour change techniques in the prevention and management of childhood

67   obesity

68

69   Introduction

70   Given the dramatic rise in childhood obesity over the last decade (2-4), it is essential to

71   design interventions that are effective in preventing and managing childhood obesity.

72   Behaviour modification or lifestyle change has become a burgeoning avenue of investigation

73   in this area. Systematic reviews of interventions and clinical guidelines clearly indicate that

74   successful interventions for preventing and managing obesity in children are complex and

75   multi-component - aimed at changing both physical (or sedentary) activity and diet or healthy

76   eating (e.g., 5-9) and comprise multiple, potentially interacting methods of changing

77   behaviour. Despite the vast amount of active investigation in this area, little research has

78   deconstructed interventions and identified which individual components are most successful

79   in changing obesity-related health behaviour in children. A lack of consistent terminology for

80   defining intervention components has also hindered interpretation and replication. It is

81   currently unclear what the active ingredients for bringing about obesity-related behavioural

82   change are and thus, evidence to support the content of effective obesity prevention and

83   management interventions in children is still relatively weak (5, 10-12).

84   There is no lack of evidence that positive changes in behaviours linked to obesity can

85   be effective in preventing and managing obesity in children. Hill, Wyatt, Reed and Peters

86   (13) report that even small changes in behaviour that amount to a decrease in calorie intake of

87   only 100Kcal per day can effectively prevent weight gain. Randomised Controlled Trials

88   (RCTs) of lifestyle interventions have reported moderate success in changing obesity-related

89   behaviour in prevention trials (5) and produce potentially clinically significant reductions in

90   overweight in management trials (7, 14). It is important that these positive findings can be

91   replicated, thus, there is clear value in identifying the specific behaviour change techniques

92   (BCTs) used in such interventions that are effective in achieving and sustaining behavioural

93   change. The complex and multi-component nature of such interventions further underlines

94   the need for developing methods to systematically deconstruct intervention content. This is a

95   particularly imperative task for the successful prevention and management of obesity in

96   childhood and adolescence, as it is important to identify specific BCTs that are particularly

97   effective for this age group that may be distinct from those used in adult interventions. There

98   may also be an important distinction between BCTs that are effective in preventing childhood

99   obesity and those that manage obesity in children who are already overweight or obese.

100   Formally evaluating the content of interventions is inherently difficult. Recent

101   guidelines in the field of health psychology aim to establish more open and detailed reporting

102   of interventions to aid the scientific development of behaviour change interventions

103   (CONSORT, 15; Workgroup for Intervention Development and Evaluation Research:

104   WIDER, 16), though these are not universally adhered to and current reporting of

105   intervention content is generally poor and inconsistent (17), thus limiting what we can learn

106   about behaviour change (18).

107   Categorising the components of behaviour change interventions in the field of

108   childhood obesity is complex and attempts to define BCTs are generally idiosyncratic (and

109   potentially non-replicable). For example, some authors have developed their own

110   classifications for extracting such data: Kamath et al. (5) extracted data concerning

111   "informational, cognitive, behavioural, environmental and social support components"

112   (p4607) of interventions, and Sargent, Pilotto and Baur (19) extracted information on

113   "strategies to achieve behaviour change" (p4). Such classifications lack the benefit of precise

114   and standard definitions that allow authentic replication and useful comparisons of BCTs

6

115   across intervention trials. More wholesome descriptions of common behaviour change

116   methods in obesity interventions do exist (see e.g., 6, 20, 21) but it is not always clear how

117   (or if) these descriptions apply to interventions aimed at children.

118   As part of the advancement of a science of behaviour change, Abraham and Michie

119   (22) developed a taxonomy of 26 conceptually distinct component BCTs, which are

120   described using consistent terminology and standard definitions. This taxonomy has been

121   reliably applied to identify and categorise BCTs featured in obesity prevention programmes

122   involving parents and children (23) and in healthy eating and physical activity interventions

123   with adults (24). More recently, the original taxonomy (22) has been revised and extended

124   into a behaviour specific taxonomy of 40 BCTs for physical activity and healthy eating

125   behaviours (CALO-RE: 1). The CALO-RE taxonomy was developed by three teams of

126   researchers to provide standard definitions to reliably identify techniques used for 1)

127   increasing physical activity and healthy eating in obese adults with additional risk factors for

128   morbidity, and 2) increasing self-efficacy to promote lifestyle and recreational physical

129   activity. A total of 72 studies across a variety of populations, behaviours and settings were

130   used as a basis of developing the taxonomy. The authors argue that the CALO-RE taxonomy

131   is more comprehensive than the original, with fewer conceptual problems and less overlap

132   between items, as well as clearer labels and definitions. This taxonomy can be used to

133   analyse the content of behaviour change interventions in depth and also provides a means of

134   improving reporting and aiding replication attempts by specifying BCTs. For the purposes of

135   this review, this taxonomy was used to identify BCTs in physical activity and healthy eating

136   interventions for the prevention and management of childhood obesity. To our knowledge,

137   this taxonomy has not yet been applied to obesity-related behaviour change interventions

138   with children and adolescents.

7

139   We conducted a systematic review to select RCTs of childhood obesity interventions

140   that utilised BCTs as a means to prevent or manage obesity in children and adolescents. From

141   this, we coded intervention descriptions using the CALO-RE taxonomy to identify BCTs that

142   were used in such interventions. In order to work towards aiding intervention designers in the

143   field to build effective BCTs into childhood obesity interventions, this paper aims to 1)

144   identify and code BCTs used in a sample of prevention and management interventions for

145   childhood obesity using the CALO-RE taxonomy, and 2) establish which individual BCTs

146   are components of effective interventions to manage and prevent childhood obesity.

147

148   Method

149   *Study selection*

150   A systematic review was conducted of RCTs of obesity management or prevention

151   conducted with children and adolescents (aged 2-18 years) that assessed the impact of

152   interventions including at least one BCT from the CALO-RE taxonomy compared with a no-

153   treatment control group. Interventions that solely tested the impact of physical activity,

154   education, and/or calorie controlled diets with no behaviour change element were excluded,

155   as were interventions that combined drug treatment or surgery with BCTs. Interventions

156   could be carried out in any setting (e.g., school, clinic, community) and be delivered by any

157   professional (e.g., health professional, teacher, therapist) over any length of time. It is

158   important that desired health outcomes are maintained over time therefore to assess the

159   maintenance of intervention effects; we selected only interventions that reported results 6

160   months beyond the point when active intervention ended. The Transtheoretical Model (TTM:

161   25) argues that long term changes in behaviour may be assessed only after this time period

162   has elapsed. The primary outcome measure was Body Mass Index (BMI). BMI is the only

163   indirect measure of adiposity in childhood that has been shown to be associated with future

8

164 risk of mortality from Coronary Heart Disease (CHD) in adulthood (11) and can be used as a

165 physiological proxy measure of later health outcomes (26-28). BMI was also the only single

166 comparative outcome reported across trials.

167 *Search Strategy and results*

168   An electronic search was conducted in the following electronic databases:

169 MEDLINE, EMBASE, PsycINFO, Cochrane library (Cochrane Central Register of

170 Controlled Trials), HMIC (Health Management Information Consortium), AMED (Allied and

171 Complementary Medicine Database), and CINAHL (Cumulative Index to Nursing and Allied

172 Health Literature) for Randomised Controlled Trials published between January 1990 and

173 December 2009. Search terms (available as a supplementary electronic file) covered the

174 concepts of 'obesity' 'children' 'behaviour change interventions' and 'BMI' and closely

175 followed the search strategies of similar reviews (e.g., 5, 7) and published guidelines for

176 identifying randomised controlled trials (29).

177   One reviewer (JM) screened 4,333 unique titles and abstracts for eligibility and a

178 second reviewer (AC) screened a random (10%) sample of records, yielding 100% agreement

179 between reviewers. After initial screening of title and abstract, full texts of 135 potentially

180 relevant studies were screened for eligibility independently by the two reviewers. Three

181 unpublished dissertations were unavailable for further screening and were excluded. We

182 explored unpublished literature and received a good response from experts, but no further

183 studies were included in the review from these avenues. Agreement regarding inclusion

184 between reviewers was 70%, and disagreements were resolved through careful discussion.

185 Seventeen published manuscripts were included in this review (30-46). The selection process

186 for studies is presented in Figure 1.

187

188

9

189   *Coding of Behaviour Change Techniques*

190   To obtain more complete intervention descriptions and assist data extraction for

191   BCTs, where intervention protocols were published or available elsewhere, the manuscript

192   was located (*n* = 11; 47-57) and the intervention characteristics were coded from both

193   sources. The authors of the further 6 intervention studies were contacted (on up to two

194   occasions) with a request for copies of the corresponding intervention protocol or any

195   additional documents detailing the intervention content. Three authors did not reply; one

196   author could not locate the original protocol; one author informed us that the protocol was

197   available in Finnish language only, and another author provided further details of the

198   intervention mechanisms, published elsewhere on which the intervention characteristics were

199   coded.

200   The content of interventions was assessed by two reviewers (JM & AC) who

201   independently coded the descriptions of each intervention using the CALO-RE taxonomy (1)

202   for inclusion of BCTs. Intervention descriptions were read line-by-line and assigned a BCT

203   label from the taxonomy where appropriate. A stringent coding method was applied so that in

204   cases where further information was required to assess whether a BCT was present or absent,

205   it was coded as absent. We chose not to seek further clarification from the authors, as we

206   wanted to assess published information only.

207   The two coders practised coding on eight intervention studies not selected for the

208   review, and discussed disagreements. All interventions were then coded independently and

209   inter-rater reliability, assessed using percent agreement, was high (93%). Disagreements

210   between the coders were discussed at length and a final decision on which BCTs were

211   assigned to interventions was agreed. Based on the nature of disagreements, we refined BCTs

212   in the taxonomy (see electronic supplementary material, Table 1 for a summary of our

213   revisions to the CALO-RE taxonomy). To summarise the revision process, we took the

10

214   following steps: 1) we revised descriptions of techniques where agreement was reduced due

215   to misapplication of the code; 2) we added examples specific to our sample of childhood

216   obesity trials within technique definitions; 3) we clarified the difference between similar

217   codes where we had encountered disagreements; and 4) one additional technique was

218   identified and defined. We verified that the revised taxonomy was also effective in

219   categorising BCTs in the same set of papers by having a third independent coder (FL) repeat

220   the coding task using the revised taxonomy. Agreement remained high (88%) showing that

221   these constructs exist independently in the selected set of papers.

222

223   *Assessing intervention and BCT effectiveness*

224   We divided coded interventions into those that aimed to prevent ($N = 8$) vs. manage

225   ($N = 9$) childhood obesity. Prevention trials included both overweight and normal weight

226   participants and management trials included overweight participants only.

227   We then divided up prevention and management trials into effective vs. non-effective

228   using BMI outcome data. Effective management trials ($N = 6$) were defined as trials in which

229   the standardised difference in the mean value of BMI between groups at follow-up was at

230   least $\geq$ -0.13 (this was the average effect size demonstrated from meta-analysis data, 58)

231   Less stringent criteria were applied to prevention studies to take into consideration that not

232   all of these trials targeted weight loss measured by a reduction in BMI. The criteria for

233   assessing effectiveness in prevention trials was defined as a significant difference ($p < .05$) in

234   BMI at follow-up between groups ($N = 4$).

235   To assess the effectiveness of BCTs, and to illustrate the relative weight of each BCT

236   taking into consideration it potentially being a component of both effective and non-effective

237   trials, a percentage effectiveness 'ratio' was calculated as the ratio of the number of times

11

238   each BCT was a component of an intervention in an effective trial divided by the number of

239   times they were a component of all trials, including non-effective trials.

240   Results

241   First, we present the BCTs coded in effective and non-effective prevention and management

242   interventions. Second, we present differences in BCTs and effectiveness ratios between

243   effective and non-effective interventions for prevention and management trials.

244   *BCTs in effective and non-effective prevention and management interventions*

245   Out of the 40 BCTs in the taxonomy, we agreed that there was no (or insufficient)

246   evidence that 11 of them were present in any of the interventions (representing 100%

247   agreement between coders). For the remaining 29 BCTs, inter-rater reliability was good (59)

248   for 17 (average kappa value = 0.71 [range = .485 to 1.00], average percentage agreement =

249   92% [range = 71% to 100%]) and sub-optimal for the remaining 12 due to missing data and

250   low counts of instances of BCTs across the studies. In the light of this, disagreements were

251   discussed at length between the coders before final codes were applied. The coders also

252   agreed a new code which was added to the CALO-RE taxonomy (Exposure to healthy

253   choices) from our revisions (*n* = 41 BCTs in total in revised CALO-RE taxonomy). This BCT

254   was encountered as an additional method of achieving behaviour change within the pool of

255   studies (see the supplementary file). The coding exercise did not identify any BCTs in any of

256   the control groups.

257   Table 1 presents BCTs (and their frequency) coded in effective and non-effective

258   prevention and management trials. BCTs that were unique features of management trials (i.e.,

259   were not used in prevention trials) were: Prompt review of behavioural goals, relapse

260   prevention/coping planning, shaping, provide information on where and when to perform the

261   behaviour, environmental restructuring, prompt self-talk and motivational interviewing.

262   BCTs that were unique to prevention trials were: Provide normative information about

       12

263   others' behaviour, prompt rewards contingent on effort or progress towards behaviour, action

264   planning, provide feedback on performance, teach to use prompts/cues, and facilitate social

265   comparison.

266

267   *Effective BCTs in obesity management*

268   All but three out of the nine obesity management interventions selected for review

269   were effective according to our criteria (30-32, 40, 42, and 43). An average of 7.5 (range = 3-

270   15) BCTs from the CALO-RE taxonomy were identified at least once across these

271   interventions (effective and non-effective) and there was little difference in mean number of

272   BCTs coded in effective ($M = 8$) vs. non-effective ($M = 7$) interventions. Twenty-four out of

273   41 (59%) BCTs were identified in at least one of the interventions. Thirteen of these

274   techniques were unique to effective trials, two were unique to non-effective interventions and

275   nine appeared at least once in both effective and non-effective trials. Figure 2 presents the

276   ratio of effectiveness for BCTs appearing two or more times in trials. In order that the ratio

277   was meaningful and to be satisfied that there was 'evidence' of effectiveness for individual

278   BCTS, we required that a BCT must be a feature of two or more trials, therefore the five

279   unique BCTs appearing only once in effective trials were excluded. These criteria have been

280   used in previous studies assessing BCT effectiveness (60, 61). Six BCTs achieved 100%

281   effectiveness ratios (Provide information on consequences of behaviour to the individual,

282   Environmental restructuring, Prompt identification as role model/position advocate, Stress

283   management/Emotional control training, General communication skills training and Prompt

284   practice) and one BCT (Provide information on consequences of behaviour in general) had a

285   100% non-effective ratio.

286

287

13

288   *Effective BCTs in obesity prevention*

289   According to our effectiveness criteria, four trials reported in favour of the

290   intervention (33-35, 46) and four trials reported no difference between groups (36-39). An

291   average of 8 BCTs (range = 1-12) from the CALO-RE taxonomy were identified at least once

292   across these interventions and there was again little difference in the mean number of BCTs

293   coded between effective ($M = 8.5$) vs. non-effective ($M = 7.5$) trials. Twenty-four out of 41

294   (59%) BCTs were identified in at least one of the effective and non-effective interventions.

295   Only one of these BCTs (prompt generalization of a target behaviour) was unique to effective

296   trials, seven were unique to non-effective interventions and 16 appeared at least once in both

297   effective and non-effective trials. Again, an effectiveness ratio was calculated to illustrate the

298   relative weight of each BCT appearing in two or more trials (Figure 3). Only prompt

299   generalization of a target behaviour achieved a 100% effectiveness ratio. Three BCTs were

300   shown to be 100% non-effective (provide information on the consequences of behaviour in

301   general, provide rewards contingent on successful behaviour and facilitate social

302   comparison).

303

304   Discussion

305   This review is the first to utilise a behaviour specific taxonomy of BCTs to formally and

306   systematically identify the components of childhood obesity interventions. We linked

307   individual BCTs with positive health and behavioural outcomes, by assessing effectiveness

308   ratios, thus providing some evidence for the inclusion of particular BCTs as active agents of

309   change in interventions aiming to prevent and manage childhood obesity in the long term. We

310   reliably identified BCTs utilised in prevention and management trials and identified BCTs

311   that were unique features of each. Effectiveness ratios demonstrated an evidence base for the

312   inclusion of BCTs that were unique features of effective interventions. Six BCTs were

14

313   identified as uniquely effective (i.e., achieved 100% effectiveness ratios) in obesity

314   management interventions and one BCT for obesity prevention interventions. Effectiveness

315   ratios also demonstrated BCTs that were components of non-effective trials. One BCT was

316   identified as uniquely non-effective for obesity management interventions and three BCTs for

317   prevention interventions.

318   There is currently little evidence supporting the inclusion (or not) of BCTs in

319   childhood obesity programmes. It is unknown in particular, 1) whether individual BCTs are

320   more effective in the prevention or management of obesity, 2) whether (and how) the content

321   of programmes may differ to those applied to adults, and 3) if particular BCTs may be more

322   or less effective when applied to specific target groups (e.g., parents vs. children) or

323   intervention modes (e.g., delivered in school vs. hospital). The only general guidance of this

324   nature we have identified was included in the UK National Institute for Health and Clinical

325   Excellence (NICE) guidance on the prevention, identification, assessment and management

326   of overweight and obesity in adults and children (9). BCTs such as self-monitoring, goal

327   setting and providing rewards are recommended in this guidance and no further information

328   is offered in relation to the above issues. In our sample of papers, we found inconclusive

329   evidence that self-monitoring and goal setting were consistently effective techniques in both

330   prevention and management trials. Our findings suggest that providing rewards was actually

331   ineffective for obesity prevention. The potential difference in content between programmes

332   aimed at adults vs. children, and the effectiveness of BCTs applied to particular groups or

333   modes of intervention delivery are important topics of further research in this area. From our

334   work here however, we would recommend intervention designers in the field build into

335   interventions the BCTs shown here in relation to specific prevention and management

336   programmes for children and adolescents.

15

337　　　　　There are a number of issues we would like to highlight from this review. First,

338　　　formally defining the content of trials is inherently problematic due to reporting

339　　　inconsistencies and differences in terminology which may have resulted in providing an

340　　　incomplete picture of some interventions and potentially led to exclusion of eligible studies

341　　　in the selection stages of this review. We applied a stringent coding strategy where BCTs

342　　　were not coded as present if there was insufficient description, therefore it may be the case

343　　　that we coded as absent techniques that the authors of the intervention would argue were

344　　　present. This issue has been identified in previous attempts to categorise intervention content

345　　　(21). To advance and implement a science of behaviour change in the field of childhood

346　　　obesity, we would echo calls for improving the quality of reporting of trials (15-18).

347　　　Likewise, given that only a small pool of studies reached our stringent criteria, we would

348　　　acknowledge the need for more studies in this field that are conducted as RCTs, contain

349　　　control conditions, and report data at least 6 months after the intervention has ended.

350　　　　　Second, this is the first time to our knowledge that the CALO-RE taxonomy has been

351　　　applied to interventions for children, and we made a number of revisions to the descriptions

352　　　of BCTs. The authors of the original taxonomy themselves identify that the development of

353　　　behaviour-specific taxonomies is an iterative process and revisions are inevitable and indeed

354　　　welcome (1). However, we would stress that, even with our revisions, the CALO-RE

355　　　taxonomy may not characterise every strategy used in childhood obesity interventions. In a

356　　　larger sample, we would anticipate that the CALO-RE taxonomy may be revised further, and

357　　　new BCTs added. For this reason, we would not recommend discarding BCTs in the CALO-

358　　　RE taxonomy that we agreed were not present in any of the interventions in this review.

359　　　　　The third issue relates to the ability to isolate and assess the effect of individual BCTs

360　　　in interventions. Our findings are limited to the impact of individual BCTs and we did not

361　　　assess the effect of combinations of BCTs. We therefore cannot assess whether BCTs

16

362 demonstrated to be individually effective did not contribute to effective outcomes only as a

363 combination, or whether, when combined differently, their effectiveness would alter. It is

364 worth noting that the BCTs we have shown to be non-effective may well prove to be

365 effective in (alternative) specific combinations, or applied to specific populations or different

366 modes of intervention delivery. Dumbrowski et al. (62) assessed the effect of combining

367 theory-congruent clusters of BCTs on outcomes of behaviour change interventions with

368 obese adults and found that interventions that included BCTs congruent with Control Theory

369 were associated with an increase in weight loss. Exploring combinations of BCTs according

370 to other theories of behaviour change may also prove fruitful, for example, goal setting might

371 be more effectively paired with action planning to enable the initiation and enaction of

372 behavioural change according to the theory of implementation intentions (63). Our findings

373 demonstrate the BCTs we have the best available evidence possible for, but this should not be

374 at the expense of investigating other BCTs, individually or in combination. Evidence

375 demonstrates that the most successful interventions contain combinations of BCTs therefore

376 addressing these issues is of prime importance.

377   Finally, we would like to comment on the clinical value of using BCTs as components

378 of childhood obesity interventions, since the effects of our sample of studies reviewed here

379 were variable and there is currently little consensus on the clinical reductions that may

380 reasonably be expected from behavioural modification. Unfortunately, evidence suggests that

381 the effects of interventions to promote healthy eating are variable (18), and this variability

382 was reflected in our sample of trials, potentially limiting our findings in relation to effective

383 vs. non-effective BCTs. Smaller effect sizes may be explained by our measurement time

384 frame (i.e., at least 6 months after the intervention had ended) as we would anticipate that

385 differences between intervention and control groups would diminish over this time period,

386 after initial weight loss in intervention groups had stabilised. However, we would argue that

17

387   this pattern of weight loss (and subsequent gain or stabilising) represents an accurate picture

388   of weight loss maintenance and it is essential to be clear about the impact of behaviour

389   change interventions over time. Observed effect sizes for trials in this review were small, and

390   our method of classifying trials as effective vs. ineffective may have limitations compared to

391   other methods of assessing effectiveness. However, our findings clearly illustrate that the

392   effectiveness of interventions is currently being hampered by the inclusion of BCTs that are

393   ineffective in achieving clinically valuable reductions in BMI, and this may explain why such

394   interventions fare so poorly in achieving (and maintaining) larger reductions in BMI over

395   time. We have reflected on the clinical meaning of our observed effect sizes and concluded

396   that although small, such unit reductions in BMI can be related to reduced risks of adverse

397   health outcomes. A linear relationship between BMI in childhood and risk of CHD (64) and

398   diabetes (65) in adulthood has been demonstrated, for example, and reductions in BMI also

399   impact upon 'secondary' health outcomes such as cholesterol levels, blood pressure, and

400   psychological well-being that exist along with obesity (66).

401   There is currently no clear evidence upon which to include (or not include) BCTs in

402   successful childhood obesity prevention and management programmes. It is absolutely

403   essential to develop such knowledge so that intervention designers in the field can apply

404   these findings to practice. We outline here a novel approach for establishing the effectiveness

405   of BCTs in childhood obesity interventions: this is the first study of its kind (to our

406   knowledge) in this behavioural domain to relate BMI outcomes at 6 months to intervention

407   content.

408   We have outlined a number of issues remaining to be addressed; however, the

409   methods used in this review represent an important first step towards establishing a method

410   by which it is possible to distinguish between effective and non-effective components of

411   interventions. The results of this study offer the first evidence for the inclusion of effective

18

412   BCTs in childhood obesity prevention and management programmes, and may contribute to

413   our theoretical understanding of the mechanisms under-pinning obesity-related behaviour

414   change. Identifying and utilising effective BCTs for childhood obesity interventions will aid

415   the development of potentially more effective, replicable and targeted interventions, policies

416   and guidelines for health professionals in the field, thus building a strong evidence-base to

417   support obesity prevention and management in children.

418   Supplementary information is available at the journal's website

419   Conflict of interest statement: The authors have no conflicts of interest to declare

420   References

421   1. Michie S, Ashford S, Sniehotta F, Dombrowski S, Bishop A, French D. A refined

422   taxonomy of behaviour change techniques to help people change their physical activity

423   and healthy eating behaviours - the CALO-RE taxonomy. Psychology and Health. 2011;

424   26(11): 1479-98.

425   2. Aylott J, Brown I, Copeland R, Johnson D. Tackling Obesities: The Foresight Report and

426   Implications for Local Government, 2008.

427   3. National Obesity observatory. (NOO). National Child Measurement Programme. Changes

428   in children's body mass index between 2006/7 and 2008/9. 2010.

429   4. WHO. World Health Organisation. Population-based prevention strategies for childhood

430   obesity: Report of the WHO forum and technical meeting, Geneva, 15-17 December 2009,

431   2009.

432   5. Kamath CC, Vickers KS, Ehrlich A, McGovern L, Johnson J, Singhal V, et al. Clinical

433   review: behavioral interventions to prevent childhood obesity: a systematic review and

434   metaanalyses of randomized trials. J Clin Endocrinol Metab. 2008; 93(12): 4606-15.

435   6. Bennett B, Sothern MS. Diet, exercise, behavior: the promise and limits of lifestyle

436   change. Semin Pediatr Surg. 2009; 18(3): 152-8.

437   7. Oude Luttikhuis H, Baur L, Jansen H, Shrewsbury VA, O'Malley C, Stolk RP, et al.

438   Interventions for treating obesity in children. Cochrane Database Syst Rev. 2009; (1):

439   CD001872.

440   8. Hillier F, Pedley C, Summerbell C. Evidence base for primary prevention of obesity in

441   children and adolescents. Bundesgesundheitsblatt. 2011; 54(3): 259-64.

442   9. NICE. National Institute for Health and Clinical Excellence. Obesity guidance on the

443   prevention, identification, assessment and management of overweight and obesity in

444   adults and children, 2006.

22

445   10. Bogle V, Sykes C. Psychological interventions in the treatment of childhood obesity:

446   What we know and need to find out. J Health Psychol. 2011; 16(7): 997-1014

447   11. Kipping RR, Jago R, Lawlor DA. Obesity in children. Part 2: Prevention and

448   management. BMJ. 2008; 337: a1848.

449   12. Van Cauwenberghe E, Maes L, Spittaels H, van Lenthe FJ, Brug J, Oppert JM, et al.

450   Effectiveness of school-based interventions in Europe to promote healthy nutrition in

451   children and adolescents: systematic review of published and 'grey' literature. Br J Nutr.

452   2010; 103(6): 781-97.

453   13. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: Where do we go

454   from here? Science. 2003; 299(5608): 853-5.

455   14. Kitzmann KM, Dalton WT, Stanley CM, Beech BM, Reeves TP, Buscemi J, et al.

456   Lifestyle interventions for youth who are overweight: a meta-analytic review. Health

457   Psychol. 2010; 29(1): 91-101.

458   15. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: Updated guidelines for

459   reporting parallel group randomised trials. J Pharmacol Pharmacother. 2010; 1(2): 100-7.

460   16. WIDER. Workgroup for Intervention Development and Evaluation Research. Available

461   at http://interventiondesign.co.uk. Accessibility verified October 29, 2012

462   17. Michie S, Fixsen D, Grimshaw JM, Eccles MP. Specifying and reporting complex

463   behaviour change interventions: the need for a scientific method. Implement Sci. 2009; 4:

464   40.

465   18. Atkins L, Michie S. Changing eating behaviour: What can we learn from behavioural

466   science? Nutr Bul. 2013; 38: 30-35.

467   19. Sargent GM, Pilotto LS, Baur, L. A. Components of primary care interventions to treat

468   childhood overweight and obesity: a systematic review of effect. Obes Rev. 2011; 12(5):

469   e219-35.

23

470   20. Johnston CA, Tyler C, Foreyt JP. Behavioral management of obesity. Curr Atheroscler

471   Rep. 2007; 9(6): 448-53.

472   21. Hardeman W, Griffin S, Johnston M, Kinmonth AL, Wareham NJ. Interventions to

473   prevent weight gain: a systematic review of psychological models and behaviour change

474   methods. Int J Obes Relat Metab Disord. 2000; 24(2): 131-43.

475   22. Abraham C, Michie S. A taxonomy of behavior change techniques used in interventions.

476   Health Psychol. 2008; 27(3):379-87.

477   23. Golley RK, Hendrie GA, Slater A, Corsini N. Interventions that involve parents to

478   improve children's weight-related nutrition intake and activity patterns - what nutrition

479   and activity targets and behaviour change techniques are associated with intervention

480   effectiveness? Obes Rev. 2011; 12(2): 114-30.

481   24. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in

482   healthy eating and physical activity interventions: a meta-regression. Health Psychol.

483   2009; 28(6): 690-701.

484   25. Prochaska JO, DiClemente CC. Stages and processes of self-change of smoking: toward

485   an integrative model of change. J Consult Clin Psychol. 1983; 51(3): 390-5.

486   26. Baker J, Olsen L, Sorenson T. Childhood Body-Mass Index and the Risk of Coronory

487   Heart Disease. N Engl J Med. 2007; 357(23): 2329-2337.

488   27. Kirk S, Zeller M, Claytor R, Santangelo M, Khoury PR, Daniels SR. The relationship of

489   health outcomes to improvement in BMI in children and adolescents. Obes Res. 2005;

490   13(5): 876-82.

491   28. Lawlor DA, Benfield L, Logue J, Tilling K, Howe LD, Fraser A, et al. Association

492   between general and central adiposity in childhood, and change in these, with

493   cardiovascular risk factors in adolescence: prospective cohort study. BMJ. 2010; 341:

494   c6224.

24

495   29. Glanville JM, Lefebvre C, Miles JN, Camosso-Stefinovic J. How to identify randomized

496   controlled trials in MEDLINE: ten years on. J Med Libr Assoc. 2006; 94(2): 130-6.

497   30. Golley RK, Magarey AM, Baur LA, Steinbeck KS, Daniels LA. Twelve-month

498   effectiveness of a parent-led, family-focused weight-management program for prepubertal

499   children: a randomized, controlled trial. Pediatrics. 2007; 119(3): 517-25.

500   31. Janicke PBJS, Perri MG, Lutes LD, Huerta M, Silverstein JH, Brumback B. Comparison

501   of parent-only vs family-based interventions for overweight children in underserved rural

502   settings: outcomes from project STORY. Arch Pediatr Adolesc Med. 2008; 162(12):

503   1119-25.

504   32. Johnson WG, Hinkle LK, Carr RE, Anderson DA, Lemmon CR, Engler LB, et al. Dietary

505   and exercise interventions for juvenile obesity: long-term effect of behavioral and public

506   health models. Obes Res. 1997; 5(3): 257-61.

507   33. Fitzgibbon ML, Stolley MR, Schiffer L, Van Horn L, KauferChristoffel K, Dyer A. Two-

508   year follow-up results for Hip-Hop to Health Jr.: a randomized controlled trial for

509   overweight prevention in preschool minority children. Journal of Pediatrics. 2005; 146(5):

510   618-625.

511   34. Fitzgibbon ML, Stolley MR, Schiffer L, Van Horn L, KauferChristoffel K, Dyer A. Hip-

512   Hop to Health Jr. for Latino Preschool Children. Obesity. 2006; 14(9): 1616-1625.

513   35. Chen S, Weiss S, Heyman MB, Lustig RH. Efficacy of a child-centred and family-based

514   program in promoting healthy weight and healthy behaviors in Chinese American

515   children: a randomized controlled study. J Public Health (Oxf). 2010; 32(2): 219–229.

516   36. Gentile GW, Reimer RA, Walsh DA, Russell DW, Callahan R, Walsh M, Strickland S,

517   Fritz K. Evaluation of a multiple ecological level child obesity prevention program:

518   Switch what you Do, View, and Chew. BMC Med. 2009; 7: 49.

25

519 37. Nader PR, Stone EJ, Lytle LA, Perry CL, Osganian SK, Kelder S, et al. Three-year

520 maintenance of improved diet and physical activity: the CATCH cohort. Child and

521 Adolescent Trial for Cardiovascular Health. Arch Pediatr Adolesc Med. 1999; 153(7):

522 695-704.

523 38. Reilly JJ, Kelly L, Montgomery C, Williamson A, Fisher A, McColl JH, et al. Physical

524 activity to prevent obesity in young children: Cluster randomised controlled trial. BMJ.

525 2006; 333(7577): 1041.

526 39. Singh AS, Chin APMJ, Brug J, van Mechelen W. Dutch obesity intervention in teenagers:

527 effectiveness of a school-based program on body composition and behavior. Arch Pediatr

528 Adolesc Med. 2009; 163(4): 309-17.

529 40. Kalavainen MP KM, Nuutinen OM. Clinical efficacy of group-based treatment for

530 childhood obesity compared with routinely given individual counseling. Int J Obes. 2007;

531 31(10): 1500-8.

532 41. McCallum WM, Gerner B, Baur LA, Gibbons K, Gold L, Gunn J, Harris C, Naughton G,

533 Riess C, Sanci L, Sheehan J, Ukoumunne OC, Waters E. Outcome data from the LEAP

534 (Live, Eat and Play) trial: a randomized controlled trial of a primary care intervention for

535 childhood overweight/mild obesity. Int J Obes. 2007; 31(4):.630-6.

536 42. Nemet D, Barkan S, Epstein Y, Friedland O, Kowen G, Eliakim A. Short- and long-term

537 beneficial effects of a combined dietary-behavioral-physical activity intervention for the

538 treatment of childhood obesity. Pediatrics. 2005; 115(4 Part 1): e443-9.

539 43. Tanofsky-Kraff DE, Wilfley P, Young JF, Mufson L, Yanovski SZ, Glasofer DR, Salaita

540 CG.,Schvey NA. A pilot study of interpersonal psychotherapy for preventing excess

541 weight gain in adolescent girls at-risk for obesity. J Eat Disord. 2010; 43(8): 701-6.

26

542 44. Wake M, Baur LA, Gerner B, Gibbons K, Gold L, Gunn J, et al. Outcomes and costs of

543   primary care surveillance and intervention for overweight or obese children: the LEAP 2

544   randomised controlled trial. BMJ. 2009; 339: b3308.(doi):10.1136/bmj.b3308.

545 45. Hughes AR, Stewart L, Chapple J, McColl JH, Donaldson MD, Kelnar CJ, et al.

546   Randomized, controlled trial of a best-practice individualized behavioral program for

547   treatment of childhood overweight: Scottish Childhood Overweight Treatment Trial

548   (SCOTT). Pediatrics. 2008; 121(3): e539-46.

549 46. Salmon J, Ball K, Hume C, Booth M, Crawford D. Outcomes of a group-randomized trial

550   to prevent excess weight gain, reduce screen behaviours and promote physical activity in

551   10-year-old children: switch-play. Int J Obes (Lond). 2008; 32(4): 601-12.

552 47. Eisenmann JC, Gentile DA, Welk GJ, Callahan R, Strickland S, Walsh M, et al.

553   SWITCH: rationale, design, and implementation of a community, school, and family-

554   based intervention to modify behaviors related to childhood obesity. BMC Public Health.

555   2008; 8: 223.

556 48. Fitzgibbon ML, Stolley MR, Dyer AR, VanHorn L, Kaufer-Christoffel K. A community-

557   based obesity prevention program for minority children: rationale and study design for

558   Hip-Hop to Health Jr. Prev Med. 2002; 34(2): 289-97.

559 49. Golley RK, Perry RA, Magarey AM, Daniels LA. Family-focused weight management

560   program for five- to nine-year-olds incorporating parenting skills training with healthy

561   lifestyle information to support behaviour modification. Nutrition and Dietetics. 2007; 64:

562   144-150.

563 50. Janicke DM, Sallinen BJ, Perri MG, Lutes LD, Silverstein JH, Huerta MG, et al. Sensible

564   treatment of obesity in rural youth (STORY): design and methods. Contemp Clin Trials.

565   2008; 29(2): 270-80.

27

566   51. McCallum Z, Wake M, Gerner B, Harris C, Gibbons K, Gunn J, et al. Can Australian

567   general practitioners tackle childhood overweight/obesity? Methods and processes from

568   the LEAP (Live, Eat and Play) randomized controlled trial. J Paediatr Child Health. 2005;

569   41(9-10): 488-94.

570   52. Perry CL, Parcel GS, Stone EJ, Nader PR, Mckinlay SM, Luepker RV, et al. The Child

571   and Adolescent Trial for Cardiovascular Health (CATCH): Overview of the Intervention

572   Program and Evaluation Methods. Cardiovascular Risk Factors. 1992; 2(1): 36-44.

573   53. Perry CL, Stone EJ, Parcel GS, Ellison RC, Nader PR, Webber LS, et al. School-based

574   cardiovascular health promotion: the child and adolescent trial for cardiovascular health

575   (CATCH). J Sch Health. 1990; 60(8): 406-13.

576   54. Salmon J, Ball K, Crawford D, Booth M, Telford A, Hume C, et al. Reducing sedentary

577   behaviour and increasing physical activity among 10-year-old children: overview and

578   process evaluation of the 'Switch-Play' intervention. Health Promot Int. 2005; 20(1): 7-17.

579   55. Singh AS, Chin APMJ, Kremers SP, Visscher TL, Brug J, van Mechelen W. Design of

580   the Dutch Obesity Intervention in Teenagers (NRG-DOiT): systematic development,

581   implementation and evaluation of a school-based intervention aimed at the prevention of

582   excessive weight gain in adolescents. BMC Public Health. 2006; 6: 304.

583   56. Stewart L, Houghton J, Hughes A, Pearson D, Reilly J. Dietetic Management of Pediatric

584   Overweight: Development and Description of a Practical and Evidence-Based Behavioral

585   Approach. American Dietetic Association. 2005; 105(11): 1810-1815.

586   57. Tanofsky-Kraff M, Wilfley DE, Young JF, Mufson L, Yanovski SZ, Glasofer DR, et al.

587   Preventing excessive weight gain in adolescents: interpersonal psychotherapy for binge

588   eating. Obesity (Silver Spring). 2007; 15(6): 1345-55.

589   58. Chater A, Martin J, Smith L. Behaviour change techniques used in randomised controlled

590   trials of obesity prevention and treatment in children: A systematic review. Annual

591   Conference of the Division of Health Psychology, 14th-16th September 2011,

592   Southampton, UK.

593   59. Cohen J. A coefficient of agreement for nominal scales. Educational and Psychological

594   Measurement. 1960; 20(1): 37-46.

595   60. Michie S, Churchill S, West R. Identifying evidence-based competences required to

596   deliver behavioral support for smoking cessation. Annals of Behavioural Medicine. 2011;

597   41(1): 59-70.

598   61. Lorencatto F, West R, Michie S. Specifying evidence-based behaviour change techniques

599   to aid smoking cessation in pregnancy. Nicotine & Tobacco Research. 2012; 14(9): 1019-

600   26.

601   62. Dumbrowski SU, Sniehotta FF, Avenell A, Johnston M, MacLennan G, Araujo-Soares V.

602   Identifying active ingredients in complex behavioural interventions for obese adults with

603   obesity-related co-morbidities or additional risk factors for co-morbidities: a systematic

604   review. Health Psychology Review. 2012; 6(1): 7-32.

605   63. Gollwitzer, PM. Implementation Intentions: Strong effects of simple plans. American

606   Psychologist. 1999; 54: 493-503.

607   64. Baker J, Olsen L, Sorenson T. Childhood Body-Mass Index and the Risk of Coronary

608   Heart Disease. *N Engl J Med* 2007; 357(23): 2329-2337.

609   65.Tirosh A, Shai I, Afek A, Dubnov-Raz G, Ayalon N, Gordon B, et al. Adolescent BMI

610   trajectory and risk of diabetes versus coronary disease. *N Engl J Med;* 2011; 364(14):

611   1315-25.

612   66. Bennett B, Sothern MS. Diet, exercise, behavior: the promise and limits of lifestyle

613   change. *Semin Pediatr Surg* 2009; 18(3): 152-8.

614

615

29

616 *Table 1 Frequency of Behaviour Change Techniques coded in effective and non-effective*

617 *obesity prevention and management trials*

Behaviour Change Techniques	Prevention		Management	
	Effective	Non-effective	Effective	Non-effective
Provide information on consequences of behaviour in general	0	2	0	1
Provide information on consequences of behaviour to the individual	3	2	5	0
Provide normative information about others' behaviour	0	1	0	0
Goal setting (behaviour)	2	3	4	3
Action planning	0	1	0	0
Barrier identification	1	1	2	3
Set graded tasks	1	0	1	0
Prompt review of behavioural goals	0	0	3	1
Prompt rewards contingent on effort or progress towards behaviour	1	1	0	0
Provide rewards contingent on successful behaviour	0	2	3	3
Shaping	0	0	1	0
Prompting generalization of a target behaviour	2	0	1	0
Prompt self-monitoring of behaviour	4	3	3	1
Provide feedback on performance	1	1	0	0
Provide information on where and when to perform the behaviour	0	0	1	0
Provide instruction on how to perform the behaviour	1	2	3	2
Model/Demonstrate the behaviour	2	1	1	0
Teach to use prompts/cues	0	1	0	0
Environmental restructuring	0	0	3	0
Agree behavioural contract	1	0	1	3
Prompt practice	3	1	2	0
Facilitate social comparison	0	2	0	0
Plan social support/social change	2	3	2	1
Prompt identification as role model/position advocate	1	0	3	0
Prompt Self talk	0	0	1	0
Relapse prevention/coping planning	0	0	3	1
Stress management/Emotional control training	1	0	2	0
Motivational interviewing	0	0	0	1
General communication skills training	2	2	2	0
Exposure to healthy choices	1	1	1	0

618   Figure captions

619   *Figure 1 Flow chart of trials selected for review*

620

621   *Figure 2 Percentage effectiveness of Behaviour Change Techniques in obesity*

622   *management trials*

623

624   *Figure 3 Percentage effectiveness of Behaviour Change Techniques in obesity*

625   *prevention trials*

```
┌─────────────────────────┐   ┌─────────────────────────┐
│   6668 records identified│   │   24 additional records  │
│   through electronic     │   │ identified through experts│
│   database search        │   │  and unpublished sources │
└─────────────────────────┘   └─────────────────────────┘
            │                             │
            ▼                             ▼
┌──────────────────────────────────────────────┐
│      4333 records after duplicates removed     │
└──────────────────────────────────────────────┘
                      │
                      ▼
┌─────────────────────────┐   ┌─────────────────────────┐
│   4333 records screened  │──▶│  4198 records excluded   │
└─────────────────────────┘   └─────────────────────────┘
                      │
                      ▼
┌─────────────────────────┐   ┌───────────────────────────────────┐
│   135 of full-text       │──▶│ 118 articles excluded:            │
│   articles               │   │ Insufficient follow-up length = 54│
│   assessed for eligibility│   │ No BCTs = 15                      │
└─────────────────────────┘   │ Non randomised = 31               │
                      │        │ No control group = 15             │
                      │        │ Unavailable dissertations = 3     │
                      ▼        └───────────────────────────────────┘
┌─────────────────────────┐
│   17 studies included in │
│   this review            │
└─────────────────────────┘
```