Integrating an exercise specialist supported by mHealth technology to increase exercise and physical activity adherence in a paediatric Complications from Excess Weight Service (MOTIVATE-CEW): A feasibility study

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Abstract

Objectives: Assess the feasibility of embedding an exercise specialist led, mHealth supported, physical activity and exercise intervention (MOTIVATE-CEW) into a UK Complications from Excess Weight (CEW) service.

Design: Feasibility, single site, parallel group, Randomised Control Trial.

Setting: Participants were recruited from Alder Hey Children's Hospital (AHCH) CEW service.

Patients: Young people (12-18 years) receiving care from the AHCH CEW service.

Interventions: Participants were randomised 1:1 to usual care or usual care and intervention (MOTIVATE-CEW). MOTIVATE-CEW participants co-designed a 3-month home-delivered, personalised progressive physical activity programme supported by virtual counselling sessions from an exercise specialist and biofeedback from wearable technologies.

Main outcome measures: The primary outcomes were recruitment rate, retention and adherence to purposeful exercise. Exploratory clinical data on effectiveness were collected at baseline and post-intervention (3-months).

Results: n=72 young people aged over 12 years were registered with the AHCH CEW service and approached to participate. n=25 were ultimately randomised (age 15 ± 1; 52% female; 84% white), giving a recruitment rate of 27%. Retention at 3-months was 88%. Over the 3-month intervention heart rate monitor data suggested MOTIVATE-CEW participants completed more exercise sessions (MOTIVATE-CEW 2±2 sessions/week; usual care 0±0 sessions/week; d=1.04) and exercised for longer (MOTIVATE-CEW 80±102 min/week; usual care 8±20 min/week; d=0.99) than usual

care. At 3-months, 33% of MOTIVATE-CEW participants were still exercising compared to 8% in usual care.

Conclusions: The MOTIVATE-CEW intervention showed promising effects on exercise behaviour. Good reach and data availability suggests the study design could be feasible within future trials.

Key Messages

What is already known on this topic – The rising prevalence of severe obesity in children has led NHS England to commission specialist paediatric Complications from Excess Weight (CEW) services. Current guidelines recommend lifestyle interventions, including increased physical activity, as the first-line treatment for children with obesity. How best to integrate structured physical activity support within CEW services is currently unknown.

What this study adds – MOTIVATE-CEW is the first intervention to combine support from an exercise specialist with mobile health (mHealth) technologies. Enabling data sharing with specialists and real-time biofeedback, for young people attending a UK CEW service.

How this study might affect research, practice or policy – This study established the acceptability and feasibility of the intervention and trial design and suggest the intervention may be an effective strategy for improving care.

Abbreviations

CEW- Complications from Excess Weight, NICE- National Institute for Health and Care Excellence, mHealth- mobile health, AHCH- Alder Hey Children's Hospital.

Introduction

To address the growing number of children living with severe obesity and its associated health risks [1-5], NHS England has established specialist paediatric Complications from Excess Weight (CEW) services. These adopt a holistic, multidisciplinary team approach to managing obesity-related conditions. Based on a Cochrane Review of children living with obesity [6] and National Institute for Health and Care Excellence (NICE) guidelines [7] lifestyle interventions, including increasing physical activity, are recommended as first-line treatment. However, severe obesity presents complex challenges, and interventions effective in children with less severe obesity may not be successful [8]. As such, optimal intervention strategies remain unclear [9], highlighting the need for tailored physical activity approaches.

A 2021 scoping review of child and family perspectives on clinic-based obesity services recommended integrating exercise specialists into multidisciplinary teams to deliver personalised physical activity programmes [10]. Families emphasised the importance of individualised action plans with specific physical activity/exercise regimens to follow on a day-to-day basis, accounting for financial resources, child and parental time constraints, and the developmental stage of both child and family. General physical activity recommendations were perceived as insufficient and overwhelming. The review also identified the potential of mobile health (mHealth) technologies to enhance support between clinic visits. In response, we developed

MOTIVATE-CEW, an exercise specialist led, mHealth supported physical activity and exercise intervention for CEW services.

This study aimed to assess the feasibility of conducting a definitive randomised controlled trial to evaluate the effectiveness of the MOTIVATE-CEW intervention. Specific objectives were to:

1. Determine the number of eligible patients, the proportion willing to participate and their characteristics, and retention at 3 months (Reach).
2. Assess adherence rates to the intervention (Dose).
3. Evaluate fidelity of intervention delivery.
4. Pilot methods for collecting outcome measures and estimate their precision to inform a future definitive randomised controlled trial.

Methods

This study followed the CONSORT 2010 statement for pilot and feasibility trials [11].

Study Design and Population

Single centre, feasibility, parallel group, randomised controlled trial in young people (12-18 years) receiving care from the Alder Hey Children's Hospital (AHCH) CEW service. Participants had a BMI >30, and those prescribed Metformin required a stable dose for ≥3-months. Exclusion criteria were severe learning or behaviour difficulties, severe autism, secondary or syndromic causes of obesity, diabetes (type 1 or 2) and use of GLP-1 analogues. Participants were recruited from all stages of care by multidisciplinary team members.

Participants were randomised 1:1 to usual care (control) or MOTIVATE-CEW plus usual care (intervention), stratified by age (12-15 years or 16-18 years). Blinding of participants and researchers was not possible. The study was approved by the East Midlands - Derby NHS Research Ethics Committee (21/EM/0030) and conformed to the Declaration of Helsinki. Written informed consent or assent (with parent/guardian consent) was obtained. The protocol was prospectively registered on clinicaltrials.gov (identifier: NCT04854915).

Interventions

Usual Care

All participants continued to receive routine care from the AHCH CEW service multidisciplinary team (Supplementary Table 1 for multidisciplinary team roles). This included an initial needs assessment and personalised care plan, with follow-ups approximately every four weeks.

Intervention: MOTIVATE-CEW

MOTIVATE-CEW integrates biofeedback, shared with participants and their exercise specialist, to optimise a 3-month home-based virtual counselling service [12]. These elements supported the delivery of co-created, personalised action plans promoting gradual increases in purposeful exercise of moderate-to-vigorous intensity, and increased daily lifestyle physical activity. MOTIVATE-CEW was guided by evidence and healthcare professional perspectives and is underpinned by behaviour change theory, drawing on processes from self-regulation [13], social cognitive [14] and self-determination theories [15]. As depicted in the logic model (Supplementary Figure 1) behaviour change techniques were employed to build exercise competence, foster

autonomy and enhance relatedness with healthcare professionals. The intervention includes three core elements targeting key change processes:

1) Behavioural counselling: Over the 3 months patients and their families engage in virtual counselling sessions. These sessions used person-centred counselling techniques [16], designed to put the participants individual's needs, values, and motivations at the heart of the conversation. During these sessions the exercise specialist helped patients understand the benefits of physical activity and developed personalised, goal-specific, action plans for purposeful exercise and lifestyle physical activity.
2) Integration of biofeedback: Patients wore a fitness watch (Polar Ignite, Polar Electro) with an integrated accelerometer and heart rate monitor, synced to a web/smartphone app (Polar Flow – Sync & Analyze). A compatible coaching platform allowed for action plans to be synced to the technology and progress monitored. Real-time heart rate feedback during exercise helped participants optimise their intensity.
3) Regular remote feedback: Biofeedback and patient comments were used to inform exercise consultations and personalised feedback messages were sent to participants (for example messages see Supplementary Table 2). These discussions informed the consistent refinement of action plans.

Outcome Measurements

Feasibility outcomes were recruitment rate, attrition and loss to follow-up, and completeness of outcome measures. Medical Research Council guidance for evaluating complex interventions was also followed [17], providing insight on:

Reach: Consented participants sex, age, ethnicity and Index of Multiple Deprivation were compared to the overall AHCH CEW service population.

Acceptability of study participation and intervention: Explored via virtual interviews and focus groups with four participants and four parents/guardians from the intervention group following the intervention. All intervention participants also completed a qualitative survey at 3 months.

Dose: Purposeful exercise sessions were recorded using heart rate monitoring throughout the three-month trial. Participants in the MOTIVATE-CEW group used the fitness watch provided as part of the intervention, while those in the usual care group were given a blinded heart rate monitor (Polar Verity Sense, Polar Electro, Finland) to wear only during purposeful exercise sessions. Heart rate data was used to calculate exercise frequency (number of sessions), total exercise duration, duration of moderate-to-vigorous intensity exercise (calculated by adding time in moderate, 50-70% HR_{max}, and time in Vigorous, ≥70% HR_{max}*2, intensity exercise), and training drop off (the week which participants no longer completed any training sessions). Self-reported exercise behaviour was assessed at baseline and 3-months using the Godin Leisure Time Exercise Questionnaire (GLTEQ) [18].

To accurately assess lifestyle physical activity participants wore a research-grade accelerometer on their wrist (GENEactiv, Activinsights, Kimbolton, Cambridge, UK). To assess sedentary behaviour participants also wore a research-grade accelerometers on their thigh (ActivPAL (PAL Technologies Limited; Glasgow,

Scotland, UK). Both accelerometers were worn for 14-days at baseline and 3-months [19]. Time spent in activity intensities was determined using published thresholds for the wrist worn accelerometer [20], with four wear-time criteria considered; ≥16 hours for 4 days including at least 1 weekend day; ≥10 hours for 4 days including at least 1 weekend day; ≥10 hours over any 4 days; and ≥10 hours over 1 day. Two wear-time criteria were considered for the thigh worn accelerometer; ≥20 hours for 4 days including at least 1 weekend day; and ≥20 hours for 1 day.

Fidelity: Contact between participants and the exercise specialist was logged, including number and duration of counselling sessions, and messages sent and reply rate (replies relative to messages sent). Attendance at AHCH CEW appointments and dietician meetings was recorded during the same period for context.

Preliminary effectiveness

Outcomes proposed for a future definitive trial were collected by attending AHCH at baseline and 3-months: Self and proxy reported health related quality of life were measured through two validated questionnaires (EQ-5D-Y [21]; and Pediatric Quality of Life Inventory, PedsQL [22]); weight; body composition (Tanita innerscan dual, Tanita Corporation of America, Inc, Arlington Heights, IL, USA); blood pressure; lipid profile (total cholesterol, high-density lipoprotein, low-density lipoprotein, and triglycerides), and; liver function (aspartate aminotransferase, alanine aminotransferase and Albumin). Free living glycemia was assessed using a continuous glucose monitor (FreeStyle Libre Pro, Abbott Diabetes Care, Alameda, CA, USA) worn for 14-days, in line with international consensus[23]. Three wear-time

criteria were explored, ≥70% of data over 14 consecutive days, ≥80% of data over 10 consecutive days, ≥80% of data over 7 consecutive days.

Statistical Analysis

As a feasibility study, no formal power calculation was performed, but sample sizes of 24-50 have been recommended [24, 25]. Data analyses for the feasibility objectives were descriptive. Outcome measures are expressed as means, with uncertainty in all estimates expressed as standard deviation (SD) for timepoint data and 95% confidence intervals (CI) for data expressing changes between timepoints. Following pilot trial analysis guidelines [11, 26], between-group changes from baseline were summarised using Cohen's d effect sizes [27] (28): trivial (<0.2), small (0.2–0.3), moderate (0.4–0.8), or large (>0.8).In line with pilot study guidance [11, 26], no p-values or null hypothesis testing were reported. Focus groups were transcribed verbatim and analysed using thematically analysed via a six-phase process [28, 29], with full results to be reported separately.

Results

Recruitment and retention of participants and acceptability of trial design

Participant flow is shown in *Figure 1*. Recruitment occurred between August 2021 and July 2022. During this period, 164 patients were registered with the AHCH CEW service. Of these, 72 were under 12 years of age and therefore excluded, leaving 92 potentially eligible patients. Among the remaining patients, 39 were not eligible and 28 declined to participate; resulting in 25 participants being randomised (MOTIVATE-CEW 12; usual care 13), representing 27% of the CEW service cohort aged over 12 years.

Data collection was completed in October 2022. Three participants were lost to follow-up, a retention rate of 88%. Participants and their parents/guardians had high satisfaction with the trial methods (Supplementary Table 3).

Participant characteristics

Baseline demographics were similar across groups and representative of the CEW population in age, sex, and deprivation level (Table 1). However, only 4% of participants were from non-white backgrounds compared to 12% in the overall service

Acceptability of the MOTIVATE-CEW intervention

Interviews and focus groups indicated high satisfaction, acceptability, and feasibility of the MOTIVATE-CEW intervention (Supplementary Table 3). Highly valued elements included personalised action plans, mHealth technology for self-monitoring, and personalised feedback from exercise specialists. A suggested area of improvement, was that the intervention should be longer. The qualitative survey reinforced these findings.

Dose

Heart rate data showed that MOTIVATE-CEW participants exercised more regularly than usual care, with moderate to large effect sizes favouring MOTIVATE-CEW for all exercise adherence measures (Table 2). 83% of MOTIVATE-CEW participants started training (completed ≥1 purposeful exercise session), compared to 15% in usual care (Figure 2). At 3-months, 33% of MOTIVATE-CEW participants were exercising, versus 8% in usual care. Usual care participants reported their heart rate monitor wear with

8% stating they wore the monitor for all purposeful exercise sessions, 8% for most sessions, 58% for some sessions and 25% did not wear it at all.

Self-reported exercise data showed MOTIVATE-CEW increased the number of sessions of moderate and strenuous intensity exercise from baseline to post-intervention (mean= 1, CI= -1 to 4, *n*= 10) while usual care reduced exercise behaviour (mean= -1, CI= -3 to 2, *n*= 12), resulting in a medium effect size favouring MOTIVATE-CEW (d= 0.62). A medium effect size favouring MOTIVATE-CEW was also reported for change in the total survey score from baseline (MOTIVATE-CEW mean= 7, CI= -12 to 26, *n*= 10; usual care mean= -6, CI= -22 to 10, *n*= 12; d= 0.47). Mean values at baseline and 3-month are presented in Supplementary Table 4.

The wrist worn accelerometer (≥16 hours for 4 days including 1 weekend day) had 46% data availability while the thigh worn accelerometer (≥20 hours for 4 days including 1 weekend day) had 40%. Using alternative wear time criteria had minimal impact on data availability (Supplementary Table 5). Due to low data availability, change from baseline was not reported, but means and SDs are presented in Supplementary Table 4.

Fidelity

MOTIVATE-CEW consultation attendance was 70% (42 out of 70), compared to 66% and 68% for AHCH CEW service appointments and dietician meetings, respectively. Consultations lasted an average of 33±11 minutes. Feedback messages had a 72% response rate (29±17 sent, 21±17 replies). In the first month, participants provided feedback on 66% of their exercise sessions.

Data Availability

Completion of outcome measures was consistently high at baseline and 3-months, ≥82% for all outcomes (Supplementary Tables 5 and 6, which includes reasons for missing data). The exception was free living glycemia, assessed using a continuous glucose monitor, with 42% data availability (70% of data over 14 days) (Supplementary Table 7). Alternative wear time criteria had little impact on data availability. Due to low data availability, changes from baseline, means and CIs were not reported.

Preliminary effectiveness

There was a large effect size favouring MOTIVATE-CEW for quality of life (specifically in the EQ-5D-Y visual analogue scale) (Table 3). The proxy report quality of life questionnaire (PedsQL) showed a medium effect size in favour of MOTIVATE-CEW for the mean score and psychosocial health summary. Mean scores for quality of life questionnaires can be found in Supplementary Table 8. Supplementary Table 9 presents the means for body composition, cardiovascular disease risk factors and liver function measures at each time point. Changes from baseline showed large and medium effect sizes favouring MOTIVATE-CEW for alanine aminotransferase and triglycerides, respectively (Table 3). However, HbA1c favoured usual care with a large effect size. All other differences were trivial to small. No serious adverse events occurred during the trial.

Discussion

MOTIVATE-CEW is the first trial within a UK CEW service to assess the feasibility of an exercise specialist led, mHealth supported, physical activity and exercise

intervention for young people with severe obesity. Results suggest it is feasible to recruit and retain a representative sample of CEW patients. The intervention was well received, with good uptake and adherence to purposeful exercise.

Recruitment of 27% of CEW patients aged over 12 years compares favourably with other feasibility trials, where recruitment rates of 20–40% are commonly used as benchmarks of feasibility [30]. However, a number of young people were excluded from the study due to neurodevelopmental problems. Recent data indicate that neurodevelopmental conditions are markedly over-represented in UK CEW services, with many additional patients presenting with suspected neurodiversity and awaiting assessment [31]. Future iterations of the intervention should therefore be adapted to include these young people to enhance reach and inclusivity.

Participants using incretin therapies were also excluded. Although exclusion due to incretin therapy was minimal in this trial, their use has since increased considerably; recent data from the AHCH CEW service indicate that 17% of patients are now prescribed these medications (unpublished data). Emerging evidence suggests that tailored physical activity and exercise programmes should complement incretin therapy to optimise changes in body composition by preserving lean mass while promoting fat loss [32]. Consequently, future versions of the trial should also aim to include young people using incretin therapy. Given the potential impact of these treatments, alternative randomisation strategies may be required to minimise confounding effects and maintain balance between groups.

The 88% retention rate aligns well with other feasibility trials where 80% of participants retained was used as a measure of feasibility [30]. These results are consistent with previous work in multidisciplinary weight management services for young people with obesity [33, 34].

Generalisability is a strength, with participants reflecting the CEW service in age, sex, and deprivation. Contrary to concerns that mHealth interventions may not engage young people from deprived backgrounds [35], recruitment in this group was successful, consistent with UK data showing 95% of young people have smartphone access [36]. However, only 4% of participants were from non-white backgrounds compared to 12% in the CEW cohort, reflecting persistent challenges recruiting ethnically diverse samples [33].

The results suggest integrating exercise specialists, supported by mHealth technologies, is a promising approach to promote purposeful exercise in UK CEW services. Heart rate monitor data showed MOTIVATE-CEW participants were more likely to initiate an exercise program and had higher weekly exercise duration, both total and at moderate-to-vigorous intensities. Comparison with previous trials is difficult, as to the authors knowledge, no studies assess adherence to exercise in young people living with obesity receiving care from multidisciplinary weight management services. While exercise data over the 3-month intervention was encouraging, only 33% of participants were still exercising in the final week, however, this was much greater than Usual Care (8%). These findings suggest the initial intervention was promising, but further refinement is needed. Future iterations should follow Medical Research Council (MRC) guidelines [17], involving service users

(young people and families) in a coproduction process. Qualitative feedback suggested extending the support period could improve engagement.

The intervention also aimed to increase lifestyle physical activity and reduce sedentary behaviour, but poor data availability from the research-grade accelerometers meant conclusions could not be drawn. In contrast, Aguer *et al*. [37] reported 78% wear time compliance in a similar study of young people with obesity completing a multicomponent weight management intervention. Given the importance of assessing lifestyle physical activity for evaluating CEW service interventions, future work should explore why data availability was low and how it can be improved.

In-clinic health outcomes had good data availability (≥82% for all outcomes), suggesting the trial design was feasible. However, free living glycemia data availability was poor. While 76% of sensors were returned, only 42% of participants met the wear time criteria (70% of 14 days). The poor data availability wasn't related to participants fitting the sensors themselves during post-intervention measures, as data availability was similar to baseline when the research team fitted them. This contrasts a recent trial investigating the feasibility of continuous glucose monitor use in young people with obesity, where 96% of data was available [38]. Qualitative feedback suggested sensors falling off was a common issue, but further than this it is unclear why data availability was low.

The study found preliminary evidence of a large effect on quality of life, in MOTIVATE-CEW participants compared to usual care. This effect was supported by parent/guardian reported quality of life. The improvement in quality of life after

MOTIVATE-CEW exceeded that of a 1-year multidisciplinary intervention in young people with severe obesity that involved an in-patient period [39]. Enhancing quality of life is particularly relevant for CEW patients, as previous data suggests quality of life in young people with severe obesity is similar to children living with cancer [5]. Other health related outcomes demonstrated trivial to small changes with the exception of improvements in triglycerides and liver enzymes in the intervention group and improvements in HbA1c in usual care participants.

This study had several limitations. Device-derived exercise data should be interpreted cautiously, as only 8% of the usual care group reported wearing the heart rate monitor for all exercise sessions. However, self-reported data also showed an increase in moderate/strenuous exercise sessions in the MOTIVATE-CEW group, while the number decreased in Usual Care. Secondly, the study was not designed or powered to definitively assess the effectiveness of the MOTIVATE-CEW intervention. Finally, as a single-centre study, the findings may not be generalisable to other CEW services in the UK.

Conclusion

The study provides promising evidence that the MOTIVATE-CEW intervention positively impacted exercise behaviour in young people attending a UK CEW service. This suggests that adding exercise specialists supported by mHealth technologies could improve multidisciplinary CEW services. However, further work may be needed to address concerns over exercise maintenance. Finally, with high recruitment and retention rates, good generalisability of participant recruitment with the target

population and strong in-clinic data availability, the findings suggest MOTIVATE-CEW is feasible for future trials in CEW services.

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Conflicts of interest statement

The authors have no conflicts of interest to declare.

Author Contributions

APD, KLH, VSS, HJ, FK, SS, and MC, conceived and designed research; APD, EC, LA, AC, performed experiments; APD, KLH, CR, and MC analysed data; APD, KLH, FK and MC interpreted results of experiments; APD, KLH and MC prepared figures; APD and MC drafted manuscript; All authors, edited and revised manuscript; All authors approved final version of manuscript.

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Figures and Tables

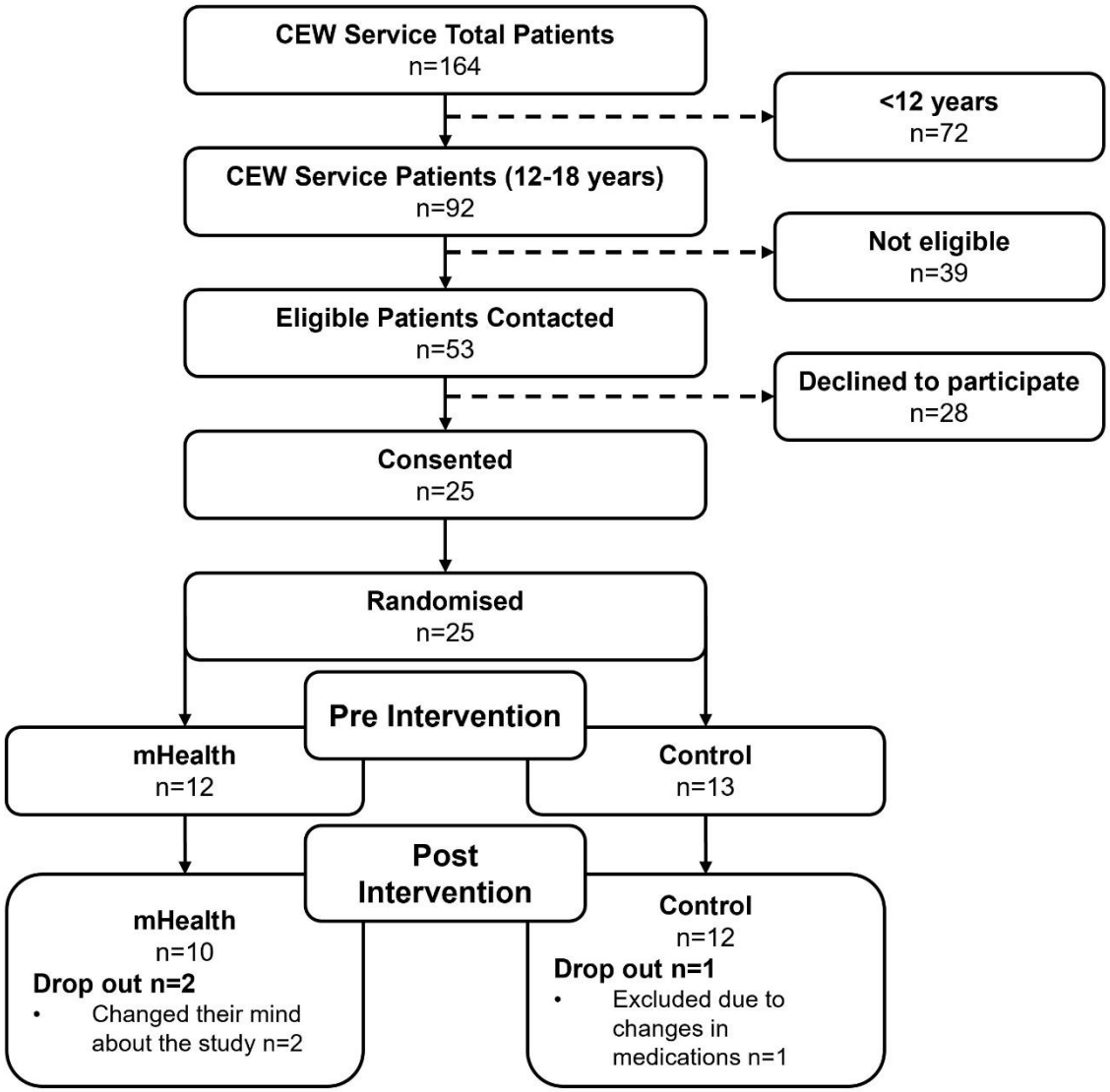


Figure 1. Participant consort diagram.

CEW, Complications from Excess Weight; mHealth, Mobile Health.

Table 1. Baseline demographics of study participants and the whole AHCH CEW cohort**.**

		Total (*n*= 25) *n* (%)	MOTIVATE-CEW (*n*= 12) *n* (%)	Usual care (*n*= 13) *n* (%)	CEW Service (*n*= 92) *n* (%)
Age	*mean ±SD*	15±1	15±1	15±2	15±2
	12-15	16 (64)	7 (58)	9 (69)	56 (61)
	16-18	9 (36)	5 (42)	4 (31)	36 (39)
Sex					
	Male	12 (48)	4 (33)	8 (62)	41 (45)
	Female	13 (52)	8 (67)	5 (38)	51 (55)
Ethnicity					
	White	21 (84)	11 (92)	10 (77)	70 (76)
	Other	1 (4)	0 (0)	1 (8)	11 (12)
	Not Stated	3 (12)	1 (8)	2 (15)	11 (12)
IMD Quintile*					
	1	18 (75)	11 (92)	7 (58)	62 (72)
	2	1 (4)	0 (0)	1 (8)	7 (8)
	3	2 (8)	0 (0)	2 (17)	8 (9)
	4	2 (8)	0 (0)	2 (17)	6 (7)
	5	1 (4)	1 (8)	0 (0)	3 (3)

AHCH, Alder Hey Children's Hospital; CEW, complications of excessive weight; SD, Standard Deviation; IMD, indices of multiple deprivation.
** Total (n=24), MOTIVATE-CEW (n=12), Usual Care (n=12), CEW Service (n=86)*

Table 2. Device derived measures of purposeful exercise sessions during the 3-month intervention period: means and SD**.**

Outcome	Timepoint	MOTIVATE-CEW	Usual Care	Effect Size
Frequency of exercise (number of sessions per week)	Intervention Period	2 ±2	0 ±0	1.04
Mean time spent exercising (mins)	Intervention Period	80 ±102	8 ±20	0.99
	Week 11&12	39 ±57	7 ±26	0.71
Time spent completing moderate to vigorous intensity exercise (mins)	Intervention Period	97 ±127	4 ±11	1.40
	Week 11&12	51 ±67	4 ±14	1.04

When calculating time spent completing moderate to vigorous intensity exercise, vigorous intensity exercise was multiplied by two.

SD, Standard Deviation

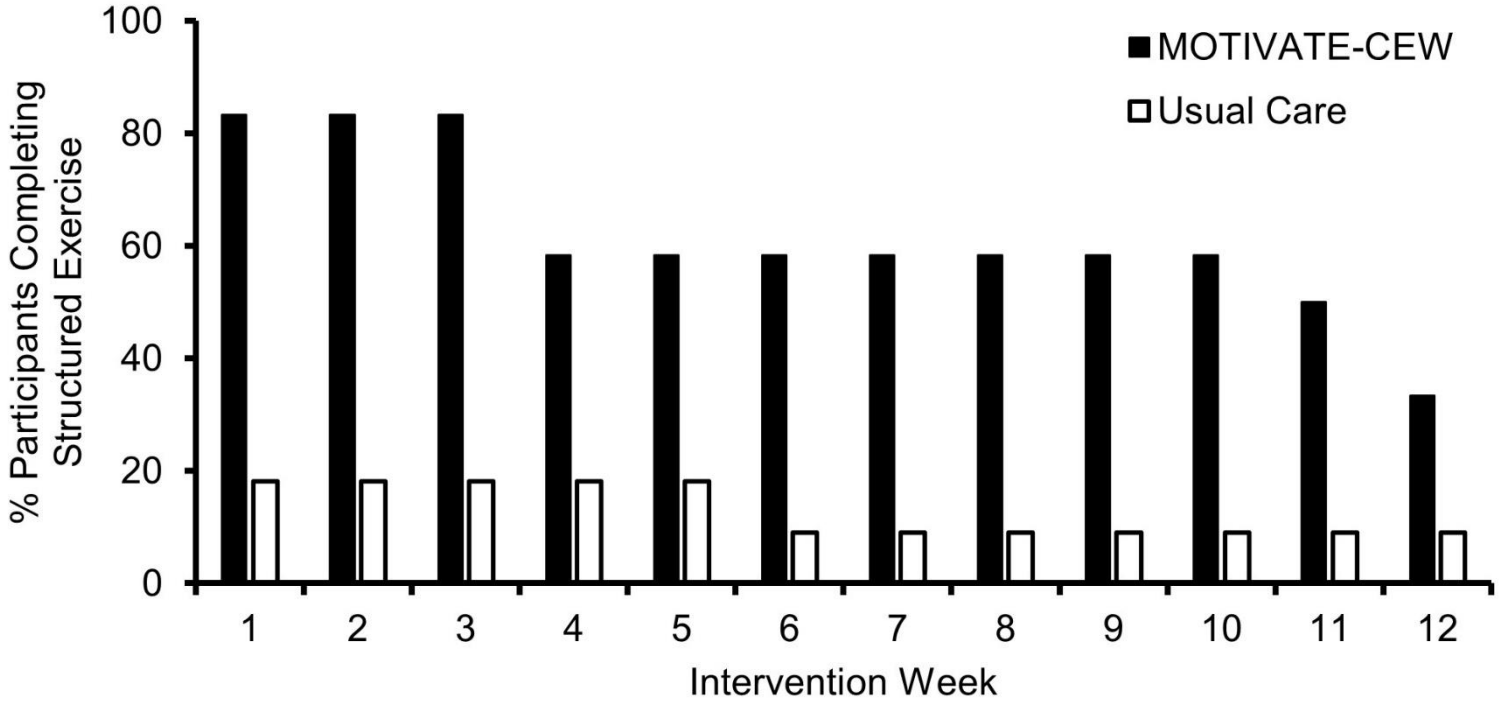


Figure 2. Training drop off by week in MOTIVATE-CEW participants and usual care.

Table 3. Health Outcome Measures: changes from baseline means and 95%CI.

Outcome	Mean change		Effect Size
	MOTIVATE-CEW	Usual Care	
Body composition			
Weight (kg)	1.3 (-1.2 to 3.7)	0.6 (-2.2 to 3.3)	0.25
n	*10*	*12*	
BMI (kg/m^2)	0.2 (-0.7 to 1)	-0.3 (-1.4 to 0.7)	-0.35
n	*10*	*12*	
SDS BMI	0.2 (-1.3 to 0.9)	0 (-0.1 to 0.1)	-0.31
n	*10*	*12*	
Body Fat (%)	-1.5 (-4.2 to 1.1)	-0.6 (-2.7 to 1.6)	0.28
n	*10*	*11*	
Cardiovascular disease risk factors			
SBP (mmHg)	1 (-9 to 12)	-1 (-7 to 5)	-0.21
n	*10*	*12*	
DBP (mmHg)	0 (-8 to 8)	-2 (-11 to 7)	-0.18
n	*10*	*12*	
HbA1c (mmol/mol)	1 (-1 to 4)	-1 (-2 to 1)	-0.80
n	*8*	*11*	
Cholesterol (mmol/l)	-0.1 (-0.4 to 0.2)	0.01 (-0.22 to 0.24)	0.38
n	*10*	*12*	
HDL (mmol/l)	-0.02 (-0.11 to 0.06)	-0.07 (-0.15 to 0)	0.22
n	*10*	*12*	
LDL (mmol/l)	-0.14 (-0.34 to 0.07)	-0.14 (-0.4 to 0.12)	0.02
n	*10*	*12*	
Triglycerides (mmol/l)	0.0 (-0.2 to 0.3)	0.5 (-0.1 to 1.1)	0.64
n	*10*	*12*	
Liver function			
AST (U/L)	-1 (-5 to 3)	-1 (-6 to 5)	0.02
n	*10*	*12*	

ALT (U/L)	-5 (-14 to 4)	7 (-1 to 14)	0.94
n	*10*	*12*	
Albumin (g/L)	1 (-1 to 2)	1 (-1 to 2)	0.02
n	*10*	*12*	
EQ-5D-Y			
EQ-5D-Y VAS	19.6 (7.91 to 31.29)	5 (-6.09 to 16.09)	0.86
n	*10*	*12*	
Mean Score	-0.13 (-0.41 to 0.14)	-0.08 (-0.28 to 0.12)	0.14
n	*10*	*12*	
PedsQL			
Mean Score	8 (-3 to 18)	5 (-3 to 13)	0.22
n	*10*	11	
Psychosocial Health Summary	9 (-4 to 22)	6 (-4 to 16)	0.19
n	*10*	*11*	
Physical Health Functioning	6 (-3 to 15)	3 (-6 to 12)	0.24
n	*10*	*11*	
Emotional Functioning	9 (-7 to 24)	5 (-4 to 15)	0.16
n	*10*	*11*	
Social Functioning	8 (-8 to 24)	2 (-8 to 12)	0.35
n	*10*	*11*	
School Functioning	9 (-5 to 23)	9 (-9 to 27)	0.01
n	*10*	*11*	
Parent PedsQL			
Mean Score	14 (2 to 25)	8 (2 to 14)	0.45
n	*10*	*12*	
Psychosocial health Summary	14 (4 to 23)	8 (3 to 13)	0.52
n	*10*	*12*	
Physical Functioning	13 (-4 to30)	7 (-4 to 17)	0.31
n	*10*	*12*	
Emotional Functioning	10 (-3 to 23)	7 (-1 to 15)	0.19
n	*10*	*12*	

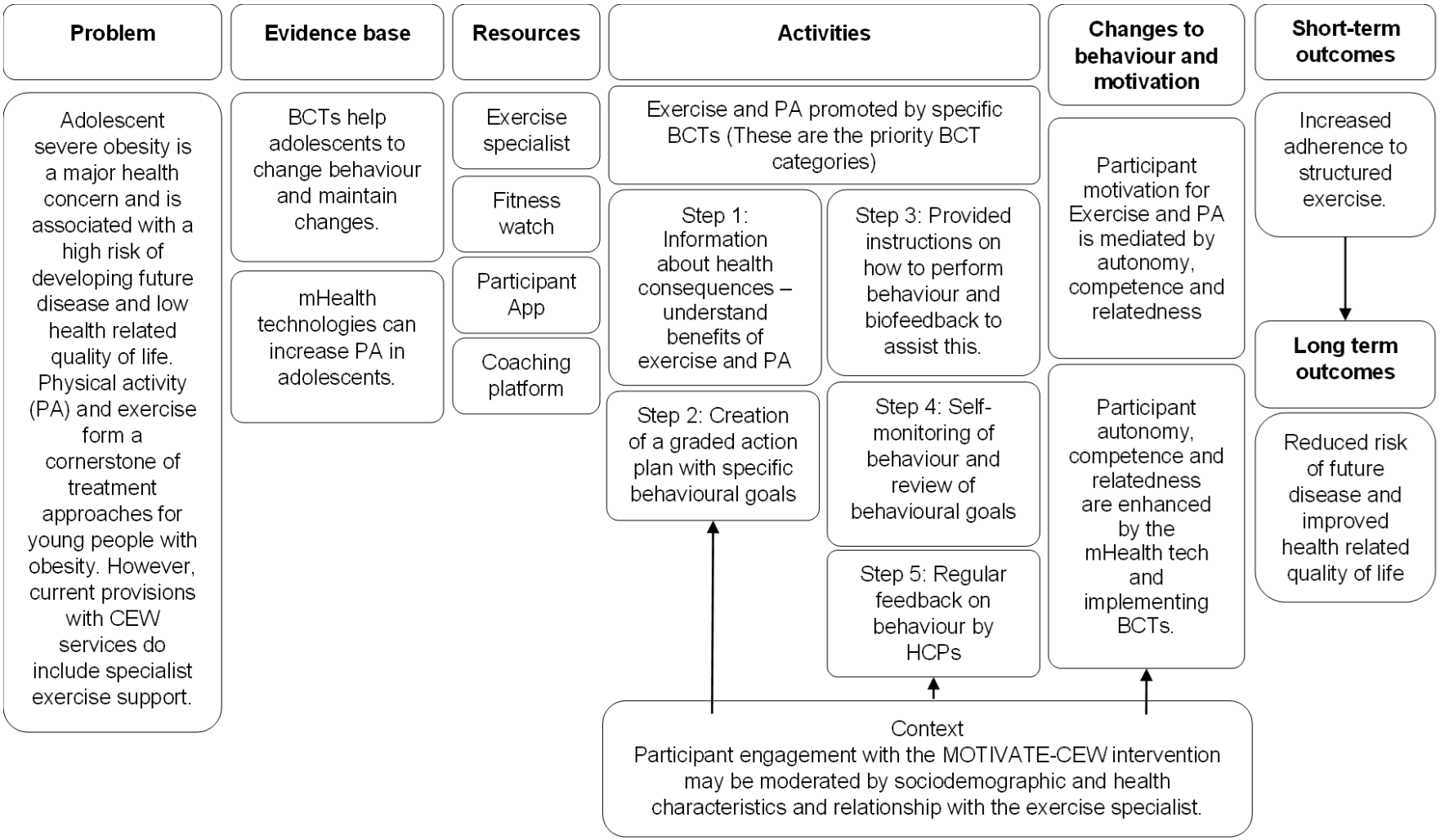
Social Functioning	14 (-3 to 30)	9 (-1 to 19)	0.23
n	*10*	*12*	
School Functioning	18 (4 to 31)	8 (-4 to 20)	0.50
n	*10*	*12*	

CI, Confidence Interval; BMI, Body Mass Index; SDS-BMI, standard deviation scores body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, glycated haemoglobin; HDL, high density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine transaminase; EQ-5D-Y, EuroQol Five-Dimensional Questionnaire, Youth Version; VAS, visual analogue scale; PedsQL, Pediatric Quality of Life Inventory 4.0; Parent PedsQL, PedsQL 4.0 parent proxy-report

Supplementary Figures and Tables

Supplementary Table 1. Multidisciplinary clinical team treatment and care methods

Role	Treatment/Care
Consultant Endocrinologist Physician Associate Clinical Fellow	• Patient History • Monitor clinical outcome and their changes over time • Referrals to other specialities that provide care for specific issues causing obesity • Prescribe medications • General lifestyle advice
Psychologist	• One to one meetings • Group sessions • School and medical team liaison
Dietician	• Food diaries • Eatwell plate • National Diet Resource leaflet • In house resources for alternative recipes and healthy swaps
Physiotherapist	• Sleep questionnaires • Sleep hygiene resources • TOSCA studies to review partial pressure of carbon dioxide (PCO_2) and oxygen saturation (SpO2). • Community links with partners offering activities • Safe exercising advice
Nurse Specialist	• Blood glucose monitoring teaching for parents and patients • Teaching parents and patients how to administer daily injections of medications
Key Worker	• School visits • Home visits • Provide contacts and facilitate links with community-based support



Supplementary Figure 1. MOTIVATE-CEW Logic Model

CEW, Complications from excessive weight; mHealth, Mobile Health; BCT, Behaviour Change Technique; HCPs, Health Care Professionals

Supplementary Table 2. Example Feedback Messages sent to MOTIVATE-CEW Participants

Scenario	Example Message
Completed all exercise sessions and did so with the correct duration and intensity of exercise	Hi_____, Great work with your exercise sessions this week! You achieved your goal and completed all your training sessions! Your gym session on Monday looked particularly good. You seem to have created an exercise plan that works for you – keep it up! If you'd would like to change anything in your plan let me know. Let's have another awesome week next week!
Completed 2 out of 3 exercise sessions. In one session they achieved the correct duration but incorrect intensity of exercise	Hi_____, Well done on completing 2 of your 3 exercise sessions this week! In your cycling session on Thursday you even exceeded your heart rate goals and spent 12 minutes in a higher zone than we discussed! Some people find that exercising consistently at this intensity isn't as enjoyable or they can't maintain that pace. If that is the case for you, don't be afraid to slow down a bit so that you can enjoy it more. Let's keep up this good work!
No recorded exercise sessions completed	Hi____, many people find starting to be one of the most challenging parts of being active. Think about some good reasons to stick to making these changes. What do you need from me to make this programme work for you? If you would like, we can have another call to discuss what might work for you at this time.

Supplementary Table 3. Participant and parent/guardian acceptability of the trial process and acceptability of MOTIVATE-CEW intervention.

The following are verbatim quotes of the positive experiences of the trial process from participants and parents/guardians
“I don't think for (the participant) putting any of (the monitors) on was an issue, there was no stigma attached to it. I think it was just part of the programme, she did it and it was fine.” *(Parent/Guardian 2)*
“I would say that it was an amazing experience. Like I would say everything about it, it's been pretty positive for me.” *(Participant 1)*
“I really can't fault the tracking. I thought it was very very good. Glucose one was a bit of a, you know, a pain.” *(Parent/Guardian 3)*
The following are verbatim quotes of the positive experiences of the MOTIVATE-CEW intervention from participants and parents/guardians
“It gave me the motivation to be able to actually get out and do it and get on the app and be like, ok, well now I'm going to do this at this time and actually do it… I had the motivation to be like, no, you’re doing it today, you're doing it at this time and that's it.” (Participant 3)
“I’ve found (the participant) is now wanting to go on long walks… (the participant) didn't really, realise they were doing exercise, and that's what I found, (the exercise specialist) made (the participant) think it's not about weight loss, it’s about getting healthy and it's about enjoying it as well, so it doesn't feel like it's exercise.” (Parent/Guardian 1)
“I think without the watch it would have been a big struggle to continue and know correctly what you're doing because when I'm doing the exercise it beeps, telling me my heart rates not in the right place and needs to be more.” (Participant 1)
“I thought it was really positive. (The messages) were one of the most motivating things. Even if I'd felt like I'd not done as good this week, (the exercise specialist) always made me feel better for what I’d done. I just thought (the exercise specialist) was really nice, that's what you want.” (Participant 2)

Supplementary Table 4. Survey reported exercise behaviour and device derived habitual physical activity and sedentary behaviour: time point means and SD.

Outcome	MOTIVATE-CEW		Usual Care	
	Baseline	3-month	Baseline	3-month
GLTEQ				
Number of Moderate/ Strenuous Exercise sessions	4 ±2	5 ±3	5 ±3	4 ±3
n	*12*	*10*	*12*	*12*
Total Score	39 ±18	42 ±24	44 ±27	39 ±26
n	*12*	*10*	*12*	*12*
GENEActiv				
Total Weekly PA	1315 ±471	1582 ±584	1193 ±455	1089 ±461
n	*10*	*7*	*8*	*2*
Sedentary Time per week	8765 ±471	8498 ±584	8887 ±455	8991 ±461
n	*10*	*7*	*8*	*2*
Light PA per week	1075 ±367	1321 ±488	1014 ±357	964 ±342
n	*10*	*7*	*8*	*2*
Moderate PA per week	230 ±134	253 ±113	173 ±110	124 ±124
n	*10*	*7*	*8*	*2*
Vigorous PA per week	11 ±11	8 ±4	5 ±9	1 ±2
n	*10*	*7*	*8*	*2*
MVPA per week	241 ±142	261 ±116	178 ±113	125 ±126
n	*10*	*7*	*8*	*2*
MVPA+10	29 ±27	25 ±17	33 ±51	34 ±59
n	*10*	*7*	*8*	*2*
ActivPAL				
Mean Steps Per Day	7115 ±3541	8523 ±2816	6738 ±3651	7377 ±1855
n	*6*	*6*	*6*	*2*

Mean Daily Sedentary Time	630 ±61	599 ± 77	598 ±48	679 ±55
n	*6*	*6*	*6*	*2*

SD, Standard Deviation; PA, Physical Activity, GLTEQ, Godin Leisure Time Exercise Questionnaire, MVPA, moderate to vigorous intensity physical activity; MVPA10+, MVPA recorded in ≥10-minute bouts. GENEActiv wear time criteria were >16 hours for a minimum of 4 days irrespective of weekday/weekend day. ActivPAL wear time criteria were >20h of data for a minimum 4 days including one weekend day and three weekdays.

Supplementary Table 5. Data Availability- Survey reported exercise behaviour and device derived habitual physical activity and sedentary behaviour

Measure	Overall (%)	MOTIVATE-CEW		Usual Care		Reasons for missing data (n)
		Baseline (%)	3-month (%)	Baseline (%)	3-month (%)	
GLTEQ Questionnaire	92	100	83	92	92	Drop Out (3), Patient refused (1)
GENEActiv						
GENEActiv Returned	82	92	83	92	62	Drop out (3), Patient refused (5), Lost in Post (1)
4 days (≥1WE, ≥3WK) (>16hrs)	46	67	42	54	23	Drop out (3), Insufficient number of days (12), Insufficient Weekend days (5), Patient refused (5), Lost in Post (1), Insufficient Weekdays (1)
4 days (≥1WE, ≥3WK) (>10hrs)	46	67	42	54	23	Drop out (3), Insufficient days (12), Insufficient Weekend days (5), Patient refused (5), Lost in Post (1), Insufficient weekdays (1)
4 days (>16hrs)	58	83	58	69	23	Drop out (3), Insufficient number of days (12), Patient refused (5), Lost in Post (1)
4 days (>10hrs)	58	83	58	69	23	Drop out (3), Insufficient number of days (12), Patient refused (5), Lost in Post (1)
1 day (>10hrs)	66	83	67	85	31	Drop out (3), Insufficient number of days (7), Patient refused (5), Lost in Post (1)
ActivPAL						
ActivPAL Returned	70	75	83	77	46	Drop out (3), Patient refused (7), Monitor Damaged/ Lost (5)
4 days (≥1WE, ≥3WK)	40	50	50	46	15	Drop out (3), Participant removed device (7), Patient refused (7), Monitor Damaged/ Lost (5), Device Failed (4), Insufficient days recorded by device (4)

4 days	42	58	50	46	15	Drop out (3), Participant removed device (7), Patient refused (7), Monitor Damaged/ Lost (5), Device Failed (4), Insufficient days recorded by device (3)
1 day	56	67	75	62	23	Drop out (3), Patient refused (7), Monitor Damaged/ Lost (5), Device Failed (4), Participant removed device (3)

GLTEQ, Godin Leisure Time Exercise Questionnaire; 4 days (≥1WE, ≥3WK), 4 day inclusive of 1 weekend day and 3 weekdays; >16hrs, 16-hour wear time validation; >10hrs, 10-hour wear time validation.

Supplementary Table 6. Data Availability- health related quality of life questionnaires, body composition, cardiovascular disease risk factors and liver function

Measure	Overall (%)	MOTIVATE-CEW		Usual Care		Reasons for missing data (n)
		Baseline (%)	3-months (%)	Baseline (%)	3-months (%)	
Health related quality of life						
EQ-5D-Y	92	100	83	92	92	Drop Out (3), Patient refused (1)
PedsQL - Self-report	88	100	83	85	85	
PedsQL - Proxy	92	100	83	92	92	Drop Out (3), Patient refused (1)
Body composition						
Weight	94	100	83	100	92	Drop Out (3)
BMI	94	100	83	100	92	Drop Out (3)
Body Fat %	90	100	83	92	85	Drop Out (3), Tanita Error (1), Patient refused (1)
Cardiovascular disease risk						
Blood Pressure	94	100	83	100	92	Drop Out (3)
Lipid Profile	94	100	83	100	92	Drop Out (3)
HbA1c	86	75	83	92	92	Drop Out (3), Lab Error (3), Insufficient Sample (1)
Liver function	94	100	83	100	92	Drop Out (3)

EQ-5D-Y, EuroQol Five-Dimensional Questionnaire, Youth Version; PedsQL, Pediatric Quality of Life Inventory 4.0; BMI, Body Mass Index; HbA1c, glycated haemoglobin

Supplementary Table 7. Data Availability- Flash continuous glucose monitoring

Measure	Overall (%)	MOTIVATE-CEW		Usual Care		Reasons for missing data (n)
		Baseline (%)	3-month (%)	Baseline (%)	3-month (%)	
Monitor returned	76	83	75	77	69	Drop Out (3), Participant refused (4), Sensor was not returned (5)
14 day	42	33	25	54	54	Drop Out (3), Sensor fell out (16), Refused (4), Sensor was not returned (5), Patient removed sensor (1)
10 day	46	42	33	54	54	Drop Out (3), Sensor fell out (14), Refused (4), Sensor was not returned (5), Patient removed sensor (1)
7 day	54	50	42	69	54	Drop Out (3), Sensor fell out (10), Refused (4), Sensor was not returned (5), Patient removed sensor (1)

Flash continuous glucose monitoring data availability was set to 70% for 14 days and 80% for 10 and 7 days

Supplementary Table 8. Health related quality of life questionnaires: time point means and SD

Outcome	MOTIVATE-CEW		Usual Care	
	Baseline	3-month	Baseline	3-month
EQ-5D-Y				
EQ-5D-Y VAS	59.67 ±22.41	76.6 ±12.69	60.83 ±16.21	65.83 ±21.72
n	*12*	*10*	*12*	*12*
Mean Score	0.60 ±0.45	0.48 ±0.25	0.72 ±0.59	0.64 ±0.76
n	*12*	*10*	*12*	*12*
PedsQL				
Mean Score	62 ±19	69 ±13	63 ±24	68 ±22
n	*12*	*10*	*11*	*11*
Psychosocial Health Summary	56 ±24	63 ±18	57 ±28	63 ±*23*
n	*12*	*10*	*11*	*11*
Physical Health Functioning	73 ±16	80 ±*11*	73 ±19	76 ±24
n	*12*	*10*	*11*	*11*
Emotional Functioning	55 ±25	63 ±18	58 ±32	64 ±22
n	*12*	*10*	*11*	*11*
Social Functioning	63 ±32	71 ±23	65 ±*29*	67 ±31
n	*12*	*10*	*11*	*11*
School Functioning	50 ±31	56 ±27	47 ±31	56 ±27
n	*12*	*10*	*11*	*11*
Parent PedsQL				
Mean Score	47 ±22	60 ±16	57 ±22	65 ±19
n	*12*	*10*	*12*	*12*
Psychosocial health Summary	44 ±*22*	57 ±19	55 ±23	63 ±21
n	*12*	*10*	*12*	*12*
Physical Functioning	54 ±*24*	64 ±18	60 ±22	67 ±19
n	*12*	*10*	*12*	*12*
Emotional Functioning	40 ±21	48 ±23	48 ±*22*	55 ±25

n	*12*	*10*	*12*	*12*
Social Functioning	50 ±31	62 ±23	58 ±30	68 ±26
n	*12*	*10*	*12*	*12*
School Functioning	43 ±32	61 ±23	60 ±28	68 ±25
n	*12*	*10*	*12*	*12*

SD, Standard Deviation; EQ-5D-Y, EuroQol Five-Dimensional Questionnaire, Youth Version; VAS, visual analogue scale; PedsQL, Pediatric Quality of Life Inventory 4.0; parent PedsQL, PedsQL 4.0 parent proxy-report

Supplementary Table 9. Body composition, cardiovascular disease risk factors and liver function: time point means and SD

Outcome	MOTIVATE-CEW		Usual Care	
	Baseline	3-month	Baseline	3-month
Body composition				
Weight (kg)	114.7 ±19.9	111.6 ±17.9	120.4 ±25.7	119.7 ±27.6
n	*12*	*10*	*13*	*12*
BMI (kg/m^2)	41.0 ±7.3	40.7 ±7.2	42.2 ±8.1	41.1 ±8.3
n	*12*	*10*	*13*	*12*
SDS BMI	3.45 ±0.58	3.42 ±0.61	3.6 ±0.55	3.5 ±0.60
n	*12*	*10*	*13*	*12*
Body Fat (%)	48.3 ±6.0	46.7 ±6.3	49.5 ±9.7	48.2 ±7.8
n	*12*	*10*	*12*	*11*
Cardiovascular disease risk factors				
SBP (mmHg)	131 ±16	134 ±13	131 ±11	130 ±10
n	*12*	*10*	*13*	*12*
DBP (mmHg)	82 ±11	82 ±11	86 ±9	85 ±12
n	*12*	*10*	*13*	*12*
HbA1c (mmol/mol)	32 ±4	34 ±4	34 ±3	33 ±3
n	*9*	*10*	*12*	*12*
Cholesterol (mmol/l)	4.1 ±0.7	3.9 ±0.5	4.5 ±0.7	4.5 ±0.7
n	*12*	*10*	*13*	*12*
HDL (mmol/l)	1.07 ±0.19	1.10 ±0.15	1.04 ±0.19	0.96 ±0.21
n	*12*	*10*	*13*	*12*
LDL (mmol/l)	2.35 ±0.58	2.18 ±0.45	2.80 ±0.61	2.63 ±0.73
n	*12*	*10*	*13*	*12*
Triglycerides (mmol/l)	1.4 ±0.6	1.3 ±0.6	1.4 ±0.6	1.9 ±0.7
n	*12*	*10*	*13*	*12*
Liver function				

AST (U/L)	22 ±8	22 ±6	29 ±15	26 ±11
n	*12*	*10*	*13*	*11*
ALT (U/L)	33 ±16	28 ±11	37 ±25	41 ±27
n	*12*	*10*	*13*	*12*
Albumin (g/L)	43 ±3	43 ±2	42 ±3	43 ±4
n	*12*	*10*	*13*	*12*

SD, Standard Deviation; BMI, Body Mass Index; SDS-BMI, standard deviation scores body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, glycated haemoglobin; HDL, high density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine transaminase.