Cover letter

The current paper aims to fill some of the gap in available literature of up-scaled, community based child weight management interventions focused on underserved populations, by presenting the results of implementing MEND 7–13 in a large sample of US families. The study material is original research and has not previously been submitted for peer-review or publication.

Conflicts of interest

JF, MK, SP and PMS are consultants for Healthy Weight Partnership, a for profit organization that delivers MEND in North America. In addition, PMS is a shareholder of Healthy Weight Partnership Inc. The other authors declare no conflict of interest.

Addressing childhood obesity in underserved families: outcomes and peer effects of MEND 7–13 when delivered at scale in US communities

Paul M Sacher, PhD[1,2]; Maria Kolotourou, MSc[2]; Stavros Poupakis, MSc[3]; Paul Chadwick, PhD[4]; Duncan Radley, PhD[5]; Jamie Fagg, PhD[2]

[1]Childhood Nutrition Research Centre, University College London, London, United Kingdom

[2]Healthy Weight Partnership Inc., Boston, United States

[3]Department of Economics, University College London, London, United Kingdom

[4]Department of Diabetes, Royal Free Hampstead NHS Trust, Pond Street, London, United Kingdom

[5]Leeds Metropolitan University, School of Sport, Carnegie Faculty, Leeds, United Kingdom

Corresponding author:

Paul M Sacher, PhD

Healthy Weight Partnership

c/o FGD

Four 13th Street

Boston, MA 02129

Tel: 866-559-5114

Email: paul.sacher@healthyweightpartnership.org

Running title: MEND 7–13 in the US: outcomes and peer effects

Abstract

Objectives: Implementation of a large-scale, child weight management program in underserved communities provided an important opportunity to evaluate its effectiveness under service level conditions.

Methods: MEND 7–13 is a community-based, multicomponent, childhood obesity intervention designed to improve dietary, physical activity and sedentary behaviors. It comprises twice weekly sessions for 10 consecutive weeks (total of 35 contact hours) and is delivered to groups of children and their accompanying parents/caregivers. The current evaluation used an uncontrolled, repeated measures design. 4,324 children attended 415 MEND 7–13 programs in seven USA states, of which 2,738 (63%) had complete data for change in zBMI. The intervention targeted underserved families (70% with an income <$40,000 per year; 85.6% Hispanic or African American). Changes in anthropometric, fitness and psychological outcomes were evaluated. A longitudinal multivariate imputation model was used to impute missing data. Peer effects analysis was conducted using the instrumental variables approach and group fixed effects.

Results: Mean changes in BMI, and zBMI at 10 weeks were -0.42 kg/m^2 (95%CI: -0.49, -0.35) and -0.06 (95%CI: -0.08, -0.04) respectively. Benefits were observed for all other study outcomes. Mean peer reduction in zBMI was associated with a reduction in participant zBMI in the instrumental variables model (B=0.78, p=0.04, 95%CI: 0.03, 1.53). Mean program attendance and retention were 70.8% and 84.7% respectively.

Conclusion: Similar to recently published efficacy trial results, implementing MEND 7–13 under service level conditions was associated with short-term improvements in anthropometric, fitness and psychological indices in a large sample of underserved overweight and obese children. A peer effect was quantified showing that benefits for an individual child were enhanced if peers in the same group also performed well. To our knowledge, this is the first study to show positive peer effects associated with participation in a childhood obesity intervention.

Introduction

Childhood obesity is a major public health issue with significant economic costs, and is particularly prevalent among disadvantaged populations.[1] The widening health disparities with regard to children's adiposity -such as the higher obesity rates in African American and Hispanic children- are particularly evident in the USA and necessitate the development of interventions which are effective in underserved populations.[2]

Up-scaling community interventions is essential in order to address the existing obesity rates. Nevertheless, evaluations of up-scaled interventions have highlighted that the impact under conditions of normal service delivery can vary from that observed under trial conditions.[3-5] Whilst such differences may be inevitable, it is important to delineate the ways in which up-scaled interventions may differ in reach and impact, in order to take steps to reduce inequities in service provision.

Up-scaled interventions are usually delivered to groups in order to be cost-effective and achieve public health outcomes.[6] Within groups, peer effects may play an important role in intervention effectiveness. Available literature indicates that higher BMIs can be contagious and that obesity may be spreading from one person to another via social ties.[7-9] However, there is currently no research investigating whether peer effects can have an inverse, positive effect in group weight management interventions, i.e. if peer positive outcomes (e.g. reduction in BMI or improvement of other health outcomes) can lead to positive outcomes for the whole group. If this theory is confirmed, successful childhood obesity interventions offered to groups may have additional benefits for participating children.

MEND 7–13 is a group-based childhood weight management program, initially developed in the UK. Following establishment of feasibility and efficacy[10, 11] it was up-scaled extensively as a national community-based childhood weight management program in the UK, with service level evaluation confirming efficacy trial outcomes both in the short and long term.[12, 13] MEND 7–13 was then comprehensively and culturally adapted, piloted and scaled-up in other countries (USA, Canada, Australia and the Netherlands).

In the USA, MEND 7–13 was evaluated as part of the Texas Childhood Obesity Demonstration (TX CORD) project, which was designed to address childhood obesity by targeting low-income, ethnically diverse children with overweight or obesity. MEND 7–13 was more efficacious in BMI reduction at 3 months but not 12 months compared to controls. Despite efforts to engage families, attendance was low during the intensive phase (approximately 50%).[14]

Following these results, the current study evaluated the impact of implementing MEND 7–13 under service level conditions, in a large sample of underserved families in the USA and investigated the potential positive peer effects.

Methods

Study design

The study employed an uncontrolled repeated measures design. Changes in outcomes were evaluated following the implementation of MEND 7–13 when delivered in community settings under service level conditions (i.e. not for research, but following the provision of MEND 7–13 as a primary care child weight management service).

Participants took part in MEND 7–13 from seven states across the USA. Recruitment was undertaken using a variety of techniques (e.g. health professional referral, media, internet). Children were eligible if they were overweight or obese,[15] aged 7 to 13 years, and had no serious parental or physician reported clinical conditions, comorbidities, physical disabilities or learning difficulties. Parent/caregiver attendance was mandatory at all program sessions. Written consent by a parent/caregiver was a requirement for participation.

Study intervention

MEND 7–13 is a multicomponent, family-based intervention designed to improve diet and physical activity through education, behavior change, skills training, and motivational enhancement.[3] It is delivered twice a week for 10 consecutive weeks (a total of 35 contact hours) to groups of up to 15 children and their accompanying parents/caregivers. MEND 7–13 is delivered in community settings (e.g. schools, recreation centers, faith-based) by trained professionals (mainly recreation and physical activity backgrounds) and by a variety of partner organizations. It is designed to support program fidelity and includes features such as manualization of the program's content, standardized training of all staff, common resources, standardized measurement procedures, online data entry, automated family feedback and continuous feedback from trainers and families, leading to continuous program development and improvement.[11] MEND 7–13 has been culturally adapted and localized to cater for families' ethnic and social backgrounds and where necessary, program delivery and resources are provided in Spanish. MEND 7–13 has been shown to be cost-effective[16] and was provided free of charge to families. The total cost per family for funding organizations varies according to factors including project size and complexity, number of children and type of delivery staff and venues. Costs generally range between $500 and $1400 per parent and child. In kind contributions (e.g. space or time) and different delivery models can reduce this further.

MEND 7–13 is in line with the US Preventive Services Task Force recommendations for child weight management (moderate intensity comprehensive behavioral program) and the Academy of Nutrition and Dietetics position on interventions for the prevention and treatment of pediatric overweight and obesity.[17, 18]

Outcome measures

Baseline and post-program measurements were part of the MEND 7–13 curriculum. Baseline measurements were taken during the first and post-program measurements during the penultimate session. All measurements were taken by the local team delivering the program at each site.

Anthropometry

Body weight (kg) and height (cm) were measured using standardized procedures.[19] BMI was calculated as body weight(kg)/height(m^2). Waist circumference was measured 4 cm above the umbilicus.[20] BMI z-score (zBMI) and % overweight were calculated using Centers for Disease Control (CDC) reference data.[15] BMI as a percentage of the 95th centile (%BMI_{p95}) was also calculated in order to address the CDC growth chart limitations for children with BMI values greater than the 95th centile.[21-23]

Cardiovascular fitness

Cardiovascular fitness was assessed by the Young Men's Christian Association (YMCA) step test.[24]

Psychological indices

The following tools were used to assess children's psychological well-being:

- The strengths and difficulties questionnaire (SDQ) was used to assess parental perception of children's psychological distress.[25]
- Body esteem was assessed using Mendelson's body esteem scale, a child-reported questionnaire that measures the way a child thinks and feels about the appearance of their body.[26]
- Self-esteem was assessed using the child-reported Harter Self-Perception Profile and the Rosenberg's self-esteem scale. [27, 28]
- Children's Quality of Life was assessed using 'Sizing them up©', an obesity-specific, parent-reported measure of health-related quality of life

and Pediatric Quality of Life Inventory (PEDSQL®), a questionnaire that measures children's self-reported health-related quality of life.[29, 30] The physical and psychosocial sub-scales of PEDSQL® were included in the current analysis, as these are consistently impaired in overweight and obese children.[31]

In addition, parental physical and mental health were assessed using the Short Form Health Survey (SF12®) questionnaire.[32]

Demographics

Socioeconomic information was collected based on the US Census questionnaire.[33]

Attendance and dropout

Attendance was calculated as the percentage of sessions attended by each child and their accompanying parent/caregiver. Children were classified as dropouts if they attended ≤5/20 (≤25%) of program sessions.[4]

Peer effects

For each participant within each group, the mean zBMI at baseline of all the other participants belonging in the same group was calculated, leaving out the index child's value. This was also done for change in zBMI. Thus, the peer variables were defined as the leave-one-out, i.e. for each child of each group a larger mean BMI was theorized to be associated with an increase in mean change in BMI.

Data cleaning and statistical analysis

Due to the data being collected under service level conditions by non-researchers, several procedures were undertaken to ensure data quality. This included 1) standardized theoretical and practical training of all professionals who performed measurements, 2) implementing validations at the point of computerized data entry and 3) removing outliers from the dataset prior to performing any statistical analysis. Between 3% (BMI) and 17% (Harter self-esteem scale) of children were missing outcome data at baseline, while between 32% (PEDSQL® physical health score) and 37% (Harter self-esteem score) were missing outcome data at follow up.

A longitudinal [repeat measures (n=8,648) nested in participants (n=4,324)] multivariate imputation model was used to impute missing data at baseline and follow up. Data were imputed using a set of auxiliary variables including all analysis variables for children (age, gender, ethnicity, all outcome variables, participant attendance), parents/caregivers data (BMI, socio-demographic), and program characteristics (group size, mean group age). Missing data were assumed missing at random. Ten imputed datasets were produced. Mean changes in outcomes were calculated across all ten datasets and parameters were combined using Rubin's rules.[34] For the analysis and reporting of missing data and multiple imputation the guidelines of Sterne et al were followed.[35]

In the peer effects analysis, the correlation between a child's change in zBMI and peers in the group was investigated. This correlation was explained by 1) endogenous effects (child zBMI change affected by peer zBMI change), 2) exogenous effects (peer pre-determined characteristics affecting change in zBMI) and 3) correlated effects (common unobserved characteristic affecting both own and peer change in zBMI, such as a talented MEND Leader with high ability).[36]

According to available literature it is reasonable to assume that there are no expected exogenous effects (e.g. effect of peer income or ethnicity on a child's change in zBMI),[9, 37-39] as peers are mostly likely to influence one's change in zBMI only through their change in zBMI. This assumption becomes more plausible in the current study, as children were assigned to a 10-week program, regardless of income or ethnicity. Thus, any peer effect should be attributed to the change in zBMI.

Endogenous effects were investigated using the instrumental variables model. Since the peer change in zBMI affects individual change in zBMI, and individual change in zBMI affects peer change in zBMI, a characteristic affecting individual change in zBMI only through peer change in zBMI was needed. In accordance with available literature, parental characteristics such as parent BMI, are good candidates.[9, 40] Peer parental BMI could have only affected the change in an individual's zBMI through peer change in zBMI, especially since peer baseline zBMI was controlled for. As suggested by Von Hinke, et al,[40] the individual instrument (i.e. parental BMI) was also included in the main second-stage equation. Finally, instructor fixed effects were used to control for any unobserved characteristic that might have influenced the group change in zBMI through instructor ability or neighborhood characteristics. Jackknife standard errors were reported for the fixed effects model, as they are more robust in cases of small number of clusters (as in this study). This approach ensures that standard errors are not driven by a particular instructor.

Analyses using pairwise complete case analysis were undertaken. Differences in dropout rate were investigated using independent sample t-test for continuous variables and chi squared test for categorical variables. Multiple imputation models were fitted in REALCOM, and other data analysis was performed using STATA version 14.

Results

4,324 children attended 415 MEND 7–13, of which 2,738 (63%) had complete data for change in BMI and zBMI. Mean program attendance was 70.8% and program retention rate was 84.7%. Dropout rate was higher among children from single parent households, who spoke a language other than English at home, who did not own their accommodation, whose parent/caregiver had lower education, those receiving food stamps as well as those with higher SDQ score and lower quality of life scores. Complete outcome data at baseline and follow-up were available to varying degrees. Descriptive statistics were therefore estimated using multiply imputed data, with complete case data for comparison (Table 1).

Outcome results

Mean change in outcomes calculated with imputed data showed that participation in MEND 7–13 was associated with reductions in BMI (B=-

0.42kg/m^2;95%CI=-0.49,-0.35), zBMI (B=-0.06;95%CI=-0.08,-0.04), % overweight (B=-3.84;95%CI=-4.93,-2.74), %BMI$_{95}$ (B=-3.17;95%CI=-4.00,-2.34), waist circumference (B=-1.01cm,95%CI=-1.44,-0.57), recovery heart rate (B=-4.36 beats per minute,95%CI=-5.20,-3.52) and psychological distress (B=-1.23;95%CI=-1.43,-1.02). Participation was also associated with increases in self-esteem (Harter: B=0.10;95%CI=0.07,0.12, Rosenberg: B=1.30;95%CI=1.05,1.54), body esteem (B=1.65;95%CI=1.45,1.85), parent-reported quality of life (B=4.20,95%CI=3.65,4.76), child-reported quality of life (Psychosocial scale: B=3.68;95%CI=2.93,4.42, Physical scale: B=4.61; 95%CI=3.91,5.30) and parental physical and mental health (B=1.47;95%CI=1.12,1.82 and B=2.53;95%CI=2.15,2.91 respectively) (Table 2).

Improvements in all study outcomes were observed in both pairwise and imputed data analysis (Table 3, columns 1, 2). Improvements were systematically smaller in imputed data for 11 out of 15 outcomes (Table 3, column 4), with changes being similar between imputed and pairwise data for zBMI and waist circumference. Improvements for change in % overweight and %BMI$_{95}$ were 5.8% and 2.6% larger in imputed data compared to complete case data. Changes in all other outcomes were between 11.5% and 28.3% smaller in imputed data than in complete case data. Despite these differences, the confidence intervals of estimates with complete case or imputed data generally overlapped. The exception to this was body esteem, where the magnitude of the improvement was significantly smaller in imputed relative to complete data.

Peer effects

According to peer effect analysis, one unit decrease of peer mean change zBMI was associated with a 0.17 unit (P=0.02) decrease in child's change in zBMI (Table 4, Fixed Effects model) accounting for correlated effects (i.e. through instructor), but not accounting for endogeneity. Using the instrumental variables (IV) approach, one unit decrease of peer mean change in zBMI was associated with 0.8 units (P=0.03) decrease in child's change in zBMI in the model not including the instrument at an individual level (Table 4, IV Fixed Effects Model 1), and 0.78 units (P=0.04) in the model including the instrument at an individual level (Table 4, IV Fixed Effects Model 2). An increase of 10% in attendance was associated with a decrease of 0.01 units (P=0.004) in a child's change in zBMI. For the IV models the F-statistics in the first stage were 33.86 and 32.11, respectively, indicating that the instrument was strongly correlated with the mean peer change zBMI. All models were controlled for individual baseline zBMI and peer baseline zBMI.

Discussion

The aim of the current evaluation was to determine outcomes following an up-scaled childhood obesity intervention, when delivered to underserved families under service level delivery conditions. The present intervention successfully targeted low income families (approximately 70% with an income <$40,000 per year, when real median income for family households in the US was $68,426 in 2014)[41] and children from Hispanic and African American backgrounds (65.5% Hispanic, 20.1% African American). Given the intensity of the intervention, MEND 7–13 achieved high levels of program attendance (70.8%) and retention rate (84.7%), which is important as available literature shows that such interventions often suffer from high attrition rates.[42-44] Attendance rate was higher than other up-scaled programs and higher than the MEND TX CORD trial.[5, 14, 43] This is an important finding, given that clinical trial retention rates are traditionally higher compared to real world implementations. As underserved populations are at increased risk of obesity and associated co-morbidities,[1] participation in culturally appropriate, weight management interventions is crucial. According to the current findings, attending MEND 7–13 was associated with short-term improvements in anthropometric, cardiovascular fitness and psychological indices in a large sample of underserved overweight and obese children.

More precisely, reductions were observed in BMI (-0.42 kg/m^2), zBMI (-0.06), % overweight (-3.84), %BMI$_{95}$ (-3.17) and waist circumference (-1.01 cm). These reductions are comparable with available literature on child weight management interventions in the USA high risk populations.[45, 46] Importantly, the current study resulted in greater reductions in BMI outcomes (BMI and %BMI$_{p95}$) compared to the recent TX CORD RCT 3-month longitudinal results of the MEND trial for children aged 6-12 years (BMI change: -0.25/-0.29 kg/m^2 for ages 6-8 and 9-12 respectively; %BMI$_{95}$ change: -2.32/-2.59 units for ages 6-8 and 9-12 respectively).[14] Larger BMI/zBMI reductions were reported in the MEND UK RCT (-0.9 kg/m^2 and -0.20 respectively),[47] a population-level MEND UK longitudinal evaluation of 9,563 participants (-0.7 kg/m^2 and -0.20 respectively)[13] and the Australian dissemination of the program in 2,812 participants (-0.65 kg/m^2 and -0.11 respectively)[5]. In terms of zBMI, it should be noted that the use of different growth charts in the USA, which have inherent problems in the assessment of children's adiposity for higher zBMI values[21-23] may at least partly justify these differences. Also, differences in population characteristics and settings do not allow direct study comparisons. And lastly, there are currently no agreed recommendations on magnitude of zBMI change required to achieve clinical significance following child weight management interventions, while benefits in several parameters have been reported irrespective of zBMI change.[48, 49]

Participation in MEND 7–13 was associated with improved cardiovascular fitness, which may be attributed to the physical activity provided during the program, as well as family encouragement to undertake additional lifestyle activities. This finding is important given the high representation of low income and minority groups, as low physical activity and increased sedentary activity are more prevalent among these populations.[50] Also, regardless of weight status and social background, improved cardiovascular fitness and increased physical activity have positive effects on children's physical and psychological wellbeing.[51]

The current study also identified improvements in self-esteem and body esteem, as well as a reduction in psychological symptoms as measured by the SDQ. This is important as body dissatisfaction and poor self-esteem are often associated with obesity in children and constitute risk factors for the development of future psychological problems such as eating disorders.[52] Therefore, the observed changes towards improved self- and body esteem indicate that the intervention conferred a short term psychological benefit in factors known to increase future risk of mental health issues in this population. Quality of life is often impaired in children with increased body weight.[31] This impairment is more pronounced among Hispanic children and those from lower socioeconomic backgrounds.[53] In the current study, improvements in the psychosocial and physical domains of the PEDSQL® were noted, as well as better parental perception of children's quality of life. The improvements in PEDSQL® physical domain indicate that the physical activity element of the intervention may have enhanced children's perceptions of their ability to perform everyday activities. Also, healthier alternatives in leisure time and sedentary activities as instructed during the intervention could have contributed to the observed improvements. Participation was also associated with an improvement in parental quality of life, as measured by the SF12®, suggesting that that the benefits of the intervention may extend to the whole family.

Community interventions need to be acceptable, easily accessible and their language and content specifically tailored to the target population. The research underpinning MEND 7–13, as well as its design and mode of delivery make the intervention suitable for such large-scale, real-world implementation. Also, the language and cultural adaptation of MEND 7–13 makes it a valuable option for children's weight management in diverse communities.

Approximately a third of the 4,324 children with BMI data at baseline were not measured at follow-up. This loss to follow-up often systematically varies with socio-demographic groups[43] and has also been observed in studies of MEND in the UK.[13] In order to understand the full impact of the intervention for all participants, a longitudinal multiple imputation model was used to impute missing data at both time points. By comparing analyses based on multiply imputed and complete case data, the direct impact of loss to follow up on findings could be evaluated. Results suggested that complete case estimates of change in outcomes were systematically greater than those for multiply imputed data. However, the direction, general magnitude of associations, and statistical significance remained the same (confidence intervals of imputed and complete case results overlapped in all but one outcome). This suggests that had all the participants who started, completed the intervention, improvements in outcomes would have been smaller on average, but would still reflect improved anthropometry, physical and psychological health.

Peer effects

Following the pioneering work of Christakis et al, who have suggested that obesity may be contagious and spread through social networks,[7] the effect of peers on weight has become an emerging field of study. It is well established that peers can affect weight via influencing food choices and activity patterns,[54, 55] however little is known about the potential peer effects that may result from an obesity management intervention, especially among children.[9, 56] In the current study, a peer effect was quantified showing that benefits for an individual child were higher if peers in the same group also performed well, i.e. group zBMI reduction was found to positively influence individual zBMI reduction. This may be attributed to peer modelling and impression management processes[55] and provides additional evidence to support group delivery of childhood obesity interventions, especially in community settings where the social network effects can have a wider impact.[9] Another important finding was that increased attendance was associated with greater decrease in zBMI. Therefore, supporting families to attend more program sessions can maximize intervention benefits.[57] These preliminary results should be further explored in order to verify the observed effects and to understand the underlying mechanisms and identify potential ways to further improve the observed benefits.

Strengths and limitations

Strengths of the current evaluation include the large, geographically spread sample size, population sociodemographic characteristics (high proportions of low income, minority groups), high program attendance and retention rates, variety of outcomes and implementation under conditions of service level delivery. Also, to our knowledge, this is the first study to investigate peer effects as a consequence of participating in a childhood obesity intervention. Limitations include short term duration, lack of a control group, lack of physical activity, diet and puberty data. Also, measurement attrition rates were relatively high. By multiply imputing outcome data at follow up, the impact that differential follow-up may have had on findings was estimated.

Conclusion

Implementation of MEND 7–13 in a large sample of low income, minority children across the USA was associated with important short-term health benefits. To our knowledge, this is the first report of an up-scaled, community-based, childhood obesity intervention delivered to underserved families in the USA and the first study to show positive peer effects associated with participation in a childhood obesity intervention. Given the urgent need for effective solutions to the growing problem of childhood obesity, such efforts should be further evaluated, in order to investigate if the observed short-term positive results are sustained in the longer term, as demonstrated in the UK

RCT and the UK longitudinal avaluation.[11, 12] Also, given that increased attendance seems to result in better intervention outcomes, future research is needed to examine ways to increase program engagement and retention, particularly in underserved families.

Funding sources

MEND 7–13 was provided free to all attending families. Program funding was received from a number of public and private organizations, including:

- American Council on Exercise
- Anthem/Wellpoint
- BG Group
- Blue Cross Blue Shield Illinois
- Blue Cross Blue Shield Kansas City
- Blue Cross Blue Shield Texas
- Chicago Community Foundation
- City of Amarillo Public Health Department
- Colorado Health Foundation
- Corpus Christi Nueces County Public Health Department
- General Mills Foundation
- Harlem Children's Zone
- Houston Endowment Inc.
- Kaiser Permanente
- Lawndale Christian Healthcare Centre
- Lexington Hospital

- OSI Pharmaceuticals Foundation
- RGK Foundation
- Rose Hills Foundation
- Scott & White Foundation
- Sequoia Healthcare District
- St. David's Foundation
- United Way
- University of Texas Brownsville School of Public Health

References

1. Harvey JR, Ogden DE. Obesity treatment in disadvantaged population groups: where do we stand and what can we do? *Prev Med.* 2014;68:71-75.

2. Wang Y, Beydoun MA. The obesity epidemic in the United States--gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev.* 2007;29:6-28.

3. Fagg J, Cole TJ, Cummins S, Goldstein H, Morris S, Radley D*, et al.* After the RCT: who comes to a family-based intervention for childhood overweight or obesity when it is implemented at scale in the community? *J Epidemiol Community Health.* 2015;69(2):142-148.

4. Lucas PJ, Curtis-Tyler K, Arai L, Stapley S, Fagg J, Roberts H. What works in practice: user and provider perspectives on the acceptability, affordability, implementation, and impact of a family-based intervention for child overweight and obesity delivered at scale. *BMC Public Health.* 2014;14:614.

5. Hardy LL, Mihrshahi S, Gale J, Nguyen B, Baur LA, O'Hara BJ. Translational research: are community-based child obesity treatment programs scalable? *BMC Public Health.* 2015;15:652.

6. NICE. Costing report: Overweight and obese children and young people - lifestyle weight management services. https://www.nice.org.uk/guidance/ph47/resources/costing-report-69149341. *Accessed: 11 May 2017.* 2013.

7. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med.* 2007;357(4):370-379.

8. Renna F, Grafova IB, Thakur N. The effect of friends on adolescent body weight. *Econ Hum Biol.* 2008;6(3):377-387.

9. Trogdon JG, Nonnemaker J, Pais J. Peer effects in adolescent overweight. *J Health Econ.* 2008;27(5):1388-1399.

10. Sacher PM, Chadwick P, Wells JC, Williams JE, Cole TJ, Lawson MS. Assessing the acceptability and feasibility of the MEND Programme in a small group of obese 7-11-year-old children. *J Hum Nutr Diet.* 2005;18(1):3-5.

11. Sacher PM, Kolotourou M, Chadwick PM, Cole TJ, Lawson MS, Lucas A*, et al.* Randomized controlled trial of the MEND program: a family-based community intervention for childhood obesity. *Obesity (Silver Spring).* 2010;18 Suppl 1:S62-68.

12. Kolotourou M, Radley D, Gammon C, Smith L, Chadwick P, Sacher PM. Long-Term Outcomes following the MEND 7-13 Child Weight Management Program. *Child Obes.* 2015;11(3):325-330.

13. Law C, Cole T, Cummins S, Fagg J, Morris S, Roberts H. *A pragmatic evaluation of a family-based intervention for childhood overweight and obesity*. Southampton (UK); 2014.

14. Butte NF, Hoelscher DM, Barlow SE, Pont S, Durand C, Vandewater EA*, et al.* Efficacy of a community- versus primary care-centered program for childhood obesity: TX CORD RCT. *Obesity (Silver Spring).* 2017.

15. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R*, et al.* CDC growth charts: United States. *Adv Data.* 2000(314):1-27.

16. NEF. (2010). The social and economic value of the Mend 7-13 Programme. Available at: http://www.physicalactivityandnutritionwales.org.uk/documents/740/Final%20report%20nef_YHEC_JULY%202010.pdf. Last accessed: 19 July 2016.

17. Whitlock EP, O'Connor EA, Williams SB, Beil TL, Lutz KW. Effectiveness of weight management interventions in children: a targeted systematic review for the USPSTF. *Pediatrics.* 2010;125(2):e396-418.

18. Hoelscher DM, Kirk S, Ritchie L, Cunningham-Sabo L, Academy Positions C. Position of the Academy of Nutrition and Dietetics: interventions for the prevention and treatment of pediatric overweight and obesity. *J Acad Nutr Diet.* 2013;113(10):1375-1394.

19. Lohman TG. Anthropometric Standardization Reference Manual. *Human Kinetics.* 1988.

20. Rudolf MC, Walker J, Cole TJ. What is the best way to measure waist circumference? *Int J Pediatr Obes.* 2007;2(1):58-61.

21. Flegal KM, Wei R, Ogden CL, Freedman DS, Johnson CL, Curtin LR. Characterizing extreme values of body mass index-for-age by using the 2000 Centers for Disease Control and Prevention growth charts. *Am J Clin Nutr.* 2009;90(5):1314-1320.

22. Woo JG, Cole TJ. Assessing adiposity using BMI z-Score in children with severe obesity. *Obesity (Silver Spring).* 2017;25(4):662.

23. Freedman DS, Butte NF, Taveras EM, Lundeen EA, Blanck HM, Goodman AB*, et al.* BMI z-Scores are a poor indicator of adiposity among 2- to 19-year-olds with very high BMIs, NHANES 1999-2000 to 2013-2014. *Obesity (Silver Spring).* 2017;25(4):739-746.

24. Golding LA. YMCA fitness testing and assessment manual. Champaign, IL: Human Kinetics. 2000.

25. Goodman R. The Strengths and Difficulties Questionnaire: a research note. *J Child Psychol Psychiatry.* 1997;38(5):581-586.

26. Mendelson BK, White DR. Relation between body-esteem and self-esteem of obese and normal children. *Percept Mot Skills.* 1982;54(3):899-905.

27. Harter S. Manual of the Self-Perception Profile for Children. University of Denver: Denver. 1985.

28. Rosenberg M. Society and the adolescent self-image. Princeton, NJ: Princeton University Press. 1965.

29. Modi AC, Zeller MH. Validation of a parent-proxy, obesity-specific quality-of-life measure: sizing them up. *Obesity (Silver Spring).* 2008;16(12):2624-2633.

30. Varni JW, Seid M, Kurtin PS. PedsQL 4.0: reliability and validity of the Pediatric Quality of Life Inventory version 4.0 generic core scales in healthy and patient populations. *Med Care.* 2001;39(8):800-812.

31. Tsiros MD, Olds T, Buckley JD, Grimshaw P, Brennan L, Walkley J*, et al.* Health-related quality of life in obese children and adolescents. *Int J Obes (Lond).* 2009;33(4):387-400.

32. Ware J, Jr., Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. *Med Care.* 1996;34(3):220-233.

33. US Census. (2000). Retrieved from: https://www.census.gov/dmd/www/pdf/d02p.pdf. Last accessed: 19 July 2016.

34. Rubin DB. Multiple Imputation for Nonresponse in Surveys John Wiley and Sons, USA. 1987.

35. Sterne JA, White IR, Carlin JB, Spratt M, Royston P, Kenward MG*, et al.* Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ.* 2009;338:b2393.

36. Manski CF. Identification of Endogenous Social Effects: The Reflection Problem. *The Review of Economic Studies.* 1993;60(3):pp. 531-542.

37. Gaviria A, Raphael S. School-Based Peer Effects and Juvenile Behavior. *Review of Economics and Statistics.* 2001;83(1):257-268.

38. Norton EC, Lindrooth RC, Ennett ST. Controlling for the endogeneity of peer substance use on adolescent alcohol and tobacco use. *Health Econ.* 1998;7(5):439-453.

39. Powell LM, Tauras JA, Ross H. The importance of peer effects, cigarette prices and tobacco control policies for youth smoking behavior. *J Health Econ.* 2005;24(5):950-968.

40. Von Hinke S, Leckie G, Nicoletti C. The use of instrumental variables in peer effects models with group fixed effects. *Mimeo University of Bristol.*

41. DeNavas-Walt C, Proctor BD. (2015). Current Population Reports. Income and Poverty in the United States: 2014. Retrieved from: https://www.census.gov/content/dam/Census/library/publications/2015/demo/p60-252.pdf. Last accessed on 19 July 2016.

42. Davis MM, Aromaa S, McGinnis PB, Ramsey K, Rollins N, Smith J*, et al.* Engaging the underserved: a process model to mobilize rural community health coalitions as partners in translational research. *Clin Transl Sci.* 2014;7(4):300-306.

43. Nobles J, Griffiths C, Pringle A, Gately P. Design programmes to maximise participant engagement: a predictive study of programme and participant characteristics associated with engagement in paediatric weight management. *Int J Behav Nutr Phys Act.* 2016;13:76.

44. Skelton JA, Beech BM. Attrition in paediatric weight management: a review of the literature and new directions. *Obes Rev.* 2011;12(5):e273-281.

45. Davis AM, Daldalian MC, Mayfield CA, Dean K, Black WR, Sampilo ML*, et al.* Outcomes from an urban pediatric obesity program targeting minority youth: the Healthy Hawks program. *Child Obes.* 2013;9(6):492-500.

46. Janicke DM, Sallinen BJ, Perri MG, Lutes LD, Huerta M, Silverstein JH*, et al.* Comparison of parent-only vs family-based interventions for overweight children in underserved rural settings: outcomes from project STORY. *Arch Pediatr Adolesc Med.* 2008;162(12):1119-1125.

47. Sacher P. *Randomised controlled trial of the MEND Programme: a family-based community intervention for childhood obesity*. London, UK: Institute of Child Health, University College London; 2011.

48. Kolotourou M, Radley D, Chadwick P, Smith L, Orfanos S, Kapetanakis V*, et al.* Is BMI alone a sufficient outcome to evaluate interventions for child obesity? *Child Obes.* 2013;9(4):350-356.

49. Cason-Wilkerson R, Goldberg S, Albright K, Allison M, Haemer M. Factors influencing healthy lifestyle changes: a qualitative look at low-income families engaged in treatment for overweight children. *Child Obes.* 2015;11(2):170-176.

50. Singh GK, Kogan MD, Siahpush M, van Dyck PC. Prevalence and correlates of state and regional disparities in vigorous physical activity levels among US children and adolescents. *J Phys Act Health.* 2009;6(1):73-87.

51. Eime RM, Young JA, Harvey JT, Charity MJ, Payne WR. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int J Behav Nutr Phys Act.* 2013;10:98.

52. Kalra G, De Sousa A, Sonavane S, Shah N. Psychological issues in pediatric obesity. *Ind Psychiatry J.* 2012;21(1):11-17.

53. Wallander JL, Fradkin C, Chien AT, Mrug S, Banspach SW, Davies S*, et al.* Racial/ethnic disparities in health-related quality of life and health in children are largely mediated by family contextual differences. *Acad Pediatr.* 2012;12(6):532-538.

54. Salvy SJ, de la Haye K, Bowker JC, Hermans RC. Influence of peers and friends on children's and adolescents' eating and activity behaviors. *Physiol Behav.* 2012;106(3):369-378.

55. Salvy SJ, Bowker JC. Peers and Obesity during Childhood and Adolescence: A Review of the Empirical Research on Peers, Eating, and Physical Activity. *J Obes Weight Loss Ther.* 2014;4(1).

56. Gwozdz W, Sousa-Poza A, Reisch LA, Bammann K, Eiben G, Kourides Y*, et al.* Peer effects on obesity in a sample of European children. *Econ Hum Biol.* 2015;18:139-152.

57. Skelton JA, Martin S, Irby MB. Satisfaction and attrition in paediatric weight management. *Clin Obes.* 2016;6(2):143-153.

Table 1: Demographic characteristics of participants and families using multiply imputed and pairwise complete case data

	Multiple imputation data		Pairwise complete case data	
Variable	**N**	**Mean/% [95% CI]**	**N**	**Mean/% [95% CI]**
Age	4,324	10.18 [10.12,10.23]	4,324	10.18 [10.12,10.23]
Gender	4,324		4,324	
Male		53.56 (52.07,55.05)		53.56 [52.07-55.05]
Female		46.44 (44.95,47.93)		46.44 [44.95-47.93]
Ethnicity	4,324		3,315	
White		61.12 (59.27,62.97)		60.33 (58.67,62.00)
Non-white		18.61 (17.24,19.97)		18.13 (16.82,19.44)
African American		20.28 (18.81,21.74)		21.54 (20.14,22.94)
Is child of Hispanic, Latino, or Spanish origin?	4,324		3,705	
Non-Hispanic		34.76 (33.31,36.21)		34.52 (32.99,36.05)
Hispanic		65.24 (63.79,66.69)		65.48 (63.95,67.01)
Language other than English spoken at home	4,324		3,441	
No		47.38 (45.62,49.14)		46.73 [45.06-48.40]
Yes		52.62 (50.86,54.38)		53.27 [51.60-54.94]
Family income	4,324		3,296	
$0 - 9,999		14.53 (13.32,15.74)		14.41 [13.21-15.61]
$10,000 - 19,999		22.20 (20.66,23.74)		21.91 [20.49-23.32]
$20,000 - 29,999		21.10 (19.67,22.54)		21.21 [19.81-22.60]
$30,000 - 39,999		12.50 (11.36,13.65)		12.65 [11.52-13.79]
$40,000 - 49,999		8.58 (7.41,9.75)		8.71 [7.74-9.67]
$50,000 - 59,999		5.95 (5.22,6.68)		5.98 [5.17-6.79]
$60,000 - 69,999		3.61 (2.98,4.23)		3.64 [3.00-4.28]
$70,000 - 79,999		2.75 (2.22,3.29)		2.73 [2.17-3.29]
$80,000 -89,999		2.14 (1.60,2.68)		2.15 [1.66-2.65]
$90,000 -99,000		1.93 (1.49,2.38)		1.94 [1.47-2.41]
$100,000 +		4.71 (3.99,5.44)		4.67 [3.95-5.39]
Parent/caregiver highest year of school	4,324		3,634	
Some high school		21.62 (20.17,23.07)		21.27 [19.94-22.60]
HS Diploma, some college or associates degree		58.63 (57.06,60.20)		58.56 [56.96-60.16]
Bachelor's degree		13.89 (12.82,14.95)		14.20 [13.06-15.33]
Master		5.86 (5.07,6.65)		5.97 [5.20-6.74]
Single parent	4,324		3,749	
No		66.89 (65.29,68.49)		67.08 (65.58-68.59)
Yes		33.11 (31.51,34.71)		32.92 (31.41-34.42)
Do you consider yourself underinsured?	4,324		3,343	
No		69.27 (67.56,70.97)		69.67 (68.11-71.23)
Yes		30.73 (29.03,32.44)		30.33 (28.77-31.89)
Number of children in household	4,324		3,359	
1		17.19 (15.91,18.47)		16.97 (15.70-18.24)
2		36.69 (35.11,38.27)		36.83 (35.19-38.46)
3		28.85 (27.28,30.41)		28.76 (27.23-30.29)
4		11.45 (10.42,12.48)		11.55 (10.47-12.63)
5 or more		5.82 (5.09,6.55)		5.89 (5.10-6.69)

CI: Confidence Interval

Table 2: Mean outcomes in first and last session, and change – using multiply imputed data (N =4,324)

	Before MEND 7–13	**After MEND 7–13**	**Change**
Variable	**B [95% CI]**	**B [95% CI]**	**B [95% CI]**
BMI (kg/m2)	27.38 [27.15,27.62]	26.96 [26.73,27.19]	-0.42 [-0.49,-0.35]
zBMI	2.04 [2.02,2.06]	1.98 [1.96,2.00]	-0.06 [-0.08,-0.04]
% overweight	160.66 [159.68,161.65]	156.83 [155.69,157.96]	-3.84 [-4.93,-2.74]
%BMI_{p95}	118.32 [117.59,119.04]	115.14 [114.29,116.00]	-3.17 [-4.00,-2.34]
Waist circumference (cm)	85.53 [85.10,85.95]	84.52 [84.05,84.99]	-1.01 [-1.44,-0.57]
Recovery heart rate (beats per minute)	106.63 [106.00,107.27]	102.27 [101.49,103.05]	-4.36 [-5.20,-3.52]
Strengths and difficulties questionnaire (score 0-40)	10.61 [10.42,10.80]	9.38 [9.19,9.57]	-1.23 [-1.43,-1.02]
Rosenberg self-esteem (score 0-30)	20.45 [20.23,20.66]	21.75 [21.52,21.98]	1.30 [1.05,1.54]
Harter self-esteem (score 1-4)	2.86 [2.84,2.88]	2.96 [2.93,2.98]	0.10 [0.07,0.12]
Body esteem (score 0-24)	12.49 [12.28,12.69]	14.14 [13.90,14.38]	1.65 [1.45,1.85]
Sizing them up© Quality of Life score (0-100)	77.08 [76.60,77.55]	81.28 [80.79,81.77]	4.20 [3.65,4.76]
SF12® physical score (0-100)	47.89 [47.63,48.16]	49.37 [49.07,49.66]	1.47 [1.12,1.82]
SF12® mental score (0-100)	48.97 [48.67,49.28]	51.50 [51.21,51.80]	2.53 [2.15,2.91]
Psychosocial Health (PEDSQL®) (0-100)	73.45 [72.90,74.00]	77.12 [76.46,77.78]	3.68 [2.93,4.42]
Physical Health (PEDSQL®) (0-100)	76.49 [75.93,77.06]	81.10 [80.54,81.67]	4.61 [3.91,5.30]

CI: Confidence Interval, BMI: Body Mass Index, zBMI: BMI z-score, %BMIp95: BMI as a percentage of the 95th centile, SF12®: Short Form Health Survey 12, PEDSQL®: Pediatric Quality of Life Inventory

Table 3: Mean change in outcomes - comparison of imputed (N=4,324) and pairwise complete case data (N varies)

	Change - imputed data		**Change – pairwise complete case**		**Difference between complete case and imputed**	**Improvement****
Variable	**N**	**B [95% CI]**	**N**	**B [95% CI]**	**Difference (diff. as % of complete case B)***	**Magnitude**
BMI (kg/m2)	4,324	-0.42 [-0.49,-0.35]	2,738	-0.50 [-0.53,-0.46]	-0.08 (16.0)	Smaller
zBMI	4,324	-0.06 [-0.08,-0.04]	2,738	-0.06 [-0.06,-0.05]	0.00 (0.0)	Similar
% overweight	4,324	-3.84 [-4.93,-2.74]	2,730	-3.63 [-3.83,-3.42]	0.21 (5.8)	Larger
%BMI_{p95}	4,324	-3.17 [-4.00,-2.34]	2,738	-3.09 [-3.25,-2.93]	0.08 (2.6)	Larger
Waist circumference (cm)	4,324	-1.01 [-1.44,-0.57]	2,720	-1.00 [-1.13,-0.86]	0.01 (1.0)	Similar
Recovery heart rate (beats per minute)	4,324	-4.36 [-5.20,-3.52]	2,829	-5.55 [-6.19,-4.92]	-1.19 (21.4)	Smaller
Strengths and difficulties questionnaire (score 0-40)	4,324	-1.23 [-1.43,-1.02]	2,632	-1.46 [-1.64,-1.28]	-0.23 (15.8)	Smaller
Rosenberg self-esteem (score 0-30)	4,324	1.30 [1.05,1.54]	2,696	1.59 [1.38,1.80]	0.29 (18.2)	Smaller
Harter self-esteem (score 1-4)	4,324	0.10 [0.07,0.12]	2,470	0.12 [0.10,0.15]	0.02 (16.7)	Smaller
Body esteem (score 0-24)	4,324	1.65 [1.45,1.85]	2,511	2.30 [2.11,2.48]	0.65 (28.3)***	Smaller
Sizing them up© QoL score (0-100)	4,324	4.20 [3.65,4.76]	2,561	5.04 [4.59,5.49]	0.84 (16.7)	Smaller
SF12® physical score (0-100)	4,324	1.47 [1.12,1.82]	2,674	1.73 [1.43,2.03]	0.26 (15.0)	Smaller
SF12® mental score (0-100)	4,324	2.53 [2.15,2.91]	2,674	3.05 [2.69,3.41]	0.52 (17.0)	Smaller
Psychosocial Health (PEDSQL®) (0-100)	4,324	3.68 [2.93,4.42]	2,623	4.16 [3.60,4.72]	0.48 (11.5)	Smaller
Physical Health (PEDSQL®) (0-100)	4,324	4.61 [3.91,5.30]	2,821	5.35 [4.73,5.96]	0.74 (13.8)	Smaller

CI: Confidence Interval, BMI: Body Mass Index, zBMI: BMI z-score, %BMI_{p95}: BMI as a percentage of the 95^{th} centile, SF12®: Short Form Health Survey 12, PEDSQL®: Pediatric Quality of Life Inventory

** Difference equals change calculated with imputed data subtracted from change in pairwise complete case. % is Difference/Change calculated with complete case data multiplied by 100.*
***** '****Smaller' improvement is used where change in outcomes for imputed data reflects a smaller improvement in the outcome than that observed in complete case data (e.g. a smaller reduction in zBMI or a smaller increase in self-esteem).*
********* *Indicates that 95% CIs of change calculated for imputed data and for complete case data do not overlap suggesting statistically significant difference in the size of the observed 'improvement' associated with the intervention using imputed and complete case data.*

Table 4: Peer effects analysis – regression results for change in zBMI

	Fixed Effects model			IV Fixed Effects Model 1			IV Fixed Effects Model 2		
	B	SE	p	B	SE	p	B	SE	p
Change (zBMI peers)	0.167	0.072	0.023	0.796	0.356	0.029	0.779	0.373	0.041
Child zBMI baseline	0.029	0.011	0.008	0.032	0.010	0.002	0.032	0.010	0.002
Parental BMI baseline							0.000	0.0004	0.467
Peer zBMI baseline	-0.027	0.019	0.157	-0.029	0.018	0.103	-0.029	0.017	0.097
Attendance (%)	-0.001	0.0002	<0.001	-0.001	0.0003	0.004	-0.001	0.0003	0.004
N	2633			1940			1940		
Instructor Fixed Effects	Yes			Yes			Yes		
First Stage F-statistic				33.860			32.106		

zBMI: BMI z-score, SE: Standard Error, IV: Instrumental variables
Jackknife clustered standard errors