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ORIGINAL ARTICLE

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Multi-disciplinary weight management compared to routine care in youth with obesity: what else should be monitored?

Indrajit Majumdar[1] · Brittany Espino[2] · Kristina Bianco[3] · Jeanette Epstein[2] · Leena Mamilly[4] · Carroll M. Harmon[5]

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Abstract

Purpose Efficacy of multi-disciplinary weight management (MDM) in youth has not been compared to their routine care.

Objectives To compare body mass index *z*-score (zBMI) and blood test (lab) changes (Δ) in youth before and after MDM and to correlate bio-impedance analysis (BIA) and lab measurements.

Methods We compared zBMI Δ (from referring providers' records), within 3 months prior to MDM, to monthly zBMI Δ after MDM, in a retrospective cohort of youth at a tertiary MDM center. BIA and lab measurements after 6 months, MDM were compared to baseline.

Results We reviewed 316 records (12.9 ± 3.5 years, 49% males, 104.8 ± 35.1 kgs). The pre-MDM zBMI Δ (0.02 ± 0.1) was reversed after MDM (−0.03 ± 0.09, visit 2, $P < 0.001$). The zBMI Δ progressed on follow-up (−0.14 ± 0.05, visit 6). Baseline BIA components correlated with Homeostatic Model Assessment of Insulin resistance (HOMA-IR), triglycerides, and systolic blood pressure. HbA1c, HOMA-IR, and liver functions significantly improved on follow-up. MDM participation showed progressive attrition and dropped to 11.6% at visit 6.

Conclusion MDM in youth resulted in zBMI and lab improvements compared to their pre-MDM measurements. BIA provided additional outcome measures that correlated with metabolic markers. MDM follow-up was limited by the progressive participant drop-out. Behavioral economic strategies are needed to improve adherence.

Keywords Youth with obesity · Multi-disciplinary management · Bio-impedance analysis

Introduction

Obesity is a major public health problem, affecting approximately 36% of adults and 17% of youth in the United States [1]. It is a complex disease, which results from interactions between socio-economic environments, dietary habits, personal behaviors, and degree of physical activity. Due to its multifactorial origin, treatment of obesity is very challenging. Lifestyle modifications that include family-based simultaneous treatment of the parent and child is integral for effective weight management in youth [2]. Adherence to a weight loss program is essential for success [3]. However, weight loss becomes progressively harder due to physiological adaptations in hormones that abrogate long-term weight loss efforts [4]. Non-responders are referred for higher level of care with multi-disciplinary weight management (MDM) [5] that are better equipped to address the multifactorial components contributing to obesity. Multiple providers at the MDM centers simultaneously focus on nutritional management and the need for increased physical activity, while additionally addressing the

✉ Indrajit Majumdar
imajumdar@upa.chob.edu

1 Division of Endocrinology, Department of Pediatrics, Jacob School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York and John R. Oishei Children's Hospital, Buffalo, NY 14203, USA

2 Department of Pediatrics, Jacob School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York and John R. Oishei Children's Hospital, Buffalo, NY 14203, USA

3 Department of Pediatrics, Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Cohen Children's Medical Center, Hofstra University, Queens, NY 11549, USA

4 Section of Pediatric Endocrinology, Nationwide Children's Hospital, The Ohio State University College of Medicine, Columbus, OH 43210, USA

5 Department of Surgery, Jacob School of Medicine and Biomedical Sciences, University at Buffalo, State University of New York and John R. Oishei Children's Hospital, Buffalo, NY 14203, USA

psycho-social barriers affecting the successful implementation of behavioral modifications. MDM is effective in the management of obesity in adults [6] and children [7–9]. However, there is a paucity of literature assessing the changes in weight parameters before and after MDM interventions in pediatric patients. This study aimed to fill this gap in the literature. We followed the changes in weight parameters sequentially in a retrospective cohort of youth participating in a MDM. We compared the measurements obtained from the referring providers' office-records, prior to their referral, to the changes at monthly follow-up visits until 6 months post-intervention. In addition, we compared the blood test (lab) parameters obtained after 3–6 months of MDM interventions to those obtained at or prior to MDM intervention, to evaluate the metabolic benefits of MDM in the cohort.

Body mass index *z*-score (zBMI) is used traditionally for pediatric obesity assessment. However, it may not accurately measure adiposity [10]. Dual energy X-ray absorptiometry and Computed Tomography scans provide accurate assessments of body mass composition [11] but are associated with high cost, need for additional appointments, and radiation exposure [12]. Multifrequency bioimpedance analysis (BIA) measures whole-body and segmental fat and muscle contents very rapidly, is FDA cleared for use in children, and has become a popular alternative for body composition assessment, despite the reduced accuracy [13]. We evaluated the association of BIA components with the lab parameters, especially the fasting glucose concentrations, markers of insulin resistance and fasting lipid concentrations. We hypothesized that BIA components (including fat and muscle mass) in youth correlate variably with the lab parameters. In addition, we reviewed clinic follow-up adherence, since weight management efforts including multidisciplinary programs face high attrition [3, 14]. Such data would facilitate the development of future strategies to improve MDM in youth.

Materials and methods

We retrospectively reviewed electronic medical records (EMR) of youth followed at a tertiary care MDM center, between December 2014 and January 2017. The study was approved by the Institutional Review Board and was in accordance with the ethical standards of the Helsinki Declaration of 1975.

All participants followed at the center were referred from primary care or specialty clinics. Health care records including growth charts from referring providers' offices were available for the majority of participants in the EMR. The participants' records were reviewed for weight management instructions provided to families prior to referral to the MDM center. Referring providers records usually demonstrated generic recommendations that included "healthy diet" and "increase daily physical activity" and often included "5-2-1-0 rule" [15].

Following referral to our center, the MDM team evaluated all participants and an individualized management plan was developed per the standardized clinic protocol. The MDM care team included a pediatric endocrinologist, bariatric surgeon, registered dietician, occupational therapist, physiotherapist, and clinical psychologists. A standardized previously published "Traffic Light Diet" [16, 17] and 60 min per day stretching and activity plans were explained and written instructions given to adolescent and parents. Families were encouraged to maintain journals of daily food intake and physical activity. Following the initial evaluation, participants were advised monthly follow up with the team for counseling and weigh-in. Weight (nearest 0.1 kg) was measured using a single electronic scale, and height (nearest 0.1 cm) was measured on a wall-mounted stadiometer at each clinic visit per standard clinic protocol. BMI was calculated as kg/m^2 and BMI *z*-score (zBMI) was calculated using software based on Center for Disease Control and Prevention (CDC) data [18]. Home food intake and physical activity records from journals or electronic apps were reviewed at clinic follow-up to motivate ongoing changes [19]. However, food logs notoriously underestimate dietary intake [20], while exercise logs have limited utility [21], therefore detailed food or activity records were not collected.

BIA assessments using multi-frequency segmental body composition analyzer (Tanita® MC-780U) were started in the program in May 2016 and measurements obtained at each visit per manufacturer's recommendations. Fasting blood tests were obtained at presentation and included glucose and insulin concentrations, HbA1c percentage (HbA1c%), complete metabolic panel, and lipid panel. However, for participants who had fasting blood tests within 3 months prior to referral, we obtained the laboratory results from their referring providers. These tests were repeated after 6 months of follow-up, or sooner (for individuals ending participation early), per MDM clinic protocol. Blood tests completed in our institutional laboratory were selected for comparison. Changes in zBMI, BIA, and laboratory parameters were used as surrogates for adherence to dietary and exercise recommendations, and these results were reviewed with the participants on follow-up.

Data collection

Data collected from the EMR included age, gender, weight, height, BMI, and zBMI. BIA data included total body fat mass (FM, Kgs), total body muscle mass (MM, Kgs), and truncal fat percentage (TF%). We collected results of

baseline blood tests done by the referring providers within 3 months prior to presentation for MDM or those done within 1 month after initial presentation. We also collected data on follow-up labs done after 3–6 months.

The diagnoses of obesity-associated comorbid conditions were obtained from EMR. These diagnoses were based on clinical evaluations, use of validated scoring systems or laboratory diagnostic criteria. Acanthosis nigricans, a clinical marker of insulin resistance, was used to identify individuals with insulin resistance by the treating pediatric endocrinologist [22, 23]. Depression was diagnosed by a clinical psychologist using Children's Depression Inventory-2 (CDI-2) [24]. Participants were diagnosed with "joint pain" if a participant reported persistent pain in any joint for more than 6 weeks. Standard diagnostic laboratory criteria were used for diagnoses of impaired glucose tolerance or diabetes [25]. A diagnosis of dyslipidemia was used for participants who had elevated fasting cholesterol concentrations as defined by National Cholesterol Education Program criteria for abnormal cholesterol in children and adolescents [26]. Participants were diagnosed with abnormal liver function/transamintis if either serum Aspartate aminotransferase (AST), and/ or Alanine aminotransferase (ALT) concentrations were elevated above the normative standards defined by the institutional laboratory. HOMA-IR, a validated marker of insulin resistance, was calculated as follows: fasting glucose (mmol/L) × insulin concentration (micro-Units/ml) divided by 22.5 to measure insulin resistance [27, 28]. Participants with polysomnography confirmed sleep apnea were included in our analysis. Standard diagnostic criteria were used for diagnosis of hypertension [29].

The primary outcome of the study was to compare the pre-intervention zBMI change (z-BMI Δ) to z-BMI Δ following participation in the MDM care. The pre-intervention z-BMI Δ was defined as the difference in the zBMI within the 3-months prior to participation in the MDM care (obtained from participants' referring providers' records). Following participation in MDM, z-BMI Δ was calculated as the difference in the zBMI at the follow-up visit from the zBMI at the initial visit. The secondary outcomes included: (a) identification of prevalence of obesity-associated comorbid conditions in the participants at baseline, (b) the changes in lab parameters after 3–6 month follow up from a baseline, (c) assessment and correlation of baseline BIA measurements (FM, and MM) with baseline lab parameters, (d) the number of participants returning for follow-up at each scheduled visit for the first 6 visits.

Statistical considerations

Data is expressed as mean ± SD for continuous variables and frequency for categorical data. The changes in zBMI and lab parameters were compared using paired Student's *t*-test. Pearson correlation coefficient was used to assess the associations between parameters. Analyses were performed using SPSS 24.0 (SPSS, Chicago, IL, USA). While designing the sample size estimates, absence of prior data comparing z-BMI Δ following participation in the MDM care provided a challenge. We used a very conservative estimate of a true difference of 0.05 in the mean z-BMI Δ between the matched pairs. With a baseline z-BMI Δ standard deviation of 0.09 in our population, we estimated that a matched sample pair of 30 subjects would provide greater than 80% power. Since the study analyzed data of all participants at the MDM program over the study period, the study was adequately powered to estimate even smaller differences in z-BMI Δ between the matched pairs. *P*-value ≤ 0.05 was considered statistically significant.

Results

We reviewed the records of 316 participants who had at least one visit at the MDM center between December 2014 and January 2017. BMI and zBMI data were available from the referring providers' clinical records within the 3-months period prior to the initial MDM visit in 303 participants. The average age of participants at presentation was 12.9 ± 3.5 years and included 49% males. The participants had extreme obesity with an average BMI percentile >99th percentile (Table 1) and had multiple obesity associated comorbid conditions. The most common obesity associated comorbidities were acanthosis nigricans (99.7%) which is indicative of insulin resistance, dyslipidemia (44.4%), impaired glucose (39.5%), sleep apnea (33%), and transaminitis (20%) while polycystic ovarian syndrome (PCOS) affected 28.4% of all females. Other comorbid conditions included depression (17.9%), joint pain (15.5%), hypertension (13.8%), and diabetes (4.1%).

Prior to participation in the MDM program, the average zBMI Δ was 0.025 ± 0.13 in the immediate 3-months pre-intervention period (Fig. 1). Post-intervention, the average z-BMI Δ (−0.03 ± 0.09) differed significantly from the pre-intervention z-BMI Δ after one visit ($P < 0.001$). The

Table 1 Baseline characteristics of participants

	Pre-visit (within 3 months) ($n = 303$)	Initial assessment ($n = 316$)
Age (years)		12.9 ± 3.5
Male (%)		49
Weight (kgs)	95.1 ± 36.5	104.8 ± 35.1
BMI	37.7 ± 8.8	36.5 ± 8.7
zBMI	2.6 ± 0.44	2.59 ± 0.4
BMI percentile	>99	>99

BMI body mass index, *zBMI* BMI *z*-score

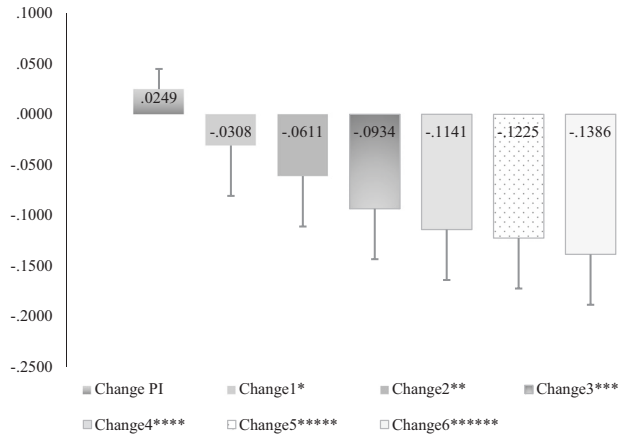

Fig. 1 Comparison of Pre-Intervention zBMI change to the zBMI changes on follow up visits. zBMI change = zBMI at a visit minus the zBMI at the initial visit. *Change PI vs. Change1 ($P < 0.001$), **Change PI vs. Change 2 ($P = 0.003$), ***Change PI vs. Change3 ($P = 0.009$), ****Change PI vs. Change4 ($P = 0.029$), ***** Change PI vs. Change5 ($P = 0.072$), ****** Change PI vs. Change6 ($P = 0.114$). PI pre-intervention, zBMI Body mass index *z*-score

z-BMI Δ from baseline progressively increased with continued follow-up (Fig. 1). However, large attritions in participants' follow-up over the study period resulted in a loss of the study power and statistical significance beyond visit 5. Overall, 66% of the participants had a zBMI reduction from baseline at 6-months or at their last follow-up visit (in participants dropping off early). Additional 14% of participants had zBMI stabilization over this assessment period. No differences were noted between male and female participants.

Participants' follow-up in MDM showed progressive attrition. The number of participants in the cohort decreased to 186 (visit 2), 125 (visit 3), 87 (visit 4), 59 (visit 5), and 36 (visit 6). Only 11.5% of participants in the cohort had 6 clinic visits or more.

Following 6 months of MDM care, changes were noted in multiple lab parameters. HbA1c improved from 5.6 ± 0.5 to 5.5 ± 0.5% ($P = 0.001$), and serum insulin concentrations improved from 205.9 ± 86.1 to 149.9 ± 87.5 pmol/L ($P = 0.02$). Fasting blood glucose concentrations did not change significantly over the 6-months period, however, HOMA-IR improved from 5.9 ± 2.5 to 4.1 ± 2.4 ($P = 0.004$). The average AST, and ALT concentrations were normal overall, however, AST concentrations improved from 23.6 ± 7.6 to 21.8 ± 7.6 units/L ($P = 0.007$) and ALT improved from 27.8 ± 16.7 to 24.7 ± 13.8 units/L ($P = 0.01$). Total cholesterol, LDL, HDL, and Tg concentrations did not change significantly over the assessment period (Table 2).

Baseline BIA data were available in 137 participants that included 55.5% females, with mean age of 13 ± 3.4 years, weight 97.9 ± 34.5 kgs, zBMI 2.6 ± 0.4, FM 42.2 ± 21.5 kgs, MM 52.8 ± 13.1 kgs, and TF% 37.1 ± 8.1%.

Table 2 Results of fasting laboratory studies at baseline and after 3–6 months of follow up

Laboratory studies	Baseline	Follow up	*P*-value (*N* for the pair[a])
HbA1c (%)	5.59 ± 0.55	5.5 ± 0.59	0.001 (71)
Serum insulin (pmol/L)	205.9 ± 86.1	149.9 ± 87.5	0.022 (21)
HOMA-IR	5.97 ± 2.49	4.13 ± 2.38	0.004 (18)
Serum glucose (mmol/L)	5.04 ± 0.9	5.05 ± 1.13	0.979 (50)
Total cholesterol (mmol/L)	4.49 ± 0.93	4.39 ± 0.93	0.112 (67)
Triglycerides (mmol/L)	1.48 ± 0.77	1.38 ± 0.58	0.147 (67)
HDL (mmol/L)	1.06 ± 0.21	1.03 ± 0.19	0.234 (67)
LDL (mmol/L)	2.76 ± 0.91	2.72 ± 0.79	0.516 (67)
AST (units/L)	23.6 ± 7.6	21.8 ± 7.6	0.007 (65)
ALT (units/L)	27.8 ± 16.7	24.7 ± 13.8	0.011 (64)

Note: HOMA-IR calculated as fasting glucose (mmol/L) x insulin concentration (μIUnits/ml) /22.5

ALT alanine aminotransferase, *AST* aspartate aminotransferase, *HDL* high density lipoprotein, HOMA-IR homeostasis model assessment of insulin resistance, *LDL* low density lipoprotein

[a]Paired *t*-tests were used to compare results. Number of participants for the pair varies based on availability of baseline and follow up blood test results for comparison

Correlation analyses demonstrated expected associations between zBMI and HOMA-IR ($r = 0.37$, $P = 0.001$), AST ($r = 0.205$, $P = 0.03$) and ALT ($r = 0.24$, $P = 0.01$). Analyses of BIA components demonstrated positive correlation between baseline FM and HOMA-IR ($r = 0.55$, $P < 0.001$), HbA1c ($r = 0.24$, $P = 0.01$), Tg ($r = 0.28$, $P = 0.002$) and systolic blood pressure (SBP, $r = 0.38$, $P < 0.001$). TF%, a surrogate for visceral adipose tissue (VAT) content, positively correlated with HOMA-IR ($r = 0.47$, $P < 0.001$), Tg ($r = 0.23$, $P = 0.01$), ALT ($r = 0.24$, $P = 0.01$) and SBP ($r = 0.22$, $P = 0.01$). Baseline MM also positively correlated with HOMA-IR ($r = 0.47$, $P < 0.001$), SBP ($r = 0.4$, $P < 0.001$), and Tg ($r = 0.33$, $P < 0.001$).

Clinic follow-up showed a progressive attrition. The number of participants in the cohort decreased to 186 (visit 2), 125 (visit 3), 87 (visit 4), 59 (visit 5), and 36 (visit 6). Only 11.5% participants in the cohort had 6 clinic visits or more.

Discussion

Obesity is a multigenerational disease affecting youth and parents simultaneously [30]. Behavioral modifications remain the cornerstone for successful weight management in youth, where weight loss medications and surgical therapies have

limited application. A MDM team is often better equipped to address the socio-behavioral modifications necessary for weight management, which are often overlooked due to pressure of routine clinical medicine. Our study uniquely evaluated the effects of MDM on the zBMI trajectory in youth with extreme obesity and compared zBMI Δ before and after MDM interventions. Pre-intervention records demonstrated rapid increases in zBMI. Following MDM intervention, zBMI Δ were reversed. zBMI stabilization or reduction were seen in majority of the participants with ongoing participation in MDM. A cost benefit analysis comparing MDM to routine care would be beneficial to assess the long-term economic impact of effective weight management in our youth, however, such analysis is beyond the scope of the current study.

The cohort of youth followed in our study had extreme obesity with an average BMI > 99th percentile and had multiple obesity-associated comorbidities. As expected, we found, significant associations between baseline zBMI and markers of insulin resistance (HOMA-IR) and liver enzymes (AST and ALT). These parameters showed significant improvement with ongoing MDM. The current study also reviewed BIA measurements to assess body compositions in our participants since repeated DXA and CT scans are not practical in clinical practice. Our results indicated that baseline FM measurements correlated with HOMA-IR, HbA1c, and SBP. TF%, a surrogate for VAT, additionally correlated with ALT concentrations. Similar associations have been reported in adults [31–33]. Interestingly, we found that baseline MM measurements were associated with HOMA-IR, Tg concentrations and SBP, which may suggest that muscle bulk does not indicate muscle health or fitness level. Fitness level can be better assessed with maximum oxygen consumption (VO2 max) [34, 35], but these assessments are challenging in routine clinical practice. Changes in MM are associated with oxidative adaptions that occur with strength training [36, 37] and these may be used in future studies.

The authors recognize the limitations of our retrospective analysis. The participants' follow-up over the study period showed progressive attrition, which may have affected the outcomes. It may be argued that only participants witnessing significant weight improvements were motivated to continue long-term follow-up resulting in the excellent outcomes demonstrated in our cohort. However, large attritions of participant follow-up commonly affect multidisciplinary programs [3, 14]. A prospective study, designed to accommodate for participants' drop-out, may be able to assess this outcome better. At the same time, it is well recognized that obesity disproportionately affects disadvantaged families [38], and practical difficulties, such as transportation access, lack of motivation, and social support often lead to treatment interruption. In the absence of significant on-going additional incentives, especially those directed towards overcoming the socio-economic changes, adherence to weight management strategies, including MDM, will remain challenging in the youth and their families. There remains a great need to develop MDM programs that integrate behavioral economic strategies to maintain and sustain healthy lifestyle modifications.

Author contributions I.M. designed the study, collected, analyzed, interpreted the data, prepared figures and prepared first draft. K.B., L. M., B.E., and J.E. collected and analyzed data. C.M.H. contributed to manuscript revision. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Institutional Review Board.

Informed consent All data were collected retrospectively from EMR. Informed consent was not obtained from participants included in this study.

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