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# Diet quality index as a predictor of treatment efficacy in overweight and obese adolescents: the EVASYON Study

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**Running title**: Diet quality index in obese adolescents

**Non-standard abbreviations:**

BMR: basal metabolic rate

DQI: Diet quality index

FBDG: Food-based dietary guidelines

FFM: Fat-free mass

FFMI: Fat-free mass index

FFQ: Food frequency questionnaire

FM: Fat mass

FMI: Fat mass index

MVPA: Moderate-to-vigorous physical activity

RD: Registered dietitians

TEE: Total energy expenditure

WHtR: waist-to-height ratio

W-to-H: Waist-to-hip ratio

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ABSTRACT

Background and Aim

A diet quality index (DQI) is a tool that provides an overall score of an individual´s dietary intake when assessing compliance with food-based dietary guidelines. A number of DQIs have emerged, albeit their associations with health-related outcomes are debated. The aim of the present study was to assess whether adherence to dietary intervention, and the overall quality of the diet, can predict body composition changes.

Methods

To this purpose, overweight/obese adolescents (n=117, aged: 13 to 16 years; 51 males, 66 females) were recruited into a multi-component (diet, physical activity and psychological support) family-based group treatment programme. We measured the adolescents' compliance and body composition at baseline and after 2 months (intensive phase) and 13 months (extensive phase) of follow-up. Also, at baseline, after 6 months, and at the end of follow-up we calculated the DQI.

Results

Global compliance with the dietary intervention was 37.4% during the intensive phase, and 14.3% during the extensive phase. Physical activity compliance was 94.1% at 2-months and 34.7% at 13months and psychological support compliance were growing over the intervention period (10.3% intensive phase and 45.3% during extensive phase). Adolescents complying with the meal frequency criteria at the end of the extensive phase had greater reductions in FMI z-scores than those did not complying (*Cohen´s d*=0.53). A statistically significant association was observed with the diet quality index. DQI-A variation explained 98.1% of BMI z-score changes and 95.1% of FMI changes.

Conclusions

We conclude that assessment of changes in diet quality could be a useful tool in predicting body composition changes in obese adolescents involved in a diet and physical activity intervention programme backed-up by psychological and family support.

**Keywords:** adolescents, multi-intervention approach, fat mass loss, dietary compliance, diet quality index

## INTRODUCTION

Obesity during adolescence is associated with several adverse health consequences in adulthood [1]. Recent reviews have shown that multidisciplinary interventions are the most effective in adolescent weight management [2, 3]. The main goal of interventions aiming at treating obesity in the adolescent is to reduce fat mass (FM) and to maintain fat-free mass (FFM) while performing periodic monitoring to ensure an appropriate growth pattern [4].

The cornerstone of a weight loss programme is to achieve a negative energy balance, with a healthy contribution of carbohydrates, proteins and lipids while improving eating habits [5]. Further, increasing the adolescent's diet quality is of interest because food habits acquired during childhood predict adult food habits, and diet-related diseases [6]. Diet quality indices (DQIs) are tools that provide an overall score of an individual´s dietary intake to assess the compliance with food-based dietary guidelines (FBDG). A number of DQIs have emerged, but their associations with health-related outcomes are debated [7]. Vyncke K et al showed good validity of the DQI for adolescents (DQI-A) by confirming the expected associations with food and nutrient intakes and biomarkers in European adolescents participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study [8].

We selected BMI and fat mass index (FMI) to assess effectiveness of treatment since these are the best anthropometric indices for assessing body fat changes in adolescents[9]. Complying with dietary advice in the treatment of obese adolescents should result in positive outcomes in terms of body composition indices. In studies assessing the effectiveness of dietary interventions to treat obesity in adolescents, measures of adherence to dietary interventions are poorly described [10] and the proportions of participants achieving and maintaining dietary goals have not been reported [11-13]. The existing scant evidence limits the possibility of estimating whether the changes in diet determine the efficacy of the interventions in overweight adolescents.

The aim of the present study (a multidisciplinary obesity treatment programme for adolescents) was to assess whether compliance to the dietary intervention, and the overall quality of the diet can predict body composition changes.

## MATERIAL AND METHODS

The study has been named ‘Development, implementation and evaluation of the efficiency of a therapeutic programme for overweight and obese adolescents: a comprehensive education programme of nutrition and physical activity [*Desarrollo, aplicación y evaluación de la eficacia de un programa terapéutico para adolescentes con sobrepeso y obesidad: educación integral nutricional y de actividad física*], the EVASYON Study’. The original programme was implemented in adolescents from five cities across Spain: Granada, Madrid, Pamplona, Santander and Zaragoza. The adolescents were aged 13 to 16 years, and all were overweight or obese. The intervention was multidisciplinary (diet, physical activity and psychological support within the family). The general aims of the EVASYON Study were to assess the feasibility of this programme and to evaluate the determinants of treatment effectiveness [14].

The project followed the ethical standards recognised by the Declaration of Helsinki (reviewed in Hong-Kong in September 1989 and in Edinburgh in 2000) and the EEC Good Clinical Practice recommendations (document 111/3976/88, July 1990), and current Spanish legislation regulating clinical research in humans (Royal Decree 561/1993 on clinical trials). The study was approved by the Ethics Committee of each hospital that participated in this project, and by the Bioethics Committee of the Spanish National Research Council (CSIC). The study was explained to the participants before commencement. The volunteers and the parents or guardians then signed an informed consent form.

### *Study population*

The goal of the study was to achieve a clinically-relevant 2.7% reduction in total body fat. For a statistical power of 90% and an alpha error of 0.05, the number of participants required was 153. This calculated sample size was increased by 25% to account for potential dropouts and loss-to-follow-up in the participating hospitals. The recruited sample comprised 206 adolescents (84 males and 122 females). Of the adolescents initially recruited, 44 left the programme before the end of the follow-up period (attrition rate of 28.2%) [15]. The flowchart of the adolescents included are shown in Figure 1.

Participants were recruited among those attending the local obesity clinics. Inclusion criteria were: 1) aged 13-16 years; 2) overweight or obese according to the criteria of Cole et al [16]; 3); of Spanish ancestry, or being educated in Spain; and 4) not having concomitant diseases.

*Intervention*

The EVASYON treatment programme has been described elsewhere [14]. Briefly, it was conducted in small groups of 9 to 11 adolescents, and included parents or guardians to facilitate family involvement and support. The protocol consisted of an intensive intervention period (over the first 2 months) and an extensive intervention period (from 2 to 13 months). The programme covers dietary intervention [17], physical activity intervention, and psychological support.

*Intensive phase*

Dietary intervention was a moderate calorie restriction of between 10 and 40% of estimated energy requirement, as described below. Energy restriction was adapted to the BMI categories according to reference values generated in Spanish adolescents [18], as described below. A fixed full-day meal plan was followed for the first 3 weeks. A food portion exchange protocol was then followed for the remaining 6 weeks. The main goal of the physical activity intervention was to achieve at least 60 minutes of moderate-to-vigorous physical activity (MVPA) 3 days per week in the first 3 weeks. In the remaining 6 weeks, the goal was to achieve at least 60 minutes of MVPA, 5 days per week. Psychological support included workshops focusing on eating and physical activity behaviour patterns. ‘Ping-pong’ techniques were used to identify negative as well as positive situations, and troubleshooting techniques to encourage adherence and to prevent relapses [19].

*__Extensive phase__*

Dietary intervention involved iso-energetic flexible meal plans, based on food-portion exchanges. In addition, to achieve at least 60 minutes of MVPA 5 days per week, the goal of the physical activity intervention was to increase ordinary daily-life physical activity (such as walking or cycling to school). Psychological support was aimed at monitoring the psycho-educational progress, and resolving any difficulties appearing in the adolescents and their families.

*Assessing energy intake and calorie restriction*

Schofield’s equation [20] ,adjusted by gender and take into consideration the weight and height of adolescents, was used to determine basal metabolic rate (BMR). To estimate total energy expenditure, we multiplied BMR by an activity factor of 1.3[14]

With respect to the BMI z-score, the suggested restriction percentage was estimated as follows: If Z $\leq 2$, total energy expenditure (TEE) was reduced by 10%; If Z=2-3, TEE was reduced by 20%; if Z=3-4, TEE was reduced by 30%; and if Z >4, TEE was reduced by 40%. A daily calorie restriction range was established on this basis. In no case were the diets $<$ 1,300 kcal or $>$ 2,200 kcal. At the end of each dietary period, it was necessary to adjust the equations depending on the body weight status. Also, the basal metabolic rate was calculated again to identify possible shifts in energy consumption/expenditure [18].

*Dietary assessment*

The EVASYON food and nutrition programme involved trained registered dietitians (RD), professionals who were directly responsible for the dietary and nutrition assessment (MªJP in Granada; BZ in Madrid; MM and TR-U in Pamplona; PR and PM-E in Zaragoza).

A detailed dietary history collected information on the family's food organisation including meal-related habits before starting the therapy (e.g. meal frequency) at the beginning of the program, and at 2 and 13 months later were filled.

Face-to-face interviews with participants and their parents (father, mother or tutor) at the beginning of the program, and at 2, 6 and 13 months later were performed. Details of food intake, dietary patterns, and nutritional knowledge were collected to evaluate adherence to the recommended diet as well as changes in food intake habits during the intervention programme. The 72h dietary records were filled by the adolescents at the beginning of the program, and at 2, 6 and 13 months later at home. Once these were filled-out, the RD and adolescents cross-checked the information in order to reduce the common forgets as water, bread, olive oil and some food from nibbling habits. Nutrient intakes from 72h dietary records were computed with an *ad hoc* computer programme specifically developed for this purpose. A trained dietician updated the nutrient data bank using the latest available information on food-composition tables from Spanish studies [21, 22]. Data on food intakes from 72h dietary records were transformed into energy and macronutrient intake. After that, the intake was transformed on percentage of total energy intake to assess dietary intervention compliance.

Moreover, a semi-quantitative food frequency questionnaire (FFQ), previously validated in Spain, was administered at the beginning, at 6 months and at the end of the programme [23]. FFQ contained 132 food items divided into the following categories: dairy products, meat and eggs, fish, fruits and vegetables, legumes, potatoes and cereals, nuts, oils and fat, sweets and beverages. For each food item, an average portion size was specified, and participants and their parents were asked how often they had consumed that unit throughout the previous period. There were nine options for the frequency of intake (ranging from never/almost never to at least six times per day). This tool was used to record usual food frequency consumption according to the standard portion size as well as energy and nutrient intake, and to detect possible nutritional risks and misbehaviours/noncompliance [23]. FFQ food intake data were transformed into food volume/weight (in mL or g) per day in order to calculate the DQI for each adolescent [24].

*Diet Quality Index for Adolescents (DQI-A)*

Based on the Spanish FBDG [25], we adapted the DQI for adolescents that had been previously validated by Vyncke et al [8] and which have been used to evaluate adolescent adherence to the Spanish dietary recommendations. The major components of this DQI are dietary quality, dietary diversity and dietary equilibrium. Details of the technical aspects of the DQI have been described elsewhere [8, 26].

Diet quality reflects whether the adolescent made the optimal food quality choices within food groups classified as: ‘preference group’, ‘moderation group’; ‘low-nutritious, energy dense group’. A comprehensive description of the food item allocation is given in the supplementary table (SM1). Dietary diversity explains the degree of variation in the diet from the recommended food groups, as illustrated in the Spanish pyramid [25]. Dietary equilibrium was calculated from the difference between the adequacy component and the excess component.

These three components of the DQI-A are presented in percentages. The dietary quality component ranged from -100 to 100%, while dietary diversity and dietary equilibrium ranged from 0 to 100%. To compute the DQI-A, the mean of these components was calculated. As such, the DQI-A ranged from 33 to 100 %, with higher scores reflecting higher diet compliance. The score was calculated at baseline, 6 and 13 months. DQI scores for an individual provide an estimate of diet quality relative to national guidelines.

*Physical activity assessment*

The EVASYON physical activity programme involved trained professionals who were directly responsible for the physical activity intervention and assessment (MMM in Granada; DM-G in Madrid; AM and TR-U in Pamplona; JPR-L and PM-E in Zaragoza). The physical activity assessment was through questionnaire and accelerometer, although this objective measurement was not available at the end of the programme. Therefore, the participants were asked for frequency of physical activity during week and weekend-days inside the questionnaire of physical activity in adolescents (PAQ-A) [27]. To compute the score of physical activity frequency Likert scale (none, low, normal, much and too much, being 1 to 5 points respectively) were applied. As such, the ranged from 7 to 35, with higher scores reflecting higher physical activity level. The score was calculated at baseline, 2 and 13 months.

*Psychological support assessment*

The EVASYON psychological support involved trained professionals who were directly responsible for the psychological assessment (MªJP in Granada; GM in Madrid; MM and TR-U in Pamplona; CM and PM-E in Zaragoza). The psychological support had assessed thought EDI-2, ABOS and AF-5 questionnaires[14]. The EDI-2 is a self-reported instrument assessing the cognitive and behavioural characteristics commonly found in individuals at risk of eating disorders (10-ref ijo). This questionnaire includes a social insecurity subscale which were found related with attrition in a group-based programmes [15]. The psychological support was assessed at baseline, 2 and 13 months.

*Compliance to EVASYON treatment*

According to the main goals of dietary intervention [17], dietary compliance criteria are: (1) Adequacy of proposed energy intake (TEI ± 20%) according to individual recommendations based on energy restriction according to the individual's BMI z-score; (2) Adequacy of carbohydrate intake; percentage of carbohydrate in energy intake, between 50-55% ± 5% ; (3) Adequacy of protein intake; percentage of proteins in energy intake, between 10-15% ± 5%; (4) Adequacy of fat intake; percentage of fat in energy intake, between 30-35% ± 5%; (5) Adequacy of meal frequency, based on 3 main meals (breakfast, lunch and dinner) and 2 snacks (mid-morning and mid-afternoon).

Adolescents who achieved 3 or more main goals of the 5 dietary intervention criteria were considered as showing “global compliance”.

According to the main goals of physical activity intervention [28], physical activity compliance criteria are: during intensive (1) adequacy of physical activity level, between 42 ±5% phase and during extensive phase (1) adequacy of physical activity level, between 71 ±5% phase.

According to the previous findings related with attrition [15], psychological support compliance criteria are: during intensive and extensive phase (1) had filled the social insecurity scale included in EDI-2 questionnaire being assumed their session attendance.

*Body composition measurements*

Body composition was assessed by anthropometry in the overall study sample at baseline, 2, 6 and 13 months. The anthropometric measurements were performed using the standardised protocols of the AVENA study [29]. Measurements were performed by the same trained investigators in each Centre (MM-M in Granada; BZ in Madrid; MM and TR-U in Pamplona; PR and PM-E in Zaragoza). Each set of variables was measured 3 times and the means used in the statistical analyses. Weight and height were obtained by standardised procedures. Body mass index (BMI) was calculated as weight/height squared (kg/m$^2$). Skinfold thicknesses were measured to the nearest 0.2 mm on the left side of the body using a skin-fold calliper (Holtain Calliper; Holtain Ltd., Wales, UK) at the following sites:1) triceps, 2) biceps, 3) subscapular and 4) supra-iliac. Body fat is usually expressed as percentage of total body weight, but an alternative is to express this variable in relation to height squared since more valuable index is: FMI [FM (kg)/height (m$^2$)] [30].

The z-score was calculated according to age and sex-specific weight and BMI reference standards for Spanish adolescents aged 13-18 years [31, 32]. Cut-off points of FMI were calculated using the sample from the AVENA Study which included 2,851 Spanish adolescents (52.5% females, 15.29 ± 1.33 years of age, with BMI 21.63±3.44 kg/m$^2$) (unpublished data).

In the present study the anthropometric indices (BMI and FMI) were used to evaluate body composition changes over the 13 months of follow-up.

*Statistical analyses*

Normality of distributions was assessed with the Kolmogorov–Smirnov test, and the Lilliefors correction. For comparisons of continuous variables segregated with respect to gender, parametric or non-parametric tests were used depending on whether the variables met the assumption of normal distribution. Age, weight, height, fat mass and fat-free mass percentages and body mass index (BMI) were non-normally distributed and, hence, the non-parametric Man-Whitney U test was applied. For the remaining variables with normal distribution, the Student *t*-test was used for comparisons between group means. The $\chi^2$ test was used for discrete variables, with the Fisher exact test when necessary. The comparison of dietary compliance distribution between intensive (2 months) and extensive phases(13months) was carried out with McNemar paired proportion test. Cohen's *d* was calculated to document differences between those adolescents adhering, and those not-adhering, to dietary compliance criteria. This coefficient measures the effect size, and may be especially relevant in cases of small samples, when the differences found do not reach statistical significance. The effect size (Cohen´s d) was classified as 'small' (~0.2), 'medium' (~0.5) or 'large' (~0.8). Non-parametric Spearman's rho correlation coefficients were used to assess associations between DQI-A and indices based on anthropometric measurements during follow-up. To assess the association between both anthropometric indices (BMI and FMI z-scores) and dietary compliance criteria and DQI-A during follow-up, we used random coefficient regression models adjusted by physical activity and psychological support compliance criteria, taking into account that successive measurements in each subject are related to each other. The proportions of body composition changes during follow-up explained by dietary compliance criteria and DQI-A were calculated using pseudo-$R^2$. Regression modelling was carried out with ‘R’ programme, version 2.9.2 (R Foundation for Statistical Computing, Vienna, Austria), with ‘nlme’ library. All descriptive analyses were performed with SPSS STATISTICS v.19 (IBM Corp., New York, NY, USA, 2010) for Windows.

## RESULTS

Baseline characteristics of 117 participants (51 males and 66 females) from four Spanish cities participating in the EVASYON Study who completed anthropometric and dietary measurements are shown in Table 1. Compared with females, males had greater height and FMI (p<0.001). With respect to dietary measurements, males also had higher energy intake than females (p=0.001) and females had higher scores on DQI-A than males (p=0.007). In terms of meal frequency, more males than did their female counterparts consumed 5 meals/day (52.9% and 51.5%, respectively; n.s.)

The compliance from single dietary criteria at 2 and 13 months of follow-up is shown in Table 2. The compliance to energy restriction was observed in <50% participants at 2 and 13 months of follow-up. With respect to compliance to macronutrient recommendations, the highest compliance rate was observed for fat intake during intensive (68.2%) an extensive (53.8%) phases (p=0.050) and the lowest compliance was observed for protein intake in the intensive phase (23.4%) and carbohydrate intake (20.9%) during the extensive phase. Compliance to meal frequency was observed in 85.1% of adolescents in the intensive phase and 69.3% in the extensive phase (p=0.021). Global compliance to the dietary intervention was 37.4% during intensive and 14.3% during extensive phase (p=0.002).

Moreover, the compliance physical activity intervention 94.1% at 2-months and 34.7% at 13-months (p<0.001). Males had better physical activity compliance than their female’s counterparts during the intensive phase (74.5% vs 63.6%, p=0.047). On the other hand, the psychological support compliance was 10.3% at intensive phase and 445.3% at extensive phases (p<0.001).

BMI and FMI z-score changes in relation to dietary compliance during 2 and 13 months are shown in Table 3. The dietary compliance criterion showed a medium Cohen´s size effect in energy intake at the end of the intensive phase; adolescents not complying with the meal frequency criteria at the end of the intensive phase had higher FMI z-score reductions than those complying (*Cohen´s d*=0.63). Cohens size effect also applied with respect to meal frequency at the end of extensive phase i.e. adolescents complying with the meal frequency criteria at the end of the extensive phase had higher FMI z-score reductions than those not complying (*Cohen´s d*=0.53).

In relation to the main variables and outcomes during follow up, mean of BMI- and FMI z-score calculated at 2-months (2.14 (1.04) and 1.85 (0.82), respectively) and 13-months (2.15 (1.22) and 1.85 (1.02)) were similar. Moreover, the DQI-A at 6-months were 71.84 (8.4) and 69.00 (70.49) at 13-months.

There was a significant correlation between DQI-A and BMI z-score changes between baseline to 13 months (rho= -0.178, p=0.037): increases in DQI-A during the follow-up are associated with decreases in BMI-z. However, the correlation between DQI-A changes and FMI z-score changes were not statistically significant (rho=-0.011, p=0.905) (Figure S2).

A statistically significant association between changes in BMI-z scores and FMI-z scores and DQI changes during follow-up adjusted by physical activity and psychological support was observed: 5-unit increases in DQI-A score resulted in BMI z-score decrease of 0.07 units (p<0.001) and in FMI z-score decrease of 0.053 units (p<0.001) (table 4). DQI-A variation explained 98.1% of BMI z-score changes (pseudo R2= 0.981) and 95.1% of FMI z-score changes (pseudo R2= 0.951).

## DISCUSSION

The main finding of the present study was that quality of diet (DQI-A) is a predictor of BMI and FMI z-score changes during the 13 months follow-up of overweight adolescents in a multidisciplinary treatment programme. Our survey of the current literature indicates that there has not been any study that examined the association between diet quality and body composition changes in adolescents, during a long follow-up intervention period while using the approach of food-based diet index quality.

Dietary interventions alone have been widely studied in weight loss programmes [33-35]. A recent systematic review indicates that an improvement in body weight can be achieved in overweight or obese children and adolescents, regardless of the macronutrient distribution of a reduced-energy diet [36]. The highest BMI reductions were achieved with the low-carbohydrate diets [33, 37] and with different protein-content diets [38, 39]; albeit the studies have had limited quality. In agreement with some previous studies [33, 37-39], our adolescents complying with the carbohydrate and protein recommendations during the intensive phase had higher losses in FMI z-scores than their counterparts who did not comply. However, the observed differences were of small effect size. Assessment of an adolescent's diet is of considerable interest because food habits and behaviour acquired during childhood and adolescence predict the adult's diet. Recently, a meta-analysis evaluating the effect of meal frequencies on body composition showed that increased meal frequency appeared to be positively associated with reductions in fat mass and body fat percentage [40]. In concordance with this meta-analysis, FMI z-score changes in our study during the extensive phase were higher in the adolescents complying with the meal frequency recommendation, despite non-significance effects being observed in the random coefficient models. This body-fat reduction associated with the increased meal frequency could have healthy benefits in the long term.

There are studies assessing the associations between diet quality and body composition, but they are all cross-sectional and had shown varying outcomes. Some of the studies showed no significant associations with BMI [41, 42] and obesity status [42], while another observed a positive association with both BMI and waist circumference [43] while yet another also showed a positive association but only after adjustment for potential confounders such as age, overall education and economic level of the household [44, 45]. Conversely, other studies found an inverse association with BMI [46, 47]. The lack of consistent results could be due to BMI the optimal adiposity index, compared to other direct estimates of body fat. The use of different types of diet quality indices could also contribute to these conflicting results.

Our study obtained similar results to those that had examined diet *vs.* body composition associations among adolescents using a country-specific diet quality index [48, 49]. Inverse associations were observed with body-fat percentage, assessed by laboratory techniques [48] and with body-fat percentage assessed by BIA technique [49]. Further, height-related indices such as BMI and FMI, were also investigated and the BMI associations were not found with healthy eating index [48] and the New Zealand Diet Quality Index (NZDQI-A) [49]. However, significant results were obtained following sex- and age-adjustment of FMI. Despite direct comparisons not being possible, our longitudinal results showed that every 5-point increase in DQI-A score was associated with BMI z-score as well as FMI z-score reductions. Observations in adults are in agreement with the current analysis i.e. longitudinal DQI is associated with less weight gain in adults [50].

The main limitation of this study is the possible presence of under-reporting which is common in nutritional studies, especially among those performed with individuals having overweight or obesity [51]. Under-reporting could more likely affect energy and macronutrients intake, than diet quality assessment. This may be the reason of some body composition changes observed in non-adherence adolescents although in a marginal significance. This could explain the stronger associations observed for DQI-A when compared to nutrient intake. Nevertheless, there is a need to design an obesity-specific diet quality index to assess compliance to obesity treatment in adolescents. On the other hand, the findings should be taken with care, because we found a low dietary compliance rate after 2 months and decrease compliance rate over time was observed. Although the obtained dietary compliance rate, our results shown a very good association with body composition changes showing the importance of multidisciplinary and family-based obesity treatment in a short and long term. The strengths of this study are the low attrition rate in dietary and anthropometric measurements despite the relatively long follow-up duration, as seen in few other studies[52]. Furthermore, we used standardised measures for collecting detailed dietary information from dietary records; a methodology that has been widely used [53].

In conclusion, our study showed diet quality (DQI-A) is a good predictor of body composition changes in overweight adolescents participating in a multidisciplinary group-based treatment programme. As such, assessment of changes in diet quality could be a useful tool in predicting body composition changes in obese adolescents involved in a diet and physical activity intervention backed-up by psychological and family support.

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## Authorship

LM, JM-G and PM-E conceived and designed this study; LM, AM, CC, JM-G and AsM conceived and designed the original EVASYON Study; PM-E and JS analysed and interpreted the data; PM-E carried-out measurements. All authors were involved in drafting the manuscript and had final approval of the version submitted for publication. EVASYON Study Group provided technical and logistic support during the study. Editorial assistance was by Dr Peter R Turner of Tscimed.com.

## Conflict of interest

The authors declare no conflict of interest.


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## Appendix

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Table 1: Characteristics of the study sample at baseline

| | Total | | | Males | | | Females | | | *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | SD | N | Mean | SD | N | Mean | SD | |
| *Anthropometric measurements* | | | | | | | | | | |
| Age, years | 117 | 14.62 | 1.25 | 51 | 14.49 | 1.08 | 66 | 14.40 [a] | (13.70-16.00) | 0.373 |
| Weight, kg | 117 | 84.34 | 14.53 | 51 | 86.64 | 14.70 | 66 | 81.0 [a] | (72.00-90.80) | 0.066 |
| Weight (z-score) | 117 | 3.20 | 1,790 | 51 | 2.74 | 1.22 | 66 | 3.55 | 1.93 | 0.007 |
| Height, cm | 117 | 164.45 [a] | (159.50- 170.00) | 51 | 166.98 [a] | (161.87-172.00) | 66 | 162.73 [a] | (156.85-166.00) | <0.001 |
| Height (z-score) | 114 | 0.25 | 1.03 | 51 | 0.26 | 0.80 | 63 | 0.23 | 1.19 | 0.027 |
| Body Mass Index, BMI kg/m$^2$ | 117 | 31.22 | 4.31 | 51 | 30.87 | 3.69 | 66 | 30.53 [a] | (27.69-35.27) | 0.779 |
| Body Mass Index (z-score) | 117 | 2.61 | 1.11 | 51 | 2.35 | 0.84 | 66 | 2.80 | 1.25 | 0.022 |
| Fat Mass Index, FMI kg/m$^2$ [b] | 116 | 10.09 | 2.14 | 51 | 11.42 | 2.28 | 65 | 9.05 | 1.30 | <0.001 |
| Fat Mass Index (z-score) | 116 | 2.10 | 0.92 | 51 | 2.78 | 0.51 | 65 | 1.57 | 0.53 | <0.001 |
| *Dietary measurements* | | | | | | | | | | |
| Diet Quality Index for Adolescents; DQI-A | 117 | 49.27 | 12.69 | 51 | 46.40 | 13.59 | 66 | 54.85 [a] | (44.77-59.28) | 0.007 |
| Energy intake, kcal | 117 | 2119.95 | 688.40 | 51 | 2336.23 | 689.03 | 66 | 1867.42 [a] | (1583.52-2217.48) | 0.001 |
| Carbohydrate, % | 117 | 37.95 | 6.94 | 51 | 38.88 | 6.87 | 66 | 37.25 | 6.95 | 0.207 |
| Protein, % | 117 | 18.74 | 3.66 | 51 | 19.18 | 3.38 | 66 | 18.39 | 3.86 | 0.241 |
| Fat, % | 117 | 42.90 | 7.26 | 51 | 41.67 | 6.63 | 66 | 43.85 | 7.61 | 0.103 |
| Meal frequency ‡ [c] | | n | % | | n | % | | n | % | |
| 3 | | 18 | 15.4 | | 9 | 17.6 | | 9 | 13.6 | 0.751 |
| 4 | | 38 | 32.5 | | 15 | 29.4 | | 23 | 34.8 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 61 | 52.1 | 27 | 52.9 | 34 | 51.5 |

Legend Table 1

Student *t*-test was applied for normally distributed variables (mean (SD)) and Mann–Whitney U test for non-normally distributed variables (median (interquartile range)), ‡: $\chi^2$ test for meal frequency.

[a]: data presented as median (interquartile range)

[b]: FMI calculated, Fat Mass (kg) obtained by skin-fold thickness

[c]: data presented as frequency (%).

Table 2: EVASYON compliance distribution in the study

| | Intensive phase (2 months) | | Extensive phase (13 months) | | |
|---|---|---|---|---|---|
| | Non-adherence n (%) | Adherence n (%) | Non-adherence n (%) | Adherence n (%) | *p* |
| Dietary criteria | | | | | |
| Global compliance (≥3 dietary compliance criteria) | 67 (62.6) | 40 (37.4) | 78 (85.7) | 13 (14.3) | 0.002 |
| Energy intake, kcal | 63 (58.9) | 44 (41.1) | 60 (65.9) | 31 (34.1) | 0.458 |
| Carbohydrate, % | 71 (66.4) | 36 (33.6) | 72 (79.1) | 19 (20.9) | 0.210 |
| Protein, % | 82 (76.6) | 25 (23.4) | 60 (65.9) | 31 (34.1) | 0.687 |
| Fat, % | 34 (31.8) | 73 (68.2) | 42 (46.2) | 49 (53.8) | 0.050 |
| Meal frequency, n | 11 (14.9) | 63 (85.1) | 19 (27.9) | 49 (72.1) | 0.021 |
| Physical activity criteria | 5 (5.9) | 80 (94.1) | 49 (65.3) | 26 (34.7) | <0.001 |
| Psychological support criteria | 105 (89.7) | 12 (10.3) | 64 (54.7) | 53 (45.3) | <0.001 |

*p*: p-value for McNemar paired proportion test.

Table 3: Comparisons of BMI and FMI z-score changes during intensive and extensive phase; non-adherence *vs.* adherence to dietary compliance criteria

| | Body Mass Index, BMI (kg/m$^2$) | | | Fat Mass Index, FMI (kg/m$^2$) | | |
|---|---|---|---|---|---|---|
| | ΔBMI z-score Mean (SD) | | Differences in BMI between groups | ΔFMI z-score Mean (SD) | | Differences in FMI between groups |
| *Intensive phase* | Non-adherence | Adherence | | Non-adherence | Adherence | |
| Overall compliance (≥3 dietary compliance criteria) | -0.48 (0.33)<br>N=65 | -0.44 (0.23)<br>N=38 | 0.04 | -0.24 (0.39)<br>N=60 | -0.19 (0.33)<br>N=38 | 0.05 |
| Energy intake, kcal | -0.47(0.33)<br>N=60 | -0.45 (0.27)<br>N=43 | 0.02 | -0.31 (0.37)<br>N=57 | -0.09 (0.33)<br>N=41 | 0.22 ** |
| Carbohydrate, % | -0.45 (0.29)<br>N=69 | -0.48 (0.33)<br>N=34 | -0.03 | -0.19 (0.37)<br>N=64 | -0.28 (0.37)<br>N=34 | -0.09 * |
| Protein, % | -0.47 (0.32)<br>N=79 | -0.44 (0.23)<br>N=24 | 0.03 | -0.19 (0.35)<br>N=74 | -0.32 (0.41)<br>N=24 | -0.13 * |
| Fat, % | -0.45 (0.23)<br>N=32 | -0.46 (0.33)<br>N=71 | -0.01 | -0.22 (0.39)<br>N=30 | -0.22 (0.36)<br>N=68 | 0 |
| Meal frequency, n | -0.51 (0.47)<br>N=10 | -0.43 (0.25)<br>N=61 | 0.08 * | -0.31 (0.50)<br>N=9 | -0.22 (0.32)<br>N=59 | 0.09 * |
| *Extensive phase* | Non-adherence | Adherence | | Non-adherence | Adherence | |
| Global compliance (≥3 dietary compliance criteria) | -0.17 (0.62)<br>N=74 | 0.02 (0.57)<br>N=13 | 0.19 * | -0.17 (0.59)<br>N=65 | -0.01 (0.65)<br>N=11 | 0.16 * |
| Energy intake, kca) | -0.21 (0.63)<br>N=59 | 0.01 (0.56)<br>N=28 | 0.22 * | -0.19 (0.58)<br>N=53 | -0.06 (0.64)<br>N=23 | 0.13 * |
| Carbohydrate, % | -0.13 (0.62)<br>N=68 | -0.17 (0.61)<br>N=19 | 0.04 | -0.15 (0.54)<br>N=56 | -0.09 (0.79)<br>N=16 | 0.06 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Protein, % | -0.15 (0.65) | -0.11 (0.56) | 0.04 | -0.13 (0.63) | -0.14 (0.54) | -0.01 |
| | N=58 | N=29 | | N=48 | N=24 | |
| Fat, % | -0.17 (0.58) | -0.11 (0.64) | 0.06 | -0.23 (0.66) | -0.05 (0.53) | 0.18 * |
| | N=38 | N=49 | | N=33 | N=39 | |
| Meal frequency, n | -0.09 (0.73) | -0.18 (0.60) | -0.09 | 0.08 (0.38) | -0.23 (0.67) | -0.31 ** |
| | N=23 | N=50 | | N=20 | N=45 | |

FMI calculated, Fat Mass (kg) obtained by skin-fold thickness;* Cohen's *d* ranging from 0.2 to 0.5; ** Cohen's *d* ranging from 0.5 to 0.8; *** Cohen's *d* ranging from 0.8 to 2.0

Table 4: Regression model to assess the relationships between BMI z-score, FMI z-score changes, and dietary compliance criteria and DQI-A changes adjusted for physical activity and psychological support.

| | Model | | | |
|---|---|---|---|---|
| | β | 95%CI | *p* | Pseudo $R^2$ |
| *BMI z-score* | | | | |
| DQI, per 5 units | -0.073 | (-0.095; -0.052) | <0.001 | 0.981 |
| Global compliance (≥3 dietary compliance criteria) | 0.158 | (-0.082; 0.399) | 0.193 | 0.955 |
| Energy intake, kcal | 0.145 | (-0.032; 0.322) | 0.107 | 0.955 |
| Carbohydrates, (% | 0.121 | (-0.136; 0.378) | 0.351 | 0.956 |
| Protein, % | 0.001 | (-0.169; 0.170) | 0.995 | 0.956 |
| Fat, % | 0.155 | (-0.025; 0.335) | 0.091 | 0.958 |
| Meal frequency, n | -0.023 | (-0.337; 0.291) | 0.883 | 0.966 |
| *FMI z-score* | | | | |
| DQI, per 5 units | -0.053 | (-0.078; -0.028) | <0.001 | 0.951 |
| Global compliance (≥3 dietary compliance criteria) | 0.008 | (-0.249; 0.265) | 0.949 | 0.932 |
| Energy intake, kcal | 0.048 | (-0.149; 0.249) | 0.629 | 0.933 |
| Carbohydrates, % | 0.051 | (-0.199; 0.302) | 0.682 | 0.932 |
| Protein, % | 0.039 | (-0.137; 0.216) | 0.660 | 0.932 |
| Fat, % | -0.038 | (-0.234; 0.157) | 0.698 | 0.932 |
| Meal frequency, n | -0.143 | (-0.476; 0.188) | 0.386 | 0.948 |

Diet Quality Index-A adapted from DQI–A as developed previously by Vyncke et al (2013) [8] and used as reference. Anthropometric indices were normalised according to sex-specific BMI and FMI reference standards for Spanish adolescents aged 13-18 years [31,32]; Regression model was adjusted by physical activity and psychological support. β = estimated regression coefficient; CI = confidence interval