

# Dietary patterns and school performance: evidence from a sample of adolescents in Sicily, Italy

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*Key words: Diet, academic performance, Mediterranean diet, school marks*

*Parole chiave: Dieta, risultati accademici, dieta Mediterranea, voti scolastici*

## Abstract

**Background.** Academic success in adolescence is a strong predictor of future wealth, productivity and health. While unhealthy dietary habits might be detrimental for academic outcomes, a positive association between healthy diet and school performance was found in adolescents worldwide.

**Study design.** A total of 213 adolescents (15 to 18 years old; 48% boys), attending three high schools in the urban area of Eastern Sicily, were enrolled in a cross-sectional study.

**Methods.** Dietary data and informations about weekly consumption of main meals were collected administering a Food Frequency Questionnaire. The Mediterranean Diet Score and Principal Component Analysis were used to identify a priori and a posteriori dietary patterns, respectively. School performance was assessed through school marks, using the previous year as reference.

**Results.** The Mediterranean Diet Score was weakly but positively correlated with performance in Italian, Science and Physical Education ( $p$ -values  $<0.05$ ). Similarly, the adherence to the prudent dietary pattern weakly positively correlated with marks in Mathematics. In contrast, we demonstrated a weak but significant negative correlation between adherence to the western dietary pattern and the performance in several subjects. The energy dense dietary pattern was instead negatively correlated with mark in Italian. We also showed that adolescents regularly eating all main meals have a better performance in several subjects, when compared to those who skipped at least one meal.

**Conclusions.** The promotion of healthy diet in youth should be a priority for Public Health, in order to improve adolescents' quality of life and prevent negative health and social outcomes later in life.

## Introduction

Academic success in childhood and adolescence is a strong predictor of future wealth, productivity and health. Public health decision makers should focus their attention on children's academic achievement, including the resources devoted to educational attainment and the

understanding of the indirect lifestyle factors that help shape childhood and adolescent academic success (1).

Dietary patterns, in terms of timing, frequency and quality, have dramatically changed over history. As reported in a study on adolescents from Tuscany (Italy), unhealthy eating behaviours - such as nutritional profiles rich in saturated fats

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and low in micronutrients - are gradually replacing the Mediterranean Diet (MD) model, which is considered the epitome of healthy diet (2). Thus, the urbanization of the Mediterranean areas led to the “nutrition transition” phenomenon, in which Mediterranean populations - especially children and younger generations - are reporting a growing adherence to a “western diet” (3).

In these life stages, the higher glucose consumption and metabolic requirements of the brain (4) are also crucial for the development of advanced cognitive functions, such as abstract thinking, deductive reasoning and problem solving (5, 6). In general, healthy behaviours are involved in learning ability of adolescents (7, 8). Among those factors that could influence a healthy lifestyle - including healthy eating behaviours - family background plays a critical role, considering that individual choices in favour of healthy foods are firstly conveyed by parents (9).

Unhealthy dietary habits might affect academic outcomes, with inadequate nutrient intakes - especially of iron, fat and added sugar - that are associated with poor school performance and metabolic diseases in children (10-12) and adults (13). In contrast, positive association between healthy diet and school performance was found in adolescents from Canada (14), Chile (8), Iceland (15, 16) and Norway (17). A heated debate regards breakfast, a form of gluttony through the Middle Ages and until a couple of centuries ago (18). In fact, skipping breakfast might be detrimental for children and adolescents (9), with particular effects on cognition and learning (19, 20).

Given this scenario, the present cross-sectional study aimed at exploring the relationship between dietary habits, in terms of quality and timing, and the school performance in Italian adolescents.

## Methods

### *Study design*

Adolescents (15 to 18 years old; 48% boys), attending three high schools in the urban area of Eastern Sicily, were enrolled in a cross-sectional study. An informative consent was signed by parents or by the students themselves if they were 18 years old or older. A structured questionnaire was administered in order to collect information on their lifestyles, weekly consumption of the three main meals (i.e. breakfast, lunch and dinner), on their anthropometric measures and also on sociodemographic data of their parents. Body mass index (BMI) was calculated according to the World Health Organization criteria (21).

### *Dietary Assessment*

Dietary assessment was performed through a previously validated semi-quantitative Food Frequency Questionnaire (FFQ) (22-24). The questionnaire is made of nine main food groups (“Breakfast Cereals, Bread and Snacks”, “Red Meat, Poultry, Seafood, Eggs”, “Dairy Products”, “Pasta and Soups”, “Vegetables and Cereals”, “Condiments and Dipping Sauces”, “Sweets”, “Fruit”, “Drinks”), each one containing specific food items for a total of 95 aliments. For each aliment listed, the students indicated the frequency of consumption (from “never” to “more than twice per day”) and the portion size, assessed through a photographic book. Specifically, the portion size was classified in three categories: small (half a medium portion size), medium and large (1.5 times or more than the medium portion size). Food intakes derived from the FFQ were calculated by multiplying the frequency of consumption with the daily portion size of each food group.

### *Adherence to the Mediterranean Diet*

Adherence to the MD was assessed through the *a priori* Mediterranean Diet

Score (MDS) (25, 26), which is made of the following nine food categories: cereals, fruits and nuts, vegetables, meat products, dairy products, legumes, fish, alcohol and ratio of unsaturated to saturated lipids. However, the “alcohol” category was excluded, since alcohol consumption is not recommended in adolescence. For each food category the median value of consumption was calculated. A value of 0 or 1 was assigned to each category of the score as follow: for categories that are more consumed in the Mediterranean countries (vegetables, legumes, fruits and nuts, cereals, fish, and a high ratio of unsaturated to saturated lipids), students whose consumption was below or equal to the median value of the population were assigned a value of 0, and a value of 1 was assigned otherwise. For categories consumed less frequently in Mediterranean countries (dairy and meat products), students whose consumption was below the median were assigned a value of 1, and a value of 0 was assigned otherwise. Thus, the MDS ranges from 0 (no-adherence) to 8 (perfect adherence) and MD adherence was categorized as follows: low adherence (MDS range: 0–3), medium adherence (MDS range: 4–6), or high adherence (MDS range: 7–8).

#### *Principal Components Analysis*

The Principal Components Analysis (PCA) was used to extract *a posteriori* dietary patterns, as previously described (27, 28). In brief, the 95 food items included in the FFQ were classified in 39 food groups, according to the similarity of nutrient profiles or the culinary usage. However, single food items were preserved if they constituted a distinct item on their own (e.g., eggs, pizza, coffee or tea, etc.) or if they were thought to represent a particular dietary pattern. For each food group, the energy-adjusted variable was entered into the factor analysis. Varimax rotation was used to maintain uncorrelated

factors and to make data interpretation easier. The number of dietary patterns was defined according to eigenvalues greater than 2.0, scree plot examination, and interpretability. Food groups that characterized dietary patterns were defined through factor loadings with an absolute value equal or greater than 0.2. Factor scores of each dietary pattern were calculated as the sum of the products between observed energy-adjusted food group intakes and their factor loadings.

#### *School Performance*

School performance was assessed through school marks, using the previous year as reference. Specifically, Italian, English, History, Science, Physical Education, Mathematics, Compartment and Grade Point Average were used as indicators, since these subjects are common to each school participating in the present study. Before asking the school’s registrar office to provide data on students’ scholastic performance, a specific informative consent was signed by parents or by the students themselves if they were 18 years old or older.

#### *Statistical analyses*

The characteristics of adolescents were described using frequency, median and interquartile range (IQR). We checked for normality of continuous variables using the Kolmogorov-Smirnov test. Accordingly, skewed variables were compared using the Mann-Whitney U test for continuous variables, while categorical variables were compared using Chi-squared test. Correlation between variables was assessed using the Spearman tests. Statistical analyses were performed using SPSS software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp) and all p-values < 0.05 were considered statistically significant.

## Results

### *Study population and school performance*

Table 1 displays the main characteristics of study population by sex. Overall, boys were heavier and taller ( $p < 0.001$ ) with a higher BMI ( $p < 0.001$ ) than girls. Moreover, boys spent more time in moderate-to-vigorous physical activity than girls ( $P < 0.001$ ). No differences in socio-demographic characteristics of parents, while it was evident that girls were more engaged in smoking than boys. With regard to school performance, girls had higher scores in History ( $p = 0.001$ ), Science ( $p = 0.027$ ) and Grade Point Average ( $p = 0.020$ ), while boys had higher scores in Physical education ( $p = 0.035$ ).

### *Adherence to the Mediterranean diet and a posteriori dietary patterns*

According to MDS (median=4; IQR=2), adherence to MD was low (42.7%) or medium (51.2%) in general, with no difference between sexes (Table 1). Next, we examined the scree plot (Figure 1) and derived three dietary patterns with eigenvalues  $> 2.0$  that explained 26.8% of total variance among the 36 food groups. Table 2 shows factor loadings that characterized each dietary pattern: the first dietary pattern, named “prudent”, was characterized by high intake of potatoes, cooked vegetables, legumes, fruits, nuts, yoghurt, offal (entrails), shellfish and tea; the second dietary pattern, named “western”, was characterized by white

Table 1 - Characteristics and school performance of adolescents overall and by sex

Characteristics, median (IQR) or %	Overall	Boys	Girls	p-value
Age, years	16.0 (0)	16.0 (0.0)	16.0 (1.0)	0.414
Weight, Kg	59.0 (14.0)	67.3 (15.0)	54.0 (8.0)	<b>&lt;0.001</b>
Height, m	1.72 (0.19)	1.80 (0.15)	1.65 (0.09)	<b>&lt;0.001</b>
BMI, Kg/m <sup>2</sup>	20.4 (3.1)	21.9 (3.2)	19.6 (2.9)	<b>&lt;0.001</b>
Maternal low education level (%)	16.1%	13.3%	18.4%	0.529
Paternal low education level (%)	19.2%	16.2%	21.8%	0.704
Maternal employment status (% no workers)	26.1%	20.2%	31.3%	0.068
Paternal employment status (% no workers)	15.7%	14.1%	17.1%	0.554
Smoking status (% smokers)	12.7%	9.2%	15.8%	0.150
MDS	4.0 (2.0)	4.0 (2.0)	4.0 (2.0)	0.688
MD adherence (%)				
Low	42.7%	42.4%	43.0%	
Medium	51.2%	50.5%	51.8%	0.859
High	6.1%	7.1%	5.3%	
Academic performance (marks 0 to 10)				
Italian	7.0 (2.0)	7.0 (2.0)	7.0 (1.0)	0.055
English	7.0 (2.0)	7.0 (2.0)	7.0 (2.0)	0.362
History	7.0 (1.0)	7.0 (2.0)	8.0 (1.0)	<b>0.001</b>
Science	7.0 (1.0)	7.0 (2.0)	8.0 (1.0)	<b>0.027</b>
Physical Education	8.0 (1.0)	9.0 (1.0)	8.0 (1.0)	<b>0.035</b>
Mathematics	7.0 (2.0)	6.0 (2.0)	7.0 (2.0)	0.121
Compartment	9.0 (2.0)	9.0 (2.0)	9.0 (2.0)	0.274
Grade Point Average	7.4 (1.2)	7.3 (1.0)	7.7 (1.2)	<b>0.020</b>

Abbreviations: BMI, body mass index; MDS, Mediterranean Diet Score  
Statistically significant p-values are in bold font

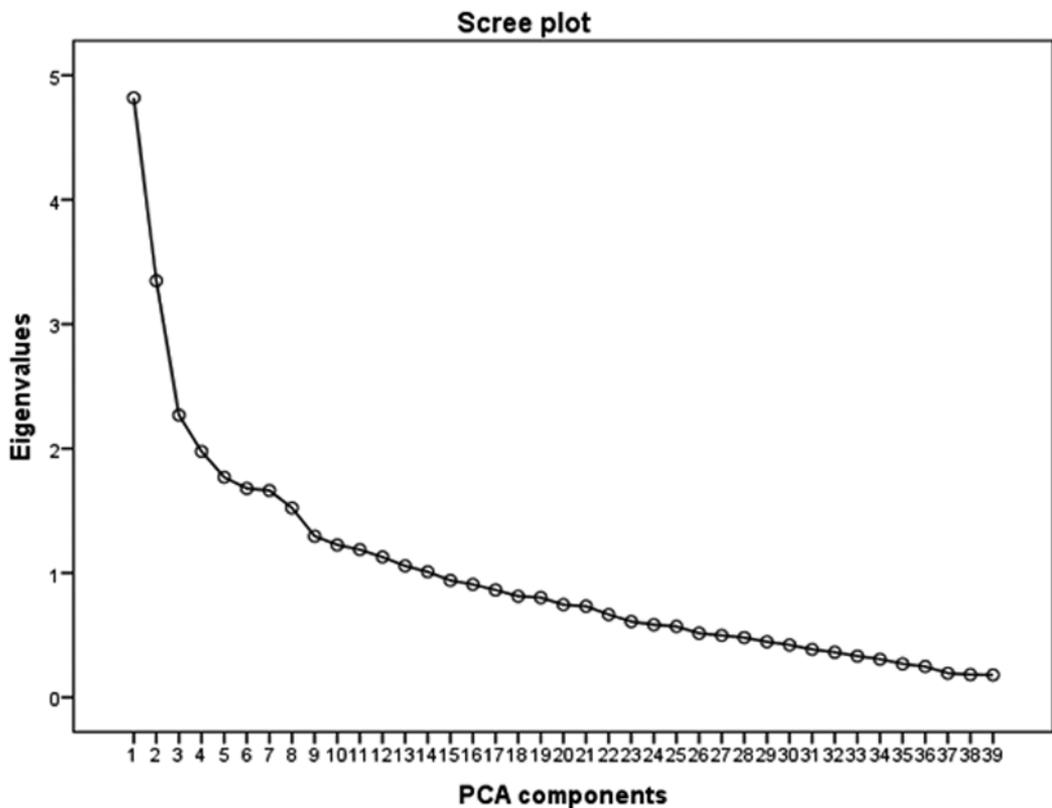


Figure 1 - Scree plot showing the eigenvalues for each dietary patterns derived by Principal Component Analysis. We used the scree plot examination to determinate the appropriate number of principal components. Scree plot shows the partitioning of the total variation (i.e. eigenvalue) accounted for each principal component, against the PCA component number.

	MDS	Prudent	Western	Energy dense
Italian	<b>0.140</b>	-0.068	-0.123	<b>-0.165</b>
English	0.084	-0.140	<b>-0.217</b>	-0.123
Mathematics	0.058	<b>0.150</b>	-0.122	-0.054
History	0.076	0.010	<b>-0.174</b>	-0.086
Science	<b>0.145</b>	-0.032	<b>-0.158</b>	-0.017
Physical Education	<b>0.143</b>	-0.038	<b>-0.221</b>	0.067
Compoment	0.020	-0.024	<b>-0.168</b>	-0.014
Grade Point Average	0.074	-0.113	<b>-0.220</b>	-0.079

Spearman Correlation Coefficient  
-0.3 0.3

Figure 2 - Correlation matrix between adherence to dietary patterns and school performance. Statistically significant p-values are in bold font.

Table 2 - Factor loadings that characterize *a posteriori* dietary patterns

Food groups	Prudent	Western	Energy dense
Potatoes	0.751		
Cooked vegetables	0.557		
Raw vegetables			
Legumes	0.330		
Fruit	0.745		
Nuts	0.264		
Milk			
Yoghurt	0.351		0.543
Curd cheese			
Ripened cheese			
Pasta			
Rice			
White bread		0.748	
Whole wheat bread			
Breakfast cereals			
Red meat		0.788	
White meat			
Processed meat		0.321	
Offals	0.867		
Canned fish			
Shellfish	0.304	0.281	
Fish			
Eggs			
Vegetable oil		0.493	
Olive oil			
Butter and margarine			0.266
Sweet and processed sugar			0.650
Fruit juice			
Coffee			
Tea	0.278		
Dipping sauces		0.314	0.561
Soup			
Pizza			0.693
Salty snacks		0.844	
Fries		0.256	0.721
Fruit salad			

Food groups that characterized dietary patterns were defined through factor loadings with an absolute value  $\geq 0.2$ .

bread, red and processed meat, shellfish, vegetable oil, dipping sauces and fries; the third dietary pattern, named “energy dense”, was characterized by high intake of yoghurt, butter and margarine, sweets and refined sugar, dipping sauces, pizza and fries.

#### *Correlations between adherence to dietary patterns and school performance*

Figure 2 illustrates Spearman correlation coefficients between adherence to dietary patterns (i.e. MDS for MD and factor scores for *a posteriori* dietary patterns) and school marks. Interestingly, the MDS weakly but positively correlated with performance in Italian, Science and Physical Education (p-values<0.05). Similarly, the adherence to the prudent dietary pattern was positively, but weakly, correlated with marks in Mathematics. In contrast, we demonstrated a weak but significant negative correlation between adherence to the western dietary pattern and the performance in English, History, Science, Physical Education, Comportment and Grade Point Average. The energy dense dietary pattern, instead, negatively correlated with mark in Italian.

#### *Main meals and school performance*

Overall, only 58.7% adolescents regularly ate all the three main meals every day; those who ate everyday the breakfast were 61.5%, the lunch 97.8% and dinner 97.2%. The comparison of school performance between adolescents eating all main meals and those who skipped at least one meal is reported in Table 3. Particularly, results showed that adolescents regularly eating all main meals have a better performance in English, History, Mathematics and Grade Point Average, when compared to those who skipped at least one meal, usually the breakfast (p-values <0.05).

Table 3 - Comparison of school performance between adolescents eating all the main meals and those who skipped at least one meals

Academic performance (marks 0 to 10)	Eating all main meals	Skipping at least one main meal	p-value
Italian	7.0 (1.0)	7.0 (2.0)	0.080
English	8.0 (2.0)	7.0 (2.0)	<b>0.009</b>
History	8.0 (1.0)	7.0 (2.0)	<b>0.012</b>
Science	7.0 (1.0)	7.0 (2.0)	0.129
Physical Education	8.0 (1.0)	8.0 (2.0)	0.103
Mathematics	7.0 (2.0)	6.0 (2.0)	<b>0.022</b>
Comportment	9.0 (1.0)	9.0 (1.0)	0.119
Grade Point Average	7.6 (1.2)	7.3 (1.3)	<b>0.006</b>

Statistically significant p-values are in bold font

## Discussion

In the present study we investigated the relationships between dietary patterns and school performance in adolescents, using both *a priori* and *a posteriori* approaches. Our results are in line with the current evidence, as we observed a general low-medium adherence to MD. In fact, dietary habits of younger generations are shifting towards a western diet, which does not provide an appropriate intake of energy and micronutrients (29). Several lines of evidence reported that dietary habits affect both adolescents' school performance and attention capacity (2, 7, 8). Among the adolescents enrolled in our study, the adherence to the MD - assessed through the *a priori* MDS - was positively correlated with better school performance in several fields. Similarly, a positive correlation with the performance in Mathematics was reported for a "prudent" dietary pattern - derived *a posteriori* - rich in potatoes, cooked vegetables, legumes, fruits, nuts, yoghurt, offal, shellfish and tea.

In contrast, we identified two *a posteriori* dietary patterns that were characterized by high intake of unhealthy foods: a "western" dietary pattern rich in white bread, red and

processed meat, shellfish, vegetable oil, dipping sauces and fries; and an "energy dense" dietary pattern rich in yoghurt, butter and margarine, sweets and refined sugar, dipping sauces, pizza and fries. Interestingly, the first negatively correlated with marks in English, History, Science, Physical Education, Comportment and Grade Point Average, while the second negatively correlated with the performance in Italian. These results are in line with others who reported an association between a "western" dietary profile and a poor academic performance in adolescents (10-12). Moreover, a Norwegian study showed how a diet rich in unhealthy foods (i.e. soft drinks, candies, chocolate, potato crisps and fast food) was associated with learning difficulties in Mathematics (17). Our results added to current knowledge, demonstrating that students who regularly consumed all the main meals had a better school performance, compared to those who skipped at least a meal. This is in line with previous evidence that skipping meals had a similar effect to unhealthy diet (17). For instance, a recent meta-analysis on regular and healthy breakfast consumption showed that lower postprandial glycaemic response was beneficial to mental performance (30).

Our study had some weaknesses, including the cross-sectional design which precluded drawing conclusions on the causality of the associations. We recognize that our study was not able to compare dietary habits and school performance in the same period, and further prospective researches are encouraged to evaluate this relationship. Moreover, we cannot rule out the possibility of bias from unmeasured factors and confounders that might affect dietary patterns and school performance in adolescents.

In conclusion, our findings confirmed the effect of dietary habits on adolescents' school performance, which in turn is a strong predictor of wealth, productivity and health in adulthood. Thus, the promotion of healthy lifestyles in youth should be a priority for Public Health, in order to improve adolescents' quality of life and prevent negative health and social outcomes later in life.

**Acknowledgments:** We are grateful to all the staff and students of high school institutes involved in the study.

## Riassunto

### *Profili nutrizionali e rendimento scolastico: evidenze da un campione di adolescenti in Sicilia*

**Introduzione.** Il rendimento scolastico durante l'adolescenza è un predittore di futuro benessere, produttività e salute. Se le abitudini alimentari poco sane possono essere dannose, nel mondo, è stata dimostrata un'associazione positiva tra la dieta sana ed il rendimento scolastico.

**Disegno dello studio.** Un totale di 213 adolescenti (età compresa tra i 15 ed i 18 anni; 48% di maschi), frequentanti tre istituti superiori della area urbana della Sicilia Orientale, sono stati arruolati in uno studio cross-sectional.

**Metodi.** I dati nutrizionali ed il consumo dei principali pasti sono stati raccolti mediante Food Frequency Questionnaire. Il Mediterranean Diet Score e la Principal Component Analysis sono stati usati per identificare i profili nutrizionali a priori e a posteriori. Il rendimento è stato valutato mediante i voti scolastici riferiti all'anno precedente il reclutamento.

**Risultati.** Il Mediterranean Diet Score era debolmente ma positivamente correlato al rendimento in Italiano,

Scienze ed Educazione fisica. Allo stesso modo, l'aderenza al profilo prudente correlava positivamente con il voto in Matematica. Al contrario, abbiamo dimostrato una debole ma negativa correlazione tra l'aderenza al profilo occidentale ed il rendimento in diverse materie. Il profilo ipercalorico, invece, era negativamente correlato al voto in Italiano. Inoltre, abbiamo dimostrato che gli adolescenti che consumavano regolarmente i pasti principali aveva un rendimento migliore rispetto a coloro che ne saltavano almeno uno.

**Conclusioni.** La promozione di una dieta sana durante l'adolescenza deve essere una priorità per la Sanità Pubblica, al fine di migliorare la qualità della vita degli adolescenti e prevenire outcome avversi sociali e di salute durante tutto il corso della vita.

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